# ASC/EN
# Airworthiness Certification Criteria
# Expanded Version of
# MIL-HDBK-516B
# 26 Sep 2005


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## FOREWORD

This document is for the use of Air Force programs to aid in the development of Tailored Airworthiness Certification Criteria (TACC) or Modified Airworthiness Certification Criteria (MACC) documents.

It contains all sections (1 – 20 plus Appendices) from the MIL-HDBK-516B, 26 Sep 2005 publication. The criteria and references (sections 4 through 20) contain the addition of recommended standards and methods of compliance for each of the criterion.

The criteria contained herein are qualitative in nature. More specific guidance and background for specific criteria may be found in the appropriate Joint Service Specification Guides (JSSG) and Title 14, Code of Federal Regulations referenced herein. Also, note that each section contains a list of typical certification source data that may be referenced for evaluating system compliance with that section's criteria. Terms such as "acceptable" used in the criteria are parameters whose specific definition must be determined and documented by the implementing office in the context of each unique air system.

This document is forms the basis for the USAF Airworthiness Certification Criteria future update to MIL-HDBK-516B currently in writing, and may be updated as the standards and methods of compliance sections for each criterion are further developed.

Note that in electronic versions, the blue highlighted paragraph headings or text in handbook sections 4 through 19 are internal hyperlinks to bookmarks in the appendix Technical Points of Contact table. Clicking the mouse cursor on the blue jumps you to the referenced location in the table. To return from the Technical Points of Contact table to your jump point in the handbook, use the back arrow ← key on the menu bar (enable View-Toolbars-Web for the back arrow tool). Gray shaded internal cross-references within the document perform similarly.

Any questions regarding this document may be directed to the POC at the MIL-HDBK-516B mailbox:

ASC.EN.516B@wpafb.af.mil

To use this document:

Criteria are either applicable or nonapplicable. Justification must be provided for nonapplicability.

Standards and methods of compliance may be tailored to the needs of the program for the applicable criterion.

References are for guidance in understanding the criterion and tailoring the standards and methods of compliance.

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# AIRWORTHINESS CERTIFICATION CRITERIA

This document is approved for use by all Departments and Agencies of the Department of Defense.

## 1. SCOPE

### 1.1 Purpose.

This document establishes the airworthiness certification criteria to be used in the determination of airworthiness of all manned and unmanned, fixed and rotary wing air vehicle systems. It is a foundational document to be used by the system program manager, chief engineer, and contractors to define their air system's airworthiness certification basis.

This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

### 1.2 Applicability.

These criteria should be tailored and applied at any point throughout the life of an air vehicle system when an airworthiness determination is necessary, especially whenever there is a change to the functional or product baseline.

Rotary wing air vehicle and unmanned aerial vehicle/remotely operated aircraft (UAV/ROA) features demand unique safety-of-flight (SOF) system requirements. Therefore, unique criteria are included for these types of systems to ensure that minimum levels of design for safe operation and maintenance are established. The UAV/ROA operating system can be built into the vehicle or be part of the control station for remotely operated aircraft. The UAV/ROA system comprises the control station, data links, flight control system, communications systems/links, etc., as well as the air vehicle. UAV/ROAs vary greatly in size, weight, and complexity. Because they are unmanned, SOF risks associated with loss of aircrew may not apply. However, as with manned air vehicles, SOF risk associated with personnel, damage to equipment, property, and/or environment must be considered. As such, the airworthiness criteria may be tailored for this unique application, including when a UAV/ROA is designed to be "expendable" or where the UAV/ROA will conduct missions with "minimum life expectancy." Consideration should be given to the environment in which the UAV/ROA will be operated (controlled test range, national airspace, fleet usage, including ship based applications), to the airframe life for which the air vehicle is designed, and to the "expendability" of the UAV/ROA in close proximity to the control system, personnel, property, or other equipment.

Similarly, air vehicles intended for use aboard ship have unique requirements in areas such as structural integrity, propulsion system dynamic response and tolerance to steam ingestion, control systems response to approach and landings in high turbulence conditions, electromagnetic environmental effects, deck handling, support and servicing, and pilot field of view.

Commercial derivative aircraft (CDA) are initially approved for safety of flight by the Federal Aviation Administration (FAA) and may have an FAA approved Certificate of Airworthiness. Any non-FAA approved alteration to a CDA may render all FAA certifications invalid. While alterations to CDA are covered by rules unique to each branch of service, the operating service always has the responsibility for the airworthiness certification approval under public aircraft

rules. Therefore, when planning any alterations to an FAA certified CDA, the modifier should contact the FAA Military Certification Office (MCO) in Wichita, KS at the earliest opportunity. Agreements for reimbursement for military service work performed by the FAA are in place, and in many cases MCO assistance on these alterations may be accomplished without additional cost.

In all instances, complete and accurate documentation of both applicability and system specific measurable criteria values is critical to ensuring consistent, timely, and accurate airworthiness assessments.

### 1.2.1 Tailoring to create the certification basis

Not all of the airworthiness criteria apply to every type of air vehicle; also, platform-unique, previously undefined criteria may need to be added to fully address safety aspects of unique configurations. Therefore, tailor the total set of criteria to identify a complete (necessary and sufficient) subset of applicable airworthiness criteria, creating the system's certification basis. This certification basis should be fully documented and maintained under strict configuration control.

Tailoring rules are as follows:

a. Identify each criterion as either applicable or nonapplicable, considering system or product complexity, type, data, and intended use. Document the rationale for identifying any criteria as nonapplicable.

b. Applicable criteria may not be deleted or modified in any manner. However, if a portion of otherwise applicable criteria does not apply, identify the applicable and nonapplicable portions, and document the rationale.

c. Supplement applicable criteria with specific measurable parameters, where appropriate (i.e., they add value to the definition of airworthiness requirements).

d. Develop additional criteria, as appropriate, for any capabilities or systems not fully addressed by the criteria contained in this handbook.

## 1.3 Cross references and technical points of contact.

The criteria included in this document are written with the intent that an experienced engineer, trained in the specific technical area under consideration, should be able to interpret, tailor, apply, and evaluate a particular system's compliance with the criteria. To assist in this effort, military and civil references are included with the specific criteria.

For additional assistance in interpreting or applying the criteria, call the appropriate section technical point of contact, or the FAA MCO, provided at appendix A.2.

## 1.4 Information sources.

Each section in the Airworthiness Certification Criteria is matched with corresponding Title 14, Code of Federal Regulations reference (14CFR reference) and Joint Service Specification Guides (JSSG). In addition, the complete listing of 14CFR reference advisory circulars was consulted for appropriate guidance in airworthiness certification.

The FAA Title 14 Code of Federal Regulations Part (i.e., 23, 25, 27, 29) referenced is dependant on airplane type, and must be consistent with airplane size and usage. The list shown is not all inclusive, and the user is cautioned to only look at the reference material as a guide, and not for purposes of citing requirements. The user is also advised to use additional FAA Advisory Circulars or other FAA Policy documents, such as Orders and Notices that may be found on the FAA website, to assist in understanding the FAA's implementation of the regulatory requirements.

## 2. APPLICABLE DOCUMENTS

### 2.1 General.

The documents listed below are not necessarily all of the documents referenced herein but are those necessary to understand the information provided by this handbook. Refer to the current version of these documents, unless otherwise indicated.

**2.1.1** Government specifications, standards, and handbooks.

The following specifications, standards, and handbooks form a part of this document to the extent specified herein.

DEPARTMENT OF DEFENSE SPECIFICATIONS

Joint Service Specification Guides (JSSG):

| | |
|---|---|
| JSSG-2000 | Air System |
| JSSG-2001 | Air Vehicle |
| JSSG-2005 | Avionic Subsystem, Main Body |
| JSSG-2006 | Aircraft Structures |
| JSSG-2007 | Engines, Aircraft, Turbine |
| JSSG-2008 | Vehicle Control and Management System (VCMS) |
| JSSG-2009 | Air Vehicle Subsystems |
| JSSG-2010 | Crew Systems |

Click the link below to view the unlimited distribution JSSGs

(http://engineering.wpafb.af.mil/corpusa/specification/jssg)

Military Specifications:

| | |
|---|---|
| MIL-PRF-5041 | Tires, Ribbed Tread, Pneumatic, Aircraft, General Specification for |
| MIL-PRF-5096 | Manuals, Technical: Inspection and Maintenance Requirements; Acceptance and Functional Check Flight Procedures and Checklists, Inspection Work Cards, and Checklists, Preparation of |
| MIL-PRF-5920 | Manuals, Technical: Sample Basic Weight Checklists and Loading Data |
| MIL-E-7016 | Electric Load and Power Source Capacity, Aircraft, Analysis of |
| MIL-DTL-7700 | Flight Manuals, Air Refueling Procedures, and Abbreviated Checklists |
| MIL-L-8552 | Landing Gear, Aircraft Shock Absorber (Air-Oil Type) |
| MIL-B-8584 | Brake Systems, Wheel, Aircraft, Design of |
| MIL-A-8591 | Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase); General Design Criteria for |
| MIL-F-8615 | Fuel System Components, General Specification for |
| MIL-S-8812 | Steering System, Aircraft General Requirements for |
| MIL-A-8865 | Airplane Strength and Rigidity Miscellaneous Loads |

| | |
|---|---|
| MIL-A-18717 | Arresting Hook Installation, Aircraft |
| MIL-A-19736 | Air Refueling Systems, General Specification for |
| MIL-G-21480 | Generator System, 400 Hz Alternating Current, Aircraft, General Specification for |
| MIL-DTL-25959 | Tie Down, Cargo, Aircraft |
| MIL-PRF-27260 | Tie Down, Cargo, Aircraft CGU-1/B |
| AFGS-87139 | Landing Gear Systems |
| AFGS-87219 | Electrical Power Systems, Aircraft |
| AFGS-87256 | Integrated Diagnostics |
| MIL-F-38363 | Fuel System, Aircraft, (for future procurement, see MIL-F-87154) (for future procurement, use AFGS-87154 Fuel Systems General Design Specifications for [inactive but soon to be reactivated]) |
| MIL-A-87166 | Aerial Refueling Receiver Subsystem |

DEPARTMENT OF DEFENSE STANDARDS

| | |
|---|---|
| MIL-STD-188-141 | Interoperability and Performance Standards for Medium and High Frequency Radio Systems |
| MIL-STD-188-242 | Interoperability and Performance Standards for Tactical Single Channel Very High Frequency (VHS) Radio Equipment |
| MIL-STD-188-243 | Interoperability and Performance Standards for Tactical Single Channel Ultra High Frequency (UHV) for Radio Communications |
| MIL-STD-411 | Aircrew Station Alerting Systems |
| MIL-STD-461 | Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment |
| MIL-STD-464 | Electromagnetic Environmental Effects Requirements for Systems |
| MIL-STD-704 | Aircraft Electric Power Characteristics |
| MIL-STD-805 | Towing Fittings & Provisions for Military Aircraft, Design Requirements for |
| MIL-STD-810 | Environmental Engineering Considerations and Laboratory Tests |
| MIL-STD-882 | System Safety, Standard Practice for |
| MIL-STD-961 | Defense and Program Unique Specifications Format and Content |
| MIL-STD-1289 | Airborne Stores, Ground Fit and Compatibility Requirements |
| MIL-STD-1310 | Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility and Safety |
| MIL-STD-1399-300 | Interface Standard for Shipboard Systems Section 300A Electric Power, Alternating Current (Metric) |

| | |
|---|---|
| MIL-STD-1399-390 | Interface Standard for Shipboard Systems Section 390 Electric Power, Direct Current (other than ship's battery) for Submarines (Metric), |
| MIL-STD-1425 | Safety Design Requirements for Military Lasers and Associated Support Equipment |
| MIL-STD-1472 | Human Engineering |
| MIL-STD-1474 | Noise Limits |
| MIL-STD-1530 | Aircraft Structural Integrity Program |
| MIL-STD-1683 | Connectors and Jacketed Cable, Electric, Selection Standard for Shipboard Use |
| MIL-STD-1760 | Aircraft/Store Electrical Interconnection System |
| MIL-STD-1787 | Aircraft Display Symbology |
| MIL-STD-1797 | Flying Qualities of Piloted Aircraft |
| MIL-STD-2169 | High-Altitude Electromagnetic Pulse (HEMP) Environment (u) classified SECRET |
| MIL-STD-3005 | Analog-to-Digital Conversion of Voice by 2,400 bit/second Mixed Excitation Linear Prediction (MELP) |
| MIL-STD-3009 | Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible |
| MIL-STD-3013 | Glossary of Definitions, Ground Rules, and Mission Profiles to Define Air Vehicle Performance Capability |
| MIL-STD-7080 | Selection and Installation of Aircraft Electric Equipment |
| MIL-STD-27733 | Modification and Marking Requirements for Test Equipment in Aerospace Vehicles and Related Support Equipment |
| MIL-STD-38784 | Standard Practice for Manuals, Technical: General Style and Format Requirements |

DEPARTMENT OF DEFENSE HANDBOOKS

| | |
|---|---|
| MIL-HDBK-61 | Configuration Management Guidance |
| MIL-HDBK-221 | Fire Protection Design Handbook for U.S. Navy Aircraft Powered by Turbine Engines |
| MIL-HDBK-244 | Guide to Aircraft/Stores Compatibility |
| MIL-HDBK-299 | Cable Comparison Handbook Data Pertaining to Electric Shipboard Cable |
| MIL-HDBK-310 | Global Climatic Data for Developing Military Products |
| MIL-HDBK-419 | Grounding, Bonding, and Shielding for Electronic Equipments and Facilities, Volume 1 & 2 |
| MIL-HDBK-454 | General Guidelines for Electronic Equipment |
| MIL-HDBK-514 | Operational Safety, Suitability, and Effectiveness for the Aeronautical Enterprise |
| MIL-HDBK-515 | Weapon System Integrity Guide |

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|---|---|
| MIL-HDBK-704 | Guidance for Test Procedure for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics (Parts 1 through 8) |
| MIL-HDBK-828 | Laser Safety on Ranges and in Other Outdoor Areas |
| MIL-HDBK-1568 | Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems |
| MIL-HDBK-1587 | Materials and Process Requirements for Air Force Weapon Systems |
| MIL-HDBK-1760 | Aircraft/Store Electrical Interconnection System |
| MIL-HDBK-1763 | Aircraft/Stores Compatibility: Systems Engineering Data Requirements and Test Procedures |
| MIL-HDBK-1783 | Engine Structural Integrity Program (ENSIP) |
| MIL-HDBK-1791 | Designing for Internal Aerial Delivery in Fixed Wing Aircraft |
| MIL-HDBK-1798 | Mechanical Equipment and Subsystems Integrity Program |
| MIL-HDBK-2165 | Testability Program for Systems and Equipments |
| MIL-HDBK-5400 | Electronic Equipment, Airborne General Guidelines for |
| MIL-HDBK-6870 | Inspection Program Requirements Nondestructive for Aircraft and Missile Materials and Parts |
| MIL-HDBK-46855 | Human Engineering Program Process and Procedures |
| MIL-HDBK-87213 | Electronically/Optically Generated Airborne Displays |
| MIL-HDBK-87244 | Avionics/Electronics Integrity |

(Copies of these documents are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094 or http://dodssp.daps.dla.mil. or http://assist.daps.dla.mil/quicksearch/. Copies of documents indicating a distribution limitation (for example, statement D) may be ordered from ASC/ENOI, 2530 Loop Rd West, Bldg. 560, Wright-Patterson AFB, OH 45433-7101 or online at https://www.en.wpafb.af.mil/engstds/engstds.asp).

**2.1.2** Other Government publications.

The following other Government publications form a part of this document to the extent specified herein.

AIR FORCE INSTRUCTIONS

| | |
|---|---|
| AFI 11-202 | General Flight Rules (Volume 3) |
| AFI 11-2C-130 | C-130 Operating Procedures |
| AFI 21-101 | Aerospace Equipment Maintenance Management |
| AFI 63-14 | Aircraft Information Programs |
| AFI 63-501 | Air Force Acquisition Quality Program |
| AFI 63-1201 | *Assurance of* Operational Safety, Suitability, and Effectiveness (OSS&E) |

AFI 63-1301 Assurance of Communications Navigation Surveillance/Air Traffic Management Performance

AIR FORCE POLICY DIRECTIVES

AFPD 62-4 Standards of Airworthiness for Passenger Carrying Commercial Derivative Transport Aircraft

AFPD 62-5 Standards of Airworthiness for Commercial Derivative Hybrid Aircraft

AFPD 62-6 USAF Aircraft Airworthiness Certification

AFPD 63-12 *Assurance of* Operational Safety, Suitability, and Effectiveness (OSS&E)

AFPD 63-13 Communications Navigation Surveillance/Air Traffic Management and Navigation Safety Performance for USAF Aircraft

(Copies of Air Force Policy Directives and Instructions can be viewed online at the AFDPO web site at http://afpubs.hq.af.mil.

AIR FORCE OCCUPATIONAL SAFETY AND HEALTH

AFOSH 48-139 Laser Radiation Protection Program

AIR FORCE TECHNICAL ORDER

T.O. 00-5-1 AF Technical Order System

T.O. 31Z-10-0 Electromagnetic Radiation Hazard

(Copies of Air Force technical orders may be obtained via https://www.toindex-s.wpafb.af.mil/.)

AERONAUTICAL SYSTEMS CENTER ENGINEERING GUIDE

ASC/EN Manufacturing Development Guide

(Copies of this ASC/EN Guide may be obtained by mail ASC/ENSM, 2530 Loop Rd W., Wright-Patterson AFB, OH 45433-7101, Commercial (937) 255-1656, DSN 785-1656; or may be viewed online at the EN website: https://www.en.wpafb.af.mil/mdg/mdg.pdf.)

ARMY AERONAUTICAL DESIGN STANDARDS

ADS-10C-SP Air Vehicle Technical Description

ADS-13F-HDBK Air Vehicle Materials and Processes

ADS-27 Requirements for Rotorcraft Vibration Specifications, Modeling and Testing

ADS-29 Structural Design Criteria for Rotary Wing Aircraft

ADS-33E-PRF Performance Specification Handling Qualities Requirements for Military Rotorcraft

ADS-36 Rotary Wing Aircraft Crash Resistance

ADS-37A-PRF Electromagnetic Environmental Effects (E3) Performance and Verification Requirements

ADS-40A-SP Air Vehicle Flight Performance Description

ADS-43A-HDBK Qualification Requirement and Identification of Critical Characteristics for Aircraft and Engine Components

| | |
|---|---|
| ADS-44-HDBK | Aeronautical Design Standard Handbook Armament Airworthiness Qualification |
| ADS-50-PRF | Rotorcraft Propulsion Performance Qualification Requirements and Guidelines |
| ADS-51-HDBK | Rotorcraft and Aircraft Qualification (RAQ) Handbook (http://www.redstone.army.mil/aed/eng/raqh/raqh.html) |
| ADS-62-SP | Data and Test Requirements for Airworthiness Release for Helicopter Sensor Data and Testing Requirements in Development Stage |
| ADS-63-SP | Radar System Airworthiness Qualification and Verification Requirements |
| ADS-65-HDBK | Airworthiness Qualification and Verification Requirements for Electro-Optics and Infrared Sensor Systems |
| ADS-66-HDBK | Guidance for Data for Safety of Flight Airworthiness Release for Helicopter Aircraft Survivability Equipment (ASE) |

(Copies of Army Aeronautical Design Standards may be obtained via http://www.redstone.army.mil/amrdec/sepd/tdmd/StandardAero.htm)

ARMY REGULATIONS

| | |
|---|---|
| AR 11-9 | The Army Radiation Safety Program |

(Copies of Army Regulations may be obtained via http://www.army.mil/usapa/epubs/11_series_collection_1.html.

ARMY TECHNICAL BULLETINS (TB)

| | |
|---|---|
| TB MED 523 | Control of Hazards to Health from Microwave and Radio Frequency Radiation and Ultrasound |

(Official Department of Army (DA) administrative publications and forms are managed by the Army Publishing Directorate (APD) under the direction of the Administrative Assistant to the Secretary of the Army (AASA). APD uses the latest publishing technologies to produce high-quality, enhanced, electronic publications and forms. This is the Army's latest collection of electronic DA administrative publications and DA forms. Copies of Army Technical Bulletins may be obtained via http://www.army.mil/usapa/med/index.html)

NAVY AERONAUTICAL REQUIREMENTS

| | |
|---|---|
| AR-56 | Structural Design Requirements (Helicopters) |
| AR-89 | Structural Ground Test Requirements (Helicopters) |

(Copies of Navy Aeronautical Requirements documents may be obtained via U. S. Mail from the following address: Structures Division, ATTN: Bldg. 2187, Suite 2340A, NAVAIRSYSCOM, 48110 Shaw Road, Unit 5, Patuxent River, MD 20670-1906. For inquiries, phone (301) 342-9381.)

NAVAL AIR SYSTEMS COMMAND INSTRUCTIONS

| | |
|---|---|
| NAVAIRINST 4200.25D | Management of Critical Application Items including Critical Safety Items. |

NAVAIRINST 13034.1C Flight Clearance Policy for Air Vehicles and Aircraft Systems

NAVAIR 00-80T-110 NATOPS Air Refueling Manual (USN/USMC)

(Copies of Naval Air System Command documents may be obtained via Commander, Naval Air System Command, 47123 Buse Rd, B2272 Unit IPT, Patuxent River MD 20670-1547. Copies of NAVAIR Flight Clearance instructions may be obtained via http://airworthiness.navair.navy.mil/.)

NAVAL SEA SYSTEMS COMMAND INSTRUCTIONS

NAV SEA OP 3565 Electromagnetic Radiation Hazard

NAV SEA TM-59310-AQ-SAF-010 Technical Manual for Batteries, Navy Lithium Safety Program, Air Vehicle Subsystems

NAV SEA TM-59310-AQ-SAF-010 Technical Manual for Batteries, Navy Lithium Safety Program, Air Vehicle Subsystems

(Copies of Naval Sea System Command documents may be obtained via Naval Air System Command, 1333 Isaac Hull Ave S. E., Washington Navy Yard, D. C. 20376, phone (202) 781-0000. Additional information is available online through the NAV SEA specs and standards website: http://www.navsea.navy.mil/specsAndstandards/. Copies of NAVSEA technical manuals can be ordered from the Naval Inventory Control Point (NAVICP), Mechanicsburg, PA. They can be ordered using the Naval Logistic Library (NLL) at http://www.nll.navsup.navy.mil/. Tech Manuals can also be acquired at Defense Automatic Addressing System Center Automatic Message Exchange System (DAMES), Standard Automated Logistic Tool Set (SALTS) or Naval Message.)

JOINT SERVICE DOCUMENTS

Joint Software System Safety Committee, Software System Safety Handbook: A Technical & Managerial Team Approach, Dec 1999. (For copies, call (301) 342-2350.)

Range Commander's Council (RCC) 316-98, Laser Range Safety

(Copies of DoD instructions and documents may be obtained via Secretariat, Range Commanders Council, ATTN CSTE-DTC-WS-RCC, Building 100 Room 138, White Sands Missile Range NM 88002-5110, Commercial (505) 678-1107/1108, DSN 258-1107. The Secretariat may be contacted via email: Secretariat (rcc@wsmr.army.mil, or online: http://jcs.mil/RCC/

DEPARTMENT OF DEFENSE DOCUMENTS

DoDD 3150.2 DoD Nuclear Weapon System Safety Program Manual

DoDD 4650.1 Management and Use of Radio Frequency Spectrum

DoD 6055.9-STD DoD Ammunition and Explosives Safety Standards

DEPARTMENT OF DEFENSE FORMS

DD Form 1494 Application for Equipment Frequency Allocation

DEPARTMENT OF DEFENSE INSTRUCTIONS

DoDI 5000.2 Operation of the Defense Acquisition System

DoDI 6055.11 Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers

DEPARTMENT OF DEFENSE TECHNICAL ORDER

| | |
|---|---|
| T. O. 11A-1-47 | DoD Ammunition and Explosives Hazard Classifications |

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

| | |
|---|---|
| ATP-56 | Air To Air Refueling, |
| STANAG 3098 | Aircraft Jacking |
| STANAG 3278 | Aircraft Towing Attachments and Devices |
| STANAG 3447 | Aerial Refueling Equipment Dimensional and Functional Characteristics |
| STANAG 4101 | Towing Attachments |

(Copies of NATO STANAGs may be obtained via SAF/AQRE, 1060 Air Force Pentagon, Washington D. C., DSN 223-3221.

FEDERAL AVIATION ADMINISTRATION CODE OF FEDERAL REGULATIONS (CFR)

| | |
|---|---|
| TITLE 14 | Aeronautics and Space |
| | Part 23, Airworthiness Standards: Normal, Utility, Aeronautic and Commuter Category Airplanes |
| | Part 25, Airworthiness Standards, Transport Category: Airplanes |
| | Part 27, Airworthiness Standards, Normal Category Rotorcraft |
| | Part 29, Airworthiness Standards, Transport Category: Rotorcraft |
| | Part 33, Airworthiness Standards, Aircraft Engines |
| | Part 133, Rotorcraft External-Load Operation |
| | SFAR 88, Special Federal Aviation Regulation, Fuel Tank System Fault Tolerance Evaluation Requirements |
| TITLE 21 | Food and Drugs, Part 1040, Subchapter J - Radiological Health, Performance Standards for Light-Emitting Products |

FEDERAL AVIATION ADMINISTRATION ADVISORY CIRCULARS (AC)

| | |
|---|---|
| AC 20-29 | Use of Aircraft Fuel Anti-icing Additives |
| AC 20-30 | Aircraft Position Light and Anti-Collision Light Installations |
| AC 20-41 | Substitute Technical Standard Order (TSO) Aircraft Equipment |
| AC 20-42 | Hand Fire Extinguishers for Use in Aircraft |
| AC 20-53 | Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning |
| AC 20-60 | Accessibility to Excess Emergency Exits |
| AC 20-115 | Radio Technical Commission for Aeronautic, Inc. Document RTCA/DO-178B |
| AC 20-119 | Fuel Drain Valves |
| AC 20-129 | Airworthiness Approval of Vertical Navigation (VNSV) Systems for use in the U.S. National Airspace System (NAS) and Alaska |

| | |
|---|---|
| AC 20-130 | Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors |
| AC 20-136 | Protection of Aircraft Electrical/Electronic Systems against the Indirect Effects of Lightning |
| AC 20-145 | Guidance for Integrated Modular Avionics (IMA) that Implement TSO-C153 Authorized Hardware Elements |
| AC 25-9 | Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures |
| AC 25-16 | Electrical Fault and Fire Prevention and Protection |
| AC 25-17 | [Large AC] Transport Airplane Cabin Interiors Crashworthiness Handbook |
| AC 25.853-1 | Flammability Requirements for Aircraft Seat Cushions |
| AC 25.869-1 | Electrical System Fire and Smoke Protection |
| AC 25.963-1 | Fuel Tank Access Covers |
| AC 25.981-1 | Fuel Tank Ignition Source Prevention Guidelines |
| AC 25.981-2 | Fuel Tank Flammability Minimization |
| AC 25.994-1 | Design Considerations to Protect Fuel Systems During a Wheels-Up Landing |
| AC 27-1 | [Large AC] Certification of Normal Category Rotorcraft |
| AC 29-2 | [Large AC] Certification of Transport Category Rotorcraft |
| AC 33-1 | Turbine Engine Foreign Object Ingestion and Rotor Blade Containment Type Certification Procedures |
| AC 33-2 | Aircraft Engine Type Certification Handbook |
| AC 33-3 | Turbine and Compressor Rotors Type Certification Substantiation Procedures |
| AC 33-4 | Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines |
| AC 33-5 | Turbine Engine Rotor Blade Containment/Durability |
| AC 33.4-2 | Instructions for Continued Airworthiness: In-Service Inspection of Safety Critical Turbine Engine Parts at Piece-Part Opportunity |
| AC 33.28-1 | Compliance Criteria for 14 CFR 33.28, Aircraft Engines, Electrical and Electronic Engine Control Systems |
| AC 43.13-1 | [Large AC. This includes Change 1.] Acceptable Methods, Techniques, and Practices- Aircraft Inspection |
| AC 90-96 | Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (B-RNAV) and Precision Area Navigation (P-RNAV), |
| AC 90-97 | Use of Barometric Vertical Navigation (VNAV) for Instrument Approach Operations Using Decision Altitude |
| AC 120-40 | Airplane Simulator Qualification |

AC 120-42 Extended Range Operation with Two-Engine Airplanes (ETOPS)

AC 120-63 Helicopter Simulator Qualification

FEDERAL AVIATION ADMINISTRATION HANDBOOK)

DOT/FAA/AR-MMPDS-01 Metallic Materials Properties Development and Standardization (MMPDS)

FEDERAL AVIATION ADMINISTRATION TECHNICAL STANDARDS ORDERS (TSOs)

TSO C70A Life Rafts (Reversible and Nonreversible)

TSO C77B Gas Turbine Auxiliary Power Units

TSO C112 Air Traffic Control Radar Beacon System/Mode Select (ATCRBS) Airborne Equipment

TSO C153 Integrated Modular Avionics Hardware Elements

(Copies of Federal Aviation Administration Regulations may be viewed at http://www.faa.gov, or may be obtained from the Federal Aviation Administration, 800 Independence Ave., SW, Washington, DC 20591.)

**2.1.3** Non-Government publications.

The following non-Government publications form a part of this document to the extent specified herein.

Aerial Refueling Systems Advisory Group (ARSAG)

ARSAG 00-03-01 Aerial Refueling Pressure Definitions and Terms

(Copies of ARSAG may be obtained via ARSAG International, P. O. Box 54903, Cincinnati, OH 45254-0903 phone (937) 429-7014; order online at http://www/arsaginc.com.)

Aeronautical Radio, Inc (ARINC)

ARINC Report 609 Design Guidance for Aircraft Electrical Power Systems

(Application for copies should be addressed to the Aeronautical Radio, Inc (ARINC), Annapolis (International Headquarters), 2551 Riva Road, Annapolis, MD 21401-7435, phone: 410-266-4000, or 301-858-4000; order online at http://www.arinc.com/.)

American Society of Mechanical Engineers

ASME Y14.5 Dimensioning and Tolerancing

(Application for copies should be addressed to the ASME Headquarters, Three Park Avenue, New York, NY 10016-5990, phone: 212-591-7722; order online at http://www.asme.org.)

American Society of Testing and Materials and Listing (ATSM)

ASTM-F33a Enclosure, Aerospace Transparent, Bird Impact, Testing of

(Application for copies should be addressed to the ASTM, 100 Barr Harbor, Drive, West Conshohocken, PA 19428-2959, phone☹610) 832-9585; order online at http://www.astm.org.)

Government Electronics and Information Technologies Association

EIA 649 National Consensus Standard for Configuration Management

(Application for copies should be addressed to the Engineering Industries Alliance (EIA), Technology Strategy and Standards Department, 2500 Wilson Boulevard, Arlington, VA 22201; order online at http://www.eia.org/technology.)

Institute for Electronic and Electrical Engineers (IEEE)

IEEE/EIA 12207.0 Software Life Cycle Processes; Industry Implementation of ISO/IEC 12207: 1995 Standard for Information Technology (DoD adopted)

IEEE/EIA 12207.1 Software Life Cycle Processes - Life Cycle Data; Industry Implementation of ISO/IEC 12207: 1995 Standard for Information Technology (DoD adopted)

IEEE/EIA 12207.2 Software Life Cycle Processes – Implementation Considerations: Industry Implementation of ISO/IEC 12207: 1995 Standard for Information Technology (DoD adopted)

(Application for copies should be addressed to the IEEE Corporate Office, 3 Park Avenue, 17th Floor, New York, NY 10016-5997 U.S.A.; order online at: IEEE Customer Service, customer-service@ieee.org)

National Fire Protection Association (NFPA)

NFPA 70 National Electrical Code

(Application for copies should be addressed to the National Fire Protection Association, 1 Battery March Park, Quincy, MA 02269-9101, phone: (617) 770-3000; order online at http://www.nfpa.org.)

Occupational Safety & Health Administration (OSHA)/American National Standards Institute

ANSI Z136.1 American National Standard for Safe Use of Lasers

(Application for copies should be addressed to the American National Standards Institute, 11 West 42nd Street, New York NY 10036; order online at http://www.ansi.org.)

Radio Technical Commission for Aeronautics (RTCA)

DO 160 Environmental Conditions and Test Procedures for Airborne Equipment

DO 178 Software Considerations in Airborne Equipment and Equipment Certification

DO 181 Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRB/Mode S) Airborne Equipment (ERRATA)

DO 185 Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Airborne Equipment

DO 186 Minimum Operational Performance Standards for Radio Communications Equipment Operating Within the Radio Frequency Range 117.975 – 137 MHz

DO 200 Standards for Processing Aeronautical Data

DO 212 Minimum Operational Performance Standards for Airborne Automatic Dependent Surveillance (ADS) Equipment

| | |
|---|---|
| DO 219 | Minimum Operational Performance Standards for ATC Two-Way Data Link Communications |
| DO 254 | Design Assurance Guidance for Airborne Electronic Hardware |
| SC 189 | Operational Safety Assessment |

(Application for copies should be addressed to the RTCA, Inc., 1828 L Street N. W., Suite 805, Washington D. C. 20036, phone: (202) 833-9339; order online at http://www.rtca.org.)

Society of Allied Weight Engineers (SAWE) Recommended Practices (RP)

| | |
|---|---|
| SAWE RP7 | Weight and Balance Control System (for Aircraft and Rotorcraft) |
| SAWE RP8 | Weight and Balance Data Reporting Forms for Aircraft (including Rotorcraft) |

(Application for copies should be addressed to the Society of Allied Weight Engineers, P. O. Box 60024, Terminal Annex, Los Angeles, CA 90060; order online at http://www.sawe.org.)

Society of Automotive Engineers (SAE)

| | |
|---|---|
| AIR 1419 | Inlet Total-Pressure-Distortion Considerations for Gas-Turbine Engines (DoD adopted) |
| AIR 4845 | The FMECA Process in the Concurrent Engineering (CE) Environment |
| AIR 5826 | Distortion Synthesis/Estimation Techniques |
| ARP 994 | Recommended Practice for the Design of Tubing Installations for Aerospace Fluid Power Systems (DoD adopted) |
| ARP 1070 | Design and Testing of Antiskid Brake Control Systems for Total Aircraft Compatibility |
| ARP 1420 | Gas Turbine Engine Inlet Flow Distortion Guidelines (DoD adopted) |
| ARP 1493 | Wheel and Brake Design and Test Requirements for Military Aircraft |
| ARP 1538 | Arresting Hook Installation, Land Based Aircraft, Emergency |
| ARP 1870 | Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety |
| ARP 4754 | Certification Considerations for Highly-Integrated or Complex Aircraft Systems |
| ARP 4761 | Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment |
| ARP 5412 | Aircraft Lightning Environment and Related Test Waveforms |
| ARP 5583 | Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment |
| AS 1055 | Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components (DoD adopted) |
| AS 1831 | Electrical Power, 270 V DC, Aircraft, Characteristics and Utilization Of |
| AS 9100 | Quality Management Systems - Aerospace - Requirements (DoD adopted) |

AS 50881 Wiring Aerospace Vehicle (DoD adopted)

(Application for copies should be addressed to the SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001; order online at http://www.sae.org/.)

# 3. DEFINITIONS & ABBREVIATIONS

## 3.1 Definitions.

All definitions, unless otherwise referenced, are to be considered within the context of this document.

**3.1.1** Advisory circular (AC) - The Federal Aviation Administration (FAA) issues advisory circulars (AC) to inform the aviation public, in a systematic way, of nonregulatory material. Unless incorporated into a regulation by reference, the contents of an advisory circular are not binding on the public. Advisory circulars are issued in a numbered-subject system corresponding to the subject areas of the Title 14, Code of Federal Regulations (14CFR reference), Chapter I, Federal Aviation Administration. An AC is issued to provide guidance and information in a designated subject area or to show a method acceptable to the Administrator for complying with a related FAR. When using 14CFR references for compliance with airworthiness certification criteria, consult applicable ACs for guidance.

**3.1.2** Air system - An air vehicle plus the training and support systems for the air vehicle, and any weapons to be employed on the air vehicle. (JSSG-2000).

**3.1.3** Air vehicle - An air vehicle includes the installed equipment (hardware and software) for airframe, propulsion, air vehicle applications software, air vehicle system software, communications/identification, navigation/guidance, central computer, fire control, data display and controls, survivability, reconnaissance, automatic flight control, central integrated checkout, antisubmarine warfare, armament, weapons delivery, auxiliary equipment, and all other installed equipment. (JSSG-2001)

**3.1.4** Airworthiness - The property of a particular air system configuration to safely attain, sustain, and terminate flight in accordance with the approved usage and limits.

**3.1.5** Airworthiness certification - A repeatable process implemented to verify that a specific air vehicle system can be, or has been, safely maintained and operated within its described flight envelope. The two necessary conditions for issuance and maintenance of an airworthiness certificate are 1) the aircraft must conform to its type design as documented on its type certificate, and 2) the aircraft must be in a condition for safe operation.

**3.1.6** Allocated baseline - The approved, performance-oriented documentation, for a configuration item (CI) to be developed, which describes the functional and interface characteristics that are allocated from those of the higher level CI and the verification required to demonstrate achievement of those specified characteristics. [Ref: MIL-HDBK-61A]

**3.1.7** Baseline (configuration) - (1) An agreed-to description of the attributes of a product at a specified point in time, which serves as a basis for defining change. (2) An approved and released document or set of documents, each of a specific revision, the purpose of which is to provide a defined basis for managing change. (3) The currently approved and released configuration documentation. (4) A released set of files consisting of a software version and associated configuration documentation. [Ref: EIA 649]

**3.1.8** Certification basis - The tailored, complete (necessary and sufficient), documented set of MIL-HDBK-516 airworthiness criteria utilized to assess the safety of a specific system design.

**3.1.9** Chief engineer - The individual responsible for all system technical activities on a single air vehicle system, in support of the system program manager.

**3.1.10** Configuration control - (1) A systematic process that ensures that changes to a baseline are properly identified, documented, etc. (2) The configuration management activity concerning: the systematic proposal, justification, evaluation, coordination, and disposition of proposed changes; and the implementation of all approved and released changes into (a) the applicable configurations of a product, (b) associated product information, and (c) supporting and interfacing products and their associated product information. [Ref: EIA 649]

**3.1.11** Configuration item (CI) - A configuration item is any hardware, software, or combination of both that satisfies an end use function and is designated for separate configuration management. Configuration items are typically referred to by an alphanumeric identifier which also serves as the unchanging base for the assignment of serial numbers to uniquely identify individual units of the CI [Ref: MIL-HDBK-61A].

**3.1.12** Configuration management - A management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design, and operational information throughout its life. [Ref: EIA 649]

**3.1.13** Configuration status accounting - The configuration management activity concerning capture and storage of, and access to, configuration information needed to manage products and product information effectively. [Ref: EIA 649]

**3.1.14** Critical safety item (CSI) - A part, assembly, installation equipment, launch equipment, recovery equipment, or support equipment for an aircraft or aviation weapons system that contains a characteristic, any failure, malfunction, or absence of which could cause a catastrophic or critical failure resulting in the loss or serious damage to the aircraft or weapons system, an unacceptable risk of personal injury or loss of life, or an uncommanded engine shutdown that jeopardizes safety. Damage is considered serious or substantial when it would be sufficient to cause a "Class A" accident or a mishap of severity category I. The determining factor in CSIs is the consequence of failure, not the probability that the failure or consequence would occur. For the purpose of this instruction, "critical safety item", "flight safety aircraft critical part", "flight safety part", "safety of flight item", and similar terms are synonymous. The term critical safety item shall be the encompassing term used throughout this instruction. [Ref: Joint Aeronautical Commanders' Group Memorandum, 22 Jan 04, "Proposed Instruction on Management of Aviation Critical Safety Items (CSIs)"]

**3.1.15** End-item - Equipment that can be used by itself to perform a military function or provides an enhanced military capability to a system and has a distinct management activity to control its technical and performance baseline. [Ref: MIL-HDBK-514]

**3.1.16** Failure modes, effects, and criticality analysis (FMECA) - A procedure for identifying potential failure modes in a system and classifying them according to their severity. A FMECA is usually carried out progressively in two parts. The first part identifies failure modes and their effects (also known as failure modes and effects analysis). The second

part ranks the failure modes according to the combination of their severity and the probability of occurrence (criticality analysis).

**3.1.17** Flight critical - A term applied to any condition, event, operation, process, or item whose proper recognition, control, performance, or tolerance is essential to achieving or maintaining controlled flight of an aircraft.

**3.1.18** Functional baseline - The approved configuration documentation describing a system's or top-level configuration item's performance (functional, interoperability, and interface characteristics) and the verification required to demonstrate the achievement of those specified characteristics. [Ref: MIL-HDBK-61A]

**3.1.19** Hazard - (1) A condition that is prerequisite to a mishap. [Ref: MIL-STD-882C] (2) Any real or potential condition that can cause injury, illness, or death to personnel, or damage to or loss of property. [Ref: MIL-STD-882D]

**3.1.20** Integrity - Refers to the essential characteristics of a system, subsystem, or equipment that allows specific performance, reliability, safety, and supportability to be achieved under specified operational and environmental conditions over a specific service life. [Ref: MIL-HDBK-87244]

**3.1.21** Interface - The performance, functional, and physical attributes required to exist at a common boundary. [Ref: EIA 649]

**3.1.22** Lead engineer - The individual responsible for all end-item technical activities, including engineering and configuration changes, in support of the end-item system program manager and/or chief engineer.

**3.1.23** Mishap - An unplanned event or series of events resulting in death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment. [Ref: MIL-STD-882D]

**3.1.24** Mission critical - A term applied to any condition, event, operation, process or item, the failure of which may result in the inability to achieve successful mission completion or to maintain combat capability.

**3.1.25** Passenger - Any person on board an air vehicle who is not mission trained regarding the passenger safety/emergency capabilities of that particular air vehicle and mission. For a specific flight, this includes any person who does not have active crewmember duties and is not essential for accomplishing mission tasks. NOTE: Mission training constitutes specialized air vehicle training beyond preflight safety briefings.

**3.1.26** Performance - A quantitative or qualitative measure characterizing a physical or functional attribute relating to the execution of an operation or function. Performance attributes include quantity (how many or how much), quality (how well), coverage (how much area, how far), timeliness (how responsive, how frequent), and readiness (availability, mission/operational readiness). Performance is an attribute for all systems, people, products, and processes including those for development, production, verification, deployment, operations, support, training, and disposal. Thus, supportability parameters, manufacturing process variability, reliability, and so forth are all performance measures.

**3.1.27** Product baseline - The approved technical documentation which describes the configuration of a CI during the production, fielding/deployment and operational support phases of its life cycle. The product baseline prescribes all necessary physical or form, fit, and function characteristics of a CI, the selected functional characteristics designated for production acceptance testing, and the production acceptance test requirements (MIL-HDBK-61A). When used for reprocurement of a CI, the product baseline documentation also includes the allocated configuration documentation to ensure that performance requirements are not compromised.

**3.1.28** Remotely operated aircraft (ROA) - A remotely operated, semi-autonomous, or autonomous aircraft and its operating system. This does not include air vehicles designed for one-time use as a weapon (e.g., cruise missile). The operating system can be built into the aircraft or be part of the control station for remotely operated vehicles. This "system" includes the control station, data links, flight control system, communications systems/links, etc., as well as the aircraft. [Ref: FAA Order 7610.4K and AFI 202 V3]

**3.1.29** Safety critical - A term applied to any condition, event, operation, process, or item whose proper recognition, control, performance, or tolerance is essential to safe system operation.

**3.1.30** Safety-of-flight (SOF) - The property of a particular air system configuration to safely attain, sustain, and terminate flight within prescribed and accepted limits for injury/death to personnel and damage to equipment, property, and/or environment. The intent of safety-of-flight clearance is to show that appropriate risk management has been completed and the level of risk (hazards to system, personnel, property, equipment, and environment) has been appropriately identified and accepted by the managing activity prior to flight of the air system.

**3.1.31** SOF items or equipment - Items or equipment that, if they failed, have the potential for precluding the continued safe flight of the air vehicle within prescribed and accepted limits for injury/death to personnel and damage to equipment, property, and/or environment.

**3.1.32** System - A specific grouping of end-items, subsystems, components, or elements designed and integrated to perform a military function.

**3.1.33** System program manager (SPM) - The single individual specifically designated to be responsible for the life cycle management of a system or end-item. The system program manager is vested with full authority, responsibility, and resources to execute and support an approved program. [Ref: DoDI 5000.2]

**3.1.34** System safety - The application of engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operational effectiveness and suitability, time, and cost, throughout all phases of the system life cycle. [Ref: MIL-STD-882D]

**3.1.35** Type certification - A repeatable process implemented to verify that an air vehicle design conforms to it's type design. It does not verify that the system has been properly maintained or operated in accordance with its technical data. (See airworthiness certification.)

**3.1.36** Type design - The type design consists of:

a. The drawings and specifications, and a listing of those drawings and specifications, necessary to define the configuration and the design features of the air system shown to comply with the airworthiness criteria applicable to the air system;

b. Information on dimensions, materials, materiel properties, and processes necessary to define the structural strength of the product;

c. Any airworthiness limitations required for safe operation and maintenance;

d. Any other data necessary to allow, by comparison, the determination of the airworthiness, noise characteristics, fuel venting, and exhaust emissions (where applicable) of later products of the same type.

**3.1.37** Unmanned aerial vehicle (UAV) - A remotely piloted, semi-autonomous, or autonomous air vehicle and its operating system. This does not include air vehicles designed for one-time use as a weapon (e.g., cruise missile). The operating system can be built into the vehicle or be part of the control station for remotely piloted vehicles. This “system” includes the control station, data links, flight control system, communications systems/links, etc., as well as the air vehicle. [Ref: NAVAIRINST 13034.2]

**3.1.38** Vehicle control functions (VCFs) - VCFs include all functions and their associated components used to transmit flight control commands from the pilot and/or other sources to appropriate force and moment producers. Flight control commands may result in control of aircraft flight path, attitude, airspeed, aerodynamic configuration, ride, and structural modes. Integrated VCFs are a combination of flight controls and any other air vehicle functions or subsystems that cause, augment, or replace pilot initiated commands or provide basic, necessary data/information for the flight control subsystem to function and ensure safety of flight.

## 3.2 Abbreviations and acronyms.

| | |
|---|---|
| 14CFR | Title 14, Code of Federal Regulations |
| AC | advisory circulars |
| ADS | Aeronautical Design Standard |
| AFGS | Air Force Guide Specification |
| AFI | Air Force Instruction |
| AFPD | Air Force Policy Directive |
| AFR | Air Force Regulation |
| APC | aircraft pilot coupling |
| APS | auxiliary power system |
| APU | auxiliary power unit |
| AR | Army Regulation |
| ARSAG | Aerial Refueling Systems Advisory Group |
| BARO VNAV | barometric vertical navigation |
| BIT | built-in-test |
| CAD | cartridge actuated devices |
| CDR | critical design review |
| CFD | computational fluid dynamics |

| | |
|---|---|
| CFR | Code of Federal Regulations |
| C.G. | center of gravity |
| CI | configuration item |
| CNS/ATM | communication, navigation, surveillance/air traffic management |
| Comm'l | commercial |
| CSA | configuration status accounting |
| CSCI | computer software configuration item |
| CSI | critical safety item |
| DoD | Department of Defense |
| DOD | domestic object damage |
| ECP | engineering change proposal |
| ECS | environmental control system |
| $E^3$ | electromagnetic environmental effects |
| EHMS | engine health monitoring systems |
| EMI | electromagnetic interference |
| EMP | electromagnetic pulse |
| EMS | environmental management system |
| EPS | emergency power system |
| FAA | Federal Aviation Administration |
| FAR | Federal Acquisition Regulation |
| FCA | functional configuration audit |
| FMECA | failure modes, effects, and criticality analysis |
| FMET | failure modes and effects testing |
| FOD | foreign object damage |
| FRACAS | failure report and corrective action system |
| FSCAP | flight safety critical aircraft part |
| g | acceleration or load factor in units of acceleration of gravity |
| HCF | high cycle fatigue |
| HERF | hazards of electromagnetic radiation to fuel |
| HERO | hazards of electromagnetic radiation to ordnance |
| HERP | hazards of electromagnetic radiation on personnel |
| HUD | head-up display |
| ICD | interface control document |
| I/O | input/output |
| JACG | Joint Aeronautical Commanders Group |
| JFS | jet fuel starter |
| JSSG | Joint Service Specification Guide |
| LCF | low cycle fatigue |
| LEP | laser eye protection |
| MSL | mean sea level |
| MWL | maximum wear limit |
| NATO | North Atlantic Treaty Organization |

| | |
|---|---|
| NBC | nuclear, biological, and chemical |
| NDI | nondestructive inspection |
| NFPA | National Fire Protection Association |
| NVIS | night vision imaging system |
| OFP | operational flight program |
| PAD | pyrotechnic actuated devices |
| PCA | physical configuration audit |
| PDR | preliminary design review |
| PFR | primary flight reference |
| PIO | pilot-induced oscillations |
| PLA | power lever angle |
| PLOC | probability loss of control |
| POD | probability of detection |
| PTO | power take-off |
| PVI | pilot vehicle interface |
| RAT | ram air turbine |
| RF | radio frequency |
| RNAV | radio navigation |
| RNAV VNAV | area navigation vertical navigation |
| RNP | required navigation performance |
| ROA | remotely operated aircraft |
| RVSM | reduced vertical separation minima |
| RTO | refused takeoff |
| SAE | Society of Automotive Engineers |
| SAWE | Society of Allied Weight Engineers |
| SDIMP | software development integrity master plan |
| SDP | software development plan |
| SFAR | Special Federal Aviation Regulation |
| SOF | safety-of-flight |
| SPM | system program manager |
| SRS | software requirements specification |
| SSHA | subsystem hazard analysis |
| STANAG | standardization agreement |
| STLDD | software top-level design document |
| TBD | to be determined |
| TEMP | test and evaluation master plan |
| T.O. | technical order |
| TSO | technical standard order |
| UAV | unmanned aerial vehicle |
| VCF | vehicle control function |
| VCMS | vehicle control and management system |
| $V_L/M_L$ | limit speed |

## 4. SYSTEMS ENGINEERING

The following criteria apply to all air vehicle systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

TYPICAL CERTIFICATION SOURCE DATA

1. Reliability, quality, and manufacturing program plans
2. Contractor policies and procedures
3. Durability and damage tolerance control plans
4. Work instructions
5. Process specifications
6. Production/assembly progress reports
7. Quality records
8. Defect/failure data
9. Failure modes, effects, and criticality analysis (FMECA) documentation
10. Tech data package
11. As-built list to include part numbers/serial numbers for all critical safety items/components
12. List of deviations/waivers and unincorporated design changes
13. List of approved class I engineering change proposals (ECPs)
14. Proposed DD Form 250, Material Inspection and Receiving Report
15. Configuration management plans/process description documents
16. Diminishing Manufacturing Sources Plan
17. Obsolete Parts Plan
18. Test reports
19. Test plans
20. FAA Airworthiness Directives and Advisory Circulars
21. Manufacturer-issued service bulletins
22. Civil aviation authority certification plan
23. Civil aviation authority certification basis
24. Civil aviation authority certification report
25. System Safety Analysis Report

CERTIFICATION CRITERIA

## 4.1 Design criteria.

FAA Doc: 14CFR references: 23.21, 23.601-23.629, 25.601-25.631

**4.1.1** Verify that the design criteria, including requirements and rules, adequately address safety for mission usage, full permissible flight envelope, duty cycle, interfaces, induced and natural environment, inspection capability, and maintenance philosophy.

Standard: Allocated high level mission and safety requirements down through the design hierarchy are defined. Allocated design criteria for all system elements and components result in required levels of safety throughout the defined operational flight envelope, usage, and life.

Compliance: Process documentation describes requirements allocation and design criteria definition. Traceability is shown among requirements, design solutions, and verification analyses and tests. Adequacy of design criteria to meet top level safety & airworthiness requirements is substantiated.

DoD/MIL Doc: Appropriate design criteria paragraphs of JSSG-2000, 2001, 2005, 2006, 2007, 2008, 2009, 2010, and others.

FAA Doc: 14CFR references: 23.21-23.3, 25.21-25.33

**4.1.2** Verify that the design criteria address all components, system and subsystem interfaces, and software.

Standard: Critical safety items (CSIs) inherent in the system design solution are defined. Design criteria and critical characteristics of these CSIs are defined, substantiated, and documented in sufficient detail to allow "form, fit, function, and interface" replacement without degrading system airworthiness.

Compliance: Documentation describes the process used to identify CSIs, and associated design criteria and critical characteristics. CSIs, design criteria, and critical characteristics resulting from this process are documented.

DoD/MIL Doc: Appropriate design criteria paragraphs of JSSG-2000, 2001, 2005, 2006, 2007, 2008, 2009, 2010, and others.

FAA Doc: 14CFR references: 23.21, 23.601-23.629, 25.601-25.631

**4.1.3** Verify that, for commercial derivative air vehicles, the air vehicle's certification basis addresses all design criteria appropriate for the planned military usage.

Standard: Commercial derivative aircraft have been assessed for their suitability for the intended military application and determined to be capable and safe.

Compliance: Intended military utilization and flight envelope of the air vehicle are shown to be wholly within the existing commercial certification basis OR the military air vehicle airworthiness certification addresses "delta" conditions and environments over and above those covered by the commercial certification. Substantiation provided that the air vehicle is suitable for its intended military usage.

DoD/MIL Doc: Appropriate design criteria paragraphs of JSSG-2000, 2001, 2005, 2006, 2007, 2008, 2009, 2010, and others.

FAA Doc: 14CFR references: 23.21, 23.601-23.629, 25.601-25.631

**4.1.4** Verify that failure conditions have been adequately addressed in the design criteria.

Standard: The air vehicle design and utilization result in a maximum occurrence rate of non-combat related catastrophic events (i.e., loss of vehicle or an event resulting in a human casualty) of one event per one million flight hours.

Compliance: A hazard analysis describes the relationship of defined critical safety items to the probability of catastrophic event occurrence. Allowable operating envelopes, classes of airspace, restrictions and placard limitations are defined. Analysis ground rules and assumptions are included. Suitability of the design criteria for critical items to achieve required level of safety is substantiated.

## 4.2 Tools and databases.

**4.2.1** Verify that all tools, methods, and databases used in the requirements definition/allocation, design, risk control and assessments of safety have been adequately validated and/or certified.

Standard: Design and performance verification analysis tools, prediction methods, models, and/or simulations are applied appropriately and exhibit accuracy commensurate with their application.

Compliance: Analysis tools, software packages, and simulations used to produce or verify flight critical product designs have been proven to achieve required accuracy through techniques like benchmarking against test results. Tool sets under configuration control to preclude unauthorized modifications.

DoD/MIL Doc: Appropriate design criteria paragraphs of JSSG-2000, 2001, 2005, 2006, 2007, 2008, 2009, 2010, and others.

FAA Doc: Refer to technical point of contact for this discipline (listed in section A.2).

## 4.3 Materials selection.

**4.3.1** Verify that the material selection process uses validated and consistent material properties data, including design mechanical and physical properties such as material defects, and corrosion and environmental protection requirements. (For Navy aircraft, see section 19, Materials)

Standard: Material selection process selects materials covered by an industry specification or government specification (Military or Federal). Draft specifications are acceptable assuming that the draft will be submitted to the SAE Aerospace Materials Division or a draft ASTM standard will be transmitted to the American Society for Testing and Materials for publication. The draft describes a product which is commercially available on a production basis, and standard manufacturing procedures are established for the fabrication and processing of production material.

Compliance: Verification by document inspection. Materials are covered by AMS specification issued by SAE Aerospace Materials Division or an ASTM standard published by the American Society for Testing and Materials, or a government specification (Military or Federal). If a public specification for the product is not available, a draft specification has been prepared.

FAA Doc: DOT/FAA/AR-MMPDS-01

## 4.4 Manufacturing and quality.

**4.4.1** Verify that key product characteristics have been identified.

Standard: Physical characteristics which are key to the successful function of critical safety items (CSIs) and components are defined and documented. Tolerance allowances for each characteristic and traceability through the design hierarchy are defined, and the effects of adverse tolerance accumulation at higher (e.g., above the CSI) levels of product assembly are analyzed and reflected in the design documentation

Compliance: Key product characteristic and tolerance definitions are verified by inspection and analysis of program design documentation at the applicable levels of the product hierarchy.

Comm'l Doc: ASME Y14.5 "Dimensioning and Tolerancing"

AS 9100

DoD/MIL Doc: ASC/EN Manufacturing Development Guide, Section 6.5, "Key Characteristics and Processes",

AFI 63-501

FAA Doc: 14CFR reference: 23.601-23.605, 25.601-25.603

**4.4.2** Verify that all critical process capabilities exist to meet key product characteristic requirements.

Standard: All key characteristics are mapped to corresponding critical processes. Critical process capabilities are characterized and process capability indices (Cpk) are calculated. Process control plans for critical processes are defined and implemented.

Compliance: Critical process capabilities and control plans are verified by inspection of design documentation throughout the supply chain.

Comm'l Doc: AS 9100

DoD/MIL Doc: ASC/EN Manufacturing Development Guide, Section 6.6, "Variability Reduction", for additional information on Cpk, Critical Processes, and Process Control Plans;

AFI 63-501

FAA Doc: 14CFR references: 23.601-23.605, 25.601-25.603

**4.4.3** Verify that all critical process controls exist to assure key product characteristic requirements are met.

Standard: Work and inspection instructions are defined, documented, and implemented for all critical manufacturing processes. Cpk of at least 1.33 is maintained for critical manufacturing processes. Quantitative product quality criteria (i.e., product acceptance criteria) are defined and used for product acceptance at all levels of the product hierarchy up to and including the air vehicle level.

Compliance: Work and product inspection instructions, product acceptance criteria are verified by inspection. Cpk is verified by analysis and inspection of design documentation and manufacturing process capability data. Design conformance (i.e., "as built" configuration is in accordance with design requirements) is verified by first article inspections, review of manufacturing process control data, and/or periodic hardware quality audits.

Comm'l Doc: AS 9100

DoD/MIL Doc: ASC/EN Manufacturing Development Guide

AFI 63-501

Joint Aeronautical Commander's Group's Performance Based Product Definition Guide, Section 5.0, "Performance Based Approach", for additional information on Product Acceptance Criteria.

FAA Doc: 14 CFR references: 23.601-23.605, 25.601-25.603

**4.4.4** Verify that production allowances and tolerances are within acceptable limits and assure conformance to design.

Standard: A Quality System is in place to assure the as-built configuration matches the as-designed configuration. The system is oriented towards defect prevention and achieving stable, capable processes. The system employs effective methods for conducting root cause analyses and implementing corrective actions.

Compliance: Compliance is determined by inspection of the Quality System's policies, processes and

procedures and examples of Material Review Board records

Comm'l Doc: AS 9100

DoD/MIL Doc: ASC/EN Manufacturing Development Guide, Section 5, "Quality Systems", and Section 6.6 "Variability Reduction"

AFI 63-501

Joint Aeronautical Commander's Group's "Engineering and Manufacturing Practices for Defect Prevention"

FAR Part 46, "Quality Assurance"

FAA Doc: 14CFR reference: 23.601-23.605, 25.601-25.603;

**4.4.5** Verify that nondestructive inspection (NDI) accept/reject criteria have been validated.

Standard: No additional clarification required.

Compliance: Compliance is determined by inspection, e.g., reviewing samples of work instructions, inspection instructions, and Acceptance Test Procedures to assure they match design requirements and result in conforming product. This may be accomplished during First Article Inspections, Physical Configuration Audits, etc.

DoD/MIL Doc: JSSG-2006 Appendix A: A.3.11.6, A.4.11.6

FAA Doc: Refer to technical point of contact for this discipline (listed in section A.2).

## 4.5 Operator's and maintenance manuals/technical orders.

FAA Doc: 14CFR reference: 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

**4.5.1** Verify that processes are in place to identify and document all restrictions, warnings, and cautions.

Standard: Operator's handbooks or manuals identify all applicable restrictions, warnings, and cautions. These items are identified in such a manner as to attract attention and set them apart from normal text. When an unsafe condition is detected and annunciated, the Airplane Flight Manual (AFM) has clear and precise corrective procedures for handling the failure without an excessive increase in workload.

Compliance: Process documentation describes procedures for deriving restrictions, warnings, and cautions from system technical data. Operating manuals incorporate appropriate cautions. Process descriptions include methods for updating this information as needed.

DoD/MIL Doc: MIL-STD-38784, Standard Practice for Manuals, Technical: General Style and Format Requirements

FAA Doc: 14CFR reference: 23.1581, 25.1581, 23.1541, 25.1541.

**4.5.2** Verify that processes are in place to identify and document the technical data, and that the technical data reflects the defined functional and product baseline.

Standard: Process is defined, documented, and implemented to update product requirement, design, manufacturing, and/or maintenance data which is used to generate technical manuals (e.g., operators handbooks, maintenance manuals). Maximum timelines to accomplish updates are consistent with the criticality of the change activity (e.g., an identified safety hazard or a performance based change having a safety impact).

Compliance: Adequacy of change/update process for technical data verified by inspection of process documentation. Examples of revised design or maintenance data provided to verify traceability back to change "event".

DoD/MIL Doc: MIL-STD-38784, Standard Practice for Manuals, Technical: General Style and Format

Requirements.

FAA Doc: 14CFR reference: 23.21, 25.21, 23.601, 25.601, 23.1301, 25.1301

**4.5.3** Verify that procedures are in place for establishing and maintaining flight vehicle integrity.

Standard: Process is defined, documented, and implemented to accomplish timely updates to operator and maintenance manuals as made necessary by product design changes, identified safety issues (e.g., class I DRs), or changes in ops concepts or usage. Current updated technical data is used to effect technical manual revisions. Maximum timelines to incorporate changes in manuals are based on the impact of the change or the severity of the identified hazard.

Compliance: Adequacy of change/update process for technical manuals verified by inspection of process documentation. Examples of change pages provided to verify traceability back to change "event".

DoD/MIL Doc: MIL-HDBK-515, Weapon System Integrity Guide

MIL-STD-1530, Aircraft Structural Integrity Program

MIL-HDBK-87244, Avionics/Electronics Integrity

JSSG-2001A: para 3.3.5.1, 3.3.7.1

JSSG-2009: Appendix I

## 4.6 Configuration identification.

**4.6.1** Verify that the functional baseline is properly documented, established, and brought under configuration control.

Standard: Configuration Control Process is in place to preclude unauthorized changes.

Compliance: Configuration Control Plan is defined and implemented in accordance with the contract.

DoD/MIL Doc: MIL-STD-961E, Defense and Program Unique Specifications Format and Content, Appendix A;

MIL-HDBK-61A, Configuration Management, sections 3, and 5.5.1 Configuration Baselines for definitions and purposes of configuration baselines

FAA Doc: 14CFR reference: 23.21, 25.21, 23.601, 25.601, 23.1301, 25.1301

**4.6.2** Verify that the product baseline is properly documented, established, and brought under configuration control.

Standard: Configuration Control Process is in place to preclude unauthorized changes.

Compliance: Configuration Control Plan is defined and implemented in accordance with the contract. Inspection of the Engineering Release System verifies adequate capture of all changes to the technical documentation.

DoD/MIL Doc: MIL-STD-961E, Defense and Program Unique Specifications Format and Content, Appendix A;

MIL-HDBK-61A, Configuration Management, sections 3, and 5.5.1 Configuration Baselines for definitions and purposes of configuration baselines

FAA Doc: 14CFR reference: 23.21, 25.21, 23.601, 25.601, 23.1301, 25.1301

## 4.7 Configuration status accounting.

**4.7.1** Verify that the configuration status accounting (CSA) information system has the capability to track the configuration of safety-critical items.

Standard: No further clarification required.

Compliance: CSA process documentation is verified by inspection. Inspection of records and reports for CI/CSCIs verifies accuracy of the configuration status accounting system and that the system is able to track and record changes to the configuration.

DoD/MIL Doc: MIL-HDBK-61A, Configuration Management, section 7 Configuration Status Accounting for purpose of CSA, lifecycle considerations, and information to be captured.

FAA Doc: 14CFR reference: 23.21, 25.21, 23.601, 25.601, 23.1301, 25.1301

## 5. STRUCTURES

The air vehicle structure includes the fuselage, wing (fixed or rotating), empennage, structural elements of landing gear, the control system, control surfaces, drive system, rotor systems, radome, antennas, engine mounts, nacelles, pylons, thrust reversers (if not part of the engine), air inlets, aerial refueling mechanisms, structural operating mechanisms, structural provisions for equipment/payload/cargo/personnel, etc.

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Loads analyses
3. Internal load and stress analyses
4. Materials, processes, corrosion prevention, nondestructive evaluation and repair data
5. Results from any design development tests conducted
6. Proof test results
7. Flutter, mechanical stability and aeroservoelastic analyses
8. Loads wind tunnel test data
9. Flutter wind tunnel test data
10. Ground vibration test results
11. Damage tolerance and durability analyses
12. Component/full-scale static and fatigue test results
13. Live fire test results and ballistic analysis
14. Bird strike test and analysis results
15. Arresting wire strike test and analysis results
16. User and maintainer manuals, or equivalent
17. Flight operating limits
18. Strength summary and operating restrictions
19. Damage tolerance and durability test results
20. Full-scale durability test results
21. Functional test results
22. Flight loads test results
23. Instrumentation and calibration test results
24. Control surface, tabs and damper test results
25. Thermoelastic test results
26. Limit-load rigidity test results
27. Flight flutter test results
28. Mass properties control and management plan (interface)
29. Weight and balance reports (interface)
30. Inertia report
31. Design trade studies and analyses
32. Fuel system test results
33. Results of actual weighing
34. Weight and balance handbook, or equivalent

35. Hazard analysis
36. Environmental criteria and test results
37. Vibration and acoustic test results
38. Aircraft tracking program
39. Landing gear and airframe drop test plans and results
40. Mechanical stability test plans and results
41. Whirl test plans and results
42. Tie-down test plans and results
43. Structural description report
44. Tipover and rollover stability analyses
45. External store interface and release data
46. Ground and/or air transport rigging procedures, interface loads, and associated inspection requirements
47. Failure modes, effects, and criticality analysis (FMECA) documentation
48. Ground and rotor blade clearance dimensional data
49. Loss of lubrication testing
50. Heat generation/rejection analysis

CERTIFICATION CRITERIA

## 5.1 Loads.

DoD/MIL Doc: ADS-29 (Army use)

**5.1.1** Verify that the flight load factors used in the airframe design are the maximum and minimum load factors authorized for flight use.

Standard: A. Maximum and minimum load factors defined for symmetric, asymmetric, and lateral maneuvers.

B. Basic flight design gross weight (normal weight) load factors designated as the highest and lowest load factors expected to be encountered by any air vehicle of the fleet performing any of the maneuvers of required operations and missions.

C. Maximum flight weight load factors of sufficient magnitude to allow the air vehicle to maneuver safely at high gross weights, such as immediately after takeoff or aerial refueling. Product of normal and maximum flight weights times their associated load factors made equal, when practical.

D. Takeoff, approach, and landing load factors compatible with air vehicle high lift configurations and the maneuvers required to safely operate the air vehicle during these flight phases.

E. High drag load factors compatible with air vehicle high drag configuration(s) and all maneuvers of required operations and missions to safely operate in that configuration.

F. Allowable load factors sufficient for minimum navigation and landing maneuvers after recovery from any detectable in-flight system failure.

Compliance: Multiple variables and factors account for development of maximum and minimum load factors. The following compliance paragraphs are applicable to all standards.

A. Load factor selection considers the following items:

1) Mission and flying techniques employed to execute the required mission

2) Weapon types and possible delivery methods

3) Anticipated weight and power plant growth

4) Maximum speed and time spent at maximum speed

5) Utilization of external stores and external fuel tanks

6) Training

7) Past experience with similar types of aircraft, mission, etc.

B. Load factor are defined which include appropriate ranges for symmetrical, asymmetrical, and directional maneuvers in each configuration. Analysis verifies that the load factors are attainable by the air vehicle.

DoD/MIL Doc: JSSG-2006: para A3.2.9, A4.2.9

**5.1.2** Verify that the airframe has sufficient structural integrity for the air vehicle to take off, land, arrest, and operate on the ground.

Standard: A. The airframe is designed such that the maximum landing touchdown vertical sink speeds of the air vehicle center of mass used in the design of the airframe and landing gear are:

1. 13 fps for landing design gross weights of primary and basic trainers; 10 fps for all other classes.

2. 10 fps for maximum landing design weights of primary and basic trainers; 6 fps for all other classes.

B. The airframe is designed such that crosswinds at take-off and landing are those components of surface winds perpendicular to the runway centerline with the landing gear loads being 80% of the vertical reaction for the inboard acting load and 60% of the vertical reaction for the outboard acting load. This is based on the vertical reaction being 50% of the maximum vertical reaction from two point and level symmetrical landings.

C. The airframe is designed such that the landing touchdown roll, yaw, pitch attitude, and sink speed combinations are based on a joint probability within an ellipsoid with axes of roll, yaw, and pitch.

D. The airframe is designed such that taxi discrete bumps and dips are as defined in JSSG 2006 for wave length, amplitude and shape for the maximum ground weight. It is also designed such that the angle between the path of the aircraft and the lateral axis of the contour are at angles up to 45 degrees.

E. The airframe is designed such that the maximum combination of wind loading and air vehicle load factor conditions that are utilized when assessing jacking of the air vehicle.

Compliance: The following compliance is applicable to all standards:

Analysis and tests that show the air vehicle is capable for take off, landing, and ground operations reflecting the operational capability of the aircraft.

DoD/MIL Doc: JSSG-2006: para A3.2.10, 3.2.10.1-6, A4.2.10, Figure 4 & 5.

JSSG-2006: Figure 4, pg 459, “Discrete bumps and dips for slow speeds up to 50 knots-single and double excitations”. (for standard development)

JSSG-2006: Figure 5, pg 460, “Discrete bumps and dips for high speeds above 50 knots-single and double excitations”. (for standard development)

**5.1.3** Verify that the limit loads used in the design of elements of the airframe subject to deterministic design criteria are the maximum and most critical combination of loads that can result from authorized ground and flight use of the air vehicle. These include loads during maintenance activity, system failures from which recovery is expected, and loads experienced throughout the specific lifetime usage.

Standard: Airframe is designed such that all loads whose frequency of occurrence is greater than or equal to 1 x 10-7 per flight are used. Airframe is designed such that analytical loads are correlated against measured ground and flight test loads.

Compliance: Correlated ground and flight loads analyses in which details of magnitudes and distribution of all applied external loads are identified for multiple air vehicle configurations, weights, c.g. and maneuvers covering all attainable altitudes, speeds and load factors. Establishment of the service and maximum loads expected to be encountered during operation under all flight conditions. Wind tunnel tests utilized for development of aerodynamic loads. Stiffness and ground vibration tests utilized to update flexibility vs. rigid characteristics of loads analytical model. Flight controls and aerodynamic flight tests utilized to update aircraft simulation models. Loads calibration tests utilized to develop ground/flight load equations. 80% and 100% flight loads surveys/demonstrations utilized to correlate analytical model and to substantiate the design loads.

DoD/MIL Doc: JSSG-2006: para A3.2.11, A4.2.11.

**5.1.4** Verify that the airframe is designed such that all loads resulting from or following single or multiple system failures are limit loads. Also verify that loads resulting from a single component failure are designed as limit loads regardless of probability of occurrence.

Standard: A. Airframe is designed such that limit loads from single or multiple system failures have a frequency of occurrence greater than or equal to 1 x 10-7 per flight.

B. The air vehicle is operated within the flight limits subsequent to a detectable failure.

C. Single or multiple system failures assessed include tire failures, propulsion system failures, radome failures, mechanical failures, hydraulic failures, flight control system failures, transparency failures, and hung stores.

Compliance: The following compliance is applicable to all standards:

Analyses and laboratory tests in which verification is preformed on as many system failures as practical in order to reduce the risk of damage to aircraft and crew. Ground and flight loads analyses correlated with test data.

DoD/MIL Doc: JSSG-2006: para A3.2.22, A4.2.22.

**5.1.5** Verify that the airframe is designed such that ultimate loads are obtained by multiplication of limit loads by the appropriate factors of uncertainty. Also verify that the ultimate loads are used in the design of elements of the airframe subject to a deterministic design approach.

Standard: A. Airframe is designed such that ultimate loads are obtained by multiplying the limit loads by a 1.5 factor of uncertainty.

B. Airframe is designed with a thermal load factor of uncertainty when thermal loads are significant.

Compliance: The following compliance is applicable to both standards:

Correlated ground and flight loads analyses. Establishment of the service and maximum loads expected to be encountered during operation under all flight conditions. Wind tunnel tests utilized for development of aerodynamic loads. Stiffness and ground vibration tests utilized to update flexibility vs. rigid characteristics of loads analytical model. Flight controls and aerodynamic flight tests utilized to update aircraft simulation models. Loads calibration tests utilized to develop ground/flight load equations. 80% and 100% flight loads

surveys/demonstrations utilized to correlate analytical model and to substantiate the design loads.

DoD/MIL Doc: JSSG-2006: para A3.2.12, A4.2.12.

**5.1.6** Verify that the airframe is designed such that all sources of repeated loads are considered and included in the development of the service loads spectra and do not detract from the airframe service life.

Standard: Airframe is designed with the following conditions as sources of repeated loads:

1. Maneuvers – Designed such that final spectra accounts for variables such as maneuver capability, tactics, and flight control laws reflecting projected average usage with the design utilization distribution and also usage such that 90% of the fleet is expected to meet the service life.

2. Gusts – Designed such that gust load spectra developed by continuous turbulence analysis methods.

3. Suppression system which enhance ride qualities such as active oscillation control, gust alleviation, flutter suppression and terrain following.

4. Vibration and aeroacoustics.

5. Landings – Designed with cumulative occurrences of sink speed per 1000 landings, by type of landing, typical of projected service usage.

6. Buffet due to non-linear flow caused by vortex shedding during high angle of attack maneuvers and transonic shock instabilities – Designed such that analytical predictions of the airframe response are generated during flight operations in the buffet regime and adjusted as needed by test data.

7. Ground operation loads – Designed with (1) the number of hard and medium braking occurrences per full stop landing along with associated braking effects, (2) number of pivoting occurrences, and (3) definition of roughness characteristics of the airfield(s) to be utilized and the number of taxi operations on each airfield.

8. Pressurization – Designed with the total number of cycles projected for one service life.

9. Impact, operational, and residual loads occurring from the normal operation of movable structures such as control surfaces.

10. Store carriage and employment loads.

11. Heat flux.

Compliance: A. The following compliance is applicable all the conditions of the standard:

Ground and flight loads analyses correlated with test data.

B. The following two compliances are applicable to condition #6 of the standard:

1. Wind tunnel tests utilized for development of buffet loads.

2. Buffet flight tests utilized to verify analytical buffet predictions.

C. The following compliance is applicable to condition #4 of the standard:

Updated predictions of the vibration and aeroacoustic environments.

DoD/MIL Doc: JSSG-2006: para A3.2.14.3, A4.2.14.

**5.1.7** Verify that the airframe is designed such that the power or thrust of the installed propulsion system is commensurate with the ground and flight conditions of intended use, including system failures, and the capabilities of the propulsion system and crew.

Standard: Airframe designed such that the attainable thrust loads include all thrust loads up to the maximum and also include engine transients due to both normal engine operation as well as

the engine system failures.

Compliance: Propulsion analyses and tests verify the power or thrust used in the loads analyses.

DoD/MIL Doc: JSSG-2006: para A3.2.17, A4.2.17.

**5.1.8** Verify, in the generation of loads, that flight control and automatic control devices, including load alleviation and ride control devices, are in those operative, inoperative, and transient modes for which use is required or likely or are due to system failure conditions.

Standard: Airframe loads are generated with stability augmentation and similar devices in which all modes likely to be encountered are addressed.

Compliance: The following compliance is applicable to the standard:

Analyses and tests verifying the normal operation as well as some potential modes of operation. Analyses and ground tests verifying the emergency associated modes of operation. Correlated ground and flight loads analyses. Wind tunnel tests utilized for development of aerodynamic loads. Flight controls and aerodynamic flight tests utilized to update aircraft simulation models. 80% and 100% flight loads surveys/demonstrations utilized to correlate analytical model.

DoD/MIL Doc: JSSG-2006: para A.3.2.18 and A.4.2.18

**5.1.9** Verify that flight loading conditions are based on realistic conditions of airframe response to pilot induced or autonomous maneuvers, loss of control maneuvers, and turbulence. Also verify that the realistic conditions considered are both required and expected to be encountered critical combinations of configurations, gross weights, centers of gravity, thrust or power, altitudes, speeds, and type of atmosphere and are used in the design of the airframe.

Standard: A. Airframe is designed such that flight loading conditions reflect symmetric and asymmetric flight operations. Also established for both primary and secondary structural components by careful selection of flight parameters likely to produce critical applied loads. Symmetric and asymmetric flight operations include symmetric and unsymmetric fuel and payload loadings and adverse trim conditions.

B. Airframe designed such that symmetric maneuver conditions accomplished with and without a specified roll rate command above 80% maximum symmetric Nz providing acceptable roll capability throughout the specified flight envelope.

C. Airframe designed such that symmetric maneuvers are performed with and without a 50 degrees per second roll rate command for A, F, TF, O and T aircraft and 30 degrees per second for all other aircraft. Symmetric maneuvers include steady pitching, abrupt pitching, flaps down pullouts, aerial delivery pullouts, and emergency stores release.

D. Airframe designed such that asymmetric maneuvers restricted to 80% of maximum design symmetric load factor (Nz). Asymmetric maneuvers are fully coordinated and, alternately, uncoordinated maneuvers. Asymmetric maneuvers include level fight rolls, elevated-g rolls, rolling pull-outs, aerial delivery rolls and takeoff/landing approach roll.

E. Airframe designed for directional maneuvers which include sideslips, rudder kicks, rudder reversals, unsymmetrical thrust with zero sideslip, engine failure, and engine out operation.

F. Airframe designed for evasive maneuvers which include jinking and missile break maneuvers as well as for stalls, departures, spins and tail slides.

G. Airframe designed for operating in the atmosphere with vertical and lateral gusts representative of those expected to be encountered in which:

1. Required missions and a gust exceedance rate of the lower of 1 x 10-5 cycles per hour or once in 10 lifetimes.

2. The power spectrum of the expected turbulence is defined by the equation located in JSSG 2006 (para A4.3.1.6) and the turbulence field parameters in Table XI of JSSG 2006.

3. The airframe does not have strength less than a level established with limit gust velocity values Yd / Ā □of:

A) Forty feet per second, EAS from 0 to 1000 feet, then

B) Varying linearly to 58 feet per second, EAS at 2500 feet, then

C) Varying linearly to 62 feet per second, EAS at 7000 feet, then

D) Varying linearly to 55 feet per second, EAS at 27,000 feet, then

E) Varying linearly to 14 feet per second, EAS at 80,000 feet.

H. Airframe designed for operating in the atmosphere with vertical and lateral gusts representative of those expected to be encountered in wake turbulence and gust plus maneuver.

I. Airframe designed for operating under aerial refueling and aerial delivery conditions.

J. Airframe designed for operating while using speed and lift controls as well as use of braking wheels in air.

K. Airframe designed for extension and retraction of landing gear.

L. Airframe designed for pressurization in which the pressure differentials used in the design of pressurized portions of the airframe, including fuel tanks, are the maximum pressure differentials attainable during flight within the design flight envelope, during ground maintenance, and during ground storage or transportation of the air vehicle. For normal flight operations, the maximum pressure differentials attainable are increased by a factor not less than 1.33 when acting separately or in combination with 1g level flight loads. For emergency flight operations or when combined with maximum maneuver flight loads, the maximum pressure differentials attainable are increased by a factor not less than 1.0. For ground operations including maintenance, the maximum pressure differentials attainable are increased by a factor not less than 1.33.

M. Airframe designed to account for aeroelastic deformations when determining the final airload distributions.

N. Airframe designed with the inclusion of dynamic response of the air vehicle resulting from the transient or sudden application of loads such as store ejection in the determination of design loads.

O. Airframe designed such that when asymmetric or dissimilar stores are on opposing store stations the required lateral c.g. position is based on 120% of the maximum loading of any single store station or the maximum attainable by loading one side of the aircraft, plus the maximum wing asymmetric fuel allowed operationally without limitations.

Compliance: The flight loading conditions used in the design of the airframe as defined in the standards is verified by a series of analyses and tests. The following compliances are applicable to all standards:

Correlated flight loads analyses in which details of magnitudes and distribution of all applied external loads are identified for multiple air vehicle configurations, weights, c.g. and maneuvers covering all attainable altitudes, speeds and load factors. Establishment of the service and maximum loads expected to be encountered during operation under all flight conditions. Wind tunnel tests utilized for development of aerodynamic loads. Stiffness and ground vibration tests utilized to update flexibility vs. rigid characteristics of loads analytical model. Flight controls and aerodynamic flight tests utilized to update aircraft simulation models. Loads calibration tests utilized to develop flight load equations. 80% and 100% flight loads surveys/demonstrations utilized to correlate analytical model and substantiate the design loads.

DoD/MIL Doc: JSSG-2006: para A.3.4.1, A.3.4.1.1-15.

JSSG-2006: Power Spectrum Equation on pg 264 under A.3.4.1.6 (for standard development)

JSSG-2006: Table XI “Turbulence Field Parameters”, pg 441 (for standard development)

**5.1.10** Verify that the airframe is designed for ground loading conditions which reflect ground and maintenance operations.

Standard: A. Airframe is designed such that the ground loading conditions considered are those required and expected to be encountered in critical combinations of configurations, gross weights, centers of gravity, landing gear/tire servicing, external environments, thrust or power, and speeds and shall be used in the design of the airframe.

B. Airframe is designed such that ground operations include symmetric and unsymmetric fuel and payload loadings and adverse trim conditions.

C. Airframe is designed for ground operations consisting of taxing, turning, pivoting, braking, landing (including arrestment) and takeoff.

D. Airframe is designed for ground handling conditions consisting of towing, jacking, and hoisting.

E. Airframe is designed for dynamic response and shimmy during ground operations as well as for rough runway conditions.

F. Airframe is designed for ground winds as a result of weather and jet blast.

Compliance: The ground loading conditions used in the design of the airframe as defined in the standards is verified by a series of analyses and tests. The following compliances are applicable to all standards:

Correlated ground loads analyses including dynamic response analyses in which details of magnitudes and distribution of all critical design loads are established. Dynamic stability/taxi analyses to assess shimmy and development of design loads. Ground vibration tests and landing gear shimmy lab tests utilized to define the dynamic characteristics of the gear. Loads calibration tests utilized to develop ground load equations. Ground loads test demonstrations, shimmy ground tests, rough runway tests utilized to correlate analytical model and substantiate the design loads.

DoD/MIL Doc: JSSG-2006: para A.3.4.2, 3.4.2.1-11, 3.4.2.12 and 15, 4.4.2

**5.1.11** Verify that in the generation of loads the airframe is able to withstand crashes and to protect personnel to the extent reflected by the ultimate loading conditions and parameters.

Standard: A. Airframe designed such that crash requirements are defined in terms of longitudinal, vertical and lateral crash load factors.

B. Airframe designed such that the minimum longitudinal, vertical and lateral crash load factors are equal to the ultimate load factors required for strength of crew and passenger seats. This is as specified in the applicable specifications for seats or is in accordance with Table XIV of JSSG 2006. Ultimate loads are based on load factor times the combination of an appropriate amount of mass, the man plus personal equipment and the weight of any seat armor.

C. Airframe designed such that all internal fuel tanks, including all critical amounts of fuel up to two-thirds of the individual tank capacities, are able to withstand the ultimate load factor requirements.

D. Airframe designed such that all fixed and removable miscellaneous and auxiliary equipment and their subcomponent installations are able to withstand the following air vehicle load factors: Longitudinal 9.0 fwd, 1.5 aft; Lateral 1.5 right and left; Vertical 4.5 down

and 2.0 up.

E. Airframe designed such the airframe attachments and carry through structure are able to withstand the following ultimate load factors: Longitudinal 3.0 fwd, 1.5 aft; Lateral 1.5 right and left; Vertical 4.5 down and 2.0 up. This is when cargo or fixed and removable equipment is located in a manner wherein failure could not result in injury to personnel or prevent egress.

Compliance: The ground loading conditions and subsequent analyses and tests used in the design of the airframe are utilized to develop the crash loads. The following compliances are applicable to all standards:

Correlated ground loads analyses in which details of magnitudes and distribution of all critical design loads are established. Ground loads test demonstrations utilized to correlate analytical model and substantiate the design loads.

DoD/MIL Doc: ADS-36 (Army use)

JSSG-2006: para A.3.4.2.11, Table XIV, “Seat Crash Load Factors”, pg 443 (for standard development)

**5.1.12** Verify that the airframe is designed to withstand foreign object damage (FOD) from birds, hail, runway, taxiway, and ramp debris.

Standard: Airframe is designed such that FOD environments do not result in the loss of the air vehicle or do not incapacitate the pilot or crew with a frequency equal to or greater than 1 x 10-7 per flight. The FOD environments do not cause unacceptable damage to the airframe with a frequency equal to or greater than 1 x 10-5 per flight.

Compliance: The following compliances are applicable to all standards:

Probabilistic analyses for FOD strikes. Lab tests such as bird strike tests.

DoD/MIL Doc: JSSG-2006: para A.3.2.24

## 5.2 Structural dynamics.

**5.2.1** Verify that the airframe, in all configurations of the air vehicle including store carriage, is free from flutter, whirl flutter, divergence, and other related aeroelastic or aeroservoelastic instabilities, including transonic aeroelastic instabilities for all combinations of altitude and speed encompassed by the limit speed ($V_L/M_L$) versus altitude envelope enlarged at all points by the airspeed margin of safety. Also verify that all aerodynamic surfaces and components of the air vehicle are free from aeroelastic divergence and that the inlet, transparency, and other aerodynamically loaded panels are designed to prevent flutter and sustained limited amplitude oscillations when exposed to supersonic flow.

Standard: A. The airframe is designed such that a margin of safety of 15% or greater is maintained in equivalent airspeed (Ve) at all points on the $V_L/M_L$ envelope of the air vehicle, both at constant Mach number and separately, at constant altitude.

B. The airframe is designed such that the total (aerodynamic plus structural) damping coefficient, g, is not less than 0.03 for any critical flutter mode or for any significant dynamic response mode for all altitudes and flight speeds from minimum cruising speeds up to $V_L/M_L$.

Compliance: Validity of the flutter requirements as identified in the standards is verified by a series of analyses and tests. The following compliances are applicable in addressing both standards:

Updated flutter analyses of the complete air vehicle including external stores if carried, as well as flutter analyses of the air vehicles control surfaces, tabs, and other components. Parametric flutter analyses involving variations of the mass, positions of center of gravity

and mass moment of inertia. Analyses involving variable fuel conditions for external tanks. Full-span flutter analyses which identify flutter characteristics of various asymmetric store loadings. Updated whirl flutter analyses in which the blade aerodynamics, flexibility and power plant flexibilities, mounting characteristics and gyroscopic effects are included especially for propeller or large turbofan driven air vehicles. Updated divergence and buzz analyses as well as panel flutter analyses. Where applicable updated whirl flutter analyses and aeroservoelastic stability analyses. Panel flutter analyses in which the aerodynamic conditions used are the local conditions existing at the panel surface including those altered from the free stream by airplane altitude or surface shape. Panel flutter analyses in which a buckled or near buckled condition is assumed for panels subjected to in-plane compressive stresses and where an accurate prediction of the compressive stresses and their effects was not possible. Wind tunnel and unsteady pressure model tests along with model tests which investigate lifting surface shock induced separation oscillations and other related transonic aeroelastic instability phenomena. Laboratory tests such as component ground vibration and stiffness tests such as that involving the engine with propeller for turbo-prop aircraft as well as pylons with and without stores/tanks, as well as launchers and racks with stores. Mass measurements of control surfaces/tabs, balance weight attachment verification tests, damper qualification tests, thermoelastic tests as well as control surface, tab, and actuator rigidity, free play, and wear tests. Complete air vehicle ground vibration modal tests which include modal tests on components attached to the air vehicle such as turboprop propeller plane as well as tests in which the modes and frequencies of flutter critical skin panels are obtained. Aeroservoelastic ground tests. Flight flutter tests and flight aeroservoelastic stability tests of the air vehicle which substantiate the air vehicle is free from aeroelastic instabilities. Incorporation of sway brace preloads into the appropriate user manual.

DoD/MIL Doc: JSSG-2006: para A3.7.1, A3.7.1.2, A3.7.1.4, A3.7.1.5, A3.7.1.6, A3.7.1.7, A.4.7

**5.2.2** Verify that the air vehicle is free from the occurrence of any aeroservoelastic instability resulting from the interactions of air vehicle systems, such as the control systems coupling with the airframe.

Standard: The air vehicle is designed such that the structural modes have stability margins involving a gain margin of least 6 dB and separately, a phase margin of at least 60 degrees for any single flight control system feedback loop at speeds up to $V_L/M_L$. The operative states (on and off) of the systems are commensurate with the uses authorized in the flight manual as applicable throughout the full flight envelope.

Compliance: The following compliances are applicable in addressing the standards:

Updated aeroservoelastic stability analyses correlated with aeroservoelastic ground tests that are conducted for the critical flight conditions, taking into account the flight control systems gain scheduling and control surface effectiveness.

Flight aeroservoelastic stability tests of the air vehicle and its flight augmentation system.

DoD/MIL Doc: JSSG-2006: para A3.7.2, A.4.7

**5.2.3** Verify that the control surfaces and tabs contain sufficient static and dynamic mass balance, or sufficient bending, torsional, and rotational rigidity; or a combination of these means to prevent flutter; or sustained, limited-amplitude instabilities of all critical modes under all flight conditions for normal and failure operating conditions of the actuating systems. Verify that all control surfaces and parts thereof are free from single-degree-of-freedom flutter, such as buzz. Also verify that all other air vehicle components exposed to the airstream, such as spoilers, dive brakes, scoops, landing gear doors, weapon bay doors, ventral fins, movable inlet ramps, movable fairings, and blade antennas are free from aeroelastic instability.

Standard: A. The air vehicle is designed such that the physical characteristics of the control surfaces, tabs, and other components are not changed by exposure to any natural or manmade environment. This is throughout the service life of the airframe.

B. The air vehicle is designed such that the following control surface free play limits are not exceeded during the service life of the airframe. This is when circuit stiffness of control surfaces or tabs is utilized to prevent any aeroelastic instability.

1. Total free play not greater than 0.13 degrees when a trailing-edge control surface extends outboard of the 75-percent-span station of the main surface.

2. Total free play not greater than 0.57 degrees when a trailing-edge control surface extends outboard of the 50-percent-span station but inboard of the 75-percent-span station of the main surface.

3. Total free play not greater than 1.15 degrees when a trailing-edge control surface is inboard of the 50-percent-span station of the main surface.

4. Total free play of all-movable control surfaces not greater than 0.034 degrees.

5. Total free play not greater than 1.15 degrees when a tab span does not exceed 35 percent of the span of the supporting control surface.

6. Total free play not greater than 0.57 degrees when a tab span equals or exceeds 35 percent of the span of the supporting control surface.

7. Total free play not greater than 0.25 degrees for leading edge flaps.

8. Total free play not greater than 0.25 degrees for a wing fold.

9. Total free play not greater than the applicable value specified in 1 through 6 for other movable components which are exposed to the airstream such as trailing edge flaps, spoilers, dive brakes, scoops, etc.

C. Flaps extending outboard of the 50 percent-span station of the main surface, rigidly locked in the retracted position when not displaced from the retracted position in flight and when practicable.

D. Establishment of maximum allowable inertia properties which are not exceeded during the service life of the airframe when circuit stiffness of control surfaces or tabs is utilized to prevent any aeroelastic instability.

E. Establishment of mass balance design requirements when mass balancing of control surfaces or tabs is utilized to prevent any aeroelastic instability.

F. Use of two parallel hydraulic dampers to prevent any aeroelastic instability of a control surface, tab, and any other movable component which is exposed to the airstream when mass balance or rigidity criteria are impracticable.

Compliance: Validity of the control surface flutter requirements as identified in the standards is verified by a series of analyses and tests. The following compliances are applicable in addressing all standards:

Updated flutter analyses including non-linear analyses of the air vehicles control surfaces and tabs. Parametric variation flutter analyses which provides the sensitivity of the airspeed and damping margins of the airplane due to the variation of mass properties of all control surfaces, tabs, flaps and components which are exposed to the airstream. Mass measurements of all control surfaces and tabs. Control surface, tab, actuator rigidity, component rigidity, free play, stiffness and wear tests which are conducted for both normal and design failure conditions. If utilized, balance weight attachment verification tests and damper qualification tests which demonstrate the integrity of the balance weight or damper installation. Flight flutter tests which also include tests that substantiate the maximum allowable freeplay.

DoD/MIL Doc: JSSG-2006: para A3.7.1.1, A3.7.1.3, A3.7.1.8, A3.7.2, A3.7.3, A3.7.4, A3.7.5, A.4.7, A4.7.5

**5.2.4** Verify that, after each of the failures listed below as well as for air vehicle augmentation system failures, the air vehicle is free from flutter, divergence, and other related aeroelastic or aeroservoelastic instabilities.

a. Failure, malfunction, or disconnection of any single element or component of the main flight control system, augmentation systems, automatic flight control systems, or tab control system.

b. Failure, malfunction, or disconnection of any single element of any flutter damper connected to a control surface or tab.

c. Failure of any single element in any hinge mechanism and its supporting structure of any control surface or tab.

d. Failure of any single element in any actuator's mechanical attachment to the structure of any control surface or tab.

e. Failure of any single element in the supporting structure of any pylon, rack, or external store.

f. Failure of any single element in the supporting structure of any large auxiliary power unit.

g. Failure of any single element in the supporting structure of any engine pod.

h. For air vehicles with turbopropeller or prop-rotor engines:

(1) Failure of any single element of the structure supporting any engine or independently mounted propeller shaft.

(2) Any single failure of the engine structure that would reduce the yaw or pitch rigidity of the propeller rotational axis.

(3) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller, and for air vehicles with four or more engines, the feathering of the critical combination of two propellers.

(4) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller in combination with the failures specified above in (1) and (2).

Standard: A. The airframe is designed such that after a failure a margin of safety of 15% or greater is maintained in equivalent airspeed (Ve) at all points on the $V_L/M_L$ envelope of the air vehicle, both at constant Mach number and separately, at constant altitude.

B. The airframe is designed such that after a failure the total (aerodynamic plus structural) damping coefficient, g, is not less than 0.03 for any critical flutter mode or for any significant dynamic response mode for all altitudes and flight speeds from minimum cruising speeds up to $V_L/M_L$.

C. The air vehicle is designed such that after a failure the structural modes have stability margins involving a gain margin of least 6 dB and separately, a phase margin of at least 60 degrees for any single flight control system feedback loop at speeds up to $V_L/M_L$. The operative states (on and off) of the systems are commensurate with the uses authorized in the flight manual as applicable throughout the full flight envelope.

D. The airframe is designed such that it will not experience failures that lead to loss of adequate structural rigidity or proper structural functioning, or structural failure resulting in the loss of the air vehicle at a rate equal to or more frequent than 1x10-7 occurrences per flight.

Compliance: The following compliances are applicable in addressing the standards:

Updated flutter analyses of the complete air vehicle including external stores if carried, as well as flutter analyses of the air vehicles control surfaces, tabs, and other components. Updated divergence and buzz analyses as well as panel flutter analyses. Where applicable updated whirl flutter analyses and aeroservoelastic stability analyses. Wind tunnel and unsteady pressure model tests along with model tests which investigate lifting surface shock

induced separation oscillations and other related transonic aeroelastic instability phenomena. Laboratory tests such as component ground vibration and stiffness tests, mass measurements of control surfaces/tabs, balance weight attachment verification tests, damper qualification tests, thermoelastic tests as well as control surface, tab, and actuator rigidity, free play, and wear tests. Complete air vehicle ground vibration modal tests as well as aeroservoelastic ground tests. Flight flutter tests and flight aeroservoelastic stability tests of the air vehicle which substantiate the air vehicle is free from aeroelastic instabilities.

DoD/MIL Doc: JSSG-2006: para A3.7.3, A3.1.2, A3.7.1, A3.7.2, A.4.7

**5.2.5** Verify that the airframe structure withstands the aeroacoustic loads and vibrations induced by aeroacoustic loads for the air vehicle specified service life and usage without cracking or functional impairment.

Standard: A. All aeroacoustic loads sources associated with the air vehicle and its usage are identified.

B. The airframe is designed such that an uncertainty factor of +3.5dB is applied on the predicted aeroacoustic sound pressure levels.

C. The airframe is designed for fatigue life such that a factor of 2.0 is applied on the exposure time derived from the air vehicle specified service life and usage.

Compliance: Predictions of the near field aeroacoustic loads and fatigue life encompassing the air vehicles service life and usage and the identified aeroacoustic load sources. Wind tunnel, jet models which define acoustic levels. Component acoustic fatigue tests based on fatigue life predictions. Ground and flight aeroacoustic measurements from full scale test aircraft including internal noise measurements.

DoD/MIL Doc: JSSG-2006: para A3.5.1, A4.5.1

**5.2.6** Verify that the structures, equipment, and equipment provisions in, adjacent to, or immediately downstream of cavities open to the airstream during flight are designed for the effects of oscillatory air forces.

Standard: Airframe is designed such that pressure oscillations within and downstream of the cavity are minimized by addition of airflow control devices.

Compliance: The following compliances are applicable in addressing the standard:

Predictions of the cavity aeroacoustic loads and fatigue life encompassing the air vehicles service life and usage. Wind tunnel models that define acoustic levels. Component acoustic fatigue tests based on fatigue life predictions. Ground and flight aeroacoustic measurements from full scale test aircraft.

DoD/MIL Doc: JSSG-2006: para A3.3.9, A4.3.9

**5.2.7** Verify that sound pressure levels in areas of the air vehicle occupied by personnel during flight are controlled as required by human factors requirements.

Standard: Sound treatments are designed and developed in conjunction with the airframe. Human factor requirements are defined in accordance with AFOSH 48-19 and multicommand ORD CAF-MAF-AETC 319-93-I-A.

Compliance: The following compliances are applicable in addressing the standards:

Predictions of internal acoustic levels based on internal noise sources and the near field aeroacoustic predictions for pertinent operational flight and ground usage. Measurements at personnel stations of internal acoustic levels for pertinent flight conditions.

DoD/MIL Doc: JSSG-2006: para A3.5.2, A4.5.2

**5.2.8** Verify that the airframe is designed such that it can operate in the vibration environments induced by the operational use for the specified service life. Also verify that the airframe

is designed such that no fatigue cracking or excessive vibration of the airframe structure or components occurs that would result in the air vehicle or the components of the air vehicle systems not being fully functional.

Standard: A. Identification of all vibratory sources associated with the air vehicle and its usage.

B. Estimates of vibration levels that are the basis for preliminary structural development testing as well as establishment of equipment qualification test criteria. Use of the levels for developing designs to control the environment in areas occupied by personnel and equipment.

C. Utilization of MIL-STD-810 during air vehicle equipment development when reasonable estimates of equipment vibration are unavailable.

Compliance: The following compliances are applicable in addressing the standards:

Updated predictions of the vibration environment. Component tests verifying analytical fatigue life predictions and which demonstrate that components meet service usage requirements in the vibration environment. Ground and flight vibration tests which identify the response characteristics of the aircraft to forced vibrations and impulses.

DoD/MIL Doc: JSSG-2006: para A3.6.2, A4.6.2

**5.2.9** Verify that equipment and structure behind and near vents and louvers are designed for the effects of flow through the vents and louvers during conditions of normal and reverse flows.

Standard: Airframe designed such that effects of FOD, thermal, sand abrasion, rain, ice, etc., are covered for one lifetime of the specified usage.

Compliance: Analyses and test of gas temperatures and airflows through vents and louvers into equipment and structure behind and near vents and louvers.

DoD/MIL Doc: JSSG-2006: para A.3.3.8

## 5.3 Strength.

**5.3.1** Verify that sufficient static strength is provided in the airframe structure to react all loading conditions loads without degrading the structural performance capability of the airframe. Verify sufficient strength for operations, maintenance functions, occurrences of systems failures, and any tests that simulate load conditions. This includes modifications, new or revised equipment installations, major repairs, extensive reworks, extensive refurbishment, or remanufacture.

Standard: 1. Detrimental deformations, including delaminations, do not occur at or below 115 percent of limit loads and during the functional, strength and pressurization tests necessary for flight clearances. Temperature, load and other induced structural deformations/deflections resulting from any authorized use and maintenance of the air vehicle does not:

A. Inhibit or degrade the mechanical operation of the air vehicle or cause bindings or interferences in the control system or between the control surfaces and adjacent structures.

B. Affect the aerodynamic characteristics of the air vehicle to the extent that performance guarantees or flying qualities requirements cannot be met.

C. Result in detrimental deformation, delamination, detrimental buckling, or exceedance of the yield point of any part, component, or assembly which would result in subsequent maintenance actions.

D. Require repair or replacement of any part, component, or assembly.

E. Reduce the clearances between movable parts of the control system and adjacent structures or equipment to values less than the minimum permitted for safe flight.

F. Result in significant changes to the distribution of external or internal loads without due consideration thereof.

2. Rupture or collapsing failures do not occur at or below ultimate loads.

3. Bonded structure is capable of sustaining the residual strength loads without a safety of flight failure with a complete bond line failure or disbond.

Compliance: Validity of static strength is verified by analyses, tests and inspections. The following compliance paragraphs are applicable to all standards.

1. Validation information includes formal checked and approved internal loads and strength analysis reports. Analytical distributions on major components are correlated with test instrumentation measurements of stress and strain from static test and the structural strength analysis is updated.

2. Development and full scale laboratory load tests of instrumented elemental, component and full scale airframe verify the airframe structure static strength requirements. The applied test loads, including ultimate loads, simulate the loads resulting from critical operational and maintenance loading conditions. Environmental effects (such as temperatures, moisture, fuel immersion, chemicals, etc.) are simulated along with the load applications on airframe where operational environments impose significant effects.

A. Element tests conducted with sufficient sample size to determine statistical compensated allowables.

B. Component tests conducted with a smaller sample size to validate the analytical procedures and establish design allowables.

C. Large component development tests of large assemblies conducted to verify the static strength capability of final or near final structural designs of critical areas.

D. Static tests, including tests to design limit load and to design ultimate load, performed on the complete, full scale instrumented airframe to verify its limit and ultimate strength capability. Structural modifications have been incorporated into the test article. Ultimate load test conditions selected for substantiating the strength envelope for each component of the airframe. The testing to ultimate performed without environmental conditioning only if the design development test demonstrated that a critical failure mode is not introduced by the environmental conditioning.

DoD/MIL Doc: JSSG-2006: para A3.2.13, A3.10.5, A3.10.9, A3.10.10 (for standard development)

JSSG-2006: para A4.10.5, A4.10.5.1, A4.10.5.2, A4.10.9, A4.10.10 (for compliance development)

**5.3.2** Verify that the allowables for materials are minimums; are established considering statistical variability, the expected environments, fabrication processes, repair techniques, and quality assurance procedures; and are validated. Verify that conditions and properties associated with material repairs satisfy design requirements.

Standard: Materials and processes are selected in accordance with the following requirements so that the airframe meets the operational and support requirements.

1. Relevant producibility, maintainability, supportability, repairability, and availability experience with the same, or similar, materials processes are a governing factor for suitability of the airframe design. Material systems and materials processes selected for design are stable, remain fixed, and minimize unique maintenance and repair practices in accordance with the specified operational and support concepts.

2. Material systems and materials processes (including radioactive materials and processes) are environmentally compliant, compliant with best occupational safety and health practices, and minimize hazardous waste generation.

3. The processes and joining methods do not contribute to unacceptable degradation of

the properties of the materials when the airframe is exposed to operational usage and support environments. Whenever materials are proposed for which only a limited amount of data is available, the acquisition activity is provided with sufficient background data so that a determination of the suitability of the material can be made. The allowable structural properties include all applicable statistical variability and environmental effects, such as exposure to climatic conditions of moisture and temperature; exposure to corrosive and corrosion causing environments; airborne or spilled chemical warfare agents; and maintenance induced environments commensurate with the usage of the airframe. Specific material requirements are:

1. "A" basis design allowables are used in the design of all critical parts. "A" basis design allowables are also used in the design of structure not tested to ultimate load in full scale airframe static testing. "B" basis design allowables can be used for all other structure.

2. "S" basis design allowables are acceptable for design when "A" or "B" basis allowables are not available, provided they are specified in a governing industry/government document that contains quality assurance provisions at the heat, lot, and batch level in the as-received material condition. Appropriate test coupons shall accompany the material in the as received condition and is subject to testing for verification of minimum design properties after final processing.

The guidance contained in MIL-STD-1568 and MIL-STD-1587 serves as the baseline approach for addressing materials/processes and corrosion requirements and is deviated from only with appropriate supporting engineering justification. MIL-STD-1568 and MIL-STD-1587 provide extensive guidance/lessons learned for materials processes selection and application.

Compliance: Inspections, analyses, and tests verify that the materials and processes selected are in compliance with requirements. The following compliance section is applicable to all standards.

Standardized test methods used to establish metallic and composite material systems properties are used. When such standardized methods are not available, a program was undertaken to explore and develop standardized test methods. All test methods used in establishing material system performance is documented. The following requirements also apply:

1. Materials and processes development and characterization and the selection process are documented. Second source materials (when established as a program requirement) are qualified and demonstrated through testing to have equivalent performance and fabrication characteristics as the selected baseline material.

2. Environmentally conditioned tests are performed at the appropriate development test level to meet relevant design conditions.

3. Materials and processes characteristics for critical parts comply with the requirements of parts control processes.

4. Environmental compliance with all applicable environmental statutes and laws for all materials systems and processes selected is verified. This includes life cycle management of hazardous materials.

DoD/MIL Doc: MIL-STD-1568

MIL-HDBK-1587

JSSG-2006: para A3.2.19, A3.2.19.1, A3.2.19.2 (for standard development)

JSSG-2006: para A4.2.19, A4.2.19.1, A4.2.19.2 (for compliance development)

**5.3.3** Verify that stresses and strains in airframe structural members are controlled through proper sizing, detail design, and material selections. Verify that all limit and ultimate loads are reacted resulting in zero or positive margins of safety for all configurations

within allowable operating conditions (including probable failure and defined emergency conditions).

Standard: 1. All structure designed to nominal dimensional values or 110 percent of minimum values, whichever is less.

2. The determination of margins of safety is based on the smaller of the design or procurement specification allowable.

3. Thermal stresses and strains are determined for structures that experience significant heating or cooling whenever expansion or contraction limited by external or internal constraints. Thermal stresses and strains are combined with concurrent stresses produced by other load sources in a conservative manner.

4. In laminated composites, the stresses and ply orientation are compatible and residual stresses of manufacturing are accounted for, particularly if the stacking sequence is not symmetrical.

5. For each fitting and attachment whose strengths are not proven by limit and ultimate load tests in which actual stress conditions are simulated in the fitting and surrounding structure, the design stress values are increased in magnitude by multiplying these loads or stress values by a fitting factor. The fitting factor is 1.15 for all bolted and welded joints and for structure immediately adjacent to the joints. A fitting factor does not have to be used for continuous lines of rivets installed in sheet-metal joints.

6. The design stress values for bolted joints with clearance (free fit) that are subjected to relative rotation under limit load or shock and vibration loads, are increased in magnitude by multiplying by a 2.0 bearing factor times the stress values. This bearing factor does not have to be multiplied by the fitting factor.

7. Structural doors and panels as well as access doors and components with one or more quick-opening latches or fasteners do not fail, open, vibrate, flap or flutter in flight. The most critical combinations of latches or fasteners are designed for left unsecure.

8. Castings are classified and inspected, and all castings conform to applicable process requirements. A casting factor of 1.33 is used. The factors, tests and inspections of this section are applied in addition to those necessary to establish foundry quality control. The use of castings or C/Hipped parts for primary or critical applications and/or castings with a casting factor less than 1.33, have successfully completed a developmental and qualification program. These castings meet the analytical requirements without a casting factor and meet the service life requirements for both crack initiation and crack growth for flaws representative of the casting and manufacturing process.

9. Due to the nature of some structural designs or materials, high variability may be encountered around the nominal design. Such design features must have a minimum level of structural integrity at the acceptable extremes of dimensions, tolerances, material properties, processing windows, processing controls, end or edge fixities, eccentricities, fastener flexibility, fit up stresses, environments, manufacturing processes, etc. In addition to meeting the standard strength requirements, the structure must have no detrimental deformation of the maximum once per lifetime load and no structural failure at 125 percent of design limit load for the critical combinations of the acceptable extremes.

Compliance: 1. Validity of internal loads, stresses and strains are verified by inspections, analyses, and tests. This compliance paragraph is applicable to all standards. Validation information includes formal checked and approved internal loads and strength analysis reports. Analytical distributions on major components are correlated with measurements of stress and strain obtained from development and static tests and the analysis is updated.

Additional compliance requirements apply for castings (5.3.3.8) and high variability structure (5.3.3.9).

1. All castings are shown to satisfy the casting factor requirements by analysis. Critical castings, castings used in primary structure, or castings with a casting factor less than 1.33

meet the following:

A. Receive 100 percent inspection by visual and magnetic particle or penetrant or approved equivalent non-destructive inspection methods.

B. Three sample castings from different lots are static tested and shown to not have experienced detrimental deformation at or below 115 percent of design limit load and no rupture or collapse failures at or below a load of the casting factor times the ultimate load. After successful completion of these tests, a casting factor of greater than 1.00 does not have to be demonstrated during the full scale static test.

C. The castings are procured to a specification that guarantees the mechanical properties of the material in the casting and provides for demonstration of these properties by test coupons cut from cut-up castings on a sampling basis and from test tabs on each casting.

3. High variability structure is shown to satisfy the requirements by analyses. These analyses are conducted considering critical combinations of the acceptable extremes including critical ranges of dimensions, thicknesses, fastener flexibilities, tolerance buildups, eccentricities, end fixities and minimum material allowables.

DoD/MIL Doc: JSSG-2006: para A3.3.1.1, A3.10.4, A3.10.4.1, A3.10.4.2, A3.10.4.3, A3.10.4.4, A3.10.5 (for standard development)

JSSG-2006: para A4.10.4, A4.10.4.1, A4.10.4.2, A4.10.4.3, A4.10.4.4 (for compliance development)

## 5.4 Damage tolerance and durability (fatigue).

**5.4.1** Verify that all safety-of-flight (SOF) airframe structure has sufficient damage tolerance to preclude adverse safety impacts throughout its service life.

Standard: 1. The initial flaws presumed to exist in the structure (defined below) do not grow to a critical size and cause failure of the structure due to the application of the maximum internal member load in two lifetimes of the service life and usage. Average crack growth data (da/dN) are used if the variation of crack growth data is a typical distribution. Minimum values of fracture toughness are used in the damage tolerance analysis.

A. At holes and cutouts, the assumed initial flaw is a 0.05 inch through the thickness flaw at one side of the hole when the material thickness is equal to or less than 0.05 inch. For material thicknesses greater than 0.05 inch, the assumed initial flaw is a 0.05 inch radius corner flaw at one side of the hole.

B. At locations other than holes, the assumed initial flaw is through the thickness flaw of 0.25 inch length when the material thickness is equal to or less than 0.125 inch. For material thicknesses greater than 0.125 inch, the assumed initial flaw is a semicircular surface flaw with a length equal to 0.25 inch and a depth equal to 0.125 inch. Other possible surface flaw shapes with the same initial stress intensity factor can be considered as appropriate; for example, corner flaws at edges of structural elements and longer and shallower surface flaws in plates which are subjected to high bending stresses.

C. For welded structure, flaws should be assumed in both the weld and the heat affected zone in the parent material.

D. For embedded defects, the initial flaw size assumption should be based on an assessment of the capability of the non destructive inspections procedure.

E. For composite structures:

(1). Surface scratch 4.0" long and 0.02" deep.

(2). Interply delamination equivalent to a 2.0" diameter circle with dimensions most critical to its location.

(3). Damage from a 1.0" diameter hemispherical impactor with 100 ft-lbs of kinetic energy or with that kinetic energy required to cause a dent 0.10" deep, whichever is less.

(4). No significant growth resulting from manufacturing defects or high energy impact damages in two service lifetimes of usage.

F. For special applications, the safe life design methodology may be used for approved structural components (e.g., landing gear components and rotorcraft dynamic components). Damage tolerance evaluations should be conducted for all safe life designed components. These evaluations should define critical areas, fracture characteristics, stress spectra, maximum probable initial material and/or manufacturing defect sizes, and options for either eliminating defective components or otherwise mitigating threats to structural safety. Such options may include design features, manufacturing processes, or inspections. Additionally, the damage tolerance evaluation should establish the individual aircraft tracking requirements so that the safe life component replacement times and any scheduled safety inspections can be adjusted based on actual usage.

2. The loads and environment spectra should represent the service life and usage adjusted for historical data, potential weight growth, and future aircraft performance at least to initial operation capability (IOC). The spectra should also reflect baseline utilization within the design utilization distribution and such that the average aircraft usage of the fleet will be expected to meet the service life.

Compliance: 1. Analyses and tests are performed to verify that the airframe structure meets the damage tolerance requirements. Damage tolerance and residual strength analyses are conducted for each critical location of every safety of flight component. The analysis assumes the presence of flaws in the most unfavorable location and orientation with respect to the applied stresses and material properties. The analysis demonstrates that cracks growing from the presumed flaw sizes do not result in sustained crack growth under the maximum flight and ground loads for a minimum of two service lifetimes. Compliance with damage tolerance requirements are obtained without considering the beneficial effects of specific joint design and manufacturing processes such as interference fit fasteners, cold-expanded holes and joint clamp-up.

Damage tolerance testing of a complete airframe is conducted to demonstrate compliance with requirements which satisfies the following:

A. The test airframe or components are structurally identical to the operational airframe as production practicalities will permit. Any differences, including material or manufacturing process changes, are assessed for impact. The assessment includes additional component testing if the changes are significant. The test article includes artificially induced damage by the techniques developed in development testing. The sharp fatigue cracks introduced are of the appropriate size and shape consistent with the initial flaw size assumptions for the component.

B. The duration of the tests is sufficient to verify crack growth rate predictions. The test duration is a minimum of one lifetime unless sufficient information is derived in a shorter period.

C. The test is subjected to the design flight-by-flight loads spectra. Truncation, elimination, or substitution of load cycles is allowed subject to approval by the acquisition activity.

D. Major inspections are performed as an integral part of the damage tolerance testing. Proposed in-service inspection techniques will be evaluated during the tests. Surface crack length measurements are recorded during the tests. The end-of-test inspection includes a structural teardown, removal of cracked areas, and fractographic analysis of all significant fracture surfaces.

2. A flight-by-flight damage tolerance stress spectra and chemical and thermal environment spectra is developed and spectra interaction effects are accounted for.

DoD/MIL Doc: JSSG-2006: para A.3.12 Damage Tolerance, pg 398

JSSG-2006: para A.4.12 Damage Tolerance, pg 400 (for compliance development)

**5.4.2** Verify the airframe structure has sufficient durability to preclude adverse safety, economic, operational, maintenance, repair, or modification cost impacts throughout its intended service life.

Standard: 1. The airframe is free of cracking, delaminations, disbonds, deformations, or defects which require repair, replacement, inspection to maintain structural integrity, cause interference with the mechanical operation of the aircraft, affect the aircraft aerodynamic characteristics, cause functional impairment, result in sustained growth of cracks/delaminations resulting from steady-state level flight or ground handling conditions, result in water intrusion, or result in visible damage from a single 6 ft-lb impact for one lifetime of service usage.

A. Typical manufacturing initial quality flaws presumed to exist in the structure do not reach functional impairment in two lifetimes of the service life and usage.

B. The design of the airframe is such that there is sufficient aeroacoustic durability. An uncertainty factor of +3.5 dB is applied on the predicted aeroacoustic sound pressure levels and a factor of 2.0 is applied on the exposure time derived from the service usage.

C. Structural components which are subjected to wear under normal operating conditions are designed to withstand the environment throughout the service life.

D. Corrosion prevention systems are effective for minimizing corrosion damage and repair.

E. The thermal protection systems are designed to be effective for minimum periods of service usage.

F. The design, manufacture, inspection, use, and maintenance (including repair) of coatings, films, and layers is a fully integrated effort and will not degrade the structural integrity of the airframe.

G. Durability criteria established to ensure the onset of widespread fatigue damage will not occur during the design service life.

2. The loads and environment spectra represents the service life and usage defined for the aircraft adjusted for historical data, potential weight growth, and future aircraft performance at least to initial operation capability (IOC), to reflect severe utilization within the design utilization distribution such that 90 percent of the fleet will be expected to meet the service life.

Compliance: 1. Durability analyses and tests are performed to verify that the airframe structure meets the durability requirements. A full scale airframe is durability tested to show that the structure meets the required service life which satisfies the following:

A. The airframe is to be as close to structurally identical to the operational airframe, as practices allow. Significant differences require additional tests.

B. Two lifetimes of testing plus the indicated inspections verify adequate durability.

C. Test anomalies which occur within the duration of the test shall be evaluated for production and retrofit modifications. Test anomaly analysis must be correlated to test results and adjusted results shown to meet the durability requirements. Modifications shall also be shown to satisfy durability and damage tolerance requirements by either test or analysis at the discretion of the acquisition activity.

D. The test is subjected to the design flight-by-flight loads spectra. Truncation, elimination, or substitution of load cycles is allowed subject to approval by the acquisition activity.

E. Inspections shall be performed as an integral part of the durability tests and at the completion of testing and are to include design inspections, special inspections, and post

test teardown inspections.

F. A minimum of two lifetimes of durability testing is required to certify the airframe structure. A third lifetime testing is performed to support damage tolerance, repairs and modifications, usage changes, and life extension potential.

G. Durability testing demonstrates that the onset of widespread fatigue damage will not occur during the design service life.

2. A flight-by-flight durability stress spectra and chemical and thermal environment spectra is developed and spectra interaction effects are accounted for.

DoD/MIL Doc: JSSG-2006: para A.3.11 Durability, pg 378

JSSG-2006: para A.4.11 Durability, pg 379 (for compliance development)

**5.4.3** Verify that a durability and damage tolerance control process is established and implemented in the engineering design and manufacturing process.

Standard: 1. Establish a durability and damage tolerance control process to ensure that maintenance and fatigue/fracture critical parts meet the requirements of durability and damage tolerance requirements.

Compliance: 1. The durability and damage tolerance control process is properly documented and implemented with the following tasks:

A. A disciplined procedure for durability design is implemented to minimize the possibility of incorporating adverse residual stresses, local design details, materials, processing, and fabrication practices.

B. Basic data (i.e., initial quality distribution, fatigue allowables, KIC, KC, KISCC, da/dn, etc.) utilized in the initial trade studies and the final design and analyses are obtained from reliable sources or developed as parts of the program.

C. A criteria for identifying and tracing fatigue/fracture critical parts is established and is approved by the procuring agency. A fatigue/fracture critical parts list should be established by the contractor and is kept current as the design of the airframe progresses.

D. Design drawings for the maintenance critical parts and fatigue/fracture critical parts should identify critical locations, special processing (e.g., shot peening), and inspection requirements.

E. Material procurement and manufacturing process specifications is developed and updated as necessary to ensure that initial quality and fracture toughness properties of the critical parts exceed the design value.

F. Experimental determination sufficient to estimate initial quality by microscopic or fractographic examination is performed for those structural areas where cracks occur during full scale durability testing.

G. Complete nondestructive inspection requirements, process control requirements, and quality control requirements for maintenance, fatigue/fracture critical parts is established and approved by the procuring agency. This task includes the plan for certifying and monitoring subcontractor, vendor, and supplier controls.

H. The durability and damage tolerance control process includes any special nondestructive inspection demonstration programs conducted to satisfy the durability and/or damage tolerance requirements.

I. Traceability requirements are defined and imposed on those fatigue and fracture critical parts that receive processing and fabrication operations which could degrade the design material properties.

J. For all fracture critical parts that are designed for a degree of inspectability other than in-service non-inspectable, the necessary inspection procedures are defined for field use for

each appropriate degree of inspectability.

DoD/MIL Doc: MIL-HDBK-6870 for guidance in the development of Nondestructive Inspection procedures.

JSSG-2006: para A.3.13, pg 417

JSSG-2006: para A4.13, pg 419 (for compliance development)

**5.4.4** Verify that corrosion prevention systems remain effective during the service life. Specific corrosion prevention and control measures, procedures, and processes are to be identified and established commensurate with the operational and maintenance capability required of the airframe.

Standard: Corrosion prevention and control process is established.

Compliance: Corrosion prevention and control measures are established and implemented.

A. The criteria for the selection of corrosion resistant materials and their subsequent treatments is defined. The specific corrosion control and prevention measures are defined and established as an integral part of airframe structures design, manufacture, test, and usage and support activities.

B. Organic and inorganic coatings for all airframe structural components and parts, and their associated selection criteria are defined.

C. Procedures for requiring drawings to be reviewed by and signed off by materials and processes personnel are defined.

D. Finishes for the airframe are defined. General guidelines are included for selection of finishes in addition to identifying finishes for specific parts, such that the intended finish for any structural area is identified.

E. The organizational structure, personnel, and procedures for accomplishing these tasks are defined and established.

DoD/MIL Doc: JSSG-2006: para A.3.11.2 Corrosion Prevention and Control, pg 389

JSSG-2006: para A.4.11.2 Corrosion Prevention and Control, pg 392 (for compliance development)

## 5.5 Mass properties.

**5.5.1** Verify that the mass properties fully support safe vehicle operations for all defined mission requirements, variation in useful load, basing/deployment concepts, interfaces, and necessary maintenance.

Standard: 1. The mass properties used in conducting the design, analysis, and test of the air vehicle are derived combinations of the operating weights, the defined payload, and the fuel configuration are verified.

2. The mass properties reflect the current configuration of the air vehicle.

Compliance: 1. The mass properties (weights and center of gravities) are verified by inspections, analyses, and actual vehicle weighing. Pieces and parts are verified by calculation as drawings are released and actual weighing when parts are available. Each vehicle will be weighed in a completely assembled and dry condition.

2. The mass properties (weights and center of gravities) are verified by inspections, analyses, and actual vehicle weighing.

Comm'l Doc: SAWE RP No. 7: para 3.2.6 and 3.3

DoD/MIL Doc: JSSG-2006: para 3.2.5

**5.5.2** Verify that center of gravity margins are properly defined to handle aerodynamic, center of gravity, and inertia changes resulting from fuel usage, store expenditure, asymmetric fuel and store loading, fuel migration at high angle of attack and roll rates, and aerial refueling.

Standard: 1. The aircraft center of gravity remains within the approved flight envelope for all mission scenarios.

2. The provisions for determining the vehicle weight and longitudinal, lateral, and vertical center of gravity of the vehicle have been provided.

3. The center of gravity envelopes are commensurate with the requirements, all weights and account for manufacturing variations, addition of planned equipment, variations in payload, flight attitudes, density of fuel and fuel system failures.

4. A fuel system calibration methodology to determine the weight and center of gravity of the fuel has been defined.

Compliance: 1. The center of gravity margins are verified by inspections, analyses and tests.

2. The center of gravity provisions are verified by inspections, analyses and tests.

3. The center of gravity envelopes are verified by inspections, analyses and tests.

4. The fuel system calibration methodology is verified by determination of trapped fuel weight and center of gravity, determination of unusable fuel weight and center of gravity, determination of the usable fuel mass properties (weight and center of gravity), and comparison of onboard fuel indicating equipment to actual usable fuel mass properties.

Comm'l Doc: SAWE RP No. 7: para 3.4.9, 3.5, 3.2.7.3.1, and 3.2.7.3.1.4

DoD/MIL Doc: JSSG-2006: para 3.2.6

**5.5.3** Verify that flight and maintenance manuals are consistent and contain all required checklists and loading data necessary to conduct required weight and balance checks while complying with specific weight and balance requirements.

Standard: No further explanation required.

Compliance: Validity of the mass properties is verified by inspections, analyses and tests.

Comm'l Doc: SAWE RP No. 7 para 3.4.9 and DI-MGMT-81502.

DoD/MIL Doc: DI-MGMT-81502

TO 1-1B-50 "USAF Weight and Balance"

TM 55-1500-342-23 "Army Aviation Maintenance Engineering Manual – Weight and Balance"

NA 01-1B-50 "USN/USMC Aircraft Weight and Balance Control"

## 5.6 Flight release.

**5.6.1** Verify that the flight release is based on up-to-date design criteria, mass properties, and the completion of all analyses, ground, and flight tests related to loads, structural dynamics, strength, and stiffness upon which the structural data substantiates the structural design.

Standard: 1. The accuracy of the loads predictive methods are validated by using an instrumented and calibrated flight test air vehicle to measure actual loads and load distributions during flight within the 100% DLL flight release envelope.

2. Prior to strength flight release for operation up to 100% of DLL for either production air vehicles or flight test air vehicles not strength proof tested to 100% of DLL, the airframe has exhibited ultimate load static test strength for ultimate loads, environmentally compensated

as applicable, which reflect verified external limit loads and validated and updated structural analysis. Test conditions selected for substantiating the strength envelope for each component of the airframe.

3. For the flight release, flight restrictions are defined as:

A. Load factors and maneuvers are limited such that the air vehicle does not experience loads greater than 100% of DLL.

B. Maximum speed is Vh/Mh such that a margin of safety of 15% or greater is maintained at all points on the $V_L/M_L$ envelope of the air vehicle, both at constant Mach number and separately, at constant altitude.

C. The loads resulting from overshoots, upsets, and the recovery from overshoots and upsets, and the loads during and following system failures are included in the establishment of the flight restrictions.

Compliance: Validity of the requirements as identified in the standards is verified by a series of analyses and tests. The following compliances are applicable in addressing the standards:

1. Formal updated structural analysis (external loads, internal loads and strength, limited durability and damage tolerance, structural dynamics) correlated to all available ground and flight testing. Strength, durability and damage tolerance analyses resulting with margins > 0.0. Finalization of the service and maximum loads expected to be encountered during operation under all flight conditions. Issuance of Strength Summary and Operating Restrictions. Established the inspection and maintenance intervals to encsure continued safe operations.

2. Wind tunnel tests. Component ground vibration, acoustic and stiffness tests. Mass measurements of control surfaces/tabs. Control surface, tab, and actuator rigidity, free play, and wear tests. Complete air vehicle ground vibration modal tests. Aeroservoelastic ground tests. Updated predictions of near field aeroacoustic, vibration and internal noise. Ground loads test demonstrations, shimmy ground tests, rough runway tests.

3. Successful completion of appropriate flight flutter, vibroacoustics, loads testing (100%) and ultimate loads static tests. The latter includes extensive examination of static test article instrumentation to ensure that test measured values are within, or well correlated to, predicted values as adjusted by verified external loads. Structural analyses are validated and updated for all testing such that the predictive methods ensure adequate strength levels and understanding of the structural behavior.

DoD/MIL Doc: JSSG-2006: para A3.5, A3.6, A3.7, A4.7, A4.10.5.3, A4.10.5.4, A4.10.5.5

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## 6. FLIGHT TECHNOLOGY

Flight technology comprises the flight mechanics functional areas consisting of stability & control, flying qualities, vehicle management functions, flight control functions, external aerodynamics, internal aerodynamics and performance. The air vehicle aerodynamic and stability configuration, engine/inlet/nozzle compatibility, performance and integrated control airworthiness of an air vehicle should be assessed using the criteria provided in the text below (not all items apply in each case; similarly, items may have to be added for vehicles employing new or innovative technology/techniques).

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Design studies and analyses
3. Design, installation, and operational characteristics
4. Simulation tests, modeling, and results (including simulation verification, validation and accreditation data)
5. Design approval and function/system compatibility tests
6. Component and functional level qualification and certification tests
7. Electromagnetic environmental effects
8. Installed propulsion compatibility tests
9. Acceptance criteria for test results
10. Failure modes, effects, and criticality analysis/testing (FMECA/FMET)
11. Hazard analysis and classification
12. Safety certification program
13. Computational, theoretical, and/or semi-empirical prediction methods
14. Configuration: aerodynamic design and component location
15. Wind tunnel test results and correction methods
16. Mathematical representation of system dynamics
17. Ground resonance and loop stability tests
18. Aeroservoelastic design criteria and analysis
19. Performance analysis
20. Flight manual
21. Natural environmental sensitivities
22. Flight path guidance analysis and simulation to include ship launch and recovery routines if applicable (including sensor or processor failure modes and effects on flight control)
23. Interface/integration control documents
24. Function, subfunction, and component specifications
25. Selection criteria and patterns selected for screens constructed to demonstrate inlet/engine compatibility
26. Flight test plan
27. Detailed flight profiles
28. Aircraft/engine operating limitations
29. Software development plan

30. Software development and product specifications
31. Software test plans, test procedures, and test reports
32. Software configuration control/management plan and procedure
33. Control laws
34. Flight test reports
35. Aerodynamic and air data uncertainty sensitivity studies
36. Trust-drag bookkeeping system
37. Mass properties: weights, C.C.s, and inertias

CERTIFICATION CRITERIA

DoD/MIL Doc: JSSG-2001 Air Vehicle

JSSG-2008 Vehicle Control and Management Systems

FAA Doc: NOTE: As each section applies, flight technology must be checked for a variety of 14CFR references and ACs. Due to the complexity of different design configurations, each section in Subpart C of 14CFR reference 23/25 should be consulted for applicability.

## 6.1 Stability and control.

DoD/MIL Doc: JSSG-2001 Air Vehicle Specification and Appendix C

MIL-STD-1797A: refer to appropriate sections to comply with the airworthiness criteria, standards, and methods of compliance for piloted air vehicles throughout this section

ADS-33E-PRF (rotary aircraft)

For UAV/ROA: TDB

FAA Doc: 14CFR references: 23.21-23.3, 23.171-23.181,

14CFR references: part 25 (Airworthiness Standards: Transport Category Airplanes)

AC-23-8B (Flight Test Guide for Certification of Part 23 Airplanes)

AC-25-7A (Flight Test Guide for Certification for Transport Category Airplanes)

### 6.1.1 Control power.

#### 6.1.1.1 Verify control power: (for criterion 6.1.1.1.1 through 6.1.1.1.13)

Compliance: General for each subsection (6.1.1.1.1 through 6.1.1.1.13)

Aerodynamic control power sufficient to assure safety throughout all flight envelopes, flight phases and missions for the combined range of all attainable angles of attack (both positive and negative), sideslip, load factor and bank angles.

Vehicle control power is sufficient to provide safe flying qualities in the presence of aerodynamic, inertial, structural and control system uncertainties.

For each axis of control (longitudinal, lateral, and vertical), ensure sufficient control power provided by the applicable control surface or combination of surfaces. In case a surface is used to control more than one axis, ensure sufficient control power exists for the worst-case combinations of requirements.

DoD/MIL Doc: JSSG-2001A: Appendix C para C.3.1, C.3.13.4.2 & C.4.1, " Control power"

MIL-STD-1797A: para 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8 and 5.9

**6.1.1.1.1** (was 6.1.1.1.a) At minimum controllable speeds

Standard: Control power adequate to:

a. Trim the aircraft about all axes at minimum controllable airspeed in takeoff and landing configurations

b. Develop TBS degrees of sideslip in the power approach.

c. Maintain air vehicle sink rates within allowable subsystem and structural limits.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.2** (was 6.1.1.1.b) For rotation on takeoff

Standard: Effectiveness of the pitch control does not restrict the takeoff and landing performance of the aircraft. Possible to control, obtain and maintain air vehicle attitudes up to and including tail strike attitude during the takeoff roll within +/- 1 degrees.

The term takeoff includes the ground run, rotation, and lift–off, the ensuing acceleration to Vmax (TO), and the transient caused by assist cessation. Takeoff encompasses operation both in and out of ground effect. Takeoff power maintained until Vmax (TO) is reached, with the landing gear and high–lift devices retracted in the normal manner at speeds from Vomin (TO) to Vomax (TO).

A. Limits on maximum push and pull forces required for takeoff be lower than those allowed for other operations. Pitch control input for takeoff need not be abrupt or require excessive effort or two–handed operation.

B. Values for aircraft with centerstick or wheel controllers:

1) Nose–wheel and bicycle–gear aircraft

2) Classes I, IV–C: 20 pounds pull to 10 pounds push

3) Classes II–C, IV–L: 30 pounds pull to 10 pounds push

4) Classes II–L, III: 50 pounds pull to 20 pounds push Tail–wheel aircraft

5) Classes I, II–C, IV: 20 pounds push to 10 pounds pull

6) Classes II–L, III: 35 pounds push to l5 pounds pull.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.3** (was 6.1.1.1.c) To handle control surface mis-trim on takeoff

Standard: Mis-trim in any axis on takeoff cannot defeat other features incorporated in the flight control system that prevent or suppress departure from controlled flight or exceedance of structural limits, or that provide force cues which warn of approach to flight limits. The failures to be considered include trim sticking and runaway in either direction. It is permissible to meet this requirement by providing the pilot with alternate trim mechanisms or override capability.

Vehicle handles the worst case mis-trim at any part of the takeoff roll (including run-up and brake release) and achieve takeoff attitude, including abort from abort takeoff attitude until the vehicle is stopped on the runway.

Compliance: Verification by simulation, analysis and test.

Flight conditions explore the boundaries of mis-trim at most forward and most aft c.g. Inducing failures at these conditions by intentionally mis-trimming the aircraft and recovering from the mis-trim at these conditions will depend on the control feel.

**6.1.1.1.4** (was 6.1.1.1.d) To prevent or stop over-rotation in takeoff

Standard: Effectiveness of the pitch control is sufficient to prevent over-rotation during all conditions of takeoff.

It is possible to control, obtain and maintain air vehicle attitudes up to and including tail strike attitude during the takeoff and landing roll.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.5** (was 6.1.1.1.e) To provide safe control for go-around with engine(s) failure (critical engine(s) inoperative)

Standard: For engine failure during takeoff, the Standard is control at speeds down to Vmin (TO); but requirements for engine–out climb capability are left to performance specifications.

Asymmetric loss of thrust may be caused by many factors including engine failure, inlet unstart, propeller failure or propeller–drive failure. The requirements apply for the appropriate flight phases when any single failure or malperformance of the propulsive system, including inlet, exhaust, engines, propellers, or drives causes loss of thrust on one or more engines or propellers, considering also the effect of the failure or malperformance on all subsystems powered or driven by the failed propulsive system. Pilot is capable of maintaining directional control of the aircraft following a loss of thrust from the most critical propulsive source, allowing a realistic time delay of seconds, as follows:

A. Airborne: After lift–off, without a change in selected configuration to achieve straight flight following critical sudden asymmetric loss of thrust at speeds from Vmin (TO) to Vmax (TO), and thereafter to maintain straight flight throughout the climbout and to perform 20–degree–banked turns with and against the inoperative propulsive unit. Automatic devices that normally operate in the event of a thrust failure may be used, and for straight flight the aircraft may be banked up to 5 degrees away from the inoperative engine.

B. Waveoff/go–around: At any airspeed down to Vmin (PA) the air vehicle can achieve and maintain steady, straight flight with waveoff (go–around) thrust on the remaining engines following sudden asymmetric loss of thrust from the most critical factor. Configuration changes within the capability of the crew while retaining control of the aircraft, and automatic devices that normally operate in the event of a propulsion failure, may be used.

C. Crosswinds: The aircraft response requirements for asymmetric thrust in takeoff and landing apply in the crosswinds from the adverse direction.

D. General: The static directional stability at all speeds above Vmin, with the critical asymmetric loss of thrust while the other engine(s) develop(s) normal rated thrust, the aircraft with yaw control pedals free can be balanced directionally in steady, straight flight. The trim settings are those required for wings–level, straight flight prior to the failure.

Five degrees is about the greatest bank angle possible without significantly reducing the vertical component of lift. A requirement for turn capability, similar to 14CFR reference 25.147, addresses the need to ensure maneuvering capability in airport environments to avoid obstacles that become a threat due to the heading change likely incurred with the loss of an engine. The requirement with rudder pedals free is intended to preclude the consequences of stalling the vertical tail in case of an engine failure. Larger bank and sideslip angles generally will be needed.

Compliance: Verification by simulation, analysis and test.

Simulated engine failures performed in flight, covering at least the critical conditions specified by the procuring activity and the contractor, and covering the range of service speed and altitude for the pertinent Flight Phases. Fuel cutoff is a representative way to simulate many critical propulsion failures.

**6.1.1.1.6** (was 6.1.1.1.f) To provide safe maneuver margins during trimmed flight on approach

Standard: Stalling of a trim system due to aerodynamic loads during maneuvers does not result in an unsafe condition.

Rate of trim operation is sufficient to enable the pilot to maintain low control forces, yet not so rapidly as to cause oversensitivity or trim precision difficulties, during waveoff/ go-around.

Yaw axis control power shall be adequate to develop 15 degrees of sideslip in the power approach.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.7** (was 6.1.1.1.g) For sufficient trim capability

Standard: All trimming devices maintain a given setting indefinitely unless changed by the pilot, or by a special automatic interconnect (such as to the landing flaps), or by the operation of an augmentation device. If an automatic interconnect or augmentation device is used in conjunction with a trim device, design for the accurate return of the device to its initial trim position on removal of each interconnect or augmentation command.

Rate of trim operation is sufficient to enable the pilot to maintain low control forces under changing conditions normally encountered in service, yet not so rapidly as to cause oversensitivity or trim precision difficulties under any conditions, including:

A. Dives and ground attack maneuvers required in normal service operation

B. Level–flight accelerations at maximum augmented thrust from 1.2 Vs to Vmax at any altitude when the aircraft is trimmed for level flight prior to initiation of the maneuver.

Stalling of trim system due to aerodynamic loads during maneuvers does not result in an unsafe condition. The entire trim system operates during the dive recoveries at any attainable, permissible load factor, at any possible position of the trimming device.

Steady–state trim changes for normal operation of control devices such as throttle, thrust reversers, flaps, slats, speed brakes, deceleration devices, dive recovery devices, wing sweep and landing gear not impose excessive control forces to maintain the desired heading, altitude, attitude, rate of climb, speed or load factor without use of the trimmer control. This requirement applies to all in–flight configuration changes and combinations of changes made under service conditions, including the effects of asymmetric operations such as unequal operation of landing gear, speed brakes, slats or flaps. In no case any objectionable buffeting or oscillation caused by such devices be present.

Automatic trimming devices do not degrade or inhibit the action of response limiters and are compliant with the above.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.8** (was 6.1.1.1.h) To provide safe control margins in the event of abnormal or asymmetric fuel function operation

Standard: The longitudinal, lateral, and vertical envelopes of center of gravity and corresponding weights that will exist for each flight phase defined. These envelopes include the most forward and aft center–of–gravity positions as defined. In addition, determine the maximum center–of–gravity excursions attainable through failures in systems or components, such as fuel sequencing or hung stores, for each Flight Phase. Newly developed aircraft must include a growth/uncertainty margin.

Flying qualities accommodate the basic lateral asymmetry due to fuel system tolerances, equipment mounted off centerline, and fuel sequencing, transfer failures or malperformance, and mismanagement that might move the center of gravity such as guns and ammunition.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.9** (was 6.1.1.1.i) To safely handle transient effects

Standard: Transient motions and trim changes resulting from the intentional engagement or disengagement of any portion of the flight control system by the pilot not produce dangerous flying qualities.

Transients for normal operation of control devices such as throttle, thrust reversers, flaps, slats, speed brakes, deceleration devices, dive recovery devices, wing sweep and landing

gear not impose excessive control forces to maintain the desired heading, altitude, attitude, rate of climb, speed or load factor without use of the trimmer control. This applies to all in–flight configuration changes and combinations of changes made under service conditions, including the effects of asymmetric operations such as unequal operation of landing gear, speed brakes, slats or flaps. No objectionable buffeting or oscillation caused by such devices.

3. Aircraft motions following sudden aircraft system or component failures avoid dangerous conditions by the crew, without requiring unusual or abnormal corrective action.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.10** (was 6.1.1.1.j) To safely handle problems arising from asymmetric or symmetric failures of trim controls and any adverse control surface positioning or special use surface(s)/devices

Standard: Straight flight path can be maintained throughout the Flight Envelope for all asymmetric conditions encountered in normal operation.

Control power with asymmetric loadings sufficient to hold the wings level at the maximum load factors with adequate control margin

No single failure of any component or system results in dangerous or intolerable flying qualities while using trim controls, any adverse control surface positioning or special use surface(s)/devices.

Crew given immediate and easily interpreted indications whenever asymmetric or symmetric failures occur that require or limit any flight crew action or decision.

Realistic time delay of at least 3 secs between the failure and initiation of pilot corrective action incorporated when determining compliance. Time delay includes an interval between the occurrence of the failure and the occurrence of a cue such as acceleration, rate, displacement, or sound indicate to the pilot that a failure occurred, plus an additional interval which represents the time required for the pilot to diagnose the situation and initiate corrective action.

In straight flight, throughout the Operational Flight Envelope, the trimming system reduces the steady-state control forces to zero or within breakout forces.

Trim systems do not defeat other features incorporated in the flight control system that prevent or suppress departure from controlled flight, exceedance of structural limits, or force cues which warn of approach to flight limits.

Failures addressed include asymmetric or symmetric failures of trim controls and any adverse control surface positioning or special use surface(s) /devices, including trim sticking and runaway in either direction. It is permissible to meet requirements by providing the pilot with alternate mechanisms or override capability.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.11** (was 6.1.1.1.k) To safely handle unwanted deployment or activation of thrust reverser or vectored thrust equipment whenever the possibility is not extremely improbable

Standard: Vehicle handles unwanted deployment or activation of thrust reverser or vectored thrust equipment from the minimum service speed, Vmin or Mmin all the way to Vmax or M max, for each altitude. Vmin is the highest of:

A. 1.1 Vs

B. Vs + 10 knots equivalent airspeed

C. The speed below which full aircraft–nose–up pitch control power and trim are insufficient

to maintain straight, steady flight.

D. The lowest speed at which level flight can be maintained with MRT.

E. A speed limited by reduced visibility or an extreme pitch attitude that would result in the tail or aft fuselage contacting the ground.

Vehicle safely handles unwanted deployment or activation of thrust reverser or vectored thrust equipment from brake release through takeoff, up and including Vmin (TO) and engine–out climb.

The control margin met with aerodynamic control power only, without the use of other effectors such as thrust vectoring.

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.12** (was 6.1.1.1.l) Sufficient for unique vehicle performance

Standard: Flying and ground handling qualities are at least Level 1 without failures and Level 2 with any failure.

Design defines the configuration or configurations which are required for each Flight Phase. This includes the settings of such controls as flaps, speed brakes, landing gear, wing sweep, high lift devices, and wing incidence that are related uniquely to each aircraft design. This produces vehicle flying qualities adequate for mission performance and flight safety regardless of the design implementation or flight control system augmentation

Compliance: Verification by simulation, analysis and test.

**6.1.1.1.13** (was 6.1.1.1.m) To safely handle engine failures during take-off ground roll

Standard: For engine failure during takeoff, the standard is control at speeds down to Vmin (TO); and engine–out climb.

During the takeoff run, the trim system able maintain the allowable ground path within +/- 10 ft deviation and within +/- 2 degrees of commanded vehicle attitude.

During the takeoff run, a straight path can be maintained on the takeoff surface without deviations of more than 50 feet from the path originally intended, following sudden asymmetric loss of thrust for the following conditions:

A. For the continued takeoff, when thrust is lost at speeds from the refusal speed (based on the shortest runway from which the aircraft is designed to operate) to the maximum takeoff speed, with takeoff thrust maintained on the operative engine(s); without depending upon release of the pitch, roll, yaw or throttle controls; and only controls not dependent upon friction against the takeoff surface.

B. For the aborted takeoff, at all speeds below the maximum takeoff speed; however, additional controls such as nose wheel steering and differential braking may be used. Automatic devices that normally operate in the event of a thrust failure may be used in either case.

Compliance: Verification by simulation, analysis and test.

**6.1.2** Stability characteristics and transients.

**6.1.2.1** Verify that safe static and dynamic stability exists with augmentation or active control functions operating. If sufficient redundancy is not provided in the air vehicle flight control functions to provide fail-safe operation, verify that the basic airframe (unaugmented) possesses the required stability characteristics and safety margins.

Standard: The controllability margin conventionally provided by static stability are translated for CCV's into margins of control authority and rate. Control adequate for the combined tasks of trim

(establishing the operating point), maneuvering, stabilization (regulation against disturbances), and handling of failures (flight control system, propulsion, etc). There are also possible malfunctions and mismanagement in fuel usage that are considered.

Aeroelasticity and dynamic control effectiveness also reduce control margins. For vehicles augmented to counter degraded static stability, the change in center of rotation from c.g. to main gear at touchdown might result in an uncontrollable situation even if ample control power exists.

In accordance with classical definitions of static stability, the prohibition of airspeed divergence is satisfied if the gradients of pitch control force and deflection with airspeed are negative, that is, if the aircraft will return toward its trim airspeed after a speed disturbance, controls fixed or free.

The following events do not cause dangerous or intolerable flying qualities:

A. Complete or partial loss of any function of the flight control system as a consequence of any single failure (approved Aircraft Special Failure States excepted).

B. Failure-induced transient motions and trim changes either immediately upon failure or upon subsequent transfer to alternate modes.

C. Configuration changes required or recommended following failure.

No single failure shall result in flying qualities less than Level 2.

The amount of control capability at extreme angles of attack, positive and negative, is adequate to recover from situations that are not otherwise catastrophic.

Control sufficient to counter the worst dynamic pitch–up tendency below stall or limit angle of attack. Propulsion and flight control system failure transients are considered, along with possibly degraded control authority and rate after failure: spin/post–stall gyration susceptibility and characteristics. Fuel system failure or mismanagement is accounted for in the design.

Augmentation and control augmentation systems and devices do not introduce any flight or ground handling characteristics less than Level 2.

Any performance degradation of stability and control augmentation systems due to saturation of components, rate limiting, or surface deflections, is only momentary, and does not introduce any flight or ground handling characteristics less than Level 2. This applies for all Normal States and Failure states in the atmospheric disturbances and during maneuvering flight at the angle–of–attack, sideslip, and load–factor limits of the vehicle flight and ground operating envelope. It also applies to post–stall gyrations, spins, and recoveries with all systems, such as the hydraulic and electrical systems, operating in the state that may result from the gyrations encountered.

Compliance: Verification by simulation, analysis and test.

A. Conventional/stable air vehicles: These are designed to naturally/aerodynamically exhibit positive static and dynamic stability. This is verified by examining wind tunnel data for the full permissible flight envelope of the air vehicle.

1). Positive characteristics, with sufficient control margin, exist throughout the service flight envelope. Stability augmentation systems may be employed to enhance static and/or dynamic response characteristics so as to comply with specification or pilot/passenger preferences (e.g., yaw damper to improve Dutch Roll characteristics).

2). Unaugmented air vehicle (with disabled augmentation) exhibits positive static and dynamic characteristics throughout the operational flight envelope.

B. Non-linear/relaxed stability air vehicles: These air vehicles may naturally exhibit reduced, neutral, and/or unstable aerodynamic characteristics within the permissible flight envelope. Stability augmentation is normally utilized to artificially enhance static and/or dynamic characteristics so as to assure safe operation. Wind tunnel data with augmented

(scheduled) control usage throughout the angle-of-attack (AoA), Mach, angle-of-sideslip (AoS) regime of the air vehicle is examined to assure that adequate control margin and control power is maintained throughout the permissible flight envelope.

C. Acceptable static and dynamic response characteristics exhibited throughout the service flight envelope using off-line and piloted simulations as well as in flight test.

D. Off-line and piloted simulations are used to verify that, if critical/flight control system failures occur outside in the operational flight envelope, adequate control margins and control power exist to safely return to the operational flight envelope.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3

FAA Doc: 14CFR reference: 25.171-25.181

**6.1.2.2** Verify that augmentation function(s), active control function(s), and related flight mode(s) engagements and disengagements do not result in unsafe transients.

Standard: The following response to configuration or control mode change defined for Aircraft Normal States:

A. Dangerous flying qualities never result from transient motions and trim changes due to configuration changes, or from the intentional engagement or disengagement of any portion of the primary flight control system in equilibrium flight due to pilot or automatic flight control system action.

B. Mode switching does not result in any large transients.

C. Functions are provided in the control system that allow transients within its design flight regime or maneuvers.

D. Transients do not violate limiters necessary for stable and controlled flight, or for structural considerations.

With controls free, transient motions following mode transitions do not exceed pitch angle limits for at least 2 seconds, or induce roll rates greater than 3 deg/sec.

Compliance: Verification by simulation, analysis and test.

A. The integrated flight control system properly designed to assure that engagement and disengagement from any of these functions does not result in unsafe transients. In particular, attention is paid to assure that a function does not, by design, defeat or overpower another critical function/mode, resulting in unsafe conditions.

1) For example, if an aircraft with an automatic angle-of-attack limiter has attitude hold engaged, the attitude hold function must be mechanized so as to not defeat the angle-of-attack limiter.

2) For Auto-GCAS, TF/TA, and similar functions which take active control of the air vehicle, the “hand off” of control back to the pilot, after the automatic mode has completed its function or the pilot actively disengages the mode, it is evident to the pilot and virtually transient free.

B. VCF mechanization is such that none of the augmentation systems/functions/modes will defeat or overpower another critical function/mode, resulting in unsafe conditions. Also, proper mode switching occurs so as to not allow unsafe conditions to occur.

C. Extensive off-line and piloted simulations conducted throughout the envelope for which the augmentation function is designed to operate within. Extensive engagements and disengagement, both manual and “automatic”, are exercised to assure safe transients result.

D. Extensive failure modes and effects testing conducted with each of the augmentation functions/modes engaged. The augmentation system must be designed to properly handle critical failure states without resulting in unsafe conditions.

E. Proper and safe disengagements, when necessary, occur and the resultant transients

are minimal. If the function is designed to operate in the presence of failures, the integrated system designed to allow graceful degradation of functionality.

Where autonomous vehicle control is on UAVs/ROAs, the same conditions and testing as noted above apply for the various modes and contingencies associated with a UAV/ROA.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR reference: 25.171-25.181

**6.1.2.3** For autonomous vehicle control, verify that the net stability, with the guidance and control system operating, is safe for the intended mission under normal operating conditions.

Standard: Vehicle control system phase and gain margins are at least 6 db and 45 degrees.

A. These margins include all functions necessary to control the vehicle including any ground or air links as applicable.

B. These margins include a realistic time delay for any normal condition between initiation and a cue of reaction.

For unmanned vehicles, the autonomous ability to accommodate failures, emergency conditions, and recovery to pre-planned routes is defined as part of the normal operating conditions. Within this context and under these conditions, autonomous vehicle control provides flying qualities are better than CH7.

Autonomous vehicle control may or may not include an active crew on the ground or onboard the vehicle. In cases where the crew is involved and where phase and gain margins are not at least 6 db and 45 degrees, flying qualities are better than CH5.

Compliance: Verification by simulation, analysis and test.

DoD/MIL Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

**6.1.3** Flying, handling, and ride qualities.

**6.1.3.1** Verify safe flying quality characteristics in turbulence (including ship's airwake/burble).

Standard: Flying qualities in atmospheric disturbances (including the wake vortex of another aircraft, jet streams, storms, wakes of buildings, etc., as well as gusts and wind) satisfy the following:

A. In atmospheric disturbances the minimum required flying qualities for all required tasks is Level 2

B. Atmospheric disturbances effects are investigated analytically and in manned simulation with severe and extreme magnitudes.

C. Control surface deflection rates in the atmospheric disturbances are sufficient to perform operational maneuvers. Control rates are adequate to retain stabilization and control in Severe disturbances. Include for powered or boosted controls, the effect of engine speed and the duty cycle of both primary and secondary control together with the pilot control techniques when establishing compliance.

D. Any performance degradation of stability and control augmentation systems due to saturation of components, rate limiting, or surface deflections, is momentary and has no objectionable flight or ground handling characteristics for all Normal States and Failure States in the presence of atmospheric disturbances.

Atmospheric/wake disturbances in the form of gusts do not prevent any maneuvering in the Operational Flight Envelope.

For all failure states and flight conditions, control margins are such that control can be

maintained long enough to fly out of atmospheric disturbances, safely terminate any flight phase, and accomplish a successful waveoff (go–around).

Compliance: Verification by simulation, analysis and test.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR reference: 23.361, 25.341, 23.1501-23.1529, 25.1501-25.1529

**6.1.3.2** Verify that the control law concepts employed are compatible with mission and safety requirements.

Standard: The best ratings are achieved in simple tracking experiments with a pure–gain pitch rate response and the resulting attitude response of K/s. Real aircraft have inertia, control power limits, and pilots who dislike excessive pitch acceleration. Design accommodates the following:

A. For Category A and Category C Flight Phases, attitude dropback values depend on the task and on the pitch rate transients.

B. Normal acceleration responses can be related to Level 1 frequency and damping requirements. Any oscillations following the first peak subside such that the ratio of successive half–cycles is less than 0.3.

C. Boundaries of satisfactory frequency responses for Category A precision attitude tracking are determined by time response limits.

D. An envelope of satisfactory Category C landing approach response meets bandwidth of 0.25 to .5 Hz at 120 degrees phase lag.

E. By the nature of the attitude frequency response, if the crossover frequency is low and the attitude attenuates only slowly towards the crossover region, the phase rate is large. If the frequency is high and there is substantial attenuation, the phase rate is low. The gain margin is increased, the stick pumping amplitude is reduced and the tendency for PIO is decreased automatically by designing a low phase rate into the control laws. For the control law designer it is sufficient to aim for a phase rate of less than 100 degrees per cps and attitude response phase rate of less than 100 degrees per cps and attitude response smaller than 0.1 deg/lb at the crossover.

F. Some level of speed stability is helpful in the approach flight condition

G. At high positive angle of attack, aileron and differential tail authority are reduced and rudder is put in to coordinate the roll. At negative angle of attack, rudder is used to uncoordinate the roll, due to a large increase in proverse yaw and a loss in dihedral effect at negative angle of attack.

Control laws optimized for flying qualities and departure resistance. Maneuvers included bank–to–bank rolls at maximum angle of attack, rolls at negative angle of attack, pushovers, pullups, and other maneuvers chosen for analysis of departure and spin characteristics.

Control laws implemented so that flying qualities remain below Level 1 with no failure and below Level 2 after one failure for most failure conditions. No worse than CH 7 for all but catastrophic failures that are extremely remote.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR reference: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.3.3** Verify that the design exhibits safe vehicle flying characteristics for: ((for criterion 6.1.3.3.1 through 6.1.3.3.3)

**6.1.3.3.1** (was 6.1.3.3.a) Classical, safe, second-order response in pitch

Standard: The longitudinal vehicle response dynamics, including flight control system nonlinearities and higher–order dynamics or aerodynamic nonlinearities, matched to an equivalent classical 2nd order system.

The phugoid and short period are generally separated by at least a factor of 10, which is adequate to consider them separately for static stability. This assumption breaks down at low and near-zero values of static stability such as for conventional aircraft with extreme aft center of gravity locations and on most STOL configurations. Another case is transonic "tuck", which occurs when a nose–down pitching moment with increasing Mach number causes the phugoid poles to split into two real roots, which may become large.

Nonlinearities or higher–order dynamics that exist do not result in Level 2 flying qualities or any dangerous characteristics.

Adequacy of the response match between equivalent and actual aircraft, or alternative criteria, agreed upon by the contractor and the procuring activity.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.3.2** Was 6.1.3.3.b) First-order, well-behaved response in roll without roll ratcheting or other roll sensitivities

Standard: The lateral vehicle dynamics, including flight control system nonlinearities and higher–order dynamics or aerodynamic nonlinearities, match to an equivalent classical system

Adequacy of the response match between equivalent and actual aircraft, or alternative criteria, agreed upon by the contractor and the procuring activity.

Nonlinearities or higher–order dynamics that may exist do not result in any Level 2 or any dangerous characteristics.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.3.3** (was 6.1.3.3.c) Equivalent system time delay

Standard: Equivalent system time delay is:

A. Less than 100 ms in all axes for Level 1.

B. Less than 200 ms in all axes for Level 2.

C. Less than 250 ms in all axes for level 3.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.4** Verify that aeroelastic, nonlinear, discontinuous, and unsteady aerodynamic effects demonstrate a safe vehicle.

Standard: Aeroelasticity and structural dynamics exert an important influence on the aircraft flying qualities. Such effects are accounted for in calculations or analyses and include the following:

A. Hinge moments limit control deflection and aeroelastic deformations that affect controllability.

B. High supersonic speed and aeroelasticity and large high hinge moments at high dynamic pressure tend to restrict the control capability.

C. Low speed, high angle of attack (high lateral stability and large aileron yaw) and high dynamic pressure (aeroelastic deformation) are common critical flight conditions.

D. Aeroelasticity tends to reduce roll control effectiveness at high dynamic pressure.

Aerodynamic nonlinearities and encounters with atmospheric upsets such as gusts and turbulence can cause an appreciable difference in the aircraft response apparent to the pilot from that of the linear model of the basic airframe. These effects are accounted for in the

analysis and CH evaluations.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

If significant nonlinearities are present in the system, the open–loop frequency response depends on the size of the input used in the identification process. When such nonlinearities are suspected, several frequency sweeps are accomplished with different input magnitudes.

Verification by simulation, analysis and test. Manned simulation used to verify control laws, flying qualities and departure resistance prior to flight and as an adjunct to flight testing.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.1.3.5 Verify that aircraft pilot coupling (APC) and pilot-induced oscillation (PIO) tendencies and flight characteristics are safe.

Standard: There is no tendency for pilot–induced or limit-cycle oscillations (i.e., sustained or uncontrollable oscillations) resulting from the efforts of the pilot or automatic flight control system to control the aircraft.

Residual oscillations are limit cycles resulting from nonlinearities such as friction, hysteresis and poor resolution. Negative static stability will contribute and low damping may augment the amplitude. Thus high speed, high dynamic pressure or high altitude are critical and accounted for in the evaluations.

Any sustained residual oscillations in calm air do not interfere with the pilot's ability to perform the tasks required in service use of the aircraft. This requirement, applicable to all axes, covers those axes of control for which there is no data base for more specific requirements.

For the analysis or design of such systems the time–response features are considered individually. Additional high–order effects are evident most importantly in tq, the delay in reaching the pitch acceleration peak which is a strong indicator of PIO and handling problems when greater than 0.3 seconds. Problems (pitch PIO in landing caused by control system phase shift and roll PIO caused by high roll control gain) have been experienced in highly augmented aircraft.

Compliance: Verification is by manned and unmanned simulation, analysis and test. Manned simulation used to verify control laws, flying qualities and departure resistance prior to flight and as an adjunct to flight testing.

A PIO rating procedure is used similar to the Cooper–Harper procedure. Comparing the Level and rating descriptions, roughly a PIO rating of 1 or 2 would be level 1, a 3 or 4 PIO rating level 2, a 5 PIO rating Level 3, and of course a 6 PIO rating extremely dangerous.

The existence of a PIO tendency is difficult to assess. Therefore, no specific flight conditions or tasks are recommended, though a high–stress task such as approach and landing with a lateral offset, terrain following, air–to–ground tracking, or in–flight refueling (receiver) may reveal PIO proneness as suggested in JSSG-2001.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

#### 6.1.3.5.1 Verify safe phase and gain margins.

Standard: Phase margin is at least 45 deg and the gain margin is at least 6 dB. Both criteria are met in all axes.

Compliance: High-fidelity simulations and analysis tools verify adequate phase and gain margins (e.g., typically, -6dB gain and 45 degrees phase) exist in every loop.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.3.5.2** Verify, under high gain conditions, that the design does not exhibit unsafe limit cycle oscillations, unbounded oscillations, unsafe triggering mechanisms during mode transitions, or unsafe sudden/steep gain changes.

Standard: For the entire flight and ground envelope under high gain conditions, limit cycle oscillations, unbounded oscillations, unsafe triggering mechanisms during mode transitions, or unsafe sudden/steep gain changes do not interfere with the pilot's ability to perform required tasks. This applies with controls fixed and free, for all possible aircraft configurations and maneuvers and during all configuration changes.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.3.6** Verify general ground handling characteristics to be safe for (for criteria 6.1.3.6.1 through 6.1.3.6.5)

**6.1.3.6.1** (was 6.1.3.6.a) Positive steering control

Standard: Positive steering control is available for all normal and abnormal center-of-gravity locations for realizable fuel states during taxi, takeoff, and landings in all mission environments (e.g., wet, snow, icy runways). Steering sensitivities, steering logic (e.g., nose wheel steering fade in/out), and potential failure conditions (weight on wheel normal and failed conditions), and other control paths/signals which may affect functionality are included.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.6.2** (was 6.1.3.6.b) Steering sensitivities

Standard: Operation of stability augmentation and control augmentation systems and devices do not introduce any objectionable ground handling characteristics.

Any performance degradation of stability and control augmentation systems due to saturation of components, rate limiting, or surface deflections, is only momentary, and does not introduce any objectionable ground handling characteristics.

This applies for all Normal States and Failure states in the atmospheric disturbances (gust, wind shear, cross winds, turbulence).

This also applies to a 20% additional delay time, 25% variations in friction, and 20% variations in controller phase and gains.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.6.3** (was 6.1.3.6.c) Steering fade in/out

Standard: Transition transients for steering fade in/out as control laws change from steering to rudder are barely perceptible to the pilot.

Transients due to gain switching in the steering control laws between modes or activated by modes are not overly large in magnitude, with no oscillatory motion.

Stability margins in the control function are not adversely affected for normal and abnormal uses of the steering mode or failures of the steering mode.

Transients do not exceed 0.1% of full stroke.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.6.4** (was 6.1.3.6.d) Failure conditions

Standard: Failure–induced transient motions from the nose wheel or differential braking do not exceed

an excursion of more than ± 10 ft from the direction the steering was pointing at the time of failure with the wheel castering within 0.1 seconds of failure and differential braking compensated within 0.25 seconds.

Vehicle porpoising is limited to ± 2 degrees.

Mission profiles, uploads, autonomous control instructions do not cause unwanted action to occur due to a bad instruction or loaded value. Checks and limits are used on mission profiles, uploads, autonomous control instructions.

Crew members are provided with immediate and easily interpreted indication whenever failures occur that require or limit any flight crew action or decision for any configuration changes required or recommended or that occur automatically following failure. To ease crew workload, the consequence of the corrective action (manual or automatic) is specified in the event of failures.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

### **6.1.3.6.5** (was 6.1.3.6.e) Ground control paths

Standard: Roll–axis control power for takeoff, landing, and taxi.

A. During the takeoff run it is possible to maintain a straight path on the takeoff surface without deviations of more than 10 ft from the path originally intended, following sudden asymmetric loss of thrust.

B. For the continued takeoff, the requirement is met when thrust is lost at speeds from the refusal speed (based on the shortest runway from which the aircraft is designed to operate) to the maximum takeoff speed, with takeoff thrust maintained on the operative engine(s); without depending upon release of the pitch, roll, yaw or throttle controls; and using only controls not dependent upon friction against the takeoff surface.

C. Takeoff can be aborted at all speeds below the maximum takeoff speed; however additional controls such as nose wheel steering and differential braking may be used. Automatic devices that normally operate in the event of a thrust failure may be used in either case.

Yaw axis control power for takeoff, landing, and taxi.

A. Aircraft can taxi on a dry surface at any angle to the TBD knot wind.

B. In the takeoff run, landing rollout, and taxi, that yaw control power in conjunction with other normal means of control is adequate to maintain a straight path on the ground or other landing surface. This applies to calm air and in crosswinds up to the values specified in TBD knots, on wet runways, and on icy runways. For very slippery runways, the requirement does not apply for crosswind components at which the force tending to blow the aircraft off the runway exceeds the opposing tire–runway frictional force with the tires supporting all of the aircraft's weight.

C. If compliance with (b) is not demonstrated by test under the adverse runway conditions of (b), directional control is maintained by use of aerodynamic controls alone at all airspeeds above 5 kt.

D. All carrier–based aircraft is capable of maintaining a straight path on the ground without the use of wheel brakes, at airspeeds of 30 knots and above, during takeoffs and landings in a 90–degree crosswind of at least 0.1 V S(L).

In the takeoff run, landing rollout, and taxi, yaw control power in conjunction with other normal means of control adequate to maintain a straight path on the ground or other landing surface. This applies to calm air and in crosswinds. Directional control can be maintained by the pilot under adverse conditions (i.e., crosswinds), and ensures a match between upsetting yawing moments due to asymmetric thrust and restoring moments from static directional stability. This provides for adequate control of the ground path following loss of thrust during the takeoff run where the pilot can either safely abort or safely continue the

takeoff. After takeoff the pilot can safely go around or continue climbout. The intent is that Vmin (TO) is normally set by other considerations and adequate control provided down to that speed.

A. Limits on maximum push and pull forces required for takeoff lower than those allowed for other operations.

B. Values for aircraft with centerstick or wheel controllers:

1) Nose–wheel and bicycle–gear aircraft

2) Classes I, IV–C: 20 pounds pull to 10 pounds push

3) Classes II–C, IV–L: 30 pounds pull to 10 pounds push

4) Classes II–L, III: 50 pounds pull to 20 pounds push Tail–wheel aircraft

5) Classes I, II–C, IV: 20 pounds push to 10 pounds pull

6) Classes II–L, III: 35 pounds push to l5 pounds pull

The aircraft can be pitched up sufficiently, in ground effect, to achieve gently lowering the nosewheel or tailwheel to the ground during landing rollout.

Five degrees is about the greatest bank angle possible without significantly reducing the vertical component of lift. A requirement for turn capability, similar to 14CFR reference 25.147, addresses the need to ensure maneuvering capability in airport environments to avoid obstacles that become a threat due to the heading change likely incurred with the loss of an engine. The requirement with rudder pedals free is intended to preclude the consequences of stalling the vertical tail in case of an engine failure. Larger bank and sideslip angles generally will be needed.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

With the aircraft configured at its lightest weight, simulation verifies vehicle performance during engine failure occurring at takeoff performed in the conditions specified. Testing is required for the ground roll portion.

Ground taxi tests verify vehicle performance in winds that are at least close in average magnitude to those specified. Choice of wind conditions accounts for variability and gustiness. Generally, the taxi takeoff and aborted run trim system tests verify the aircraft's ability to maintain the allowable ground path within +/- 10 ft deviation and within +/- 2 degrees of commanded vehicle attitude.

**6.1.3.7** Verify safe aerodynamic/flight characteristics for: (for criteria 6.1.3.7.1 through 6.1.3.7.10)

Standard: General Standards for all subsections (6.1.3.7.1 through 6.1.3.7.10)

Vehicle control surface effectiveness is sufficient to the prevent loss of control and to recover from any situation, including deep stall trim conditions, for all maneuvering, including pertinent effects of factors such as regions of control–surface–fixed instability, inertial coupling, fuel slosh, the influence of symmetric and asymmetric stores, stall/post–stall/spin characteristics, atmospheric disturbances (gusts and moderate turbulence), environmental conditions (moderate icing) and Aircraft Failure States failures transients and maneuvering flight appropriate to the Failure State are to be included).

The degree of effectiveness and certainty of operation of limiters, center of gravity, control malfunction or mismanagement, and transients from failures in the propulsion, flight control and other relevant systems accounted for.

**6.1.3.7.1** (was 6.1.3.7a) High ange of attack

Standard: Amount of control capability at extreme AOAs, positive and negative, adequate to recover from situations that are not otherwise catastrophic.

The vehicle does not have any locked-in deep stall.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.7.2** (was 6.1.3.7b) Pitch-up tendencies

Standard: Pitch ups due to the following are controllable:

A. Turbulence or gusts (60ft/s sharp edge gust)

B. Pitch-up tendencies in max side slips (especially at TO and PA.)

Sufficient control power exists to counter the worst dynamic pitch-up tendency below stall or limit AOA.

Propulsion and flight control system failure transients are accommodated, along with degraded control authority and rate after a failure. The effect of failure transients on pitch-up tendency characteristics must be determined. The effects of fuel system failure or c.g. mismanagement is defined.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.7.3** (was 6.1.3.7c) Recovery from stall angles of attack

Standard: Sufficient aerodynamic control power, control surface rate and hinge moment capability at stall angles of attack, (positive and negative) are available to assure recovery.

There is no tendency for locked-in deep stall.

Propulsion and flight control system failure transients analyzed, along with possibly degraded control authority and rate after failure to assess recovery from stall angles of attack.

The effects of fuel system failure or c.g. mismanagement defined.

Approach to stall clearly indicated to the pilot with a margin (airspeed or angle of attack) sufficient to recover from the incipient stall, yet small enough to be meaningful.

Recommended warning ranges:

Warning required to occur outside the Operational Flight Envelope even where the Operational and Service Flight Envelopes coincide, as they may at the low–speed boundaries. Some multiengine aircraft exhibit violent, unacceptable rolling or yawing tendencies in engine–out stalls, while the need to maximize aircraft performance for recovery from an engine failure increases the possibility of stalling.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

**6.1.3.7.4** (was 6.1.3.7d) Post-stall maneuvering/control

Standard: Where sustained post-stall maneuvering is possible, predictable and positive vehicle control is available with no worse than CH6 exhibited.

Post–stall gyration and spin requirements are applied to all modes of motion that can be entered from upsets, decelerations, and extreme maneuvers appropriate to the Class and Flight Phase Category.

A. Entries from inverted flight and tactical entries are included. Entry angles of attack and sideslip up to maximum control capability and under dynamic flight conditions are included, except as limited by structural considerations.

B. Thrust settings up to and including MAT are included, with and without one critical engine inoperative at entry.

C. The requirements hold for all Aircraft Normal States and for all states of stability and control augmentation systems except approved Special Failure States.

D. Store release is not allowed during loss of control, spin or gyration, recovery, or

subsequent dive pullout.

E. Automatic disengagement or mode–switching of augmentation systems and automatic flight control system modes is permissible if necessary. Re–engagement in the normal mode is required in flight following recovery.

Propulsion and flight control system failure transients are considered, along with possibly degraded control authority and rate after a failure. The affect of failure transients are determined on spin/post-stall gyration susceptibility.

Recovery characteristics:

A. The proper recovery technique(s) is/are readily ascertainable/discernable by the pilot/crew and simple and easy to apply under the motions encountered.

B. A single technique provides prompt recovery from all post–stall gyrations and incipient spins. The same technique, or a compatible one, is available for spin recovery. For all modes of spin that can occur, these recoveries arrest spin within 2 turns after the post stall gyration initiates.

C. Avoidance of a spin reversal or an adverse mode change does not depend upon precise pilot control timing or deflection.

D. Operation of automatic stall/departure/spin prevention devices and flight control modes do not interfere with or prevent successful recovery of the aircraft by the pilot.

E. Safe and consistent recovery and pullouts are accomplished without exceeding pilot capabilities, and without exceeding structural limitations.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

When the post–stall region is not banned by structural design considerations, flight testing is a necessity since it is difficult to define an accurate aerodynamic model for post–stall flight. Fixed–base simulation may be preferable over moving–base to avoid problems with confusing or unrealistic motions that might influence pilots' perceptions. Even for Class III aircraft, which will have no spin flight tests, stall/post–stall wind–tunnel tests and analysis are necessary.

### 6.1.3.7.5 (was 6.1.3.7e) Recovery from the loss of control during accelerated/non-accelerated flight

Standard: For any loss of control from accelerated/ nonaccelerated flight, sufficient control power is available to recover the vehicle into the service flight envelope.

The pilot can prevent loss of control from accelerated/ nonaccelerated flight by moderate use of the pitch control.

Recovery is achievable by simple use of the pitch, roll and yaw controls with cockpit control forces not exceeding pilot capabilities, and level flight regained without excessive loss of altitude or buildup of speed.

Operation of automatic departure recovery devices and flight control modes do not interfere with the pilot's ability to prevent departure or recover the vehicle.

Accelerated–stall warning provisions must be consistent with those for unaccelerated stalls.

Level flight can be regained without excessive loss of altitude or buildup of speed. Control forces do not exceed the following limits:

| CONTROL TYPE | PITCH | ROLL | YAW |
|---|---|---|---|
| Sidestick | 20 lb | 15 lb | |
| Centerstick | 50 lb | 25 lb | |

| | | | |
|---|---|---|---|
| Wheel | | | |
| (two-handed tasks) | 75 lb | 40 lb | |
| (one-handed tasks) | 50 lb | 25 lb | |
| Pedal | | | 75 lb |

Recovery from loss of control from accelerated/ nonaccelerated flight must be easy and instinctive. The preferred method of stall recovery for both light trainer (Class I) and heavy (Class III) aircraft is to release back pressure on the wheel, lower the nose to the horizon, and add power, whether airspeed has begun to increase or not.

If loss of control from accelerated/ nonaccelerated flight produces engine flameout, the effect on recovery is defined. Application of control to balance propeller torque may limit the application of power for recovery at very low airspeeds. Abrupt uncommanded rolling or yawing could be especially critical in accelerated flight, where it is possible to pull rapidly through any stall warning or g–break, and into a departure. On the other hand, some current fighter designs exhibit no distinct “g–break”; only progressive deterioration in drag and lift, with CL(alpha) remaining positive, as angle of attack continues to increase at full–scale Reynolds number.

Compliance: Verification is by manned and unmanned simulation, analysis and test.

### 6.1.3.7.6 (was 6.1.3.7f) Recovery from buffet effects

Standard: Warnings and indications of approach to a dangerous condition are clear and unambiguous. For example, a pilot must be able to readily distinguish Mach buffet from normal aircraft vibration. The preferred pilot cues are buffet itself and stick force and position.

For all pertinent flight conditions, buffet which impairs the tactical effectiveness of the aircraft is not caused by the following:

A. Operation of movable devices such as weapon bay doors, cargo doors, armament pods, refueling devices and rescue equipment

B. Firing of weapons, release of bombs, or delivery or pickup of cargo

Within the boundaries of the Operational Flight Envelope, there are no objectionable buffet regions which might detract from the effectiveness of the aircraft in executing its intended missions. Available control does not aggravate the problem and adequate warning devices are available to allow proper crew inputs for recovery of the vehicle.

A safe margin is provided between the speed at which intolerable buffet or structural vibration is encountered and the maximum service speed.

Safe margins are provided between the load factor(s) at which intolerable buffet or structural vibration is encountered and the maximum and minimum service load factors.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

Flight testing at elevated angles of attack and load factors, and at lower angles transonically, reveal any buffeting tendencies. A windup turn maneuver while tracking a target can be especially useful in identifying buffet regions. Buffet intensity can be measured in-flight with accelerometers.

### 6.1.3.7.7 (was 6.1.3.7g) Normal and abnormal effects of secondary/infrequently used control surfaces/devices

Standard: Response to normal and abnormal operation of secondary or infrequently used control surfaces and devices are not objectionable or dangerous.

Transients associated with normal deployment of secondary control surfaces and devices do

not degrade handling qualities below Level 1. In the event these surfaces deploy uncommanded to full throw, the aircraft must remain controllable with Level 2 handling qualities.

Engine effects on flying qualities include influence of engine gyroscopic moments on airframe dynamic motions, the effects of engine operations (including flameout and intentional shutdown) on characteristics of flight at high angle of attack, and the reduction of engine–derived power for operating onboard systems after engine shutdown.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

### 6.1.3.7.8 (was 6.1.3.7h) High slip angles

Standard: Right yaw–control–pedal force and deflection produces left sideslips, and left yaw–control–pedal force and deflection produces right sideslips. The variation of sideslip angle with yaw–control–pedal deflection is linear for sideslip angles the vehicle is designed for.

For larger sideslip angles, an increase in yaw–control–pedal force is required for an increase in sideslip.

There is no rudder lock tendencies or stalling of the directional control surfaces.

Recommended maximum sideslip excursions for large roll control commands.

The following values are met to ensure adequate yaw–control effectiveness for coordination during rapid turn entries and exits as well as during steady rolls, without extreme rudder–pedal forces:

MAX ADVERSE SIDESLIP (RIGHT ROLL COMMAND CAUSES RIGHT SIDESLIP): 15 degrees

MAX PROVERSE SIDESLIP (LEFT ROLL COMMAND CAUSES RIGHT SIDESLIP): 4 degrees

Flying qualities shall be Level 1 up to max sideslip and Level 2 up to 50% past max side slip.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

### 6.1.3.7.9 (was 6.1.3.7i) Large and unusual attitudes

Standard: Controllability is sufficient to recover the aircraft from large and unusual attitudes that may be attained from unusual atmospheric disturbances, wakes, landing and takeoff, aggressive maneuvering, and pitching up or down to undesirable attitudes in catapult takeoffs. Recovery is possible from large and unusual attitudes throughout the operational envelope. Controllability implies a CH of 7 or better.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

### 6.1.3.7.10 (was 6.1.3.7j) Spin recovery

Standard: Recovery from post–stall gyrations and spins ensure:

A. The proper recovery technique(s) are readily ascertainable by the pilot and simple and easy to apply (i.e., repeatable, recognizable, recoverable) under the motions encountered.

B. A single technique provides prompt recovery from all post–stall gyrations and incipient spins. The same technique, or a compatible one, is required for spin recovery. For all modes of spin that can occur, these recoveries are attainable within 2 turns at a reasonable loss of altitude. Avoidance of a spin reversal or an adverse mode change is independent from precise pilot control timing or deflection.

C. Operation of automatic or manual stall/departure/spin prevention devices and flight control modes do not interfere with or prevent successful recovery of the aircraft by the pilot.

D. Displayed recovery information always presents the correct flight control system status (e.g., mode) and recovery control information.

E. Safe and consistent recovery and pullouts are accomplished without exceeding structural or system limitations.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

Spin tunnel and rotary balance testing verifies probable spin modes and sizes the recovery parachute.

**6.1.3.8** Verify hinge moment characteristics are adequate to satisfy safety requirements.

Standard: Hinge moment capability is sufficient to assure safety throughout the combined range of all attainable angles of attack (both positive and negative) and sideslip. This applies to the prevention of loss of control and to recovery from any situation, including deep stall trim conditions, for all maneuvering, including pertinent effects of factors such as pilot strength, regions of control–surface–fixed instability, inertial coupling, fuel slosh, the influence of symmetric and asymmetric stores, stall/post–stall/ spin characteristics, atmospheric disturbances and Aircraft Failure States. Failure transients and maneuvering flight appropriate to the Failure State are included. Verification considers the degree of effectiveness and certainty of operation of limiters, c.g. control malfunction or mismanagement, and transients from failures in the propulsion, flight control and other relevant systems.

Additionally, for all failure states and flight conditions, control margins can be maintained long enough to fly out of atmospheric disturbances, all Flight Phases can be terminated safely, and a waveoff (go–around) can be accomplished successfully.

A 50% margin applied to primary flight control surface hinge moments for normal usage. Under worst-case hardover conditions no component failure is permitted and vehicle flying qualities must remain at least Level 2.

Hinge moment does not stall or reverse trim systems and the available control effectors capability is able to handle a pitch mistrimmed while countering any adverse gust–induced pitching, rolling and yawing motions.

Rate or position limiting due to control surface hinge moment capability not result in any instabilities or pilot coupling tendencies.

Compliance: Verification is by unmanned and manned simulation, analysis and test. Iron bird testing verifies actuator hinge moment capability.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.3.9** Verify safe stability and control dynamics under symmetrical and asymmetrical maneuvers, with and without stores, for: (for criteria 6.1.3.9.1 through6.1.3.9.6)

**6.1.3.9.1** (was 6.1.3.9.a) Control surface float angles

Standard: Control surface float angle characteristics do not degrade flying qualities below Level 2. No float is allowed for powered systems except in a failed condition where float does not couple structurally or cause loss of control.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

**6.1.3.9.2** (was 6.1.3.9.b) Control surface blow-back

Standard: Control surface blow-back does not result in loss of control or handling qualities worse than CH 5.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

**6.1.3.9.3** (was 6.1.3.9.c) Control surface nonlinearities

Standard: Control surface nonlinearities do not cause uncontrollable instabilities or degrade flying

qualities below CH 3.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

**6.1.3.9.4** (was 6.1.3.9.d) The vehicle control system or actuation functions to overcome actual moments

Standard: Sufficient control power exists to overcome worst-case moments encountered about any axis throughout the permissible flight envelope.

Actuation is capable of handling normal loads due to moments from the flying vehicle producing CH 3 or better. Rates are adequate to prevent rate limiting under normal flight conditions.

Compliance: Verification by unmanned and manned simulation, analysis and test.

**6.1.3.9.5** (was 6.1.3.9.e) Establishing levels of flying qualities for the vehicle

Standard: Flying Quality levels are adequate to perform the intended mission with CH 3 or better. Flying qualities do not degrade below Level 2 after 1 failure.

UAVs/ROAs basic static and dynamic stability coupled with remote piloting or mission planning with override commands are defined. The basic stability with or without augmentation have satisfactory level of controllability consistent with CH 3. Inclusion of a remote pilot is consistent with CH 3. Mission planning with and without command override intervention results in CH 4 or better.

The design of the configuration or configurations which the aircraft has during each Flight Phase is defined. This includes the settings of such controls as flaps, speed brakes, landing gear, wing sweep, high lift devices, and wing incidence that are related uniquely to each aircraft design. This enables vehicle flying qualities adequate for mission performance and flight safety regardless of the design implementation or flight control system augmentation

Compliance: Verification is by unmanned and manned simulation, analysis and test.

**6.1.3.9.6** (was 6.1.3.9.f) Control surface hinge moment limiting

Standard: Control surface stall or blowback due to hinge moment limiting is permitted but does not result in any instabilities or pilot coupling tendencies.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

**6.1.3.10** Verify that the stability and control effects of basic design features, as well as unique features, are safe in the entire flight envelope(s).

Standard: The following minimum flying quality levels are maintained:

A. Operational flight envelope: Level 1 for normal operation, Level 2 with one failure.

B. Service flight envelope: Level 2 for normal operation, Level 3 with one failure.

C. Permissible flight envelope: Level 3

Stability and control characteristics are safe for phase and gain margins, transitions, gain changes, mode changes, switching & schedule changes, non-linearities and unique features such as stealth, autopilots, autotrim, threat avoidance, speed brakes, flaps etc. The needed margins are met for each loop, time to bank, CAP, F/g etc. 6 db and 45 degrees of margin are met for the entire flight operational and service envelopes.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.3.11** Verify all rate-limiting functions of the control function are safe to fly under flight scenarios employing all types of gain changes.

Standard: Stability or command/ control augmentation systems and devices do not introduce any objectionable flight or ground handling characteristics due to rate limiting. The quantitative aspects of such rate–limiting are given in the appendix of Norair Rpt No. NOR–64–143 and involve gain and phase decrements that are functions of the ratio of commanded to saturation rate.

Degradation of stability and control augmentation systems due to saturation of components, rate limiting, or surface deflections, is only momentary, and does not introduce any objectionable flight or ground handling characteristics. This particularly applies for all Normal and Failure states with atmospheric disturbances and during maneuvering flight at the angle–of–attack, sideslip, and load–factor limits of the flight envelope. It also applies to post–stall gyrations, spins, and recoveries with all systems, such as the hydraulic and electrical systems, operating in the state that may result from the gyrations encountered.

All normal rate limits encountered for the entire operational flight envelope environment do not produce any departures or loss of control on their own and when coupled with the crew. The training conducted is adequate to prevent adverse consequences at rate limits.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

Simulation verifies that all normal rate limits encountered do not produce any departures or loss of control on their own and when coupled with the crew, that training is adequate to prevent adverse consequences at rate limits.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.4** Mission evaluations including flight path guidance.

**6.1.4.1** Verify that the air vehicle responds safely in all axes to commands coming from the flight path guidance devices and processors.

Standard: Flight path guidance devices and processors do not produce aperiodic flight path divergence within the operational flight envelope. This includes devices used for transferring crew inputs.

The relation of the flight path response to pitch attitude, for pilot control inputs, is as follows:

A. The short–term flight path response to attitude generally have:

1) Frontside operation of "T-Theta-2"

2) Backside operation where an aircraft for the power–required curve (delta gamma/dV positive) must rely on thrust vectoring.

B. Attitude/Path Consonance where experience has shown that the path response bandwidth must be well separated from the pitch response bandwidth

C. If a designated controller other than attitude is the primary means of controlling flight path, the flight path response to an attitude change is equivalent.

D. In all cases the pitch attitude response lead the flight path angle by 45 degrees and must have a magnitude equal to or greater than the flight path angle.

Flight path control primarily through the pitch attitude controller, the steady–state path and airspeed response to attitude inputs generally have:

For flight control modes using another designated flight path control the required flight path response to attitude changes is generally expected to be the same as 3. above.

At all flight conditions the pilot–applied force and deflection required to maintain a change in flight path is in the same sense as those required to initiate the change.

If a separate controller (other than the pitch controller) is provided for primary control of direct lift or flight path, it is capable of producing the changes in flight path following full actuation of the controller

Flight path guidance devices and processors provide bank angle control necessary to straighten the flight path while sideslipping.

Flight path guidance devices and processors provide bank angle control necessary to follow the heading while maintaining the flight path

Compliance: Verification is by unmanned and manned simulation, analysis and test.

Simulation for normal pilot commands, including any function/device that autonomously issues commands, verifies that there are no departures or loss of control.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.1.4.2 Verify that flight path guidance systems safely compensate for degraded modes/failures of operation.

Standard: Flight path guidance systems modes/failures of operation do not allow a single failure of any component or function to result in dangerous or intolerable flying qualities.

The crew members receive immediate and easily interpreted indications whenever failures occur that require or limit any flight crew action or decision.

Dangerous aircraft motions following sudden flight path guidance systems or component failures can be avoided by the pilot, without requiring unusual or abnormal corrective action. A realistic time delay of at least 3 seconds between the failure and initiation of pilot corrective action is incorporated when determining compliance. This time delay includes an interval between the occurrence of the failure and the occurrence of a cue such as acceleration, rate, displacement or sound that definitely indicates to the pilot that a failure has occurred, plus an additional interval which represents the time required for the pilot to diagnose the situation and initiate corrective action.

Limits on transient motions within the first 2 seconds following failure are as follows:

A. Levels 1 and 2 (after failure): -0.5 g incremental normal acceleration at the pilot's station, 10 deg per second roll rate, Category A, -2 deg bank angle, except that neither stall angle of attack nor structural limits are exceeded. In addition, for Category A, vertical excursions of 5 feet.

B. Level 3 (after failure): No dangerous attitude or structural limit is reached, and no dangerous alteration of the flight path results from which recovery is impossible. For at least 5 seconds following the failure, the change in pitch force does not exceed 20 pounds. The change in roll control force required to maintain constant attitude following a failure in the flight control system does not to exceed 10 pounds. Maximum yaw pedal forces: 50 lb for both takeoff run and airborne.

Malfunctions:

A. Probable malfunctions > 10–3 per hour allowed to have only very minor effects.

B. Improbable malfunctions greater than 10-9 but less than 10–3 per hour allowed to have only minor effect.

C. Extremely improbable failures (extremely remote) < 10–9 per hour need not be considered.

D. Continued flight and landing assured for all other failures/ combinations with better than CH 5.

For any failure combination not extremely improbable failures (remote) < 10–9 per hour, no dangerous attitude or structural limit is reached, and no dangerous alteration of the flight

path results from which recovery is impossible.

Oscillation with a period of 15 seconds or longer have the following damping: T2 > 55 seconds.

A sound analytical method for accounting for the effects of failures is provided. It serves to force a detailed failure mode and effect analysis from the flying qualities standpoint. Such an analysis is vital as both system complexity and the number of design options increase.

Safe recovery is possible at any service speed following sudden simultaneous failures.

Compliance: Verification is by unmanned and manned simulation, analysis and test.

In simulation for function/device that autonomously issues commands, no departures or loss of control result for all failures not extremely remote (10E-9).

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.1.4.3 Verify that all transitions to and from normal flight path guidance modes, whether augmented or manually selected, are safe.

Standard: The transient motions from normal flight path guidance modes, whether augmented or manually selected, and trim changes resulting from the intentional engagement or disengagement of any portion never result in dangerous flying qualities. Allowable transients are:

A. Transients changes for normal operation of control devices such as throttle, thrust reversers, flaps, slats, speed brakes, deceleration devices, dive recovery devices, wing sweep, landing gear and normal flight path guidance modes, whether augmented or manually selected,do not impose excessive control forces to maintain the desired heading, altitude, attitude, rate of climb, speed or load factor. This applies to all in–flight configuration changes and combinations of changes made under service conditions, including the effects of asymmetric operations such as unequal operation of landing gear, speed brakes, slats or flaps. In no case shall there be any objectionable buffeting or oscillation caused by such devices.

B. In calm air, any sustained residual oscillations do not interfere with the pilot's ability to perform the tasks required in service use of the aircraft.

C. For Levels 1 and 2, oscillations in normal acceleration at the pilot station greater than 0.02g is excessive for any Flight Phase. These requirements apply with the pitch control fixed and with it free.

D. Roll axis response to configuration or control mode change due to engagement or disengagement of any portion of guidance modes are not exceeded for at least 2 seconds following the transfer (within the Operational Flight Envelope, 3 deg/sec roll and within the Service Flight Envelope, 5 deg/sec roll).

E. Yaw axis response to configuration or control mode change due to engagement or disengagement of any portion of guidance modes are not exceeded for at least 2 seconds following the transfer for the lesser of 5 degrees sideslip or the structural limit.

F. In any case, the transient motions and trim changes resulting from configuration changes or the intentional engagement or disengagement of any portion of the control guidance in equilibrium flight, with controls free, are not exceeded for at least 2 seconds following the transfer 0.05g. in any axis

Compliance: Verification is by unmanned and manned simulation, analysis and test.

In simulation, all normal transitions to and from function/device that autonomously issues commands, do not result in departures or loss of control.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5** Other effects.

**6.1.5.1** Verify that no unsafe roll-yaw-pitch coupling(s) occur due to aerodynamic, kinematic, or inertial effects.

Standard: Any coupled roll–spiral modes have, as a minimum, a coupled roll-spiral damping coefficient characteristics of 0.3.

No uncontrollable motions or roll autorotation result from yaw–control–free maximum–performance rolls through TBD degrees, entered from straight flight or during turns, pushovers, or pullups ranging from 0 g to 0.8 nz, including simultaneous pitch and roll commands. None of the resulting yaw or pitch motions, or sideslip or angle of attack changes, result in a departure from controlled flight or other dangerous condition.

No controller or automatic system creates a secondary kinematic response which is objectionable or dangerous.

Rudder pedal inputs used to roll the aircraft with lateral control fixed, or when used in a coordinated manner with lateral control inputs, do not result in departures in pitch, roll, or yaw.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represents the air vehicle system (aerodynamically and subsystems-wise)

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.2** Verify that no unsafe roll-yaw-pitch coupling(s) occur due to engine coupling for symmetrical or asymmetrical thrust and gyroscopic effects.

Standard: No unsafe roll-yaw-pitch coupling(s) occur as a result of engine coupling from symmetrical or asymmetrical thrust or gyroscopic effects.

Compliance: Verification through analysis and simulation which includes: influence of engine gyroscopic moments on airframe dynamic motions, effects of engine operations (including flameout, unstart and intentional shutdown) on characteristics of flight at high angle of attack, and reduction at low rpm of engine–derived power for operating the flight control system.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.3** Verify that stall or loss of control warning function(s) and limiting and prevention functions to be safe for all required combinations of maneuver configurations, flight conditions, and loadings.

Standard: Stall or loss of control warning function(s) and limiting and prevention functions do not degrade flying qualities below CH 3. This requirement applies for all required combinations of maneuver configurations, flight conditions, and loadings.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represents the air vehicle and include all loss of control, stall prevention, warning, limiting devices, and functions

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.4** Verify that "WRONG CONFIGURATION" warning functions are safe in all flight regimes. These include wing sweep, flap and landing gear position, and other variable geometry features.

Standard: Crew members are given immediate and easily interpreted indications whenever wrong configurations occur that require or limit any flight crew action or decision.

Aircraft motions following sudden aircraft system or component reconfiguration or failures are such that dangerous conditions can be avoided by the crew, without requiring unusual or abnormal corrective action.

Dangerous conditions may exist for wrong configurations at which the aircraft is not to be flown. When approaching these flight conditions, clear and unambiguous means are provided for the pilot to recognize the impending dangers and take preventive action.

Wrong configuration warning devices, prevention systems and recovery systems perform their function whenever needed and do not limit flight within the Operational Flight Envelope.

A. Neither normal nor inadvertent operation of such devices create a hazard to the aircraft.

B. Nuisance operation are not possible.

C. Functional failure of the devices are indicated to the pilot.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represents the air vehicle and its various configurations/ modes and/or variable geometry features.

The simulation uses a realistic time delay between the wrong configuration warning and initiation of pilot corrective action.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references:23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.5** Verify that flying quality nonlinear effects are safe when these effects or characteristics influence the vehicle characteristics including degradation and retention of critical pilot vehicle interface (PVI) and vehicle control functions (VCF) due to failures.

Standard: There are no objectionable nonlinearities in the variation of aircraft response with control deflection or force. Sensitivity or sluggishness in response to small control deflections or force is not permitted.

Compliance: Analysis, simulation and test verify that the vehicle has no tendency to depart and that no degradation of the control system and warning functions occurs with these airframe and control system nonlinear effects and uncertainties added. Sensitivity analysis coupled with failure at most adverse flight conditions suffice.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.6** Verify adequate actuator dynamics for a safe vehicle.

Standard: Actuator dynamics are correctly modeled and their dynamics do not degrade vehicle flying qualities below CHR 3 with no failures and CHR 6 after 1 failure.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represent the air vehicle including accurate actuator dynamics.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.7** Verify sensor dynamic characteristics for a safe vehicle.

Standard: Sensor dynamics are correctly modeled and their dynamics do not degrade vehicle flying

qualities below CHR 3 with no failure and CHR 6 after 1 failure.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represents the air vehicle including sensor (rate, accel, air data) dynamics, both linear and nonlinear. Sensitivity analysis coupled with nonlinear models suffice.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.8** Verify adequate cockpit control dynamics for a safe vehicle.

Standard: Cockpit or vehicle controller dynamics are correctly modeled and these dynamics do not degrade vehicle flying qualities below CHR 3 with no failure and CHR 6 after 1 failure.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represents the air vehicle including controller dynamics both linear and nonlinearities.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.9** Verify safe failure mode effects with operator-in-the-loop.

Standard: Failure mode effects are correctly implemented and the failure dynamics do not degrade vehicle flying qualities below Level 2 during or after the failure.

For all single failures not extremely remote (10E-9), flying qualities after the failure do not degrade below CHR 6.

No independent combination of single failures result in departure or loss of control.

Compliance: Verification by simulation, analysis and test utilizing failures which accurately represent the air vehicle failure states.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.10** Verify that control gradient forces are safe for the entire range of applications.

Standard: Control gradient dynamics correctly modeled and these dynamics do not degrade vehicle flying qualities below CHR 3 with no failure and CHR 6 after 1 failure.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represent the air vehicle including accurate models of the rudder, throttle and stick both linearly and with nonlinearities.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.11** Verify safe, unimpeded crew visual characteristics for all flight and ground conditions.

Standard: Cockpit design compatible with aircraft attitude for all intended operations do not impede visual references required for the intended operations.

Compliance: Verification by simulation, analysis and test utilizing models which accurately represent the air vehicle and pilot field of view for the intended mission, TO, PA, Landing and taxi.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.12** Verify that proposed ship launch/recovery wind envelopes and ship pitch and roll limits are safe.

Standard: Vehicle flying qualities for ship launch/recovery (including boltering/waveoffs), wind

envelopes and ship pitch and roll limits do not degrade below CHR 3 with no failure and CHR 6 after 1 failure.

Compliance: Verification by simulation, analysis and test utilizing ship launch/recovery wind envelopes and ship pitch and roll limits which accurately represents the air vehicle.

DoD/MIL Doc: TBD: Refer to NAVAIR technical point of contact for this discipline (listed in section A.2).

**6.1.5.13** Verify that the control tasks and workload levels associated with fight profiles are safe.

Standard: Flying qualities workload levels associated with fight profiles do not degrade below CHR 3 with no failure and CHR 6 after 1 failure.

Compliance: Verification by simulation, analysis and test which accurately represents the air vehicle including control tasks and workload levels associated with fight profiles.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.5.14** Verify that handling qualities with backup power sources are safe.

Standard: Vehicle flying qualities while on back-up power (electrical or hydraulic) do not degrade below CHR 6.

Compliance: Simulation of each mission phase utilizing backup power sources (electrical or hydraulic) verify that flying qualities do not degrade below Cooper-Harper Rating 6 while on the backup source.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.6** Envelopes.

**6.1.6.1** Verify that stability and response characteristics are safe for the anticipated critical flight conditions for the entire ground and flight envelopes.

Standard: The following minimum flying quality levels are maintained:

A. Operational flight envelope: Level 1 for normal operation, Level 2 with one failure.

B. Service flight envelope: Level 2 for normal operation, Level 3 with one failure.

C. Permissible flight envelope: Level 3

Compliance: Verification by simulation, analysis and test using the most adverse flight maneuvers with single failures in each of the safety critical functions, considered one at a time.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.6.2** Verify that the air data function is safe.

Standard: Vehicle flying qualities do not degrade below CHR 6 with no failure and CHR 8 after 1 failure.

The loss of the air data function are on the order of remote - better than (10E-7). Air data system and associated redundancy management provides for safe flight during and after air data component failures including: mechanically induced damage to probes and pressure ports, and the effects of rain, icing, and other hostile environments.

Compliance: Simulation verifies that the vehicle is recoverable and landable from the most adverse flight condition with the loss of the air data function.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.6.3** Verify that the flight-critical parameters list for completeness.

Standard: A complete list of safety critical function parameters is identified.

Compliance: The safety-critical parameter list is approved by the procuring activity.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

FAA Doc: 14CFR references: 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.1.6.4** Verify that the flight manual, and any supplements containing the air vehicle/engine operating limits, adequately describes the air vehicle's: (for criteria 6.1.6.4.1 though 6.1.6.4.4)

**6.1.6.4.1** (was 6.1.6.4.a) Performance

Standard: The vehicle flight manual accurately documents/identifies aircraft performance limits (AEOLs).

Compliance: Review of the flight manual verifies adequacy in documenting aircraft/engine performance limits

**6.1.6.4.2** (was 6.1.6.4.b) Flight characteristics under normal and emergency conditions

Standard: The flight manual accurately documents/identifies aircraft operating limits and emergency characteristics and procedures.

Compliance: Review of the flight manual and demonstrations verify that the emergency procedures documented are appropriate and adequate.

**6.1.6.4.3** (was 6.1.6.4.c) Control functions under normal and emergency conditions

Standard: The flight manual accurately documents/identifies aircraft control functions under normal and emergency conditions

Compliance: Review of the flight manual verifies adequate control function description under both normal and emergency conditions.

**6.1.6.4.4** (was 6.1.6.4.d) Other critical limits to ensure safe flight

Standard: The vehicle flight manual accurately documents/identifies aircraft critical limits to ensure safe flight under normal and emergency conditions

Compliance: Review of the flight manual ensures that all critical limitation are identified under normal and emergency conditions.

**6.1.7** Store carriage and separation.

**6.1.7.1** Verify that store carriage and separation response characteristics and limitations are safe.

Standard: Weight and center of gravity remain within published limits with the carriage of stores and after release of any store or combination of stores.

Flying qualities for these store carriage and separation effects do not result in loss of air vehicle control while under symmetrical and asymmetrical maneuvers, with and without stores.

Normal or emergency release or jettison of any store or combination of stores, within published limitations, do not result in departure, loss of control, or exceedance of any aircraft flight limitations.

Normal or emergency release or jettison of any store or combination of stores, within published limitations, do not result in contact between the released store and other stores or the aircraft.

Compliance: Verification by simulation, analysis and test utilizing a qualified air vehicle database which is under configuration control for store loadings and configurations.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

**6.1.7.2** Verify that existing stores are safe for use in the intended envelope and environment.

Standard: Weight and center of gravity remain within published limits with the carriage of stores and after release of any store or combination of stores.

Within the published flight limitations, no store or combination of stores induce aerodynamic or other effects which cause loss of control, departure susceptibility, or flying qualities degradation to the next lowest Level. All flight control parameters that change as a function of stores loading are adequately safeguarded if the stores loading data does not come from redundant sources.

Compliance: Verification by simulation, analysis and test utilizing a qualified air vehicle database which is under configuration control.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1 thru 3.3.11.1.3; and Appendix C

**6.1.7.3** Verify the safety and envelope of intentional and unintentional asymmetric stores combinations.

Standard: Weight and center of gravity remain within published limits with the carriage of stores and after release of any store or combination of stores.

A straight flight path can be maintained throughout the Service Flight Envelope with the worst-case store asymmetry.

For all store asymmetries encountered in normal operation, any changes in handling qualities, permitted maneuvers, or flight limits are noted in the Flight Manual. As a minimum, flying qualities are not degraded beyond Level 2 throughout the Service Flight Envelope, and the vehicle can be safely landed with the asymmetry.

Compliance: Verification by simulation, analysis and test utilizing a qualified air vehicle database which is under configuration control.

DoD/MIL Doc: JSSG-2001: para 3.4.2.1, JSSG-2008: 3.1.5.3, 3.1.5.8, 3.2.1.2

**6.1.8** Validation of modeling, simulation and analysis tools.

Standard: Modeling and simulation data, databases and tools are validated to ensure predictions of vehicle stability and control, flying and handling qualities characteristics correctly and accurately represent vehicle for trim, dynamic maneuvers and failures across the vehicle envelopes and configurations.

Compliance: Review of documentation verifies that the analytically predicted data is generated by validated and verified tools and processes. Review of the documentation validates and verifies the frequency and time domain based tools, models and components of models and simulations completed. Flight test data is used in the validation process. Validation occurs across the flight envelope, natural environment, center-of-gravity and inertial properties, flight control modes, configurations and store loadings.

DoD/MIL Doc: MIL-STD-1797A sections 4.1.9 and 4.1.10

JSSG-2008: section 3.0

## 6.2 Vehicle control functions (VCF).

DoD/MIL Doc: MIL-STD-1797A, "Flying Qualities of Piloted Aircraft"

**6.2.1** VCF architecture design.

**6.2.1.1** Verify the functional criteria to be safe.

Standard: A. The VCF requirements include but is not limited to operational states, safety, criticality function classifications, mission accomplishment reliability, data latency, VCF system reliability, mixed redundancy of functions, pilot/crew vehicle integration, communication paths, controls and displays, control laws, control power, structural interactions, installation, natural environments, induced environments, redundancy management, integration management, security of the VCF, auto control modes, survivability, vulnerability, asymmetric conditions, loss of engines, engine control, system architecture, redundancy levels, fail states, failure transients, mode switching transients, control signal transmission within the airframe and external to the airframe, diagnostics, in flight BIT, pre-flight BIT, maintenance BIT, software and communication security, aerodynamic control and margins, air vehicle performance, actuation, air data, inertial sensing feedbacks, integration with fuels, electrical power, propulsion, stores, ground control and displays, annunciations and warnings to the crew, personnel hazards, crew and maintenance training, operational life, maintainability, support, processing resources, software code, processing communications, synchronization, growth, throughput, software language, software maintenance, software certification, physical component damage tolerance, airworthiness and qualification design, product assurance, product manufacturing, and product support equipment. The VCF documentation is configuration controlled and current. The testing of the VCF includes but not limited to component development, qualification, and failure mode and effect tests. All test documentation is configuration controlled and current.

Compliance: The design criteria conforms to set of requirements that is checked to assess safety of the design. There are additional derived requirements (criteria) that cover a particular functional design. If a design is to be flown but does not have adequate probability for loss of function, then the design is not safe and high risk. The following reviewed for compliance:

A. Evidence of allocation of criteria to components, including developmental and non-developmental, COTS and modified COTS

B. Evidence the criteria for design, installation, operational characteristics, and sustainment

C. Design trades and analyses

D. Simulation, modeling, development testing

E. Design approval and function/system compatibility tests

F. Component, and functional level qualification and certification tests

G. Acceptance tests.

H. Failure modes, effects, and criticality analysis/testing (FMECA/FMET)

I. Hazard analysis and classification

J. Safety certification program

K. Computational, theoretical, and/or semi-empirical prediction methods.

The following exists to an adequate level for a safe air vehicle.

I- Design Requirements:

The system design requirements are adequate for Safety Of Flight (SOF).

Acceptable environmental prediction techniques used.

Findings from design reviews satisfactorily resolved as they affect SOF.

Adequacy of integrated software or system simulation testing accomplished.

The kind of verification/validation performed on the software adequate.

Adequacy of the software architecture, regression testing and requirements traceability.

II- Primary Flight Control System (PFCS), or Manual Flight Control System (MFCS):

Primary flight control systems consist of electrical, electronic, mechanical, hydraulic, optical and pneumatic elements which transmit pilot control commands or generate and convey commands which augment pilot control commands and thereby accomplish primary control functions. This classification includes the longitudinal, lateral, directional, lift, drag, and wing geometry control systems as well as their associated augmentation, performance limiting, and control functions. The typical assessments needed to determine the integrity and safety of installed PFCSs accomplished.

III- Automatic Flight Control System (AFCS) or Autopilot:

An AFCS consists of electrical, electronic, mechanical, hydraulic, optical, and pneumatic elements which generate and transmit control commands to provide pilot assistance through integration and control of the flight path, attitude, or airframe responses to disturbances or commands by references internal or external to the air vehicle. This classification includes autopilots, stick or wheel steering, primary control modes (i.e., collision avoidance), structural mode control, and similar control mechanizations. The typical assessments needed to determine the integrity and safety of installed AFCSs accomplished.

IV- Mission Flight Controls (MFC):

MFC consists of all components and devices used to enhance or augment the basic control system for a particular phase of flight. The generated commands are used by the primary or AFCS to control the aircraft. The typical assessments needed to determine the integrity and safety of installed MFCSs accomplished

V- Iron-Bird Testing:

The dynamic test facility (iron-bird) realistically duplicates the aircraft installed and integrated VCMS, hydraulic system, and electrical power system and component installations. Power sources used to drive installed equipment must provide required flow rates, fluid pressures, electrical voltages and currents, and duplicate the regulation characteristics of the respective subsystems. Primary aircraft structure need not be duplicated; however, production configuration mounting brackets used and attached to structure(s) which simulates actual mounting compliance are typically used. Inertias and compliances of flight control surfaces or other devices are duplicated or accurately simulated. Aerodynamic load effects are simulated. The typical assessments needed to determine the integrity and use of the iron bird accomplished.

VI- Electrical/Hydraulic Power Interface/ Integration. A safety of flight determination of this item involves the following:

The flow rates are adequate to satisfy hinge moment, stiffness, and control surface rate requirements.

The servoactuator design is adequate.

The actuator component flight worthiness test defined.

The hydraulic plumbing distribution system defined.

The backup hydraulic power system defined.

The hydraulic filter's adequate.

The hydraulic motor/torque drive systems adequate.

Flight control safety effects due to the loss of each or part of each hydraulic system defined.

The backup electrical power capability adequate.

Independent, direct, uninterruptible power sources of adequate quality are available.

The acceptability of power transients defined.

The charging method and battery charge check methods before flight adequate.

Buses are separated to prevent single-failure points following shorts.

The effects of normal, abnormal and all possible failure modes of the electrical power system defined.

The electrical power interface supplies direct, uninterrupted electrical power of the quality needed under all conditions.

VII- Component Flight Worthiness Testing. Evaluation of this item consist of determining that:

All critical components successfully complete minimum flight worthiness tests prior to first flight including individual performance tests, high and low temperature extremes, vibration, humidity (moisture resistance), shock (mechanical and thermal), acceleration, Electromagnetic Interference (EMI), altitude (if performance is sensitive to altitude variations) etc., and reasonable life cycling tests. All electronic components are normally subjected to a minimum of 50 hours burn-in and testing prior to first flight.

VIII- Failure Modes, Effects and Criticality Analyses (FMECA). Consider the following actions in a review of this item:

Contractor's FMECA procedures and test methods adequate.

Transient effects of failures and impact on pilot controllability or structural impact defined.

Contractor's work adequate:

a) Hazard analysis done

b) Safety recommendations and changes incorporated.

Analysis of VCMS reliability data complete.

IX- Flight Control Software Processing. Evaluation of this item involves the following:

Formal software documents and procedures exist

Procedures and tests are established for verification and validation of software.

Procedures have been established and all interfaces are defined and controlled.

Analysis and testing, using the final flight software version is adequately accomplished.

Adequate formal procedures and tests have been established

The software program is compatible with all interfacing systems.

The software design has the necessary interrupt, re-initialization, re-synchronization, recheck, reconfiguration, etc., provisions to restart or reset part of the software program safely, and quickly, in-flight.

The software design has adequate self-check, failure monitoring, redundancy management, reconfiguration, voting, transient suppression, overflow protection, antialiasing, saturation prevention, interlocks, memory protection, failure propagation prevention, etc. techniques to prevent safety of flight situations associated with digital design.

Built-In-Test (BIT) procedures are adequate

COMPUTER RESOURCES AREAS ADEQUATE:

Air Vehicle (AV) System Processing Architecture

Configuration Management of VCMS Software.

Functional Integration of Processing Elements

Integrated/Integration Testing of Elements

For each flight/safety critical subsystem/element the entire software development process

and design for:

a) Organizational Structure

b) Development Scheduling

c) Digital Technology and Attributes

d) Software Architecture

e) Software Engineering Environment (SEE)

f) Resource Utilization

g) Software Load Verification

h) Software Development and Documentation Methodologies

i) Software Test Process/Activity

j) Action Item Closure

k) Final Acceptance/Qualification Test

l) Software Turn-around Process

m) Configuration Management Procedures

n) Quality Assurance Process and Procedures

o) Development, Integration and Test of Simulation Facilities

COMPUTER RESOURCES ELEMENT CRITERIA:

AV Processing Architecture.

A) The architecture established.

B) Flight/safety critical configurations identified

C) All processing elements are developed and tested.

D) Block diagram for the full-up and first flight configuration defined.

E) Redundancy addressed.

F) Separate and independent power sources provided for redundant operations.

G) Single component failure not impede redundant operations.

Configuration Management of Software.

A) Categorization of individual computer program configurations established.

B) Adequate interface control procedures in place.

C) Adequate configuration management practices exist for software baseline control at laboratories, build sites

DoD/MIL Doc: JSSG-2008: para 3.0 thru 3.8, 4.0 thru 4.8

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.1.2** Verify the VCF high-level architecture function to be safe for the supporting control function.

Standard: Requirements defined for architecture of vehicle control with other functions such as electrical power, hydraulics, avionics, inertial platforms, engines, unique functions. Non-safety critical functions are properly accounted for.

Safety critical functions are properly managed for redundancy and integration. Functional separation exists for all equipment/ components/ functions that affect air vehicle control.

VCF control system has sufficient control power through hydraulics, electrical, pneumatic or mechanical means to maintain flying qualities at Level I in at least operational state I. The other operational states, reconfiguration and associated flying qualities is also addressed.

Compliance: Inspection and analysis of safety critical function classifications for a safe and balanced design verified.

Architecture design criteria conforms to set of requirements that is checked to assess safety of the design.

Additional derived requirements (criteria) to cover a particular functional design defined and adequate. The following general areas are reviewed for compliance.

A. Evidence of allocation of criteria to components, including developmental and non-developmental, COTS and modified COTS.

B. Evidence the criteria considers design, installation, operational characteristics, and sustainment

C. Design trades and analyses finished.

D. Simulation, modeling, development testing defined.

E. Hazard analysis and classification completed.

F. Safety certification program in place.

DoD/MIL Doc: JSSG-2008: para 3.1.7 thru 3.1.7.3, 4.1.7 thru 4.1.7.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.1.3** Verify that the integrated VCF architecture safely implements the proper levels of redundancy, fault tolerance, physical/functional separation of flight/safety-critical functions/components and other aspects.

Standard: Each function is properly examined through some type of test - e.g., walk around, preflight, BIT, PBIT, CBIT, Crew monitoring, flight test monitoring, and any other test that shows each integrated function has a high likelihood of finding its own problem, better than (10E-8).

Compliance: Every facet of the design, fabrication, installation and operation of each subsystem including human elements adequate.

Suitable mathematical models for testing each critical failure mode in place.

The flight safety analysis includes all various failure modes of hardware performing flight/safety critical or mission phase critical functions.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.11 thru 3.1.12.1, 4.1.11 thru 4.1.12.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.1.4** Verify the autonomy of each function integrated in or by the VCF design to be safe.

Standard: No single failure or dissimilar failure in the VCF result in any failure effect which may create significant in-flight hazards before a pilot or safety device can take effective corrective action.

Requirements are defined for redundancy and integration management and all vehicle control aspects.

Adequate FMET using adequate test facilities verify that the design is safe.

Compliance: The following are addressed:

A. FMECA for the VCF.

B. Hazard analysis for the air vehicle

C. Fault tree analysis.

D. Analyses that identify those failures and failure combinations which are not classed as extremely remote (10E-9).

E. Analyses, simulation, ground and flight tests used, as appropriate, show that none of the failures, not extremely remote, can result in any dangerous condition.

F. Software development and the verification and validation methods used addressed in sufficient detail.

DoD/MIL Doc: JSSG-2008: para 3.1.1 thru 3.1.4, 4.1.1 thru 4.1.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.1.5 Verify that failure mode effects are safe for the entire VCF operation.

Standard: VCF control paths from the pilot or guidance device have no single failures to remove an axis of control and that any combination of safety critical failures is extremely remote (10E-9) for the entire normal range of crew or guidance inputs.

Compliance: Inspection, analysis or both verify the VCF operational state classifications. Testing and hazard analyses on the display/VCF interface are complete.

Placement, design and functionality of control and displays verified by inspection and ground tests.

Compliance through analytical techniques and simulations adequate.

Analyses demonstrate and validate system and subsystems including integrated redundant systems and subsystems aspects.

Failure modes and effects testing expose problems which would not be accounted for when performing testing at the integrated level completed.

DoD/MIL Doc: JSSG-2008: para 3.1.9, 4.1.9

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.1.6 Verify that special failure states of single fail, dual fail, and special single fail/combination failure(s), as well as order of failure(s), are safe.

Standard: Failure combinations and special failure states for the integrated architecture defined. No single failure, combination of single independent failures and failures of unique/little used functions e.g., flaps, speed brakes including single hard-overs result in a departure or loss of control.

Mode selection prevents the engagement of incompatible modes that could create an immediate undesirable situation or hazard.

Compliance: Compliance with specification and flight worthiness certification requirements verified through testing, inspection, or analytical techniques and simulations.

Analyses demonstrate and validate system and subsystems performance including redundant systems and subsystems aspects.

Failure modes and effects testing expose problems which would not be accounted for when performing testing at the integrated level completed.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.11 thru 3.1.11.2, 4.1.11 thru 4.1.11.2

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2** Basic VCF.

**6.2.2.1** Verify that the VCF which transmit crew control commands or generate and/or convey commands are safely implemented for the entire range of vehicle and crew responses.

Standard: Mechanical/ analog/ electrical component functional characteristics are defined and do not to induce a departure or loss of control.

Compliance: VCF command control elements verified by physical inspection, test, qualification and integration testing, and simulation and demonstration.

Probability that common mode failure is extremely remote verified by evaluating fault tree and hazard analysis.

DoD/MIL Doc: JSSG-2008: para 3.1.1, 4.1.1, 3.1.11.10, 4.1.11.10, 3.1.11.11 thru 3.1.11.11.4, 4.1.11.11 thru 4.1.11.11.4, 3.2.2 thru 3.2.2.5.4, 4.2.2 thru 4.2.2.5.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.2** Verify that functional characteristics of friction levels, breakout forces, dead zones, hysteresis, and backlash are safe.

Standard: Functional characteristics of friction levels, breakout forces, dead zones, hysteresis, and backlash do not induce a failure or loss of control or a departure and that the combined levels of these items producing a failure setup is extremely remote (10E-9).

Non-linear characteristics are properly accounted for in the design.

Non-linear characteristics are properly accounted for in any math models, simulations or emulations.

Compliance: Analysis and simulation of the design includes features where asymmetric operation not result in hazardous conditions.

Analysis verifies the aerodynamic control effectors can control the vehicle for the intended flight envelope.

Control law analysis accounts for non-linear characteristics in phase and gain margins, for example.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.2.2.5.1.1, 4.2.2.5.1.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.3** Verify that longitudinal, lateral-directional, lift, drag, performance limiting, and variable geometry control functions are safely mechanized.

Standard: Any device or method used to monitor longitudinal, lateral-directional, lift, drag, performance limiting, and variable geometry control functions is properly designed.

Compliance: Analysis, simulation or testing verifies the adequacy of the cockpit controls and control surface responses, overshoot and saturation throughout the flight envelope.

Analysis and test verifies the effectiveness of monitoring and redundancy management schemes for longitudinal, lateral-directional, lift, drag, performance limiting, and variable geometry control functions completed.

Analysis and integrated testing verifies the adequacy of control power.

DoD/MIL Doc: JSSG-2008: para 3.1.5.3, 4.1.5.3, 3.2.1 thru 3.2.1.4, 4.2.1 thru 4.2.1.4, 3.2.2.5.4, 4.2.2.5.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.4** Verify that the vehicle control system is safely able to obtain the maximum required control surface positions without mechanical interference.

Standard: Under the most adverse flight, manufacturing, environmental and load conditions, required control surface positions are attained without mechanical interference from structure or surrounding devices.

Compliance: Freedom of movement is verified by analysis and test of the actual installation simulating manufacturing, environmental and flight conditions.

DoD/MIL Doc: JSSG-2008: para 3.2.1 thru 3.2.1.4, 4.2.1 thru 4.2.1.4, 3.2.2.5 thru 3.2.2.5.1.1, 4.2.2.5 thru 4.2.2.5.1.1, 3.2.3, 4.2.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.5** Verify actuation for surface rate and hinge moments under normal conditions and capability under blowback conditions to be safe.

Standard: Under the most adverse flight, environmental and load conditions, no actuator hinge moments or blow back cause a departure, loss of control or pilot coupling.

Compliance: No loss of control due to surface rate and hinge moments of the actuation system is verified by analysis and simulation.

No loss of control due to the surface rate and hinge moments is verified by iron bird testing and aircraft ground testing.

DoD/MIL Doc: JSSG-2008: para 3.1.5.6 thru 3.1.5.7, 4.1.5.6 thru 4.1.5.7, 3.2.2.1, 4.2.2.1, 3.2.1, 4.2.1, 3.2.1.1, 4.2.1.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.6** Verify that the cockpit control forces are safe for any control mechanization.

Standard: Cockpit control forces including trim for all axes meet the anticipated mission and flight condition with no obstructed movement for the crew.

Probability of mission abort is no greater than (10E-6).

Probability of aircraft loss due to crew system control failure is no greater than (10E-8).

Compliance: Analysis and simulation verifies the cockpit control forces are adequate for all modes of flight. On aircraft gorund test verifies all forces measured meet the design requirement. Pilot evaluation during the flight testing verifies the compliance.

DoD/MIL Doc: JSSG-2008: para 3.2.2.3, 4.2.2.3, 3.2.2.5.1, 4.2.2.5.1, 3.2.2.5.1.1, 4.2.2.5.1.1, 3.2.2.5.1.3, 4.2.2.5.1.3

FAA Doc: 14CFR references: 23.779, 25.779, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.7** Verify that functional control nonlinearities are safe.

Standard: Every mechanical interface, electrical interface, hydraulic interface, digital interface, analog interface, computational paths nonlinearities as an aggregate cannot induce a departure, loss of control or pilot coupling.

(Usually expressed as lack of response and delay times)

Gain margin is not worse than 6 db and the phase margin is not worse than 45 degrees.

Compliance: Analysis and simulation verifies the stability gain and phase margins to ensure system operation both in the linear and nonlinear ranges.

Analytical results and simulation results with ground and flight test results verify a safe

vehicle.

DoD/MIL Doc: JSSG-2008: para 3.2.2.5.4 thru 3.2.2.5.4.5, 4.2.2.5.4 thru 4.2.2.5.4.5

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.8 Verify that trim ranges and rates are safe.

Standard: Trim range for all axes leaves adequate control to the crew. Rates cannot induce over or under trim and do not produce any coupling with the crew.

Generally, trim authority limited to + 1.5g in pitch, + 0.5g roll, and + 0.2g yaw.

Probability of aircraft loss due to trim failure is no greater than (10E-8).

Probability of mission abort due to trim failure is no greater than (10E-5).

Flying qualities are no less than operational state II and level II/CH 5 or better for loss of trim.

Compliance: Analysis and simulation verify trim ranges and rates.

Ground tests and inspection verify the ranges and rates.

Flight tests verify requirements against the flying qualities.

DoD/MIL Doc: JSSG-2008: para 3.2.2.5.1.3, 4.2.2.5.1.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.9 Verify that trim failure protection is safe.

Standard: Methods for detecting and accommodating trim failures of all kinds established. For example: prevent hard-overs, compensate for jams or mis-trims to prevent an induced departure, loss of control or pilot coupling.

Compliance: Analysis and simulation verify trim failure effects.

Normal trim system operation are verified with injected failures during ground tests.

DoD/MIL Doc: JSSG-2008: para 3.2.2.5.1.3, 4.2.2.5.1.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.10 Verify that control devices in normal and failed states intended for intermittent operation are safe (e.g., flaps, speed brakes, geometry mechanisms, auxiliary control devices).

Standard: Latent failures are not permitted for devices used only in parts of the mission, or are seldom used or are only for some type of backup capability.

Latent failures cannot induce a departure, loss of control, loss of vehicle or pilot coupling.

Compliance: Adequate control is verified by analysis and integrated test.

Failure mode and effects are verified by using iron bird, hybrid simulation, and/ or DT&E aircraft..

Performance and operational capabilities of the special modes are verified by functional tests and specific parameter analyses.

Redundancy management requirements are verified by appropriate analysis, simulation and FMET.

DoD/MIL Doc: JSSG-2008: para 3.1.8, 4.1.8, 3.2.1.3, 4.2.1.3, 3.2.1.4, 4.2.1.4, 3.2.1, 4.2.1, 3.2.2.5.4.5, 4.2.2.5.4.5, 3.1.12 thru 3.1.12.1, 4.1.12 thru 4.1.12.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.11** Verify that safety protection functions/devices are safely implemented.

Standard: The VCF has a safety program compatible with the weapon system for the VCF development, integration, manufacturing and personnel.

The safety program defines that devices, procedures or limitations implemented to accommodate failures not cause loss of control, loss of vehicle or pilot coupling.

No single dynamic component or software fault nor sneak circuit or safety device, limitation or procedure result in a category 1 or category 2 hazard that is not extremely remote (10E-9).

Compliance: Safety aspects are verified by reviewing the safety program.

VCF safety program is verified by ensuring the use of applicable DoD, Air Force AFOSH and OSHA standards or guidelines and checklists and evaluation matrix criteria.

Safety provisions are verified by inspection, analysis simulation, development test, integration tests and ground tests.

DoD/MIL Doc: JSSG-2008: para 3.1.5.3, 3.1.5.2, 3.1.5.4, 3.1.9, 3.1.11.1, 3.1.10, 3.1.11.1.1, 3.1.13 to 3.1.13.2, 3.1.16, 3.2.2.5.4.1, 3.2.4 thru 3.2.4.6, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.12** Verify that alternate control paths available for each control axis or mode are safe.

Standard: The VCF provides failure detection, isolation, and corrective action within 0.10 seconds.

The VCF prevents propagation of failures among vehicle control elements.

The VCF provides physical and electrical isolation between redundant elements.

The VCF redundancy requirements meet the handling qualities and flight safety requirements for all operational states.

Compliance: Redundancy and redundancy management requirements are verified by analysis, software emulation, simulation, hardware/software in-the-loop failure modes, effects testing and flight testing.

DoD/MIL Doc: JSSG-2008: para 3.1.2.1, 4.1.2.1, 3.1.11.1, 4.1.11.1, 3.1.12 thru 3.1.12.1, 4.1.12 thru 4.1.12.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.13** Verify that ratio changers and artificial feel devices with proper protection are safely implemented.

Standard: Any artificial feel device does not have any changes in feel that could produce departure, loss of control or pilot coupling.

A loss of the artificial feel function is extremely remote (10E-9) and the vehicle may be recovered with better than a CH6.

Units, components, and parts which transmit control signals mechanically meet design limit conditions and have 50% margin over the design.

Compliance: Operational status of devices are verified by inspection, test, integration testing, FMET and ground testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1.7.2, 4.1.7.2, 3.1.11.11, 4.1.11.11, 3.1.11.11.1, 4.1.11.11.1, 3.1.12.1, 4.1.12.1, 3.1.14.4, 4.1.14.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.14** Verify that no single, like dual, second, or single combination failure points in any VCF function result in an unacceptable probability of loss of function.

Standard: The probability of loss of the control function for any axis is extremely remote (10E-9) for the failure combinations described.

As a minimum, no single or single dissimilar combination of failures degrade flying qualities below level I (worse than CH 3) for a period of one hour. The remainder of the flight is no worse than level II.

As a minimum, second or dissimilar combination of second failures not result in a catastrophic incident, have at least CH 7 flying qualities and not cause loss of aircraft

Any likely dual failure or combination of single failures does not cause loss of control or any of the following:

(a) Flutter, divergence, or other aeroelastic instabilities within the permissible flight envelope of the aircraft, or a structural damping coefficient for any critical flutter mode below the fail-safe stability limit of MIL-A-8870.

(b) Uncontrollable motions of the aircraft or maneuvers which exceed limit airframe loads.

(c) Inability to land the aircraft safely.

(d) Any asymmetric, unsynchronized, unusual operation or lack of operation of flight controls that results in worse than FCS Operational State IV

(e) Exceedance of the permissible flight envelope or inability to return to the service flight envelope.

(f) FCS failures that could cause loss of total thrust.

(g) Erroneous, false, mis-leading, or missing a/c alt/attitude/AOA/etc., information displayed to the aircrew that could result in either the incorrect or no pilot inputs to the FCS.

Compliance: Failure combinations meet the standard by iron bird test or high fidelity simulation integration lab with all hardware and software.

DoD/MIL Doc: JSSG-2008: para 3.1.11.1, 3.1.11.1.1, 3.1, 3.1.2, 3.1.5.5, 3.1.5.6, 3.1.7.3, 3.1.9, 3.1.11.4, 3.1.11.7, 3.1.12, 3.1.13.2, 3.1.14.4, 3.1.17, 3.2.2.2 thru 3.2.2.2.13, 3.3.3, 3.4.2, 3.5.7 and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.15** Verify that the VCF components meet safety requirements.

Standard: Degradation in VCF operation due to anticipated and delineated environments is within limits for effects of relative humidity up to 100%, pressure altitude from -2000 to 80,000 ft and resistance of formation of fungi, etc.

The VCF physical characteristics do not cause a single point failure by virtue of the design of components nor the interfaces nor integration of functions.

The assemblies, subassemblies and item parts used within the VCF are capable of withstanding physical, induced, chemical, biological and nuclear stresses.

Compliance: Inspection, environmental test, and failure mode effects analysis (FEMA) verify safety requirements.

Physical characteristics are verified by inspection, analysis and tests of component and drawings.

VCF design operational usage are verified by evaluation and correlation of flight test measured data to the analysis.

DoD/MIL Doc: JSSG-2008: para 3.1.14 thru 3.1.14.9, 4.1.14 thru 4.1.14.9, 3.1.15 thru 3.1.18, 4.1.15 thru 4.1.18, 3.2.3 thru 3.2.3.3, 4.2.3 thru 4.2.3.3, 3.4 thru 3.5.2, 4.4 thru 4.5.2

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.16** Verify that no unsafe mechanical interference or jamming situations exist in VCF mechanization.

Standard: Mechanical transmission devices and units meet the design limit conditions and provide margin of 50% over the design.

Under the most adverse flight, manufacturing and environmental conditions, no control surface binds or is interfered with by the structure or any other device mechanism.

Degradation in VCF operation due to anticipated and delineated environments is within specified limits.

Probability of aircraft loss due to unsafe mechanical interference or jamming is no greater than (10E-8).

Compliance: Mechanical signal transmissions requirements are verified by analysis and ground testing.

Verification of invulnerability requirements is by a combination of analysis, similarity, demonstration and test.

Verification of mechanical components and functions is accomplished by inspection, demonstration and testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1.11.11, 4.1.11.11, 3.1.11.11.1, 4.1.11.11.1, 3.1.14, 4.1.14, 3.2.2.1, 4.2.2.1, 3.5.7, 4.5.7

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.17** Verify that the clearances available safely tolerate foreign object damage (FOD).

Standard: No probable combination of temperature effects, air loads, structural deflections, vibration, buildup of manufacturing tolerances, wear, sag, or installation which can cause binding or jamming of any portion of the VCF result in insufficient clearance.

A minimum of six inches or more is maintained between wiring and plumbing which carries combustible fluids and three inches between wiring and control cables.

A minimum of 0.25 inches is maintained around any control routing and connections such as bellcranks, cables, actuator attachments, path changers, etc.

In particular cases where surrounding material such as fasteners, rivets, nuts, bolts, washers etc., exceed 0.25 inches, the design accommodates these particulars.

Compliance: Clearance criteria is verified by inspecting and measuring clearance area around wirings, cables and plumbing systems and any other control mechanisms.

Installation drawings are reviewed for accuracy and currency.

Clearance analysis verify that temperature effects, air loads, structural deflections, vibration, buildup of manufacturing tolerances, wear, installation and flight loads were accounted for in establishing the clearance requirements.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.7.2, 4.1.7.2, 3.1.7.3, 4.1.7.3, 3.1.11.11, 4.1.11.11, 3.1.13, 4.1.13, 3.1.14, 4.1.14, 3.1.14.5, 4.1.14.5, 3.2.3, 4.2.3, 3.2.3.3, 4.2.3.3, 3.4.4, 4.4.4, 3.5.7, 4.5.7

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-

23.1529, 25.1501-25.1529

**6.2.2.18** Verify that control laws are safe for the normal intended application.

Standard: Control laws provide a phase and gain margin of at least 45 degrees and 6 db for the entire flight envelope covering critical flight conditions for each control feedback loop and different modes.

Control laws have a CH of 4 or better. This applies for 25% sensitivity changes in key stability derivatives one and two at time.

Compliance: The integration requirements for unique systems and subsystems are verified by simulation and testing.

Verification of the actuation components and subsystems behavior is accomplished by laboratory testing at the system level.

Air data function is verified by software certification, hardware qualification and system test.

Sensor performance is verified by analysis, simulation subject to flying qualities evaluation.

Adequacy of control laws are verified by analysis of gain and phase margins. Phase and gain margins are measured for the entire flight envelope covering critical flight conditions, each control feedback loop and different modes. These are repeated for 25% sensitivity changes in key stability derivatives one and two at time.

Off-line quantitative analyses demonstrate at least CH4 flying qualities.

Piloted 6 DOF demonstrate CH4 or better for all intended mission tasks, vehicle configurations & modes, and flight conditions.

DoD/MIL Doc: JSSG-2008: para 3.1, 3.1.5.2, 3.1.5.5, 3.1.5.7, 3.1.8, 3.1.11.6, 3.1.11.8, 3.1.13, 3.1.14.8, 3.1.16, 3.1.17, 3.1.18, 3.2.2.1, 3.2.2.4, 3.2.2.5.2, 3.2.2.5.4 thru 3.2.2.5.4.5, 3.2.2.6, 3.3.1, 3.3.4, 3.3.5, 3.3.7, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.19** Verify that control laws transients for gain and mode changes prevent unsafe flight conditions.

Standard: In general, with controls free, transients limits for mode transitions is 0.05 g normal or lateral acceleration with 1 up to 5 deg/sec roll rate (recommended is 3 deg/sec) at the pilot station and 5 degrees of sideslip or a period of 2 seconds.

For at least 5 seconds in the pitch axis, pitch force does not exceed 20 lb., a roll force of 10 lb. and 10 lb. in yaw force.

These transient conditions also apply for 25% sensitivity changes in key stability derivatives one and two at time.

Compliance: The VCF mode transition performance is verified by simulation, laboratory and flight testing. For the simulation and laboratory testing, mode transitions are verified at worst case conditions as well as nominal flight conditions.

Stability margins with any transition long term effects are verified for nominal and off nominal cases.

DoD/MIL Doc: JSSG-2008: para 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.5, 3.1.5.1, 3.1.5.2, 3.1.5.4, 3.1.5.5, 3.1.5.7, 3.1.5.8, 3.1.7, 3.1.7.2, 3.1.7.3, 3.1.9, 3.1.10, 3.1.11, 3.1.11.2, 3.1.11.4, 3.1.11.5, 3.1.11.6, 3.1.11.9, 3.1.11.10, 3.1.11.11.2, 3.1.11.11.3, 3.1.12, 3.1.12.1, 3.1.13.1, 3.1.13.2, 3.1.14.2.2, 3.1.14.2.4, 3.2.2.1, 3.2.2.2, 3.2.2.5, 3.3 thru 3.3.4, 3.3.6, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.20** Verify that control laws do not induce any kind of unsafe oscillatory effects.

Standard: Limit cycles are prevented in the control system or structural oscillations that might compromise safety, or cause crew or passenger dangerous conditions. Flying qualities require the measuring of residual pitch and lateral oscillations at the pilot's station. Historically control induced aircraft residual oscillations at the crew station have not exceeded 0.04 g's vertical or 0.02 g's lateral peak to peak acceleration. CH4 or better required.

These effects are absent for 25% sensitivity changes in key stability derivatives one and two at time.

Compliance: Vehicle stability, system architecture and compliance with residual oscillations are verified by analyses, simulation, failure modes and effects testing, ground and flight testing. These tests are done with 25% sensitivity changes in key stability derivatives one and two at time.

The allocated time delay limits are verified by performing a combination of analyses, simulation and flight test.

The VCF flight/safety critical and flight phase critical hydraulic/ pneumatic signal transmission requirements are verified by inspection of drawings.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5, 3.1.5.1, 3.1.5.6, 3.1.5.9, 3.1.7, 3.1.7.3, 3.1.11.11.3, 3.2.1.1, 3.2.2.1, 3.2.2.5.4, 3.2.2.5.4.2, 3.2.2.5.4.3, 3.2.2.5.4.4, 3.2.2.6, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.21** Verify that control laws do not have unsafe PIO tendencies.

Standard: Gain switching in the control laws between modes or activated by modes must accommodate overly large gradients, surface saturation rates and surface positions, transients, for oscillatory inputs and no PIO trigger. Particular attention is given to points in the flight envelope where nominal phase and gain margins are less than the traditional and lower margins may result in a vehicle instability or PIO.

These conditions are to be good for 25% sensitivity changes in key stability derivatives one and two at time.

Compliance: The VCF mode transition performance is verified by simulation, laboratory, and flight test requirements.

Stability margins are verified by analysis including variations due to tolerances affecting system characteristics and uncertainties in modeling. These are repeated for 25% sensitivity changes in key stability derivatives one and two at time.

System arrangement certification is verified by inspection. Redundant and simplex source information is verified by analysis, simulation, demonstration, ground test or flight test.

Control law requirements are verified by analysis of gain and phase margins, simulation, ground and flight testing. PITL simulations include high gain mission tasks in conjunction with triggering mechanisms like mode/configuration changes and failure accommodations. No pilot coupling evident.

DoD/MIL Doc: JSSG-2008: para 3.1, 4.1, 3.1.5.2, 4.1.5.2, 3.1.5.7, 4.1.5.7, 3.1.7.2, 4.1.7.2, 3.1.11.6, 4.1.11.6, 3.1.14.7, 4.1.14.7,3.2.2.5.4, 4.2.2.5.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.22** Verify that control laws redundancy and failure management designs are safely implemented.

Standard: The VCF integrates all required functions to achieve compliance to the system level

classifications.

The VCF operates in natural, induced and hostile environments without impairment of its ability to accomplish its designated mission and maintain operational state III.

Within the flight envelope, no single failure or single dissimilar failure combinations in the VCF, which are not extremely remote, produce any uncontrollable state.

Allowable transient limits:

A. Operational State I or II (after failure): No more than +/-0.5g incremental normal or lateral acceleration at the pilot's station and +/-10 degrees per second roll rate. Under no condition, stall AOA or structural limits are exceeded. In addition, for tasks requiring tight control of spatial position, vertical or lateral excursions limits of 5 ft, and +/-2 degrees bank angle apply.

B. For Operational State III (after failure): No dangerous attitude or structural limit is reached, and no dangerous alteration of the flight path results from which recovery is impossible

Compliance: The safety critical function classifications are verified by inspection and analysis.

Survivability requirement is verified by analysis, simulation, inspection, and ground and flight tests.

Compliance with the failure immunity and safety requirements are demonstrated by hazard analysis and FMECA for the VCF and the air vehicle.

Redundancy and failure management designs are verified by off-line and PITL simulation, demonstration and ground test to include FMET.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.1, 3.1.2, 3.1.2.1, 3.1.4, 3.1.5.5, 3.1.5.7, 3.1.7, 3.1.7.2, 3.1.9, 3.1.10, 3.1.11, 3.1.11.2, 3.11.5, 3.1.11.6, 3.1.11.7, 3.1.12, 3.1.12.1, 3.1.13.1, 3.1.17, 3.2.2.4, 3.2.2.5, 3.2.2.5.1.4, 3.2.2.5.4, 3.2.5.2, 3.3.1, 3.3.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.23** Verify that control laws sensitivity margins and phase and gain margins for each feedback loop are safe (see 6.1).

Standard: The VCF meets the required gain and phase margins about nominal (see table in ref)

VCF tolerances on feedback gain and phase are established at the system level based on the anticipated range of gain and phase errors. Key stability derivatives are varied by 25% in the most adverse affecting way.

During normal operation, the VCF provides a safe level of operation and maintains mission accomplishment capability while flying in atmospheric disturbances.

Sensitivity analyses include errors which exist between nominal test values or predictions and in-service operation due to such factors as poorly defined nonlinear and higher order dynamics, anticipated manufacturing tolerances, aging, wear, maintenance and non-critical materiel failures. Key stability derivatives are varied by 25%.

Compliance: Stability margins are verified by analyses and simulations including variations due to tolerances affecting system characteristics and uncertainties in modeling. Prediction of aerodynamic characteristics, aeroelastic effects, structural modes, and manufacturing / installation issues are the types of uncertainties found in modeling the air vehicle and its characteristics.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5, 3.1.5.7, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11.2, 3.1.11.10, 3.1.11.11.1, 3.1.17, 3.2.2.1, 3.2.2.2.9, 3.2.2.5.4, 3.2.2.5.4.2, 3.2.2.5.4.3, 3.2.2.5.4.4, 3.2.2.6, 3.3.2.1, 3.3.4, 3.5, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-

23.1529, 25.1501-25.1529

**6.2.2.24** Verify that functional command control authority limits are safe.

Standard: The VCF prevents and/or compensates for any hazardous flight condition which results from the dynamic VCF functional performance and asymmetric operation.

The VCF manages and integrates all functions which provide crew augmentation or assistance through manual and/or semi and/or automatic means for air vehicle control. Integration and security meet all requirements for the application.

The VCF design usage does not permit core functions or failures that place the air vehicle in an unrecoverable situation.

The VCF components meet the environments and needs for an operational life.

The VCF dynamic conditions of control laws, control logic and failure accommodation schemes as related to changing environment, flight, combat, training, mode or flight phase usage, and or auto guidance modes do not permit the air vehicle and/or crew to enter into an unrecoverable situation.

Compliance: The VCF function is verified by analyses, non-real time and piloted simulations with all integrating functions. This includes failure modes and effect ground test on the air vehicle for full functional as well as structural test, and flight testing for operational capability, including fault insertion.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.3, 4.1.5.3, 3.1.7, 4.1.7, 3.1.8, 4.1.8, 3.1.12, 4.1.12, 3.1.13.2, 4.1.13.2, 3.2.2.5, 4.2.2.5, 3.2.2.5.1.2, 4.2.2.5.1.2, 3.2.2.5.1.3, 4.2.2.5.1.3, 3.2.2.5.1.4, 4.2.2.5.1.4, 3.2.2.5.4.1, 4.2.2.5.4.1, 3.2.2.6, 4.2.2.6

FAA Doc: 14CFR references: 23.345, 23.397, 23.672, 23.675, 23.677, 23.679, 25.345, 25.397, 25.672, 25.675, 25.677, 25.679

**6.2.2.25** Verify that dynamic VCF functional performance is safe.

Standard: The VCF prevents and/or compensates for any hazardous flight condition which results from the dynamic VCF functional performance and asymmetric operation.

The VCF manages and integrates all functions which provide crew augmentation or assistance through manual and/or semi and/or automatic means for air vehicle control. Integration and security meet all requirements for the application.

The VCF design usage does not permit core functions or failures that place the air vehicle in an unrecoverable situation.

The VCF components meet the environments and needs for an operational life.

The VCF dynamic conditions of control laws, control logic and failure accommodation schemes as related to changing environment, flight, combat, training, mode or flight phase usage, and or auto guidance modes do not permit the air vehicle and/or crew to enter into an unrecoverable situation.

Compliance: The VCF function is verified by analyses, non-real time and piloted simulations with all integrating functions. This includes failure modes and effect ground test on the air vehicle for full functional as well as structural test, and flight testing for operational capability, including fault insertion.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.26** Verify that the vehicle provides the crew with the capability to override the design-limited vehicle control functions safely.

Standard: The air vehicle is capable of control override to safely maintain air vehicle control.

Appropriate methods of interlocks for engagement/ disengagement of mission or flight phase particular controls are provided with override capability.

The VCF pilot integration provides clear and unambiguous warning, caution, and advisories.

Compliance: The performance and operational capabilities of the special modes are verified by hardware/software and pilot in the loop simulation and flight test.

The mission functions are verified by analyses, simulation, inspection, ground test and flight test.

Integrated Pilot/VCF is verified by simulation and ground testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5.2, 3.1.5.4, 3.1.7, 3.1.10, 3.1.11, 3.1.11.1, 3.1.11.1.1, 3.1.11.10, 3.1.14.7, 3.2, 3.2.2.3, 3.2.2.5.1, 3.2.2.5.1.2, 3.2.2.5.1.4, 3.2.2.5.4, 3.2.2.5.4.1, 3.2.2.5.4.3, 3.2.2.5.4.4, 3.2.2.5.4.5, 3.2.2.6, 3.5.3, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.27** Verify that nonoperative devices/programs can be safely locked out of any functions.

Standard: Positive interlocks prevent hazardous operation or sequencing of nonoperative devices/programs.

Appropriate methods of interlocks are provided to ensure that the nonoperative devices/programs can never be turned on inadvertently. Some methods may be removal of memory or processor chip, double access to partitioned memory, removal of power, cockpit switches, etc..

Of particular concern are parts of OFPs that deal with diagnostics. BITs that are not to be run inflight must have interlocks that preclude them from ever starting inflight. As a minimum, for the nonoperative inflight devices/ programs , there are at least two independent types of interlocks to prevent inflight engagement. As a general rule of thumb, the redundancy of the interlocks match the redundancy of the basic functions.

Compliance: Verification of nonoperative devices /programs are done by analyses, simulation, inspection, demonstration, ground test including pre and post flight and flight test. FMET cases to specifically introduce attempts to access non-operative devices/programs including a rogue partition.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.13, 4.1.13, 3.1.13.1, 4.1.13.1, 3.1.13.3, 4.1.13.3, 3.1.14.7, 4.1.14.7, 3.2.2.2.2, 4.2.2.2.2, 3.2.2.5.1.3, 4.2.2.5.1.3, 3.2.2.6, 4.2.2.6

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.28** Verify that engage/disengage functions/devices are safely assigned and identified for the crew.

Standard: Engage/disengage functions/ devices assignment prevent the engagement of incompatible modes that could create an immediate undesirable situation or hazard and provide:

A. Flexibility and ease of selection

B. Proper engagement and mixing of modes

C. Appropriate disconnection of modes when choosing different modes

D. Emergency disengagement of modes to the basic flying air vehicle control mode

E. Appropriate pilot notification of modes as selections or de-selections are made

Compliance: FMECA, simulation, FMET, inspection, and ground testing verify the safe performance of the engage/disengage functions/devices.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5.2, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.2,

3.1.13.1, 3.1.13.3, 3.1.14, 3.1.14.7, 3.2.2.2.4, 3.2.2.2.5, 3.2.2.2.9, 3.2.2.2.11, 3.2.2.4, 3.2.2.5.1, 3.2.2.5.1.1 thru 3.2.2.5.1.4, 3.2.2.5.4.1, 3.2.2.6, 3.3.2.1, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.29** Verify that interlocks safely preclude incompatible modes, simultaneous engagement, and engagement with incompatible flight conditions or air vehicle configurations.

Standard: VCF interlocks prevent the engagement of incompatible modes that could create an immediate undesirable situation or hazard that are incompatible with flight conditions or air vehicle configurations and provide

A. Proper engagement and mixing of modes

B. Appropriate pilot notification of modes as selections or de-selections are made providing:

1) Protection against improper mode engagement or positioning of any control functions

2) Protection against in-flight engagement of any surface locks affecting aircraft stability

3) Protection against simultaneous engagement, and engagement with incompatible flight conditions or air vehicle configurations

A process of evaluating whether mode selections result in a transition to known, desirable states, or are blocked is defined and appropriate feedback is provided to the weapon system operator

Compliance: Analysis, simulation, demonstration, ground test verify that mode selection prevents the engagement of incompatible modes that could create an immediate undesirable situation or hazard.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.7.3, 4.1.7.3, 3.1.11.2, 4.1.11.2, 3.2.2.5.4.3, 4.2.2.5.4.3, 3.2.2.5.4.4, 4.2.2.5.4.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.30** Verify that engage and disengage transient times are safe.

Standard: Automatic engage and disengage transient times for the entire integrated VCF is on the order of 0.1 sec or less. Larger transient times maybe justified and acceptable depending on the application. This time allocation is based on a study by Calspan Advanced Technology Center & BBN Laboratories Inc. as documented in "An Investigation of Time Delay During In-Flight and Ground based Simulation". This report investigates pilot ratings based on various system delays.

Manual engage and disengage transient time is determined in concert with the crew and is compatible with multiple conditions for the application.

Compliance: Simulation, flight, ground and laboratory testing verify engage/ disengage transient times at worst case conditions as well as nominal flight conditions.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5.2, 3.1.5.4, 3.1.5.5, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.5, 3.1.12, 3.1.12.1, 3.1.13.2, 3.1.14, 3.2.2.1, 3.2.2.2.1, 3.2.2.2.2, 3.2.2.2.6, 3.2.2.2.12, 3.2.2.5.4, 3.2.2.5.4.3, 3.2.2.6, 3.3.1, 3.3.2, 3.3.2.1, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.31** Verify that mode change transient times are safe.

Standard: Automatic engage and disengage transient times for the entire integrated VCF is on the order of 0.1 sec or less. Larger transient times are justified.

Studies define the appropriate delay:

A. An Investigation of Time Delay During In-Flight and Ground based Simulation", Calspan Advanced Technology Center & BBN Laboratories Inc. The report investigates delays with pilot ratings as the result. All the ratings and comments are reviewed and the following table devised based on the specific area of PIO comments:

(%-satisfactory, #- not satisfactory, @- neutral, 0- not evaluated)

| Time Delay (milliseconds) | 0 | 30 | 90 | 130 | 180 |
|---|---|---|---|---|---|
| F-16 | % | % | @ | # | # |
| C-17 | % | 0 | % | @ | # |
| C-21 | % | 0 | % | @ | # |
| C-141 | % | 0 | @ | # | # |

B. Manual engage and disengage transient times is determined in concert with the crew and is compatible with multiple conditions for the application.

Compliance: Simulation, flight, ground and laboratory testing verify engage/ disengage transient times at worst case conditions as well as nominal flight conditions.

DoD/MIL Doc: For more guidance on mode change transient times:

JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.5, 3.1.5.1, 3.1.5.2, 3.1.7, 3.1.7.3, 3.1.11.2, 3.1.11.10, 3.1.14.7, 3.1.17, 3.2.2.2.9, 3.2.2.5, 3.2.2.5.1.1, 3.2.2.5.1.2, 3.2.2.5.4, 3.2.2.5.4.3, 3.2.2.5.4.5, 3.2.2.6, 3.2.4.6, 3.2.5.1, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.32 Verify that warning and caution functions safely operate and properly notify the crew.

Standard: The warning and caution system shall provide the pilot with fast and adequate information to minimize workload and maintain acceptable flying qualities and situational awareness (Level I).

The VCF devices/functions displays, panels, switches and indicators provide positive unambiguous state/status information, problem recognition, and corrective action to the crew.

VCF warning and caution functions discern the most probable cause of multiple warning and caution functions occurring at the same time and lead the crew to the most probable corrective action.

Compliance: The warning and caution functions/devices are verified by inspection, simulation, and ground testing. Test cases include multiple failures occurring nearly simultaneously.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.11.10, 4.1.11.10, 3.1.13.4, 4.1.13.4, 3.1.17, 4.1.17, 3.2.2.2.7, 4.2.2.2.7, 3.2.2.5.1.2, 4.2.2.5.1.2, 3.2.2.5.1.4, 4.2.2.5.1.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.33 Verify that sensors are safely located to minimize/avoid structural mode coupling including vibration from configuration loading and gun fire, and to have safe sensitivity margins.

Standard: Sensors are located to prevent erroneous feedback and disruption of the VCF or air vehicle in the operational environments.

Sensors do not aggravate structural mode coupling including vibration from configuration loading and contain features to minimize these interactions.

Sensors location analyses account for sensitivities to actual manufacturing and variations in key stability derivatives and structural mode frequencies.

Compliance: Adequacy of design drawings are verified by review.

Verification of air vehicle structural interactions done by analyses, simulation, ground and flight test. Ground testing conducted with the aircraft on a soft suspension system to eliminate any constraints imposed by the landing gears. Aircraft/envelope limits established for investigating interactions in flight, such as 80% load and speed limits.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2.1, 3.1.5, 3.1.5.6, 3.1.7.2, 3.1.11, 3.1.13, 3.1.15, 3.1.17, 3.2.2.2, 3.2.2.5, 3.2.2.5.1.1, 3.2.2.5.2, 3.2.2.5.4.3, 3.2.2.5.4.4, 3.3.4, 3.3.6.2, 3.5.7, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.34 Verify that sensitivities with variations in slope and bias conditions of air data functions have safe margins.

Standard: VCF tolerances on air data functions are established on the anticipated range of gain and phase errors which will exist between nominal test values or predictions and in-service operation due to such factors as poorly defined nonlinear and higher order dynamics, anticipated manufacturing tolerances, aging, wear, maintenance and non-critical material failures.

Areas to consider for air data system errors and failures include:

A. Noise on air data signals

B. Calibration table errors in slope and bias

C. Intermittent signal failures (especially failures of duration shorter than the persistence counter)

D. Lags; pneumatic, sensor, computational, electrical

E. Out of range failures; just within range failures

The air data model accounts for any lags in the function and considers variations in the above parameters especially with consideration to slope and bias conditions.

Probability of mission abort due to an air data system failure is no greater than 1 x 10E-5.

Probability of aircraft loss due to an air data system failure is no greater than 1 x 10E-8.

Compliance: Air data sensitivities are verified by analysis including variations due to tolerances affecting system characteristics and uncertainties in modeling.

Air data sensitivities are verified by simulation, flight, ground and laboratory testing to worst case conditions as well as nominal flight conditions.

Air data sensitivities are evaluated in flight test during calibration flights.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5, 4.1.5, 3.1.5.7, 4.1.5.7, 3.1.7, 4.1.7, 3.1.7.2, 4.1.7.2, 3.1.17, 4.1.17, 3.2.1.1, 4.2.1.1, 3.2.1.2, 4.2.1.2, 3.2.2.5, 4.2.2.5, 3.3.2.5.4.2, 4.3.2.5.4.2, 3.2.2.5.4.4, 4.2.2.5.4.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.35 Verify that the processor design of VCF is safe.

Standard: The processor is classifies as safety critical based on criticality of VCF function.

Harmonics of microprocessor clocks and other oscillators conducted out of electronics boxes on interface cabling and subsequently radiated is accounted for in the design.

VCF processor accounts for electromagnetic fields radiated from transmitter antennas. High Frequency (HF) transmitters are particularly troublesome due to the long wavelengths associated with HF and their high power output.

Computer processor capacity requirements (absolute, spare, or both), have 50% margin after considering:

A. Character Set Standard. The character set standard is ASCII.

B. Instruction Set Architecture. All architectures incorporated in the air vehicle require justification approval. The selection must be standardized across the weapon system platform including special purpose architectures and varying word length processors.

C. Interrupt Capabilities. Interrupt capability requirements of the hardware preclude masking of critical interrupts and are standardized across the weapon system.

D. Memory Access. Transfer of data to memory is identical among redundant channels.

Single processor computers can be specified as well as distributed, multiprocessor computational systems.

The VCF uses common microprocessors. A valid requirement requiring the use of a special purpose processor may exist. The processor needs could be a specialized signal processor or an image processor for electro-optical data processing. The special purpose processor may not be definable by a standard Instruction Set Architecture, or it may be a specialized Von Neuman or data flow architecture machine. The specialized requirements for the processor must be specified. The use of other processors such as ASIC or customized hybrids to be compatible with the basic processing set. The instruction set architectures, alternate architectures, including special purpose architectures and varying word length processors, are capable of being replaced with other microprocessors (interchangeability), used in an open architecture environment, not cause single fail conditions or propagate faults to other processors and be compatible with the entire microprocessor suite within the air vehicle. All microprocessors utilize the same Instruction Set Architecture or a subset from the same Instruction Set Architecture as much as practicable.

If different types of processors are used with different Instruction Set Architectures, rigorous analysis and tests defined with the processor suite so that the processors are transparent to each other. This may necessitate the development of an interface set of software and communication packages in the form of an open architecture.

Synchronization method of processor input data and commanded outputs parameters specified.

Redundancy achieves the safety requirements and does not propagate failures.

The processing hardware within the VCF allows for common, conditioned power to all elements, continued operation with no cooling for 30 minutes, single point OFP load and verification, and withstands all induced and natural environments.

The design is to be Operational State I in the presence of any single failure or combination of single independent failures.

Compliance: The VCF processing hardware requirements are verified by inspection, analysis, demonstration, component test, integration tests ground and flight test to include FMET.

Testing considers noise sources of narrow-band signals such as harmonics of microprocessor clocks and power supply choppers requiring a more thorough evaluation of receivers. Spectrum analysis equipment allows the entire operating range of the receiver assessed, analysis performed on potential interfering signals, and subsequent refinement of procedures for any follow-on testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.14.6, 4.1.14.6, 3.1.18, 4.1.18, 3.2.2.2, 4.2.2.2, 3.3,

4.3, 3.3.1, 4.3.1, 3.3.2, 4.3.2, 3.3.2.1, 4.3.2.1, 3.3.2.2, 4.3.2.2, 3.3.2.3, 4.3.2.3, 3.3.4, 4.3.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.36** Verify that preflight checklists of VCF are all-inclusive and safe.

Standard: Pre-flight Test/Diagnostics/Redundancy/Monitoring includes all test sequence required to determine the status of the VCF and integrated systems prior to takeoff.

The tests and checklists are ground safe for crew and the vehicle.

Automatic pre-flight does not to exceed 30 seconds for a complete end to end check of the VCF.

Initiated pre-flight and post-flight BIT detect at least 98% of all subsystem faults, with less than 1% false indications.

Pre-flight tests do not rely on ground test equipment for their successful completion. Interlocks are provided to prevent in-flight engagement and to terminate Pre-Flight Built-in Test when the conditions for engagement no longer exist.

Pre-flight tests can by performed by manipulation of all the VCF functions.

Test provisions include the capability for determining the integrity of functions by the corresponding test:

A. Fault monitoring and failure isolation systems for sensors, electronics, and servo-systems. The functional capability of their fail operational modes are also determined.

B. The overall tests performed (Built-in Test, Visual Inspection, Physical Parameter Measurement, Special) contain the necessary specific tests to establish full VCF integrity.

Inflight restart is accomplished in less than the time for 2 double amplitudes.

Compliance: Inspection, analysis, demonstration, integration tests, ground and flight test to include FMET verify that the preflight checklist provides the necessary check for proper functionality.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.12, 3.1.13, 3.1.13.1, 3.1.14.7, 3.2.2.2, 3.2.2.5, 3.2.2.5.1, 3.2.2.5.2, 3.2.2.5.3, 3.3.6.2, 3.7.1, 3.7.1.1, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.37** Verify that interfaces/integration with other functions and sub-functions are safe.

Standard: Adequate test cases for all of the inter/intra functions and their integration are defined.

The probability of air vehicle loss due to the VCF and integration does not exceed 10E-7 per flight hour. This probability must take into account the interdependence of all aircraft functions within the integrated VCF.

Each operational state meet the probability levels of:

| Probability of Encountering a Failure Mode | Minimum Ops State |
|---|---|
| Greater than 1 x 10E-3 | I |
| Less than 1 x 10E-3, but greater than 1 x 10E-5 | II |
| Less than 1 x 10E-5, but greater than 1 x 10E-6 | III |
| Less than 1 x 10E-6, but greater than 1 x 10E-7 | IV |
| Less than 1 x 10E-7 | V |

Compliance: The quantitative flight safety requirement is verified by analysis considering all failure modes that threaten flight safety, whether single failures or combination of failures, and whether extremely remote or not. Of special consideration, where integration has several fault layers

such as hydraulic branch 1a, 2a, etc., the integration and fault accommodation may be order sensitive and is considered in the analysis.

Interfaces/integration with other functions and sub-functions are verified to be safe through testing and FMET performed on an iron bird or high fidelity integration lab with all hardware and software.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.5, 3.1.7, 3.1.8, 3.1.11, 3.1.12, 3.1.13, 3.1.14.4, 3.2.2.2, 3.2.2.4, 3.2.2.5, 3.2.2.6, 3.3, 3.2.4, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.38 Verify the effects of loss of function(s) on safety.

Standard: Complete hazard analysis combined with failure modes and effects testing establish the effects of loss of function(s). Piloted evaluations demonstrate CHR 5 or better for failures more likely than 10E-7 per flight hour.

Separation/isolation/accommodation between inter/intra VCF interfaces prevent propagated or common mode failure to the level of extremely remote, 10E-9.

The VCF does not have any single failure, combination of functionally single independent failures, multiple failures greater than PLOC 1x10E-5; PLOF 1x10E-9.

Compliance: The quantitative flight safety requirement are verified by analysis considering all failure modes that threaten flight safety, whether single failures or combination of failures, and whether extremely remote or not.

Effects of loss of function(s) are verified through testing and FMET performed on an iron bird or high fidelity integration lab with all hardware and software.

DoD/MIL Doc: JSSG-2008: para 3.0 thru 3.3.8, 4.0 thru 4.3.8

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.2.39 Verify that any functional modes do not defeat any limiters designed for vehicle safety.

Standard: VCF integrates all functions that provide control of the aircraft for all tasks throughout the flight envelope. Control law limiters usually protect the crew and vehicle from unsafe flight regimes. There may be structural limiters or filters, angle of attack and sideslip limiters, data input rate limiters, command limiters, data input max and min limiters, time limiters, persistence limiters, stale data limiters, and other limiters defined by the application at hand.

Each limiter used accomplishes the intended limiting without causing loss of the control function, a departure from controlled flight, loss of vehicle and/or crew for any condition or use throughout the entire flight and ground envelopes.

No VFC or integrating control function induce conditions that defeat control law limiters.

Compliance: Analysis establishes what limiters are used, where in the control scheme they are used, the conditions that need to be limited and the most adverse conditions the limiter functions in.

Hardware in the loop (HITL) testing of each function or probable combinations of functions conducted at worst case limiting conditions verify the adequacy of the limiter. Example might be a pilot relief mode defeating an angle of attack limiter in the absence of compatibility logic.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5.2, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.2, 3.1.13.1, 3.1.13.3, 3.1.14, 3.1.14.7, 3.2.2.2.4, 3.2.2.2.5, 3.2.2.2.9, 3.2.2.2.11, 3.2.2.4, 3.2.2.5.1, 3.2.2.5.1.1 thru 3.2.2.5.1.4, 3.2.2.5.4.1, 3.2.2.6, 3.3.2.1, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-

23.1529, 25.1501-25.1529

**6.2.2.40** Verify that data transfer and update rates are safe with adequate margins.

Standard: Time delays are measured from the instant of a controller input to the time at the intersection of the line representing the maximum response slope on the time axis. This sum total delay allowed is 100 msec for Level I flying qualities in the applicable axis of control.

Limits on effective time delay apply to the open loop airplane response which includes aerodynamic and aero-elastic influences. The allocation of VCF elements must be less than the empirically derived total value of 100 msec in all axes.

VCF synchronization allows for autonomous channel execution and is not a single point failure in the VCF function.

The iteration and sampling rates for the VCF functions are compatible with the control law iteration rates and provide sufficient sampling ability to discern the nature of the sampled signal.

Compliance: A combination of analyses, simulation, and flight test verifies the allocated time delay limits.

Full hardware and software integration testing verifies the VCF data transfer and rates.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.1, 4.1.5.1, 3.1.5.5, 4.1.5.5, 3.1.5.6, 4.1.5.6, 3.1.7.3, 4.1.7.3, 3.1.17, 4.1.17, 3.3.2.1, 4.3.2.1, 3.3.4, 4.3.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.41** Verify that air vehicle functional/transient interruption characteristics are safe.

Standard: Total time delay within the fully integrated VCF is 100 msec in each axes. Within this framework, any transient conditions associated with switching functions or interruptions to perform some other function or failure handling within normal flow of the control law is allocated from the 100 msec.

In assessing the ability of the VCF to maintain phase and gain margins, the longest control path is used to perform the gain and phase margin analysis considering transient conditions associated with functions or interruptions. These conditions do not adversely affect the time delay or margin characteristics of the VCF.

Functional/transient interruption for a frame overrun in a digital VCF is not allowed.

Compliance: Analysis establish what functional/transient interruption characteristics produce the most adverse conditions.

Functional/ transient interruption characteristics are verified by Hardware in the Loop (HITL) testing of each function or probable combinations of functions conducted at limiting conditions.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.5, 3.1.5.1, 3.1.5.2, 3.1.7, 3.1.7.3, 3.1.11.2, 3.1.11.10, 3.1.14.7, 3.1.17, 3.2.2.1, 3.2.2.2, 3.2.2.5, 3.2.2.5.1.1, 3.2.2.5.1.2, 3.2.2.5.4, 3.2.2.5.4.3, 3.2.2.5.4.5, 3.2.2.6, 3.2.4.6, 3.2.5.1, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.42** Verify that failure mode effects for critical maneuvers and critical flight regions are safe.

Standard: The maximum acceptable mission unreliability due to VCF failures is not greater than 10E-5. The maximum acceptable loss of VCF is not greater than 10E-7.

Critical failure modes that degrade performance below Operational State III, that may result in aircraft loss and can reasonably be expected, is on the analytical order of 10E-8 or better.

As a minimum, no single or single dissimilar combinations of failures within the VCF or in systems outside the boundaries of the VCF which integrate with functions within the VCF, unless the failure is extremely remote, does not degrade flying qualities below Level I for a period of one hour.

No second failure, unless it is extremely remote, with like or dissimilar combinations within the VCF or in systems outside the boundaries of the VCF which integrate with functions within the VCF, reach a flight condition where crew evacuation is not safely accomplished. Digital systems prevent propagation of software errors from any source.

Failure mode effects are considered in 1g trimmed flight, for critical maneuvers and critical flight regions. The effects at these critical flight regimes do not cause loss of the vehicle or crew nor loss of vehicle control unless extremely remote/improbable/impossible, on the order of 10E-9.

Compliance: Criticality, fault tree, and multiple failure analyses verify the VCF reliability requirements.

Criticality, fault tree, and multiple failure analyses verify the mission accomplishment reliability requirements.

Failure mode effects are verified by Hardware in the loop (HITL) testing of each function or probable combinations of functions conducted at critical flight regimes.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5, 3.1.5.7, 3.1.5.8, 3.1.5.9, 3.1.9, 3.1.14, 3.2.1.3, 3.2.1.2, 3.2.2.2, 3.2.2.5, 3.2.2.5.4, 3.2.2.6, 3.3, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.43** Verify that flow rates for hinge moment, stiffness, and control surface rates are safe.

Standard: Flow and control surface rates are fast enough to meet VCF gain and phase margins, preclude PIOs, and support dynamic control surface stiffness requirements that preclude structural coupling, aero-elastic coupling and flutter specified.

The backup hydraulic power system reduced flow rates or pressures may have on overall aircraft controllability or flutter margin. The flight limitations, the adequacy of "switch-over" time constants, and the static and dynamic hinge moment stiffness characteristics associated with the backup hydraulic power system are defined. No loss of vehicle or crew is allowed.

Compliance: Flow rate requirements of the actuation/hydraulic system are verified by analysis, demonstration, and test or combination of these methods.

PITL simulations and iron bird testing verify that the hydraulic sizing is adequate for all probable combinations of mission tasks and hydraulic failure modes. CH 3 or better and no hydraulic system saturation is attained for the primary function and CH 5 or better for the backup function.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.6, 4.1.5.6, 3.1.5.7, 4.1.5.7, 3.2.1, 4.2.1, 3.2.2.1, 4.2.2.1, 3.2.2.2.1, 4.2.2.2.1, 3.2.2.5.4.4, 4.2.2.5.4.4

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.44** Verify that the actuator design meets safety requirements for: (for criteria 6.2.2.44.1 through 6.2.2.44.4)

**6.2.2.44.1** (was 6.2.2.44.a) Actuator redundancy techniques

Standard: Actuator redundancy requirements meet the handling qualities and flight safety probability requirements for appropriate operational states as follows:

| Probability of Encountering a Failure Mode | Minimum Ops State |
|---|---|
| Greater than 1 x 10E-3 | I |
| Less than 1 x 10E-3, but greater than 1 x 10E-5 | II |
| Less than 1 x 10E-5, but greater than 1 x 10E-6 | III |
| Less than 1 x 10E-6, but greater than 1 x 10E-7 | IV |
| Less than 1 x 10E-7 | V |

| Operational State | Service Envelope |
|---|---|
| | All tasks |
| I | Level II |
| II | Level III |
| III | Recoverable |
| IV | Recoverable |
| V | Safe ejection |

Switching between redundant functions from detection and isolation do not cause a disruption which jeopardizes the vehicle or crew or combat mission.

Actuators can have special feedback features in the design such as delta pressure or velocity sensors to enable the VCF to maintain stability. For cases where there are 2 or more actuators per control element, force fights between actuators are prevented.

The interface between actuation system, support structure, control, control surface stops, control surface gust protection, control surface locks, and control surface flutter and buzz are accounted for in VCF stability margins.

Compliance: Actuator redundancy is verified by failure analyses, software emulation and actual hardware/software in-the-loop failure modes and effects testing.

**6.2.2.44.2** (was 6.2.2.44.b) Failure isolation design capability and limitations

Standard: Separation and isolation is provided for the VCF actuation to ensure that the probability of propagated or common mode failure is extremely remote (10E-9).

Actuator performance testing, failure detection, and failure isolation to the LRU/WRA/Line Replaceable Module (LRM) is provided.

Actuator combinations of redundancy and integration management is monitored, conditioned, and transmitted at a sufficient rate for PVI display requirements.

A hydraulic failure, followed by an actuator failure, are independent single fail combinations that can be withstood.

Actuator failure isolation design capability addresses redundant servos, redundancy techniques for possible safety of flight single-failure points, failure isolation capability or limitations, hole in the wall design, susceptibility of design to hydraulic contamination effects, valve shearing force or clearing chips or other contamination, bottoming of the input valve, and the valve load limitations. Transients during actuator failure detection and isolation are safe.

Compliance: Actuator redundancy is verified by failure isolation design capability analyses.

Actual hardware/software in-the-loop failure modes and effects testing verifies failure

isolation. Testing with a fully integrated iron bird facility that mates actual VCF control hardware with functioning air vehicle subsystems such as hydraulics, actuation, and electrical power, provide the best facility to develop, integrate and test the aircraft as a total system.

Stability of the actuation system is verified by a combination of simulation and laboratory testing of individual components.

**6.2.2.44.3** (was 6.2.2.44.c) Hydraulic contamination effects

Standard: Actuators are susceptible to numerous and various types of failures induced by environmental contamination. For example, sand and dust grind screw actuators to dust, piston rings freeze to the actuator barrel body, icing prevented screw jacks from working, and water pooling is always a problem. Actuators accommodate the following:

A. Actuation provides protection from hydraulic contamination due to the largest particle able to block or wedge an actuation spool in the smallest passage.

B. Hydraulic contamination does not contribute to cavitation, adverse effects from passage diameter changes, passageway direction changes, or connections.

C. Actuation works with hydraulic contamination and is able to chip shear the largest chip thay fits in a passage of the hardest material in the actuator or hydraulic system.

Compliance: Analysis, inspection and demonstration verifies safe protection against actuation contamination effects.

**6.2.2.44.4** (was 6.2.2.44.d) Bottoming and snubbing

Standard: Bottoming of any valve or ram is designed out.

The actuator is capable of withstanding bottoming loads in the event of miss-rigging.

The VCF provides electronic or mechanical snubbing at 5% of stop-to-stop travel.

Compliance: Bottoming loads and load limitations are verified by test.

Bottoming and snubbing verified by inspection, test and analysis

**6.2.2.45** Verify that the actuation system is safe (e.g., burst pressure, normal performance, high and low temperature, pressure impulses).

Standard: The VCF actuation is designed to withstand:

A. The full range of natural environment extremes established for the vehicle without permanent degradation of performance below VCF operational state I or temporary degradation below operational state II.

B. Reductions below operational state III experienced at adverse environmental extremes not normally encountered but transient in nature. The function recovers as soon as the aircraft passes through the adverse environment.

The probability of loss of the actuation system be extremely remote, 1x10E-9.

Mechanical Advantage Actuation, both force and torque actuation, includes the following:

A. Mechanical elements endure for one aircraft life.

B. Inspection and lubrication devices are easily accessible and serviced.

C. Material used in friction, bearing, or wear out components withstand the operating and environmental temperature range.

D. Means are provided to hold loads, hold position, prevent runaways, and limit surface displacement in the event of a catastrophic failure provided.

E. Means are provided to gather and supply data for catastrophic events and prognostics provided.

F. Materials and lubricants are corrosive resistant.

G. Limit load is 1.5 times the normal load, and ultimate load is at least two times the normal load.

H. Backlash accumulation and hysteresis does not exceed a total of one degree when measured at the surface or prevent the performance of its function throughout the aircraft service life.

I. Steady state and variable loads do not produce buffeting or buzz.

J. Pre-flight, post-flight and in-flight testability and monitoring is provided for integrity.

Hydraulic actuation and drives includes the following:

A. Prevention of fluid lock or loss of pressure.

B. Loop closure at the servo-control.

C. Chip shear capability for the largest chip to fit in a passage of the hardest material in the actuator.

D. Full functionality at fluid temperature range.

E. Failure detection and reconfiguration allocated from 0.1 sec for the VCF.

F. Rip stop design at common junctures of hydraulic systems.

G. Area switching, as needed, to match flow rate and hinge moment as a function of flight condition.

H. Full operation after two electronic failures and one hydraulic failure. Fail safe/conservative for all other failures.

I. Service life for the application.

J. Anti-cavitation protection.

K. Flow direction protection.

L. Pre-flight, post-flight, and in-flight testability and monitoring provisions.

M. In-line filtering of the supply fluid to prevent contamination from lodging inside the actuator.

N. Open loop gain margin of 6 dB, a phase margin of 45o and a damping ratio of 0.7.

O. Snubbing that covers the required deflection for the needed control power.

P. Bandwidth with no buzz or coupling to the first or second fuselage bending modes and the first wing bending mode

Q. Excitation of flutter modes prevention.

R. Hysteresis not to exceed 0.1% differential of any stroke to null.

S. Feedback tracking lnot to exceed 4% of full scale ram movement.

T. Resolution of position within +/-0.04% of any commanded stroke.

U. Linearity within +/-0.02% of full stroke.

V. Accuracy for any commanded position within 0.02%.

W. Null offset for returning to null within 0.02% of full stroke and maintain an accuracy of 0.01% for any start up.

X. Maximum load does not stall the actuator until full position is achieved.

Y. Transients due to switching not to exceed 0.1% of full stroke.

Z. Threshold for movement not to exceed 0.01% of commanded input.

AA. Leakage, internal or external less than TBD gpm defined for the application.

BB. Self-cleaning of rods to prevent seal contamination.

Electrically powered actuators, including electro-hydrostatic actuators and electro-mechanical actuation and electric power used to actuate relatively low-duty cycle, such as trim, require specific approval from the procuring activity before use in flight/safety critical applications.

Pneumatic actuation devices have been used for the control of relatively low-duty-cycle and withstand the following:

A. Prevention of air lock for loss of pressure.

B. Loop closure at the servo-control.

C. Chip shear capability for the largest chip to fit in a passage of the hardest material in the actuator.

D. Failure detection and reconfiguration as allocated from the VCF.

E. Full operation after two electronic failures and one pneumatic failure. Fail safe for all other failures.

F. Service life of for the application.

G. Flow direction protection.

H. Pre-flight, post-flight, in-flight testability and monitoring provisions.

I. Open loop gain margin of 6 dB a phase margin of 45 degrees and a damping ration of 0.7.

J. Snubbing that covers the required deflection for the needed control power.

K. Bandwidth with no buzz or coupling to the first or second fuselage bending modes and the first wing bending mode.

L. Hysteresis not to exceed 0.1% differential of any stroke to null.

M. Feedback tracking no worse than 4% of full scale ram movement.

N. Resolution of position within +/-0.04% of any commanded stroke.

O. Linearity within +/-0.02% of full stroke.

P. Accuracy for any commanded position within 0.02%.

Q. Null offset for returning to null within 0.02% of full stroke and maintain an accuracy of 0.01% for any start up.

R. Maximum load does not stall the actuator until full position is achieved.

S. Transients not to exceed 0.1% of full stroke.

T. Threshold not to exceed 0.01% of commanded input.

The control actuation mechanisms redundancy requirements meet the handling qualities and flight safety requirements for all operational states.

Compliance: Test and analysis verifies VCF invulnerability of the actuation system.

SOF Tests include the following:

A. Low pressure test

B. Low/High temperature test

C. Temperature shock test

D. Temperature-Altitude (Cycling)

E. Vibration test

F. Humidity test

G. Mechanical shock

H. Acceleration

I. Adequate acceptance testing

J. FMET

Analysis includes :

A. Control and analysis of random vibration

B. Hazard analysis

C. Failure Modes, Effects and Criticality Analysis and Testing (FMECA/FMET) or equivalent

D. Operational state analysis

E. Analysis of Performance with respect to:

1) Parameters that change with temperature, atmospheric pressure and other environmental factors

2) Parameters that change with failures or manufacturing tolerances

3) Parameters that critically affect system performance or stability

4) Parameters that are not accurately known (if they are significant)

5) Parameters that change as a result of aging or wear

6) Flight safety, reliability, maintainability, and vulnerability

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.6, 4.1.5.6, 3.1.14.1, 4.1.14.1, 3.1.14.3, 4.1.14.3, 3.2.2.1, 4.2.2.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.46** Verify that motor/torque tube driven and similar control actuation mechanisms are safe (e.g., performance, implementation, redundancy management).

Standard: The probability of loss of the motor/torque tube driven and similar control actuation mechanisms is extremely remote 1x10-9.

Ball screws meet the following:

A. Limiting factors when all ball bearings are to be load carriers:

1) The number of ball bearings in any single circuit is less than 125.

2) Maximum circuit length is less than 3-1/2 turns.

B. The load carrying capacity of ball screws parallels that of conventional ball bearings.

C. Manufacturing limits are 3/16 inch minimum and 8 inches maximum diameter of the circle pitch diameter.

D. Leads of 0.125 time pitch diameter are minimum; there is no maximum top limit.

E. Failure mode is almost always broken ball bearings.

F. Impact loading of ball bearings determines life. Impacts are the number of ball bearings that pass one point on the nut in one revolution of the screw. Number of impacts are kept between 5 and 13 per revolution.

All torque tubes are mounted on antifriction bearings with supported couplers (jackshafts mounted to structure on antifriction bearings) spaced at close enough intervals and with

sufficient misalignment capability (within the couplers) to prevent undesirable bending or whipping of the tubes. A minimum of parts, joints, and related components are used to accomplish the required purpose; however, it must be possible to remove the torque tube sections from the air vehicle and replace them readily.

Helical splines (also known as Yankee screwdrivers) can transmit high torque (or translate linear force to torque) in thin airfoil sections.

A. When used, lubrication provisions are adequate for controlling efficiency, wear, and heating to acceptable values.

B. If the design is dependent on inherent friction to maintain irreversibility, this characteristic is adequate under all expected operating conditions; including the full range of loads, temperatures, and environmental vibration over the full service life of the unit, both steady loads and reversing or variable magnitude loads which may be encountered due to control surface loads, buffeting, or buzz.

Rotary mechanical actuators (often referred to as power hinges) with torque limiters and no-back brakes have been used in some relatively recent applications (e.g., wing tip fold actuation on the RS-70, weapon bay door actuation on the F-111, and LEF actuation on the F-16 and the Boeing 747), but, prior to their selection for actuation of the B-1 rudder, have not been used for actuation of a primary control surface. As an alternate to no-back brake, a mechanically irreversible actuator is used, provided it can react to a rated static limit load applied to the output coupling (with the input coupling disconnected), without being back-driven under vibration. Where torque limiters are used, they release upon removal of the downstream jamming load without a requirement for change in the upstream torque value or direction. Loading is a serious life issue and side loads must be kept to a minimum.

No-back brakes, or Sprague clutches are suitable for transmitting large power loads or holding heavy loads. When installed in a large transport aircraft for the pitch trim actuator, they were rough in operation, chattered, and failed to hold the overriding loads. These units depend on maintaining precise friction values and wedging angles, and are sensitive to surface finish, environmental conditions, method of operation, etc. These parameters are defined for the design.

The VCF control actuators are designed in accordance with the required static and dynamic stiffness to prevent flutter.

Motor/torque actuators support the mission requirements of the weapon system. After loss of hydraulic or electrical power, the actuator and feedback components do not experience flutter or any other instabilities anywhere in the flight envelope.

The motor/torque actuation mechanisms redundancy requirements meet the handling qualities and flight safety requirements for all operational states.

The motor/torque actuation mechanisms are designed to withstand the full range of natural environment extremes established for this air vehicle without permanent degradation of performance:

A. No permanent degradation below operational state I and temporary degradation below operational state II.

B. Reductions below operational state III experienced only at adverse environmental extremes not normally encountered and transient in nature only. The function recovers as soon as the aircraft has passed through the adverse environment.

The motor/torque actuation mechanism withstands induced environmental changes without permanent degradation or loss of capability to maintain operational state II. Induced environmental changes do not result in temporary degradation below operational state III.

Compliance: Analysis and test verify that the VCF motor/torque tube driven and similar control actuation mechanisms are safe.

Analysis include:

A. Control and analysis of random vibration.

B. Hazard analysis

C. Failure Modes, Effects and Criticality Analysis and Testing (FMECA/FMET) or equivalent

D. Operational state analysis

E. Analysis of Performance with respect to:

1) Parameters that change with temperature, atmospheric pressure and other environmental factors.

2) Parameters that change with failures or manufacturing tolerances.

3) Parameters that critically affect system performance or stability.

4) Parameters that are not accurately known (if they are significant).

5) Parameters that change as a result of aging or wear.

6) Flight safety, reliability, maintainability, and vulnerability.

Tests include:

A. Low pressure test.

B. Low/High temperature test.

C. Temperature shock test.

D. Temperature-Altitude (Cycling).

E. Vibration test.

F. Humidity test

G. Mechanical shock

H. Acceleration

I. Adequate acceptance testing

J. FMET

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.6, 4.1.5.6, 3.1.5.7, 4.1.5.7, 3.1.9, 4.1.9, 3.1.11, 4.1.11, 3.1.11.1, 4.1.11.1, 3.1.11.1.1, 4.1.11.1.1, 3.1.12, 4.1.12, 3.1.14.1, 4.1.14.1, 3.1.14.3, 4.1.14.3, 3.2.2.1, 4.2.2.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.47** Verify that command and control communications on the vehicle, other linked vehicles, and ground control are integrated safely with an acceptable probability of failure.

Standard: Separation and isolation among Inter/Intra VCF interfaces make the probability of propagated or common mode failure extremely remote (10E-9).

Command and control/ground control communication function integration does not result in aircraft loss and allow for the sharing of information among different systems/functions.

Communication of information is:

A. Verified for integrity of the passed information prior to use.

B. Capable of determining self integrity.

Command and control processing resources support the functional requirements as allocated to computer hardware and software.

Command and control data integrity takes advantage of characteristics of the data or communications medium whenever possible. Command and control accommodate the following:

A. Fail operation/safe mechanization to keep Level I and safe flying qualities.

B. Communication path checks.

C. Reasonableness checks based on expected state information.

D. State change check.

E. Range verification checks.

F. Rate of expected change checks.

G. Source (heartbeat) checks.

H. Sample problem checks.

I. Information control limiting.

J. Anti-aliasing filters

K. De-bounce protection.

Command and control hardware must have segregated channels, power supplies and communications.

Command and control serial and/or parallel communications between physically separated internal VCF components meet an established standard, whether it be military or commercial. Serial and/or parallel communications commercially available are supportable with commercial tools.

Interface standards are clearly specified to avoid special purpose, one-of-a-kind interfaces that are program peculiar. Specific standards are selected based on baseline requirements plus spare and growth

Command and control within the system architecture are managed along with the specific type of processing that the architecture will support. Flight critical data, classified data, distributed processing, centralized processing, diagnostics, and sensor support are but a few of the elements that drive communication requirements and complexity. Standard interfaces continue to evolve and stabilize as they reach maturity. These include processor, software, display, and communications standards.

Compliance: Ground testing verifies system operation and interface, warm-up time and engage/ disengagement.

Analysis and simulation verifies communication requirements. In-flight and ground testing include the signal types and component interfaces. Component and integration testing verifies the communication and interface paths.

DoD/MIL Doc: JSSG-2008: para 3.1, 4.1, 3.1.8, 4.1.8, 3.1.7.3, 4.1.7.3, 3.1.11, 4.1.11, 3.1.11.7, 4.1.11.7, 3.1.11.9, 4.1.11.9, 3.1.13, 4.1.13, 3.2.2.2, 4.2.2.2, 3.2.2.5.1.2, 4.2.2.5.1.2, 3.2.2.5.3, 4.2.2.5.3, 3.3, 4.3, 3.3.1, 4.3.1, 3.3.2.3, 4.3.2.3, 3.3.3, 4.3.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.48** Verify that all command and control communications are secure against unwanted intrusions and security techniques used are implemented safely.

Standard: VCF command and control communications meet the system security requirements as specified in the air vehicle/weapon system specification.

The VCF command and control communications incorporates security protection due to the safety and mission criticality of its functions. Command and control system security levels

are selected based upon the sensitivity of data present, the access level of personnel and the approach taken at the top level air vehicle architecture design. The National Computer Security Center (NCSC) has extensively researched and published criteria for command and control security.

The VCF contains features to prevent unauthorized access or use of the system to change or add data, limits, or information that could result in loss of the aircraft due to improper control laws.

Command and control communications security procedures apply to all field support as well as depot support.

Compliance: The command and control communications security provisions are verified by inspection of requirements, analysis of the security provisions and their effectiveness, and demonstration of the security design methods and procedures.

Verification that all the air vehicle command and control communications security requirements are properly flowed down to the VCF is by inspection.

Verification that all Safety-Critical and Mission-Critical functions are properly identified and protected is by inspection, analysis, and demonstration.

Security requirements compatibility with VCF processing resources verified by analysis.

Compliance to DoD-security requirements verified by analysis, demonstration and test in accordance with the verification section of the standard itself.

DoD/MIL Doc: JSSG-2008: para 3.1.8, 4.1.8, 3.1.14.6, 4.1.14.6, 3.1.16, 4.1.16, 3.2, 4.2, 3.3.1, 4.3.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.49** Verify that single space radiation upset events do not cause loss of control and that the probability of encountering multiple upsets producing loss of control is acceptably low.

Standard: No single space radiation upset event causes flight phase critical flight controls to exceed an extremely remote probability of failure (10E-9) for loss of function.

In-flight diagnostics of the VCF and critical flight conditions:

A. Detect and accommodate single space radiation upset events by themselves and those which if combined with another subsequent failure cause loss of control

B. Monitor circuitry failures, which could mask failures of functional circuitry due to single space radiation upset events.

VCF functional air vehicle subsystems such as hydraulics, actuation, and electrical power accommodate single space radiation upset events.

Compliance: System operation and interfaces are verified by fully integrated iron bird testing that mates actual VCF control hardware with functioning air vehicle subsystems such as hydraulics, actuation, and electrical power with the piloted simulation to verify the VCF immunity to detect space radiation events.

The proper operation of the in-flight TDRM to detect space radiation events is verified by laboratory test.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.2, 4.1.2, 3.1.3, 4.1.3, 3.1.7.3, 4.1.7.3, 3.1.8, 4.1.8, 3.1.9, 4.1.9, 3.1.11.1, 4.1.11.1, 3.1.12, 4.1.12, 3.1.13.2, 4.1.13.2, 3.1.14.4, 4.1.14.4, 3.1.17, 4.1.17

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.50** Verify that propulsion control integration, control mechanisms, feedback loops, automatic throttle control systems, asymmetric thrust controlling conditions, special thrust control use conditions, atmospherics and hypersonic effects on thrust control are safe.

Standard: The probability of air vehicle loss due to VCF propulsion control integration does not exceed 10E-8. This probability accounts for the interdependence of all aircraft functions affecting the propulsion function and meets the Operational State Table.

The VCF prevents and/or compensates for any hazardous flight condition which results from asymmetric operation of air vehicle controls including the propulsion system.

The VCF accommodates control mechanisms, feedback loops, automatic throttle control systems, asymmetric thrust controlling conditions, special thrust control use conditions, atmospherics and hypersonic effects.

The engine control functions integrated with the aircraft control functions satisfy:

A. Fault tolerance

B. Functional performance

C. Invulnerability and self sufficiency

D. Integrated diagnostics and reporting

E. Data latency and equivalent time delay requirements

F. Match the aircraft control redundancy level

The engine control includes over-speed and over-temperature protection for single failures in either aircraft or engine systems.

The VCF accommodates integrated propulsion controls (IPC) by providing propulsion control reconfiguration. The propulsion control diagnostics and fault isolation to an IPC failure results in a functional loss no greater than 10E-8.

Compliance: The quantitative flight safety requirements including asymmetric operation is verified by analysis considering all failure modes (Hazard and FMECA) that threaten flight safety.

Integrated propulsion control requirements are verificatied by analysis, simulation, and ground test to include failure modes and effects testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.2, 4.1.2, 3.1.5.3, 4.1.5.3, 3.1.5.5, 4.1.5.5, 3.1.7.3, 4.1.7.3, 3.1.11, 4.1.11, 3.1.13, 4.1.13, 3.1.13.3, 4.1.13.3, 3.1.17, 4.1.17, 3.2.2.2.9, 4.2.2.2.9, 3.2.2.5.1.1, 4.2.2.5.1.1, 3.2.2.5.4.5, 4.2.2.5.4.5, 3.3.1, 4.3.1

FAA Doc: 14CFR references: 25.901

**6.2.2.51** Verify that VCF primary and integrated control function(s) security design is implemented safely.

Standard: Primary and integrated control function(s) security design, as a minimum, do not allow degraded flying qualities below level I for a period of one hour in the advent of a security breach or failure.

The VCF meets the system security requirements as specified in the air vehicle/weapon system specification.

Safety-Critical and or Mission Critical functions have extra security measures to prevent physical, electronic, and software tampering.

The primary and integrated control function(s) security is designed and partitioned to facilitate ease of safety and survivability.

Compliance: Single/second failure verification of primary and integrated control function(s) security design is by analysis, simulation, demonstration, ground test.

VCF invulnerability to software tampering protection requirements for primary and integrated functions is verified by coverage analysis and bottom-up testing.

The VCF security provisions are verified by inspection of requirements, analysis of the security provisions and their effectiveness, and demonstration of the security design methods and procedures.

The VCF primary and integrated control function(s) security design is verified by non-real time and piloted simulations with all integration functions to include failure modes and effect, ground tests on the air vehicle for full function.

The computer systems/subsystems security architecture requirements are verified by analysis of software and hardware and test of the integrated hardware and software package.

DoD/MIL Doc: JSSG-2008: para 3.1.11, 4.1.11, 3.1.14.6, 4.1.14.6, 3.1.16, 4.1.16, 3.2, 4.2, 3.3.1, 4.3.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.52** Verify that air data is safe for the following: (for criteria 6.2.2.52.1 through 6.2.2.52.5)

**6.2.2.52.1** (was 6.2.2.52.a) Implementation

Standard: The VCF air data architecture provides control scheduling/inputs for all tasks throughout the flight envelope and provides sufficient processing, memory, and data communications capability to meet the requirements for various VCF functions like the functions of navigation, flight control, engines, displays and mission management, both within the domain of the VCF and external to the VCF.

Air data information coming from any source or combination of sources is accepted and used and/or transmitted only after verification of its correctness.

Communication of air data information is continuously verified for the integrity of the passed information.

Provisions allow retrieving the air data information after a crash.

System accommodates degradation in VCF operation due to air data.

The air data function supports:

A. Pre-flight, in-flight and post-flight testability and monitoring

B. Fail operational/fail operational/ fail safe capability

C. Heater operation to de-ice

D. Fail operational heater operation

E. Repeatability of measurement

F. Verification of all transferred data

G. Crew information of heater state

The air data function exhibits the following reliability, as a minimum:

A. Probability of mission abort due to an air data system failure no greater than 10E-5.

B. Probability of aircraft loss due to an air data system failure no greater than 10E-8.

Air data lags allocated from the VCF allowable delay.

Compliance: Simulation, system analysis, FMET, ground testing and flight testing verifies:

A. The requirements of the control functionality

B. Air data performance.

C. VCF realistic air data system errors and failures including:

1) Noise on air data signals

2) Calibration table errors in slope and bias

3) One source each in combination – blocked pneumatics; one probe blocked in total pressure, one port blocked in static pressure.

Information coming from any air data source or combination of air data sources are verified by analysis, simulation, demonstration, ground and flight test.

Air data communication is verified by HITL simulation and air vehicle ground tests.

Verification of crash survivable air data is verified by analysis for the data types to be saved and component testing demonstrating their ruggedness to withstand the required impact and explosive environment.

The air data functional software certification and hardware qualification is verified by testing (including FMET) which includes the following:

A. VCF tolerance to realistic air data system

B. Noise on air data signals

C. Calibration table errors in slope and bias

D. Intermittent signal failures (especially failures of duration shorter than the persistence counter)

E. Lags; pneumatic, sensor, computational, electrical

F. Out of range failures; just within range failures

G. Failed head and strut pitot heat and freeze air data at high AOA, medium Q; recover and land; repeat dual heater fail for upper head. Static Flush Port (SFP) failures for each location to address as a minimum:

1) One SFP - blocked pneumatics; one pitot probe blocked in:

a) total pressure port

b) a static pressure port

### **6.2.2.52.2** (was 6.2.2.52.b) Accuracy

Standard: Air data accuracy for the functionality of: Dynamic Pressure, Static Pressure, Altitude, Angle of Attack, Mach No., and other functionality are defined by the parameters of Accuracy, Scaling, Linearity, Resolution, Lag, Latency, and any other parameters such as voting thresh-holds that affect overall accuracy.

The needed accuracy is appropriate for the application and have 10% margin for an adverse affects..

Compliance: Accuracy requirements and performance of the air data function is verified by analysis, lab, ground and flight testing.

### **6.2.2.52.3** (was 6.2.2.52.c) Ground and air safety provisions

Standard: The air data function has ground and flight safety provisions.

A. The ground provisions accomplish the following:

1) Allow ground checkout prior to flight for functionality

2) Have protection from the elements

3) Have protection for the crew when the heaters are on such as crew aircraft display notification, ground panel display notification, circuit breaker protection and personnel

protection

4) Allow for maintenance fault isolation to the individual probe level

B. The inflight protection consist of the following:

1) Inflight monitoring for air data health

2) Crew display for heater indication and circuit breaker status

3) Alternate method for air data to compensate for transient conditions

4) Alternate method for air data to compensate loss of air data such as inertial derived air data or standby gains

5) Operation after physical damage due to refueling basket contact

6) Safe operation after jams of angle-of-attack probes or blocked pressure ports

Compliance: The VCF air data function is verified by analysis, inspection, HITL simulation test to include FMET, ground test, and flight test.

**6.2.2.52.4** (was 6.2.2.52.d) Anti-ice or ice prevention

Standard: Anti-ice or ice prevention for air data are provided by heaters or material that rejects the formation of ice when it is cooled.

This protection is provided wherever the probes/sensors are located.

Design does not allow the entrapment of moisture that can result in the formation of ice.

Display and testing provisions determine and display the health of the air data anti-ice components.

Ice prevention identifies the loss of anti-icing and the appropriate flight envelope to minimize ice formation. Automated instructions are defined.

Compliance: The VCF air data anti ice function are verified through simulation, systems analysis, failure modes and effects test, ground test and flight tests.

**6.2.2.52.5** (was 6.2.2.52.e) Bird strike vulnerability

Standard: The air data system accommodates bird strikes for the following:

A. Shorting of power wires that removes electrical power from the VCF.

B. Loss of the mounting structure such as a radome that takes out more than one probe at a time.

C. Bird splatter that can affect one or more probes.

D. Bird/ animal nesting that may affect one or more probes.

Ground checkout provisions accommodate assessing the air data function for bird anomalies.

Compliance: The VCF air data anti ice function verified through simulation, systems analysis, failure modes and effects test, and ground tests.

**6.2.2.53** Verify that the environmental design and the equipment installation are safe.

Standard: The VCF is designed to withstand the full range of natural and induced environment requirements established for the air vehicle without permanent degradation of performance below VCF operational state I or temporary degradations below operational state II.

Minimum natural environments are lightning, dielectic strength, EMI/EMC compatability, sand and dust, fungus, extreme temperatures, humidity, corrosion, and icing.

Minimum induced environments are fluctuating pressure, turbulent aerodynamic flow, acoustic noise, vibration, shock, nuclear environment, explosive atmosphere.

Compliance: Verification that VCF meets all natural and induced environmental requirements is by analysis and test.

DoD/MIL Doc: JSSG-2008: para 3.1.14, 4.1.14, 3.4, 4.4, 3.5, 4.5(all)

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.2.54** Verify that vehicle control, payload, and ground system latencies and synchronizations are safe for mission accomplishment.

Standard: The vehicle control function integrated with any payload (mission) or ground functions do not induce latencies that have handling (flying qualities) worse than a CH3 or affect any or part of primary mission completion. Data latency time delays are measured from the instant of a control input to the time a recognizable response occurs. This is specified as 100 msec for Level I flying qualities.

With the advent of open architectures, rapidly changing technologies, it is essential that different functions and hardware are compatible with each other and do not cause basic fundamental problems such as timing, synchronization rates, Instruction Set Architecture misinterpretation of instructions or data, and inability to handle basic faults such as divide by zero and recover. Any synchronization done in any of or the integrated functions, including a single synchronization failure or multiple single independent synchronization failures, do not cause loss of the vehicle or crew or handling quality levels worse than a CH3 or affect any or part of primary mission completion.

Vehicle control, payload and ground redundant or integrated portions of these functions are able to operate autonomously and asynchronously without loss of the vehicle or crew or handling quality levels worse than a CH5 or affect any or part of primary mission completion.

Where any ground or payload function exerts any control with the VCF, these functions during that phase are classified flight/safety critical and are developed and tested using rigorous discipline.

Compliance: The VCF vehicle control, payload, and ground system latencies and synchronizations verified through simulation, systems analysis, failure modes and effects test, and ground tests.

Synchronization test cases to consider are:

A. Disrupt one channel - maximum out signals

B. Disrupt two channels - maximum and equalize

C. Disrupt synchronization command to each LRU/ WRA/ function

DoD/MIL Doc: ADS-51-HDBK

ADS-33E-PRF

Refer to Army Aviation technical point of contact for this discipline for specific guidance (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

**6.2.2.55** Verify that emergency procedures are appropriate and safe for the emergency that they address.

Standard: Development of VCF emergency procedures covers in-flight and ground failures and actions to minimize the failures impacts specified.

Emergency procedures reviewed are approved by the cognizant contractor functional expert as well as the program office.

Other experts are required to complete the review and assure the procedures are adequate. Among these are the pilots and or crew, ground personnel such as crew chiefs and

maintenance personnel. Logisticians address the correctness of format and publication.

UAVs/ROAs are a special category and absolutely must include crew and or ground personnel.

The flight manual must be useable and the emergency procedures, even if red lined, must be clear and unambiguous concerning the problem and corrective action necessary. Usually this means that one type of fault is recognizable and correctable without misleading any type of crew or ground personnel. Example - a battery failure does not indicate an entire electrical failure nor have many causes lead to lighting a caution or warning light. There must be one set of procedures that are followed every time for a given condition.

Procedures are configuration controlled and no procedure is released without meeting the above requirements and verification.

Compliance: Emergency procedures are verified by functional contractor and program engineers review for completeness and accuracy. This is accomplished though analysis, demonstration during FMET and ground testing in a functional mockup or on the actual aircraft with the air and ground crews.

Configuration control and release of procedures are verified by analysis and demonstration.

Control room and/or ground personnel review of procedures for completeness and accuracy. This is accomplished though analysis, demonstration during FMET and ground testing in functional mockups or on the actual aircraft with the air and ground crews and any control room type environments to be used.

DoD/MIL Doc: ADS-51-HDBK

ADS-33E-PRF

Refer to Army Aviation technical point of contact for this discipline for specific guidance (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

**6.2.2.56** Verify, for rotary wing air vehicles, adequate transient response for single axis (collective or pedal) inputs.

Standard: This criteria is for rotary wing type vehicles but all other criteria in section 6 also apply to rotary vehicles as applicable for the particular program.

Rotary wing air vehicles for single axis (collective or pedal) inputs meet a probability of loss of function better than 25x10E-7.

Automatic hovering: Position is maintained relative to the point of reference to an accuracy of ±4 to ±10 feet. This accuracy requirement applies during gust intensities of 5 feet/sec, and wind, and point of reference velocities up to 45 knots.

Accuracy requirements are based on the mission specified for the air vehicle and the capability which it is feasible to provide during the hover mode of operation. Values in the range of ±4 to ±10 feet may be used for longitudinal, lateral, and vertical positional accuracy. These accuracies are maintained in gust intensities up to 5 feet per second rms and wind or reference point velocities up to 45 knots.

With controls free, transients limits for mode transitions are +0.5g normal or lateral acceleration with +/-1 up to 5 deg/sec roll rate (recommended is +/-3 deg/sec) at the pilot station and 5 degrees of sideslip for a period of 2 seconds. For at least 5 seconds in the pitch axis, pitch force does not exceed 20 lb, a roll force of 10 lb, and 10 lb in yaw force.

Transition transients for forward flight to hover to vertical flight as control laws change are barely perceptible to the pilot.

Gain switching in the control laws between modes or activated by modes are not overly large in gradient, for transients suppressed, account for oscillatory inputs, and do not trigger

a PIO.

Stability margins in the control function are not adversely affected for normal and abnormal uses of the modes or failures of the modes.

Compliance: Rotary wing air vehicle: Performance for transient response for collective or pedal inputs are verified by analysis, simulation, FMET, laboratory testing, and flight test. The analysis and testing cover all of the transition points with special emphasis on major transition points of lift off, hover to forward or lateral motion, forward or lateral motion to hover, touch down and rollout.

DoD/MIL Doc: ADS-51-HDBK

ADS-33E-PRF

Refer to Army Aviation technical point of contact for this discipline for specific guidance (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

**6.2.2.57** Verify that multi-axis inputs (e.g., collective, pedal, and cyclic) are safe during typical operational mission maneuvers.

Standard: This criteria is for rotary wing type vehicles but all other criteria in section 6 also apply to rotary vehicles as applicable for the particular program.

Rotary wing air vehicles for single axis (collective and pedal and cyclic) inputs meet a probability of loss of function better than 25x10E-7.

No single failure not extremely remote (10E-9) within the multi-axis inputs (e.g., collective, pedal, and cyclic) function result in loss of the vehicle or crew.

Control harmony between the rotary and normal flight functions and input mechanisms are specified. The movement and use of crew controls are intuitive and in concert with known control practices.

All transmission elements, components, and functions rotary wing inputs are:

A. Suitably protected to resist jamming by objects, shielded by heavy structural members, existing armor, protected from usage such as steps and handhelds, and by placement of the other equipment used to protect critical elements.

B. Clearance between elements and structure or other components is provided as necessary to ensure no probable combination of temperature effects, air loads, structural deflections, vibration, buildup of manufacturing tolerances, or wear can cause binding or jamming of any portion of the VCF. In locally congested areas only, the following minimum clearances are used after all adverse effects are accounted for:

1) One-eighth inch between static elements except those within an LRU/WRA where closer clearances can be maintained or where contact is not detrimental.

2) One-eighth inch between elements which move with respect to each other and which are connected to or are guided by the same structural or equipment elements except those within an LRU/WRA where closer clearances can be maintained or where contact is not detrimental.

3) One-fourth inch between elements which move with respect to each other and which are connected to or are guided by different structural or equipment elements.

4) One-half inch between elements and aircraft structure and equipment to which the elements are not attached. Clearances at the ends of the swept paths may not be critical and smaller clearances or zero clearances may be allowed at such extremes of travel unless contact is detrimental.

Compliance: Analysis, demonstration, simulation including FMET, flight, ground and laboratory testing, verify at worst case conditions as well as nominal flight conditions, multi-axis inputs (e.g.,

collective, pedal, and cyclic) to have a probability of loss of function better than 25x10E-7and that no single failure not extremely remote results in loss of the vehicle or crew.

Hazard, fault tree and diagnostic verify no loss or instabilities.

DoD/MIL Doc: ADS-51-HDBK

ADS-33E-PRF

Refer to Army Aviation technical point of contact for this discipline for specific guidance (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

**6.2.3** VCF power source criteria.

*(Note: See section 12 for specific electrical power system criteria.)*

**6.2.3.1** Verify that hydraulic distribution has no single failure points resulting in loss of more than one hydraulic function.

Standard: No single failure within the hydraulic distribution function results in loss of the hydraulic function.

No single failure within the hydraulic distribution function result in loss of VCF or any VCF instabilities.

No single failure within the hydraulic distribution function is worse than a CH of 4.

Gain and phase margin reductions of 25% are allowed after a single failure.

Compliance: Hazard, fault tree and diagnostic analyses for actual hardware and software verify no loss or instabilities of VCF.

Analysis assesses hydraulic failure effects.

Failure modes and effects testing where actual hardware and software are used show no loss of hydraulic function for any single independent hydraulic failure.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.11.3, 3.1.12, 3.1.12.1, 3.1.14.4, 3.1.14.9, 3.2.1.3, 3.2.2.2.1, 3.2.2.2.5, 3.2.3.1, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.3.2** Verify that hydraulic function dynamics do not have any unsafe pressure pulsating or resonant conditions.

Standard: The primary and secondary hydraulic functions do not have any dynamic pulsating and/ or resonant conditions that result in loss of vehicle control or loss of VCF or any instabilities.

For any pulsating or resonant conditions, phase and gain margins for the VCF is 45 degrees and 9 db for the loop which these conditions occur.

Compliance: Analysis required assesses hydraulic dynamic effects.

Laboratory tests verify no loss of VCF for any pulsating or resonant condition. The laboratory mockup is as close in nature to the actual installation as possible when performing these tests.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.6, 4.1.5.6, 3.1.7.2, 4.1.7.2, 3.1.11.11.3, 4.1.11.11.3, 3.2.2.2.1, 4.2.2.2.1, 3.3 thru 3.3.4, 4.3 thru 4.3.4, 3.3.6, 4.3.6, 3.3.6.2, 4.3.6.2

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.3.3** Verify that backup and emergency hydraulic power function(s) do not have any unsafe effects from reduced flow rates or pressure or flutter margin.

Standard: The emergency/secondary hydraulic power system does not cause loss of vehicle control or loss of VCF or any instabilities due to flow rates, lower pressure or reduced flutter margin.

Compliance: Hazard, fault tree and diagnostic analyses for actual hardware verify no loss or instabilities of VCF.

Hardware in the loop tests (including FMET) verify that the VCF is not lost or has any induced instabilities due to lower rates, pressures and flutter margin.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.6, 4.1.5.6, 3.1.7.2, 4.1.7.2, 3.1.11.11.3, 4.1.11.11.3, 3.2.2.2.1, 4.2.2.2.1, 3.2.2.2.5, 4.2.2.2.5

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.3.4** Verify that any VCF flight limitations with emergency/backup hydraulic power and switchover time constants are safe.

Standard: Hydraulic power transients due to switching sources pumps (APU, EPU, etc.), accumulators, valves, relays, controllers, and any other devices do not result in any power upset that causes loss of loss of vehicle control by the VCF.

Hydraulic power specified transient times do not cause loss of the VCF.

The backup/ secondary hydraulic power system does not cause loss of the VCF when it fails and the primary system is available.

The backup/ secondary hydraulic power system does not cause loss of the VCF when it used in place of the primary system.

Health monitoring is provided and meets other criteria in section 6.0 with regards to diagnostics and BIT.

Compliance: Analysis verifies acceptability of hydraulic power transients.

Laboratory tests verify no loss of VCF for any power transient condition.

Aircraft ground tests verify no loss of VCF for any power transient condition.

Failure modes and effects testing where actual hardware is used with transients induced verify no loss of VCF.

The backup/secondary hydraulic power system shows by analysis and test (including FMET) that the VCF is not lost when the primary is available.

The necessary health checks and reliability needed to support the hydraulic and VCF functions are verified through ground and flight testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.2, 4.1.5.2, 3.1.5.6, 4.1.5.6, 3.1.7.2, 4.1.7.2, 3.1.10, 4.1.10, 3.1.11.11.3, 4.1.11.11.3, 3.1.13, 4.1.13, 3.2.2.2.1, 4.2.2.2.1, 3.2.2.2.5, 4.2.2.2.5

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.3.5** Verify that VCF effects due to loss of each or part of each hydraulic function are safe. (See 8.1 for specific criteria.)

Standard: No single hydraulic function failure propagates to all sources with the result of loss of hydraulic power.

Control coordination with the hydraulic power system and the VCF for engagement, redundancy control, and auto start capability is required.

Design includes redundancy and fault tolerance, latency added to the hydraulic control

function, and type of interfaces. The probability of loss of all hydraulic power is better than 1x10E-8.

Compliance: VCF effects due to loss of each or part of each hydraulic function via design documents verified by FMET test facility.

Analyses, lab testing, and on-aircraft ground testing verify the VCF is unaffected by loss of parts of the hydraulic system. Piloted evaluations demonstrate CHR 4 or better for failures more likely than 10E-5 per flight hour.

Analysis verifies hydraulic loading and failure mode assessment. Understanding the hydraulic loading of each component of the hydraulic power subsystem under various flight and ground conditions is necessary.

Laboratory tests performed on a mockup that accurately simulates the aircraft installation verifies hydraulic function is safe under the most adverse hydraulic loading, environmental, fault, and endurance conditions.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11.11.3, 3.1.12.1, 3.1.13, 3.1.14.4, 3.1.14.9, 3.2.1.3, 3.2.2.2, 3.2.2.2.1, 3.2.2.2.5, 3.3 thru 3.3.4, 3.3.6, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.3.6 Verify that electrical power normal/backup/emergency capability following loss of engine(s) and generator(s) for VCF is safe.

Standard: The electrical power system provide power long enough for an immediate descent and landing following loss of the engines and generators. The minimum safe time of this electrical power capability is 30 minutes if no other time is specified. The time may be longer depending on the application.

Provisions for constantly determining the health of this capability provided.

Compliance: Analysis verifies electrical power emergency capability.

Laboratory tests verify no loss of VCF in this condition for 30 minutes for the most likely recovery flight profile.

Laboratory testing including FMET shows that the methods used to determine electrical power normal/backup/emergency health are adequate.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.5.2, 3.1.5.4, 3.1.7.2, 3.1.10, 3.1.11, 3.1.11.11.2, 3.1.13, 3.2.2.2, 3.2.2.2.2, 3.2.2.2.5, 3.3 thru 3.3.4, 3.3.6, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.3.7 Verify that independent electrical power sources provide safe redundancy for VCF.

Standard: Electrical power is defined to include all components of sources, wiring and grounding schemes. Electrical power sources used to power the VCF or be backups to the VCF do not induce any conditions that result in loss of the VCF.

No single failure in any source propagate to all sources with the result of loss of power.

No wiring or grounding architecture propagate failures or cause loss of electrical power sources or the VCF.

No combination of independent single failures among sources cause loss of the VCF unless all sources are failed.

The probability of loss of all electrical power is better than 1x10E-8.

Compliance: Laboratory tests verify no loss of VCF for any power source condition.

Aircraft ground tests verify no loss of VCF for any power source condition.

Failure modes and effects testing where actual hardware is used with the most critical combination of failures induced verify no loss of VCF.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.2, 4.1.2, 3.1.2.1, 4.1.2.1, 3.1.3, 4.1.3, 3.1.7.2, 4.1.7.2, 3.1.11, 4.1.11, 3.1.11.11.2, 4.1.11.11.2, 3.1.12, 4.1.12, 3.1.12.1, 4.1.12.1, 3.2.2.2.2, 4.2.2.2.2, 3.2.2.2.5, 4.2.2.2.5, 3.3 thru 3.3.4, 4.3 thru 4.3.4, 3.3.6, 4.3.6, 3.3.6.2, 4.3.6.2

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.3.8 Verify that electrical power transients, both normal and switchover, are safe.

Standard: Electrical power transients due to switching sources, shorts, opens, contactors, relays, fuses, diodes and any other devices that can cause power transients do not result in any power upset to or loss of VCF.

Electrical power transient times do not upset or cause loss of the VCF.

Compliance: Laboratory tests to verify no loss of VCF for any power transient condition.

Aircraft ground tests to verify no loss of VCF for any power transient condition.

Failure modes and effects testing where actual hardware is used and the transients induced verify no loss of VCF.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.5.2, 4.1.5.2, 3.1.7.2, 4.1.7.2, 3.1.10, 4.1.10, 3.1.11.11.2, 4.1.11.11.2, 3.2.2.2.2, 4.2.2.2.2, 3.2.2.2.5, 4.2.2.2.5

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.3.9 Verify that, if batteries are employed for SOF backup power, adequate charging methods and checks are provided and installation provisions for all batteries are safe.

Standard: 30 minute capability is provided where batteries are used.

NiCad batteries are prohibited.

VCF batteries capacity is constantly checked and status provided to the crew.

Location of lead acid batteries in the same bay as flight critical components is prohibited.

Adequate charging methods and checks to determine battery health are provided.

The VCF battery function does not have any non-critical functions using the VCF battery.

Compliance: Analysis confirms the battery architecture and loads.

Assumptions are validated via testing in representative environment.

Laboratory tests confirm battery life, loads and battery health. Included are the most adverse electrical loading, environmental, fault, and endurance conditions required of the subsystem.

Battery installation is verified by pre/post flight checklists, maintenance tech data, analyses and ground testing.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.2, 4.1.2, 3.1.5.2, 4.1.5.2, 3.1.7.2, 4.1.7.2, 3.1.11.11.2, 4.1.11.11.2, 3.1.13, 4.1.13, 3.2.2.2.2, 4.2.2.2.2, 3.2.2.2.5, 4.2.2.2.5

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.3.10** Verify that electrical power bus separation for prevention of single failure points is safe.

Standard: Electrical power bus failures are passive, i.e., do not result in lose the main bus due to component failure of a device.

The degree of isolation of the generating system channels can be compromised by a switchable bus. A transfer bus scheme used with essential electrical control systems eliminates the possibility of a single fault causing unacceptable disturbances to more than one power source.

VCF control systems are provided in varying degrees of redundancy and this imposes the requirement that power sources to these systems are equally mission reliable. A parallel system, if composed of three or four generating channels, are a highly reliable source but is vulnerable to several single failure modes (failure of current transformer shorting contacts, excitation loss, open current transformer loop, main bus or load circuit faults, synch bus faults), which can transiently interrupt or seriously degrade the quality of power on all main buses simultaneously. Abnormal power quality will be supplied to all loads for a time ranging from 0.020 to 3.0 seconds. This time is dependent on the specific type of failure and the delays associated with the protective circuitry. It is noted, however, that simultaneous failures will be normally of very short duration and will be automatically cleared from all but the faulted bus. Past experience shows that nuisance trips can occur which may result in overloading of the remaining buses and a brief “all power lost” situation. In the unlikely event that multiple failures result in an inability of the system to automatically clear a fault, automatic or manual proper crew actions are identified to restore power to the unfaulted buses.

Compliance: Design documentation, installation drawings, and ground test verify separation/ isolation of redundant buses.

Analysis assesses adequacy of electrical loading, distribution bus structure, and failure mode. Electrical load analysis techniques are crucial to understanding the electrical loading of each component of the electrical power subsystem under various flight and ground conditions.

Laboratory tests performed on a subsystem mockup that accurately simulates the aircraft installation verifies safe operation. Testing includes the most adverse electrical loading, environmental, fault, and endurance conditions required of the subsystem. Simulation verifies failure modes that are not hazardous to personnel or the aircraft.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.10, 3.1.11.11.2, 3.1.12, 3.1.12.1, 3.1.14.4, 3.2.1.3, 3.2.2.2.2, 3.2.2.2.5, 3.2.3.1, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.3.11** Verify that effects of normal, abnormal, and failure modes of the electrical power function are safe for VCF.

Standard: an independent emergency power source is provided.

The failure modes and transitions to and from the auxiliary power or emergency power sources provide the VCF with uninterruptible, quality power.

The electrical power sources for the VCF must be a equally dependable and redundant. Independent, direct source of electrical power for each redundant channel of flight/safety critical or flight phase critical control function is provided. In this context, direct means that the power source only powers the VCF and has nothing between the source and VCF such as relays, breakers, fuses. Diodes are allowed. No other devices requiring electrical power not related to the VCF or integrated with the VCF is allowed use of the direct source.

Control coordination with the electrical power system and the VCF for engagement and auto start capability is provided.

Design accommodate redundancy and fault tolerance, high availability of electrical power sources for the common displays, latency for certain display formats such as roll attitude, and type of interfaces including optical or electrical.

Memory, LRU and other protection is such that neither electrical power source transients nor EMI causes loss of program memory, memory scramble, erroneous commands, or loss of ability for continued operation and over/under-voltage/ over-current shutdowns of the VCF or electrical power control.

Compliance: Analyses, lab testing, and on-aircraft ground testing verify normal, abnormal, and failure modes of the electrical power function do not result in loss of VCF channel or function. Piloted evaluations demonstrate CHR 4 or better for failures more likely than 10E-5 per flight hour.

Laboratory tests performed on a subsystem mockup accurately simulates the aircraft installation. Testing includes the most adverse electrical loading, environmental, fault, and endurance conditions required of the subsystem. Failure modes that are not hazardous to personnel or the aircraft are simulated.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11.11.2, 3.1.13, 3.1.14.4, 3.2.1.3, 3.2.2.2.2, 3.2.2.2.5, 3.3 thru 3.3.4, 3.3.6, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.3.12 Verify that direct, uninterruptible, quality electrical power implementation for VCF is safe.

Standard: Independent, direct, uninterruptible power sources of adequate quality meet requirements of essential redundancy of VCF channels including after power system malfunction(s). The degree of isolation and number of isolated channels that may be required are dependent upon specific requirements of the vehicle.

Direct means that the power source only powers the VCF and has nothing between the source. No other devices requiring electrical power not related to the VCF or integrated with the VCF is allowed use of the direct source.

The electrical power to the VCF is designed for 30 minutes operation when VCF is totally dependent on battery for electrical power for 1g flight with minimum maneuvering.

Compliance: Complete hazard analysis coupled with failure modes and effects testing verify that no single failure results in loss of VCF function.

Piloted evaluations demonstrate CHR 4 or better for failures more likely than 10-5 per flight hour.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.11.2, 3.1.12, 3.1.12.1, 3.1.14.4, 3.2.1.3, 3.2.2.2.2, 3.2.2.2.5, 3.3 thru 3.3.4, 3.3.6, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.4 Flight worthiness evaluations.

### 6.2.4.1 Verify that flight-critical components meet safety criteria.

Standard: As a minimum, sufficient testing is accomplished to demonstrate the aircraft is safe for flight.

Compliance: Component, system level and on-aircraft ground tests verify compliance with the environmental criteria document, supplier specification, and the system level integration.

DoD/MIL Doc: JSSG-2008: para 3.0, 4.0, 3.1, 4.1, 3.1.2, 4.1.2, 3.1.2.1, 4.1.2.1, 3.1.5, 4.1.5, 3.1.13, 4.1.13,

3.1.14, 4.1.14, 3.5.3, 4.5.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.4.2** Verify that all single point failures are identified with the associated probability of failure(s) and that they demonstrate an acceptable flight safety risk.

Standard: The VCF does not have any single failures, combination of functionally single independent failures, multiple failures greater than the Probability Loss Of Control (PLOC) or Probability Loss Of Function (PLOF) or single failures following undetected failures that result in flying quality levels below those in the weapons systems specification or produce a probability of aircraft loss greater than that specified. In the absence of any specified PLOC and PLOF (Function) the following apply: PLOC 1x10E-5; PLOF 1x10E-9.

Compliance: Hazard analysis supported by FMECA verifies that single point failures are less likely than 10E-9 per flt hour.

Analyses of reliability, design integrity and redundancy alone are not acceptable as the sole mitigation justification of these types of failure modes without understanding the complete system interaction.

DoD/MIL Doc: JSSG-2008: 3.0, 4.0, 3.1, 4.1, 3.1.2, 4.1.2, 3.1.2.1, 4.1.2.1, 3.1.5.6, 4.1.5.6, 3.1.11, 4.1.11, 3.1.11, 3.1.11.1, 4.1.11.1, 3.2.4.1, 4.2.4.1, 3.5.3, 4.5.3

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.4.3** Verify that transient effects of failures impacting controllability or structure do not have any safety impacts to the vehicle or crew.

Standard: Separation and isolation are provided between primary VCF and the integrated VCF to make the probability of propagated or common mode failure extremely remote, i.e., 1x10E-9.

Operational performance is met by the VCF in 2 double amplitudes in flight and 30 seconds on the ground after power is applied.

Positive means of disengagement is provided for non-primary VCF functions. VCF does not permit failures to place the aircraft in an unrecoverable situation.

To minimize transient effects, balanced circuits using twisted, shielded wires are used where possible and the wiring is physically separated from likely lightning current paths. Redundant channels are physically separated from each other.

Compliance: Analyses and tests addressing gain and phase margins, simulations of the vehicle, sensor and actuator models, piloted simulation with failure transient effects and hardware/ software in the loop, and ground and flight test of the air vehicle verify handling qualities and structure compatibility.

DoD/MIL Doc: JSSG-2008: para 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.5, 3.1.5.1, 3.1.5.2, 3.1.5.4, 3.1.5.5, 3.1.5.7, 3.1.5.8, 3.1.7, 3.1.7.2, 3.1.7.3, 3.1.9, 3.1.10, 3.1.11, 3.1.11.2, 3.1.11.4, 3.1.11.5, 3.1.11.6, 3.1.11.9, 3.1.11.10, 3.1.11.11.2, 3.1.11.11.3, 3.1.12, 3.1.12.1, 3.1.13.1, 3.1.13.2, 3.1.14.2.2, 3.1.14.2.4, 3.2.2.1, 3.2.2.2, 3.2.2.5, 3.3 thru 3.3.4, 3.3.6, 3.3.6.2, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.4.4** Verify that the VCF can safely recover the air vehicle under worst-case flight envelope and engine failure conditions and identify any flight limitations in the flight manual.

Standard: The limits of the VCF is defined for worst-case flight envelope and engine failure conditions. The limits are the point where the integrated VCF can no longer guarantee safe recovery of

the vehicle or crew or both. These limits set the safe envelope for the vehicle and/or crew.

Compliance: Offline analyses coupled with simulator testing identify flight restrictions. Documentation review verifies that limitations and controls are identified in the flight manual.

DoD/MIL Doc: JSSG-2008: para 3.0, 3.1, 3.1.5, 3.1.5.3, 3.1.5.7, 3.1.5.8, 3.1.5.9, 3.1.9, 3.1.14, 3.2.1.3, 3.2.1.2, 3.2.2.2, 3.2.2.5, 3.2.2.5.4, 3.2.2.6, 3.3, and associated section 4 paragraphs

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.4.5 Verify that undetected, latent, or unannounced failures do not result in unacceptable flying qualities.

Standard: No instabilities, limit cycle oscillations or worse than CH5 ratings are allowed for undetected, latent or unannounced failures. These types of failures are assigned a probability of occurrence of 1 for analyses purposes.

No undetected, latent or unannounced failures are allowed in critical control modes.

Undetected, latent or unannounced failures are those failures that by design exist at the component selection level, the manufacturing level, the installation level and the operational level where the item/feature is not readily checkable on a frequent basis to ascertain that item/feature's ability to be used when needed.

Compliance: Analysis and simulation supported by failure testing of undetected, latent, or unannounced failures verify that they are extremely remote. Probability of occurrence less likely than 10E-9 per hour.

Demonstrations verify the consequence of these failures and what actions are needed to achieve the probability of loss for that function/component/item.

DoD/MIL Doc: JSSG-2008: para 3.1.8, 3.1.9

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.4.6 Verify that no unsafe handling characteristics are exhibited in critical flight phases for aerodynamic and air data uncertainty sensitivity studies/analyses.

Standard: No instabilities, limit cycle oscillations or worse than CH5 ratings occur in critical phases with at least 25% variation in key stability derivatives varied one at a time and two at a time.

Compliance: Analyses and simulation verify that no instabilities, limit cycle oscillations or worse than CH5 ratings occur in critical phases with at least 25% variation in key stability derivatives varied one at a time and two at a time.

DoD/MIL Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

### 6.2.4.7 Verify that vehicle control's and payload system's latency and synchronization responses are safe.

Standard: Where the VCF is part of the payload/ mission control function or integrates with said functions, the increased latency and synchronization schemes are accounted for in determining the phase and gain margins.

These margins for the total system consideration are equal to or better than 6 db in gain and 45 degrees in phase for each feedback loop and control loop for all flight conditions throughout the entire flight envelope.

Compliance: For each control and feed back loop, analysis and simulation verify that the phase and gain margins are better than 6 db and 45 degrees. The analysis and simulation is validated by actual flight data.

DoD/MIL Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: TBD: Refer to technical point of contact for this discipline (listed in section A.2).

**6.2.5** VCF software.

*(Note: VCF software verification is accomplished under section 15.)*

**6.2.5.1** Verify the safe operation of each computer software configuration item (CSCI)/operational flight program (OFP) from unit to full flight program levels for all modes, inputs, failure detection, reconfiguration techniques, self-check operations, interfaces, and integration under all dynamic conditions.

Standard: This criteria defines the complete system evaluation including hardware.

The architecture is established/arrived at as a result of functional allocation of requirements to the subsystems or groupings of subsystems.

All hardware and software configuration items are identified and flight critical items are defined.

Hardware and software interfaces are clearly defined and documented. Control flow and information flow is established.

Contractors and/or organizations responsible for each item of hardware and software is identified and procedures established and implemented to ensure that these organizations and/or contractors work together to solve the system's problems.

Separate and independent power sources are provided for redundant operations.

Single component/ functional failures do not impede redundant operations.

Compliance: Review of documentation verifies that all processing elements have been developed and tested to a level commensurate with its criticality, regardless of configuration designation.

Design documents demonstrate safe operation of each computer software configuration item (CSCI)/operational flight program (OFP) from unit to full flight program levels for all modes, inputs, failure detection, reconfiguration techniques, self-check operations, interfaces, and integration under all dynamic conditions verified by FMET in the ground test facility.

Analyses, lab testing, and on-aircraft ground testing verify the VCF is unaffected by single failure.

DoD/MIL Doc: JSSG-2008: para 3.3.6.2

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.5.2** Verify that the flight software version demonstrates acceptable performance and safety.

Standard: Configuration management capability is defined.

Unambiguous traceability exists between software functions tested at all levels to the final flight version.

Regression testing requirements are clearly defined.

Full functional coverage is provided.

Compliance: Action items and minutes from reviews, audits, and interchange meetings are reviewed to ensure that all required actions are sufficiently resolved and do not reveal unattended discrepancies.

An acceptance test procedure/process exist for final check of each software baseline prior to flight.

Turn-around process/time is safe/compatible with the flight test activities.

Software version/build turnaround process/time is safe and compatible with the flight test activities.

Software configuration management plan to ensure that adequate change procedures are defined and used, and that appropriate control boards exist and are functioning.

Adequate software library controls are being applied and that changes are tracked and controlled with each change implemented.

Quality assurance and configuration management organizations are sufficiently staffed to assess the development.

Adequate procedures for quality evaluation and baseline control exist.

Development methodology, integration, and test of simulation facilities assessed.

All reports or other documentation pertinent to the review are current with the configuration of the first flight article.

DoD/MIL Doc: JSSG-2008: para 3.2.4.6, 3.3.6-3.3.8

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.5.3 Verify that critical control modes in all flight conditions are safe.

Standard: Every VCF and integrating critical control mode (eg., primary control, autopilot modes, mission modes such as terrain following) demonstrate a probability of loss of the mode better than 1x10E-9 and a fail safe/conservative last condition.

Compliance: Extensive analyses and tests, including PITL/ FMET stress testing in critical flight conditions or configurations, verify that the design is safe.

All processing elements are developed and tested to a level commensurate with its criticality, regardless of configuration designation

The usual number of test cases to demonstrate this vary from 1,000 to 10,000 depending on the application.

DoD/MIL Doc: JSSG-2008: para 3.1.5.2, 3.1.5.8, 3.1.9, 3.1.11.2, 3.2.1.2, 3.2.3.2

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.5.4 Verify that single-point or probable multiple failures that can paralyze redundant controlling functions are within the required safety probabilities.

Standard: The VCF software and firmware do not have any single failure, combination of functionally single independent failures, multiple failures greater than the Probability Loss Of Control (PLOC) or PLOF, or single failures following undetected failures that result in flying quality levels below those in the weapons systems specification or produce a probability of aircraft loss greater than that specified in the weapon systems specification. In the absence of any specified PLOC and PLOF (Function) the following apply: PLOC 1x10E-5; PLOF 1x10E-9.

Compliance: Software and firmware analyses and test including FMET verify that the VCF meets the PLOC and/or PLOF.

DoD/MIL Doc: JSSG-2008: para 3.1.9-3.1.11.1.1

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

### 6.2.5.5 Verify that software compatibility with external, integrating software functions is safe.

Standard: The Hardware/Software Compatibility Matrix is defined. This matrix defines the

configurations of air vehicle hardware and software that meet the functions specified. The hardware and software listed is compatible, but may have limitations that can degrade functions or inhibit specific usage. The Hardware/Software Compatibility Matrix state the limitations of the hardware or software.

Compliance: Hardware/Software Compatibility is demonstrated by test and analysis. System level integrated testing validates that ommunications and data exchange meets the system functional requirements. Deviations, waivers, and trouble reports are documented and dispositioned according to the program Deficiency Reporting (DR) process and guidelines.

DoD/MIL Doc: JSSG-2008: para 3.2.4.6, 3.3.6-3.3.8

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.5.6** Verify that effects of the following are safe:

a. Software interrupts
b. Reinitialization
c. Resynchronization
d. Recheck
e. Reconfiguration
f. Restarts
g. Resets
h. Negation of environmental and generic error

Standard: In an OFP for a digital VCF, integration techniques, filter implementations, iteration intervals, and failure isolation and switching do not have any single point failures. Instruction set architecture, misinterpretation of instructions or data, and inability to handle basic faults such as divide by zero are known and verified by test.

Synchronization does not result in a single point failure where there is a master-slave relationship. Typically, frame synchronization is the technique used to accomplish VCF synchronization. The synchronization of processor input data and commanded outputs ensures that the processing elements are not operating off of stale or drifting input data. Synchronization is balanced across the major frame of execution. Frame extensions are allowed for worst case minor frame loading, but not for normal processing operation.

Safety-Critical software incorporates a failure-recovery concept that ensures continuous processing in the event of a data dependent common-mode software failure or anomalous behavior. Software can create hazards by failing to perform a required task, performing a task that is not required, or performing a task out of sequence or for an incorrect amount of time. Category I and II hazards are identified and controlled according to guidelines.

Compliance: VCF synchronization and rates are verified by full hardware and software integration testing.

Software reviews show it discriminates between invalid and valid interrupts.

Tests conducted on integrated unit modules verify that the software performs as required for the component function while varying items such as parameter ranges, timing, Boolean expressions, integers, real numbers, overflow, synchronization, logic flow, etc. Conditions to include are:

A. Disrupt one channel - maximum out

B. Disrupt two channels - maximum and equalize

C. Disrupt synchronization command to each LRU/WRA/system

VCF software interrupts, reinitialization, resynchronization, recheck, reconfiguration, restarts, resets and negation of environmental and generic error effects are verified by full hardware and software integration testing

DoD/MIL Doc: JSSG-2008: para 3.2.4.6, 3.3.6-3.3.8

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.5.7** Verify that software design of self-check, failure monitoring, redundancy management, reconfiguration, voting, transient suppression, overflow protection, anti-aliasing, saturation, interlocks, memory protection, failure propagation, and other techniques prevent unsafe flight situations.

Standard: Software design includes data processing, program storage, I/O, control, and signal transmission. Scaling provides safe and desirable responses.

The computation rates and sample rates are at a level which ensures the computational process does not introduce unacceptable phase shift, nonlinear characteristics, or frequency fold over or aliasing into the system response.

The word size, input limiting, and overflow protection provide satisfactory resolution and sensitivity.

Conditions capable of producing an overflow in any VCF function are precluded by overflow detection and accommodation.

Memory protection features are provided that avoid inadvertent alteration or loss of memory contents. Memory protection is such that neither electrical power source transients nor EMI cause loss of program memory, memory scramble, erroneous commands, or loss of ability for continued operation.

All possible hazardous failure conditions for the computers are identified along with fail-safe provisions identified. Power source variations do not result in operation below VCF Operational State I.

Compliance: Hazard Analyses of Safety Critical Function Thread Analysis demonstrate that top level FMEA, program safety requirements (fail op/fail safe) and PLOC/ PLOF are complete and support the architecture trade study that ensures proper levels of redundancy exist throughout the architecture to mitigate safety risks.

Extensive FMET performed at all levels verifies the robustness of the architecture design mechanization.

Items addressed in the above analyses and testing include but are not limited to:

A. Computer Resources Utilization

B. Design Review/ Audits/ Meeting Minutes and Action Items

C. Software Requirements Specification (SRS)

D. Software Top Level Design Document (STLDD)

E. Software Development Plan (SDP) and/or Software Development Integrity Master Plan

F. Software Test Plans, Procedures and Reports

G. Quality Assurance and Configuration Management Plans

H. Master Test Planning Documents and Scheduling

I. Software Regression Testing Criteria/ Procedures (all levels)

J. Software Development Folders for specific code relating to the design implementation

K. Failure Modes, Effects and Criticality Analysis and Testing (FMECA/ FMET) or equivalent

L. Hazard Analyses (Software)

DoD/MIL Doc: JSSG-2008: para 3.2.4.6, 3.3.6-3.3.8

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.5.8** Verify that built-in-test implementation operates failure free and safely identifies, isolates, and corrects malfunctions.

Standard: All critical failures are addressed at the appropriate level. Voting, failure or mode switching thresholds are based on transient and component tolerance analyses and are properly implemented.

The redundancy management approach is fully responsive to the need for the Pre-flight Built In Test (PFBIT) to ensure that the designed redundancy is present before flight.

The VCF coordinates the various BITs and resolves the functional inter/intra integrating systems reported discrepancies down to the cause of the problem. The integrating functions are tested in the applicable flight phase.

All performance testing, failure detection, and failure isolation is to the LRU/WRA/Line Replaceable Module (LRM) provided by BIT combinations and redundancy and integration management. All flight safety and mission critical functions are monitored, conditioned, and transmitted at a sufficient rate for PVI display requirements

On-Equipment Fault Detection/Fault Isolation (FD/FI) use Continuous and PBIT that detect at least 95% of all subsystem faults with less than 1% false indications. Initiated pre-flight and post-flight BIT detect at least 98% of all subsystem faults, with less than 1% false indications.

The overall tests (BITS, VI, PM, SPCL) perform the following:

A. Redundancy fault initiation to verify signal selection, fault detection, fault isolation, reconfiguration of the primary control paths, and required aircraft subsystems.

B. Integration checks to determine the stability, reasonableness health and validity of all other integrating subsystems.

In-flight engagement through interlocks are prevented while allowing acceptable levels for ground test signals.

Compliance: Review of Built-In-Test (BIT) procedures verify that the software is programmed properly, failure free, operating properly and is adequate to isolate and identify inoperative areas. Proper interlocks are verified to prevent inadvertent activation of BIT modes that will interfere with the basic Operational Flight Program (OFP).

FMECA supported by lab testing demonstrates proper implementation of BIT function.

For flight/safety critical and flight phase critical controls, the following mockup test failures of VCF BIT and failure reversion capability meet VCF requirements:

A. Over temperature test of VCF computers, panels, and sensors to evaluate the BIT capability of detecting failures induced by progressive overheating.

B. Wire hardness failures (shorts between wires and ground and open circuits) to evaluate BIT capability to detect wiring damage/failures.

On-aircraft ground demonstration verifies that the inhibit logic prevents unwanted in-flight BIT engagement. Analysis verifies that the number of interlocks to prevent in-flight engagement is acceptable.

DoD/MIL Doc: JSSG-2008: para 3.1.11.11.2, 3.1.13

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

**6.2.5.9** Verify that security design of VCF software loading techniques is safe.

Standard: Computer security requirements are identified. Requirements are allocated to

subsystems/functions within the system, CSCIs within a subsystem, CSCs within CSCIs, etc.

The software control and security procedures apply to all field support as well as depot support whether or not it is contracted out.

VCF logistics is consistent with the deployment, operations, maintenance, and security

Security considerations include the following:

A. Raising the required clearance level of some personnel to lower the overall level of computer security requirements for the system.

B. Security isolation of high sensitivity data.

C. Security that is sufficient for U.S.-only personnel may not be sufficient for FMS purposes. Modularization allows for sensitive portions to be removed before delivery.

D. Encryption for on-line storage

E. Careful review of the Technical Guides from NCSC that pertain.

F. Computer security requirements that are realized in software are developed with the software.

Security uses classifications, such as Safety Critical and Mission Critical functions, to establish extra security measures that prevent physical, electronic, and software tampering.

The VCF has inherent protection of safety critical functions and items, mission critical functions and items, classified components and data against physical, electronic, and software threats.

The VCF prevents unauthorized access or use of the system to change or add data, limits, or information that could result in loss of the aircraft due to improper control laws.

The VCF prevents unauthorized acts by personnel to tamper with the system, intercept program tape updates, and equipment shipments of items that pose a single point threat. Some exclusions include outright attacks with the intent to destroy the aircraft on the flightline.

Compliance: The National Computer Security Center (NCSC) at Ft. Meade, Maryland for computer security has assistance in this area for demonstrating computer resource security.

Up to date information, and exhaustive testing of systems and software demonstrate that comprehensive measures have been taken for protecting computer security assets.

Security conformance is verified by analyzing the system and verifying the results used for the system.

Analysis verifies that Security requirements are compatible with VCF processing resources.

DoD/MIL Doc: JSSG-2008: para 3.1.14.6

FAA Doc: 14CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

## 6.3 Aerodynamics and performance.

DoD/MIL Doc: JSSG-2001: Appendix D

### 6.3.1 Flight vehicle.

#### 6.3.1.1 Verify that the air vehicle can be recovered safely over the entire flight envelope in the presence of malfunctions.

Standard: No single failure results in a loss of the air vehicle. Combination of failures/malfunctions are evaluated to determine that the air vehicle can recover with an allowable degradation in

performance.

Compliance: 1. Documentation review verifies that all air vehicle failure states are defined that can affect the air vehicle's ability to recover, and safely terminate flight over the entire flight envelope.

2. Documentation review verifies that any impact on the normal operating flight envelope based on the malfunction(s) is identified, along with any limitations imposed.

3. Air vehicle performance is verified by analysis, simulation and test using empirical data, wind tunnel data, flying prototype data, flight test data, etc., as appropriate. All characteristics and performance data are based on the latest validated/documented aerodynamic, propulsion, and mass properties information available to be used in the analysis.

4. Documentation review verifies that the scope and adequacy of the models, databases, methods, and simulation used to predict the desired parameters have been validated and placed under configuration control.

5. Review of the technical orders (or flight manual) verifies that the procedures are clearly written and the data represents the air vehicle. All limitations are properly documented and traceable back to the data basis.

DoD/MIL Doc: MIL-STD-1797

MIL-HDBK-516: para 14.1.1.4j-k

JSSG-2001A: para 3.3.11.1, 3.3.11.1.1.3, 3.3.11.2, C.3.1-2, C.3.6

JSSG-2006: para 3.7.3

JSSG-2007: para 3.7.2.1, Appendix A

JSSG-2008: para 3.1.4, 3.2.1.2, 4.3.10, A3.3.3.2

JSSG-2000: para 3.3.6.1

FAA Doc: 14CFR references: 23.21, 23.141, 23.347, 23.671-2, 25.21, 25.143, 25.671-2, 27.21, 27.141, 27.671-2, 29.21, 29.141, 29.671-2

### 6.3.1.2 Verify that safe takeoff, landing, and critical field length performance are safe for the intended atmospheric conditions.

Standard: Requirements for takeoff, landing and critical field length performance are defined for all operational and atmospheric conditions. Air vehicle meets these requirements.

Compliance: 1. Requirements are verified by inspection of program documentation.

2. Air vehicle performance is verified by analysis, simulation and test using empirical data, wind tunnel data, flying prototype data, flight test data, etc., as appropriate. All characteristics and performance data are based on the latest validated/documented aerodynamic, propulsion, and mass properties information available to be used in the air vehicle performance analysis.

3. Documentation review verifies that the scope and adequacy of the models, databases, methods, and simulation used to predict the desired parameters have been validated and placed under configuration control.

4. Review of the technical orders (or flight manual) verifies that the procedures are clearly written and the data represents the air vehicle. All limitations are properly documented and traceable back to the data basis.

DoD/MIL Doc: MIL-STD-3013: para 3.2, 3.2.10, 3.8, Appendix A

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JSSG-2001A, Appendix E

FAA Doc: 14CFR references: 23.45, 25.101, 27.45, 29.45

**6.3.1.3** Verify that engine(s) inoperative performance (if appropriate) is safe, including optimum speeds for energy management and possible autorotation.

Standard: 1. For a multi-engine air vehicle with "x" engines failed, sufficient power is available in the remaining engine(s) to allow safe return of the air vehicle. The "x" number of required engine failures is defined by the Program Office but must be a minimum of one.

a. As a minimum, level 3 flying qualities are exhibited with an engine(s) out.

2. For a single engine air vehicle (as well as multi-engine), various scenarios are explored to develop recovery procedures to limit the loss of life or air vehicle.

a. An example is that loosing an engine at lift off may only allow time to trade any excess speed for altitude to eject prior to allowing a sink rate to develop.

Compliance: 1. Documentation review verifies that the impact on the normal operating flight envelope based on an engine(s) inoperative is identified, along with any limitations imposed.

2. Air vehicle performance is verified by analysis, simulation and test using empirical data, wind tunnel data, flying prototype data, flight test data, etc., as appropriate. All characteristics and performance data shall be based on the latest validated/documented aerodynamic, propulsion, and mass properties information available to be used in the air vehicle performance analysis.

a. Factors that affect engine inoperative performance such as atmospheric conditions, air vehicle weight and configuration, engine used to drive accessories (i.e., hydraulic pump), etc., should be considered in the analysis.

3. Documentation review verifies that the scope and adequacy of the models, databases, methods, and simulation used to predict the desired parameters have been validated and placed under configuration control.

4. Review of the technical orders (or flight manual) verifies that the procedures are clearly written and the data represents the air vehicle. All limitations are properly documented and traceable back to the data basis.

DoD/MIL Doc: MIL-STD-3013: para 3.2.11, 3.3.1.4, 4.2.2.1.2

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JSSG-2001A: Appendix E

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FAA Doc: 14CFR references: 23.903, 23.1501, 23.1541, 23.1581, 25.903, 25.1501, 25.1541, 25.1581, 27.175, 27.547, 27.691, 27.917, 27.1027, 29.175, 29.547, 29.691, 29.917, 29.1027

**6.3.1.4** Verify that the flight manual data limits for takeoff, landing, hover, climb, maneuver, cruise, descent, emergency conditions, including height/velocity diagrams for rotary wing air vehicles, and any other critical factors, are adequate to conduct safe flights.

Standard: 1. Any limitation that affects the operation of the air vehicle are identified, evaluated, documented, and observed during normal and emergency operations.

a. Examples of some limits to evaluate are: aerodynamic, engine operating limits, transmission, weight and C.G., store restrictions, airspeed and altitude, environmental, brake energy, barrier engagement, prohibited flight maneuvers, etc.

Compliance: 1. Analysis verifies that the acquisition of data is sufficient in scope to permit definition of the performance limitation. All characteristics and performance data is determined to be based on the latest validated/documented aerodynamic, propulsion, and mass properties information available.

a. The data basis identified for a given limitation is evaluated against the best available data (i.e., analytical methods, wind tunnel data/reports, flight test data/reports, etc.).

2. Air vehicle performance is verified by analysis, simulation and test using empirical data, wind tunnel data, flying prototype data, flight test data, etc., as appropriate.

3. Documentation review verifies that the scope and adequacy of the models, databases, methods, and simulation used to predict the desired parameters have been validated and placed under configuration control.

4. Review of the technical orders (or flight manual) verifies that the procedures are clearly written and the data represents the air vehicle. All limitations are properly documented and traceable back to the data basis.

DoD/MIL Doc: JSSG-2001A Appendix C: C.3.2

MIL-STD-3013: para 4.1.10

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FAA Doc: 14CFR reference Part: 23.45, 23.1501, 23.1541, 23.1581, 25.101, 25.1501, 25.1541, 25.1581, 27.45, 27.79, 27.1501, 27.1587, 27.1541, 27.1581, 29.45, 29.87, 29.1501, 29.1517, 29.1541, 29.1581, 29.1587

### 6.3.1.5 Verify that store carriage and separation characteristics for the prescribed stores are safe.

Standard: 1. Under all flight and ground conditions including taxi, takeoff, and landing, the air vehicle can safely carry the specified store loadout whether or not it is intended to be separated in flight.

a. The stores do not make contact with the air vehicle other than via its suspension equipment while being carried.

b. The stores or its suspension equipment do not make contact with other stores or suspension equipment in the air vehicle weapons loadout.

c. The stores or suspension equipment do not make contact with the ground during air vehicle taxi, takeoff and landing operations.

d. The presence of stores or suspension equipment do not cause other stores or suspension equipment in the air vehicle weapons loadout to violate a, b, or c.

2. The air vehicle can safely separate the stores loadout within the prescribed release/launch envelope.

a. After separation, the stores or suspension equipment do not make contact with any part of the air vehicle, including any remaining stores or suspension equipment in the weapons loadout (download).

Compliance: Analytical analysis, computational fluid dynamic (CFD) and wind tunnel test data in conjunction with computer simulation and flight test verify the safe carriage and separation of a prescribed stores loadout from the air vehicle. Safe separation is contingent upon acceptable repeatability in trajectory data for the released store/suspension equipment relative to the air vehicle and any download.

DoD/MIL Doc: JSSG-2000A: para 6.3.25

JSSG-2001A: para 4.1.1.2, 4.4.1.1, 4.4.1.2

JSSG-2001A Appendix C: 4.4, 4.5

MIL-HDBK-1763, Aircraft/Stores Certification Process

MIL-HDBK-244A, Guide to Aircraft Stores Compatibility

MIL-HDBK-516B: para 17.2.1, 17.2.2, 17.2.3

**6.3.1.6** Verify that flight manual specified performance or other predictions of power available, power required, fuel flow, ground effect, engine out and autorotation performance are sufficiently accurate to assure safe conduct of flight operations throughout the range of gross weights and ambient conditions.

Standard: 1. Methods used for computing thrust (or power) required are documented, accompanied with appropriate curves covering from stall speed to maximum speed throughout the altitude range of the air vehicle.

2. Methods used for establishing thrust (or power) are documented, including all losses and efficiencies. Appropriate engine curves are also documented.

3. All operating restrictions are documented.

Compliance: 1. Analysis verifies that the acquisition of data is sufficient in scope to permit definition of the performance limitation. All characteristics and performance data is determined to be based on the latest validated/documented aerodynamic, propulsion, and mass properties information available.

a. The data basis identified for a given limitation is evaluated against the best available data (i.e., analytical methods, wind tunnel data/reports, flight test data/reports, etc.).

2. Air vehicle performance is verified by analysis, simulation and test using empirical data, wind tunnel data, flying prototype data, flight test data, etc., as appropriate. Evaluation of the analysis/simulations considers the configuration(s) of the air vehicle, range of weight and atmospheric conditions the air vehicle is to operate.

3. Documentation review verifies that the scope and adequacy of the models, databases, methods, and simulation used to predict the desired parameters have been validated and placed under configuration control.

4. Review of the technical orders (or flight manual) verifies that the procedures are clearly written and the data represents the air vehicle. All limitations are properly documented and traceable back to the data basis.

DoD/MIL Doc: MIL-STD-3013: para 4.1.10

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ADS-10C-SP Air Vehicle Technical Description

FAA Doc: 14CFR references: 23.21, 23.25, 23.29, 23.45, 23.333, 23.1501, 23.1563, 23.1581, 25.21, 25.25, 25.27, 25.29, 25.101, 25.333, 25.1501, 25.1563, 25.1581, 27.21, 27.25, 27.27, 27.29, 27.45-75, 27.1501, 27.1581, 29.21, 29.25, 29.27, 29.29, 29.45-85, 29.1501, 29.1581

**6.3.2** Installed propulsion capability.

Comm'l Doc: ARP 1420 Gas Turbine Engine Inlet Flow Distortion Guidelines

AIR 1419 Inlet Total-Pressure-Distortion Considerations for Gas-Turbine Engines

AIR 5826 Distortion Synthesis/Estimation Techniques

DoD/MIL Doc: JSSG-2001: para 3.3.1.1.1, 4.3.1.1.1, 3.3.1.1.1.1, 4.3.1.1.1.1, 3.3.1.1.1.2, 4.3.1.1.1.2, 3.3.1.1.2, and 4.3.1.1.2

JSSG-2007A: para A.3.2, A.4.2, A.3.11, A.4.11, A.3.12, A.4.12, A.3.2.2, A.4.2.2, A.3.2.2.7, and A.4.2.2.7

FAA Doc: 14CFR references: 33.5, 33.7, AC 33-2B

**6.3.2.1** Verify that airframe/inlet/engine compatibility evaluations are adequate for safe operation (see Section 7).

Standard: Propulsion system remains stable and compatible over the flight and maneuver envelope.

Engine operational limits are defined with acceptable margins.

Compliance: Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2001: para 3.3.1.1.1, 4.3.1.1.1, 3.3.1.1.1.1, 4.3.1.1.1.1, 3.3.1.1.1.2, 4.3.1.1.1.2, 3.3.1.1.2, and 4.3.1.1.2

JSSG-2007A: para A.3.2, A.4.2, A.3.11, A.4.11, A.3.12, A.4.12, A.3.2.2, A.4.2.2, A.3.2.2.7, and A.4.2.2.7

FAA Doc: 14CFR references: 23.1521, 25.1521

**6.3.2.2** Verify safe operation for the following: (for criteria 6.3.2.2.1 through 6.3.2.2.8)

**6.3.2.2.1** (was 6.3.2.2.a) Engine steady and transient response characteristics of the engine and engine control system (see 7.2.4.1.3 and 7.2.4.1.5)

Standard: Propulsion system remains stable and compatible over the flight and maneuver envelope. Engine operational limits defined with acceptable margins

Compliance: 1. Propulsion system instabilities identified through analysis, test, and demonstration. Flight testing verifies that the air vehicle will not operate in the defined instabilities zones.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.28, 33.53, AC 33-2B, 33.28-1

**6.3.2.2.2** (was 6.3.2.2.b) Fuel flow modulation (see 7.2.2.2 and 7.2.4.1)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.35, 33.67, AC 33-2B, 33-5

**6.3.2.2.3** (was 6.3.2.2.c) Engine responses to input signals at different frequencies (see 7.2.4.1)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins.

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.28, 33.53, AC 33-2B, 33.28-1

**6.3.2.2.4** (was 6.3.2.2.d) Engine control and vehicle control system communication (see 7.2.4.1.1)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins.

3. Rotary wing rotor speed maintained throughout power and maneuver transients.

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.28, 33.53, AC 33-2B, 33.28-1

**6.3.2.2.5** (was 6.3.2.2.e) Fuel, air induction, exhaust and bleed air extraction systems, ambient temperatures, ambient pressures, and vibratory environment (see 7.2.5.2.2, 7.2.5.2.3, 7.2.5.3, 7.2.5.4, and 7.2.5.5)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.28, 33.53, AC 33-2B, 33.28-1

**6.3.2.2.6** (was 6.3.2.2.f) Sensitivity, stability, control response, and torque predictability for engine and vehicle control during engine power changes (acceleration and deceleration) (see 7.2.2.2, 7.2.4.1.3, and 7.2.4.1.5)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.2, 4.2, 3.11, 4.11, 3.12, 4.12, 3.2.2, 4.2.2, 3.2.2.7, 4.2.2.7

FAA Doc: 14CFR references: 33.5, 33.7, AC 33-2B

**6.3.2.2.7** (was 6.3.2.2.g) Auxiliary engine control functions (see 7.2.4.1.3 and 7.2.4.1.4)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.28, 33.53, AC 33-2B, 33.28-1

**6.3.2.2.8** (was 6.3.2.2.h) Altitude cold start and hot restart capability (see 7.2.2.3 and 7.2.2.4)

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.1.1.15, 4.1.1.15, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.7, 4.7, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.35, 33.67, AC 33-2B, 33-5

**6.3.2.3** Verify that engine performance restrictions resulting from thermal boundaries (reflected in the proper databases and manuals) are safe (see 7.1.4).

Standard: Operational limits defined with acceptable margins and documented in flight manual.

Compliance: Propulsion system stability/compatibility and performance verified through test, analysis, and demonstration.

DoD/MIL Doc: JSSG-2001: para 3.3.1.1

FAA Doc: 14CFR references: 23.901-23.943, 25.901-25.945

**6.3.2.4** Verify that inlet buzz boundaries and flight limitations are well defined (see 7.1.4).

Standard: Inlet buzz regions defined through ground and flight testing and documented in the flight manuals.

Compliance: Process continues into flight testing. Complete when inlet buzz boundaries are defined and flight limitations implemented.

DoD/MIL Doc: JSSG-2001: para 3.3.1.1

FAA Doc: 14CFR references: 23.901-23.943, 25.901-25.945

**6.3.2.5** Verify that there are no severe performance impacts due to flow disturbance and blockage items. Also ensure that these items are safely implemented and located, especially ahead of or near the inlets.

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, inlet testing with items that can cause flow disturbance and blockage are tested to determine the impact to performance and inlet/engine compatibility.

2. Process continues into flight testing with test measurements..

DoD/MIL Doc: JSSG-2001: para 3.3.1.1

FAA Doc: 14CFR references: 23.901-23.943, 25.901-25.945

**6.3.2.6** Verify that engine performance for hot anti-icing air discharged into the inlet or inlet duct surface is safe (see 7.2.1.2 and 7.2.4.1.8).

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.2, 4.2, 3.11, 4.11, 3.12, 4.12, 3.2.2, 4.2.2

FAA Doc: 14CFR references: 33.5, 33.7

AC 33-2B

**6.3.2.7** Verify safe engine performance for an inlet sand and dust separator (see 7.2.1.2 and 7.2.5.3.1).

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility and performance characteristics verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.2, 4.2, 3.11, 4.11, 3.12, 4.12, 3.2.2, 4.2.2

FAA Doc: 14CFR references: 33.5, 33.7

AC 33-2B

**6.3.2.8** Verify that effects of armament gas (and debris) ingestion on engine performance (i.e., surge and resulting torque spikes) are safe (see 7.2.2.4).

Standard: 1. Propulsion system remains stable and compatible over the flight and maneuver envelope.

2. Operational limits defined with acceptable margins

Compliance: 1. During design and development, propulsion system instabilities identified.

2. Propulsion system stability/compatibility verified through test, analysis and demonstration.

DoD/MIL Doc: JSSG-2007: para 3.3, 4.3, 3.4, 4.4, 3.11, 4.11, 3.12, 4.12

FAA Doc: 14CFR references: 33.14, 33.19, 33.63, 33.75, 33.76, 33.77, 33.90, 33.94, 33.97

AC 33.1B, AC 33.3, AC 33.4, AC 33.4-2, AC 33.5

**6.3.3** Flight limits.

**6.3.3.1** Verify that buffet boundaries and flight limitations are safe.

Standard: 1. The air vehicle is free from any vibration and buffeting that would prevent safe flight in any operating configuration/condition.

a. All air vehicle buffet characteristics (including stall and Mach number effects as well as the impact of deployed flaps, spoilers and landing gear) are identified and assessed.

b. Both low speed and high speed buffeting is examined.

c. Evaluations are conducted beyond the boundary of buffet onset to ensure adequate capability to maneuver out of the buffet region.

2. Flight limitations due to (but not limited to) engine operability, airspeed, acceleration, crosswind takeoff and landing, hover, rate-of-climb, rate-of-descent, speed brakes, landing gear, structural (limit load), center-of-gravity, maneuver limits, and store carriage are understood and documented.

Compliance: 1. Comprehensive analysis of empirical, computational, wind tunnel, simulation, and flight test results with supporting data/documents verify that the air vehicle is free from any vibration and buffeting that would prevent safe flight in any operating configuration/condition.

a. Wind tunnel and flight test data is evaluated to ensure that it is sufficient in scope to permit definition of the buffet boundary and flight limitations.

b. Simulations consider the configuration(s) of the air vehicle, range of weight and atmospheric conditions the air vehicle is to operate.

c. The identified database is evaluated against the best available data (i.e., analytical/computational methods, wind tunnel data/reports, flight test data/reports, etc.).

2. Air vehicle performance is verified by analysis, simulation and test using empirical, computational, wind tunnel, flying prototype and flight test data.

3. Inspection verifies that the scope and adequacy of the models, databases, methods, and simulations used to predict the desired parameters are validated and placed under configuration control.

4. Analysis verifies that published technical orders (or flight manual) utilize databases that represent the proper air vehicle configuration. All limitations (final or temporary) are properly documented and traceable back to the data basis.

DoD/MIL Doc: JSSG-2001A: para 6.4.6.1

JSSG-2001A Appendix C: para 4.2, 4.3, 4.5

MIL-STD-3013: para 3.2.2, 3.5.16

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ADS-27 Requirements for Rotorcraft Vibration Specifications, Modeling and Testing

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FAA Doc: 14CFR references: 23.251, 23.333, 25.251, 25.333

### 6.3.3.2 Verify that stall angle of attack and velocity reflected in the flight manual are safe.

Standard: 1. The air vehicle does not operate outside the prescribed limits so as to place the air vehicle in a hazardous situation.

a. Per the flight manual (MIL-DTL-7700), angle of attack (AoA) charts are plotted, showing calibrated airspeed (KCAS) versus indicated AoA (units) and fuselage AoA (degrees), as a function of gross weight.

b. Separate charts are provided for various flap settings as required.

2. The air vehicle can and will stall when going faster than the published stalling speed. Therefore, charts that depict angle of bank versus stall speed are provided for normal flight configurations.

Compliance: 1. Comprehensive analysis of empirical, computational, wind tunnel, simulation, and flight test results with supporting data/documents verify that the air vehicle does not operate outside the prescribed limits so as to place the air vehicle in a hazardous situation.

a. Wind tunnel and flight test data is evaluated to ensure that it is sufficient in scope to

permit definition of the stall region.

b. Evaluation of the analysis/simulations considers the configuration(s) of the air vehicle.

2. Inspection verifies that the scope and adequacy of the models, databases, methods, and simulations used to predict the desired parameters are validated and placed under configuration control.

3. Analysis verifies that published technical orders (or flight manual) utilize databases that represents the proper air vehicle configuration. All limitations (final or temporary) are properly documented and traceable back to the data basis.

DoD/MIL Doc: JSSG-2001A Appendix C: para 4.2, 4.13.2, 4.13.3; Appendix D: para 4.2.2; Appendix E: para 11.2.2

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FAA Doc: 14CFR references: 23.49

### 6.3.3.3 Verify that maximum allowable angle of attack, angle of attack limiter, and set margins are safe.

Standard: 1. The air vehicle does not operate outside the prescribed limits so as to place the air vehicle in a hazardous situation.

2. Each function or combination of functions are identified and tested at the limiting conditions to ensure that no limitations are violated, along with any safety of flight issues.

a. Identified deficiencies are corrected and documented.

3. Limits and margins are defined to enhance stall prevention, resistance to departure from controlled flight, and the ability to control the air vehicle at high alpha air combat maneuvering.

Compliance: 1. Comprehensive analysis of empirical, computational, wind tunnel, simulation, and flight test results with supporting data/documents verify that the air vehicle does not operate outside the prescribed limits so as to place the air vehicle in a hazardous situation.

a. Wind tunnel and flight test data are evaluated to ensure that it is sufficient in scope to permit definition of the stall region and flight limitations.

b. Evaluation of the analysis/simulations consider the configuration(s) of the air vehicle.

2. Inspection verifies that the scope and adequacy of the models, databases, methods, and simulations used to predict the desired parameters are validated and placed under configuration control.

3. Analysis verifies that the published technical orders (or flight manual) utilize the database that represents the proper air vehicle configuration.

a. All limitations (final or temporary) are properly documented and traceable back to the data basis.

DoD/MIL Doc: JSSG-2001A Appendix C: para 4.2

FAA Doc: 14CFR references: 23.333, 25.333

### 6.3.3.4 Verify that center of gravity and gross weight limitations are safe.

Standard: 1. C.G. limitations are identified and documented.

a. Effects such as forward, aft, and lateral c.g. position on towing, taxing, hover, stall, takeoff, inflight, and landing are documented.

2. Weight limitations are identified and documented.

a. Maximum allowable gross weight for ground handling and inflight use are documented.

3. All limitations ensure that the air vehicle is within its operational envelope.

4. All mass properties analysis reflect the current configuration(s) of the air vehicle.

Compliance: 1. Review of analysis/data/documentation verifies the weight reporting.

a. Weights assessed for the air vehicle are validated by actual weighing.

b. C.G. position of the weights are verified by actual weighing of an empty air vehicle, fuel calibration, and analysis.

2. Analysis of the published technical orders (or flight manual) verify that the data basis for the published charts reflects the proper database. All limitations are properly documented and traceable back to the data basis.

Comm'l Doc: SAWE RP#7 & 8

DoD/MIL Doc: JSSG-2006: para 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.3, 4.2.4, 4.2.5, 4.2.6

MIL-HDBK-516: para 5.8.1-3

MIL-DTL-7700: para 3.4.5, 3.5

MIL-STD-3013: para 3.10

MIL-PRF-5920

FAA Doc: 14CFR references: 23.23, 23.25, 23.29, 23.31, 23.1519, 25.23, 25.25, 25.27, 25.29, 25.31, 25.1519, 27.21, 27.25, 27.27, 27.29, 27.31, 27.1519, 29.21, 29.25, 29.27, 29.29, 29.31, 27.1519

**6.3.3.5** Verify that safe flight limitations account for vortex ring state, settling with power, retreating blade stall, advancing blade compressibility, and critical azimuth factors.

Standard: 1. All rotorcraft are potentially subject to the effects of vortex ring state (VRS), and a tendency for the retreating blade to stall in forward flight is inherent in all present rotorcraft, which is a major factor in limiting their forward speed. All conditions conducive to compressibility have been considered and include as a minimum: high airspeed, high rotor RPM, high gross weight, high density altitude, low temperature, and turbulence.

2. VRS is often referred to by pilots as "settling with power" or "power settling". All rotorcraft are potentially subject to the effects of VRS which is nominally encountered at low airspeed, high rates-of-descent, downwind approaches, etc. The basic VRS phenomenon manifests itself as a substantial increase in the power required to overcome the additional aerodynamic losses (induced losses) as the rotor descends into its own wake. Rotor flow field dynamics is documented.

3. Directional Control margin during hover is a minimum when cross wind is from a certain "critical" azimuth and greater than a certain magnitude. Single rotor helicopters are subject to experiencing "critical" azimuth minimum directional control margins. Main rotor/tail rotor (anti-torque system), tail aerodynamic interferences causes this variation and is accounted for in the design.

Compliance: 1. Analysis performed on empirical data, wind tunnel data, flying prototype data, flight test data, etc., coupled with supporting data/documentation verifies that the database minimizes the amount of risk.

2. Documentation review verifies that the scope and adequacy of the models, databases, methods, and simulation used to predict the desired parameters have been validated and placed under configuration control.

3. Review of software documentation verifies that any flight control software modifications that can result in dangerous flight control inputs in susceptible situations do not create an unsafe condition.

4. All characteristics and performance data must be based on the latest

validated/documented aerodynamic, propulsion, and mass properties information available. Review of documentation verifies that the latest approved flight test data is used as the basis for performance analyses. Data from any other source is explained as to why it is sufficient to use.

5. Review of the published technical orders (or flight manual) charts verify that the proper database is being utilized. All limitations are properly documented.

DoD/MIL Doc: ADS-51-HDBK

ADS-33E-PRF

ADS-40A-SP Air Vehicle Flight Performance Description

ADS-10C-SP Air Vehicle Technical Description

FAA Doc: 14CFR references: 27.21, 27.33, 27.143, 27.177, 27.1509, 27.1581, 29.21, 29.33, 29.143, 29.177, 29.1509, 29.1581

## 7. PROPULSION AND PROPULSION INSTALLATIONS

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Design studies and analyses
3. Design, installation, and operational characteristics
4. Engine ground and simulated altitude tests
5. Engine design function/system compatibility tests
6. Engine component and functional level qualification and certification tests
7. Electromagnetic environmental effects
8. Installed propulsion compatibility tests
9. Acceptance test results
10. Failure modes, effects, and criticality analysis/testing (FMECA/FMET)
11. Hazard analysis and classification
12. Safety certification program
13. Engine endurance and accelerated mission testing
14. Engine and component structural and aeromechanical tests
15. Flight test plans and results
16. Engine structural integrity program (ENSIP) analyses and tests
17. Engine life management plans
18. Over-speed and over-temperature tests
19. Overall engine and component performance analyses
20. Flight manual
21. Natural environmental sensitivities
22. Inlet airflow distortion/engine stability assessments and audits
23. Interface/integration control documents
24. Function, subfunction, and component specifications
25. Selection criteria and inlet distortion patterns selected to demonstrate inlet/engine compatibility.
26. Engine control system rig tests
27. Engine health monitoring system design reports and tests
28. Aircraft/engine operating limitations
29. Engine software development plan and product specifications
30. Engine software test plans, test procedures and test reports
31. Engine software configuration control/management plan and procedure
32. Propulsion and Power Flight Clearance Plan, JSSG-2007A, Table XLVIIIb
33. Diminishing manufacturing sources plan
34. Obsolete parts plan

CERTIFICATION CRITERIA

## 7.1 Propulsion safety management.

### 7.1.1 Verify that safety-critical propulsion system risks are identified, probabilities are validated, and risk controls are in place.

Standard: Failure of any propulsion system or component does not result in exceeding the Loss of Aircraft (LOA) rate for the system.

Propulsion risk management practices are in place to manage risk levels to meet established safety thresholds:

- Single engine: Non-recoverable in-flight shutdown rates less than 0.5 per million EFH and/or propulsion system related Class A's less than 0.5 per million EFH for the life of the weapon system.

- Multi engine: Non-recoverable in-flight shutdown rates less than 1per million EFH and/or propulsion system related Class A's less than 0.5 per million EFH for the life of the weapon system.

Hazard controls are reflected in technical data to include normal operating procedures, emergency procedures, restrictions, limits for the air vehicle propulsion system. Maintenance and inspection requirements are documented in the technical data.

Compliance: A Failure Modes Effects and Criticality Analysis (FMECA) and System Safety Hazard Analysis details all known potential failure modes and their associated probabilities. Evaluation of these documents show that propulsion system allocated LOA rate has not been exceeded.

The documented system safety approach describes the practices to manage propulsion risks to the required in-flight shutdown rates.

Inspection/review of technical data ensures maintenance and inspection requirements and special procedures have been documented.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.3.2.1, A.3.3.1, A.3.3.2, A.3.3.7, A.3.5.1, A.3.11, A.3.12, A.4.2, A.4.2.1, A.4.3.1, A.4.3.2, A.4.3.7, A.4.5.1, A.4.11, A.4.12, propulsion system failure analysis and reliability.

PCOE-BP-99-06C, Aircraft Gas Turbine Engine Flight Safety Risk Management Process, (an ASC Propulsion Squadron Best Practice).

FAA Doc: 14CFR references: 33.5, 33.35, 33.7, 33.8

AC 33-2B

### 7.1.2 Verify that an engine out condition on multi-engine aircraft allows safe recovery of the aircraft.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.4.2, A.3.11, A.4.11, A.3.12, A.4.12.

FAA Doc: 14CFR references: 33.35, 33.5, 33.7, 33.8

AC 33-2B

### 7.1.3 Verify that single engine direct lift systems comply with specified safety requirements.

DoD/MIL Doc: JSSG-2007A: para A.3.2.1.4/A.4.2.1.4, Thrust Retention and A.3.11, A.4.11, A.3.12, A.4.12 for guidance on Direct Lift and STOVL thrust requirements.

FAA Doc: 14CFR references: 33.35, 33.5, 33.7, 33.8

AC 33-2B

**7.1.4** Verify that technical data includes all operational and maintenance procedures and limitations necessary for safe operation of the air vehicle.

Standard: All propulsion systems maintenance and inspection procedures and limits are documented in the applicable technical orders and manuals.

Critical engine performance and emergency procedures are documented in the flight manual. Mission performance data in flight manuals are generated with engine performance data that has been validated and under configuration control.

A system is in place to properly maintain and update all maintenance and inspection technical orders and flight manuals for the engine and propeller or rotary wing drive systems.

Compliance: Inspection of the maintenance and inspection technical orders and flight manuals provides assurance that all information is current and up to date.

Review of the system used to maintain the technical orders and flight manuals provides assurance that critical information will be correctly updated in a timely manner.

FAA Doc: 14CFR references: 23.1585

**7.1.5** Verify that the engine configuration is controlled.

Standard: The Configuration Management Plan (CMP) defines how configuration management will be implemented (including policies and procedures) for a particular acquisition or program.

Configuration documentation identifies and defines the item's functional and physical characteristics.

All engine hardware is documented in the engineering drawings and qualified parts lists.

The CMP addresses procedures for qualification of modifications, instrumentation, test specific configurations, etc.

Compliance: Inspection of the CMP ensures a process and plan are in place to monitor and control the engine configuration.

Inspection of the engine drawings verifies all hardware components are documented.

DoD/MIL Doc: JSSG-2007A: para A.3.10/A.4.10.;

MIL-HDBK-61A.

**7.1.6** Verify that critical safety items (CSI) and critical characteristics are identified.

Standard: Documentation identifies and categorizes all critical aircraft parts, assemblies, or installations containing critical characteristics whose failure, malfunction, or absence may cause a catastrophic or critical failure resulting in the loss or serious damage to the aircraft or weapons system, an unacceptable risk of personal injury or loss of life, or an uncommanded engine shutdown that jeopardizes safety.

Compliance: Inspection of the Critical Safety Item (CSI) list and FMECA ensures that all items have been accounted for.

DoD/MIL Doc: DoD 4140.1-R, Section C8.5, Material Management, DoD Flight Safety Critical Aircraft Part (FSCAP) Program.

NAVAIRINST 4200.25D Management of Critical Application Items Including Critical Safety Items.

Critical Item Management Desktop Guide (to NAVAIR 4200.25D)

(Draft) JACG Instruction on Management of Aviation Critical Safety Items.

## 7.2 Gas turbine engine applications.

### 7.2.1 Performance.

**7.2.1.1** Verify that engine performance is adequate for safe operation of the air vehicle. This includes consideration of all installation effects imposed by the air vehicle, and all intended operational environments.

Standard: Engine thrust or power and fuel consumption is characterized with representative installation effects over the range of flight conditions expected and is shown to support the safe performance of the air vehicle. Installation includes inlet effects due to external protuberances (sensors, probes), anti-ice devices, sand and dust separators; exhaust system effects due to IR or noise suppressors; customer extractions of air bleed and mechanical power. Operational environments include cold and hot days, and weather such as rain, snow, or ice.

Compliance: Verification methods include a combination of engine test and analysis.

Testing is done at representative ground and altitude conditions to characterize and verify baseline performance.

Analysis is performed with a model based on measured test data for characterization of performance at conditions that have not been tested.

DoD/MIL Doc: JSSG–2007A: para A.3.2, A.4.2, A.3.2.1, A.4.2.1, A.3.2.1.1, A.4.2.1.1, A.3.3.1, A.4.3.1, A.3.3.2, A.4.3.2, A.3.3.7, A.4.3.7, A.3.11, A.4.11, A.3.12, A. 4.12 and JSSG-2001B 3.3.1.1/4.3.1.1.

FAA Doc: 14CFR references: 33.5, 33.35, 33.7, 33.8, AC 33.2B

**7.2.1.2** Verify that degraded engine performance meets requirements for safety considerations. Degraded engine performance includes performance in any backup control mode, as well as performance after bird, ice, and sand ingestion.

Standard: Installed engine thrust or power is characterized in backup control mode, at field removal limits (if defined), and after bird, ice and sand ingestion and allows safe operation of the air vehicle.

Compliance: Verification is accomplished by engine testing and analysis.

DoD/MIL Doc: JSSG-2007A: Backup control: A.3.7.2.1.1, A.4.7.2.1.1; Bird ingestion: JSSG-2007A A.3.3.2.1, A.4.3.2.1; Ice ingestion: A.3.3.1.4, A.4.3.1.4; and Sand ingestion: A.3.3.2.4, A.4.3.2.4

FAA Doc: 14CFR references: 33.1, 33.68, 33.89

AC 33-76

### 7.2.2 Operability.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.4.2, A.3.11, A.4.11, A.3.12, A.4.12, A.3.2.2, A.3.2.2.7, A.4.2.2, A.4.2.2.7

FAA Doc: 14CFR references: 33.5, 33.7

AC 33-2B

**7.2.2.1** Verify that positive stability margin exists at all flight conditions or that placards are documented in the flight manual.

Standard: Stability audits show positive engine surge margin at conditions that are critical to the safety of the flight vehicle. Evaluation conditions include crosswind takeoff, take-offs on cold days following a rapid reaction start, and extreme maneuvers. Stability audits use the correct installation effects (bleed, horsepower extraction, nozzle suppression, and inlet recovery,

distortion, and swirl), and consider all destabilizing effects, such as: engine deterioration, non-standard day effects, steam ingestion, armament gas ingestion, liquid water ingestion, and transient response. When pilot actions are used to mitigate risk of engine stalls, the flight manual includes proper pilot instructions, placards, warnings or cautions.

Compliance: Verification of the stability audits follow guidelines outlined in ARP 1420 “Gas Turbine Engine Inlet Flow Distortion Guidelines” and AIR 1419 “Inlet Total Pressure Distortion Considerations For Gas Turbine Engines. The audits are based on data from numerous rigs and engines throughout the development program. Rig and/or engine tests are conducted to measure fan and compressor stall lines. A stability methodology is developed by testing fan/compressor sensitivity to distortion and other destabilizing influences. Inlet model tests are conducted to quantify the levels of performance, distortion, and inlet stability. Analysis is conducted via the stability audit which combines the above factors.

DoD/MIL Doc: JSSG-2007A: para A.3.2.2.6, A.4.2.2.6, A.3.2.2.11, A.4.2.2.11, A.3.3.2.5, A.4.3.2.5, A.3.3.2.6, A.4.3.2.6, A.3.3.2.7, A.4.3.2.7.

FAA Doc: 14CFR references: 33.65, 33.73 (stability), 33.5 (distortion)

**7.2.2.2** Verify that the engine has adequate stability during throttle transients. The entire range of required transients should be considered, including those during land and ship approaches, aerial refueling, and quick stops; for rotorcraft, bob-up and remask, and nap of the earth ridgeline crossings.

Standard: Thrust or power response times meet air system mission performance requirements during all required maneuvers. Stall margin is evaluated per criteria 7.2.2.1. Control system phase and gain margin is as described in criteria 7.2.4.1.3.

Compliance: Verification is accomplished by analysis, electronic and closed loop bench tests, engine tests, and vehicle integration tests.

DoD/MIL Doc: JSSG-2007A: para A.3.2.2.6, A.4.2.2.6, A.3.2.2.7, A.4.2.2.7.

MIL-HDBK-516 criteria 7.2.4.1.3.

FAA Doc: 14CFR references: 33.65, 33.73, 33.89

**7.2.2.3** Verify that air start requirements are met and documented in the flight manual. Air starts include spool-down, windmill, cross-bleed and starter-assisted as appropriate for the air vehicle system.

Standard: Airstart capability is documented in the flight manual.

Compliance: The airstart envelope is initially verified from ground testing in altitude test cells, and then verified by flight test.

DoD/MIL Doc: JSSG–2007A: para A.3.2.2.3.2, A.4.2.2.3.2.

FAA Doc: 14CFR references: 33.89

**7.2.2.4** Verify that the engine recovers from instability induced by external influences (such as inlet distortion and steam and armament gas ingestion) after the external influence is removed, without employing measures such as commanded idle or shutdown and without exceeding thermal or structural limits.

Standard: Engine control system can detect and recover from engine stall without commanded idle or shutdown - OR engine demonstrates ability to self-recover.

Single engine applications possess an automatic relight system for recovery from combustor blowout, unless it has been demonstrated that automatic relight offers no improvement in engine recoverability.

Compliance: Control system detection is verified by engine ground and bench testing; self-recovery is demonstrated from engine ground and altitude cell testing.

DoD/MIL Doc: JSSG–2007A: para A.3.2.2.3.5, A.4.2.2.3.5, A.3.2.2.11.2, A.4.2.2.11.2, A.3.7.2.1, A.4.7.2.1.

FAA Doc: 14CFR references: 33.27, 33.28, 33.91

**7.2.3** Structures.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.4.2, A.3.11, A.4.11, A.3.12, A.4.12

FAA Doc: 14CFR references: 23.901-23.1165, 25.901-25.1167

**7.2.3.1** Verify that the engine structure does not exhibit detrimental permanent set or deflect to the extent that operation or performance is impaired when operated to limit load conditions (singly or in combination) within the flight and ground envelope. Verify that the engine structure does not experience catastrophic failure under ultimate load conditions or combinations of ultimate loading.

Standard: 1. Factors of safety (SF) are applied to loads that occur within the flight and ground envelope to establish limit load and ultimate load conditions.

Limit loads:

1.0 SF for in-flight loads

1.5 SF for pressure vessels/cases

1.33 SF for cast structures (unless the material has been fully characterized)

Ultimate loads:

1.5 SF for in-flight loads

2.0 SF for pressure vessels/cases

2.0 SF for cast structures.

Positive margins of safety exist for the range of manufacturing tolerances and operational conditions.

2. Rotor Integrity: The engine is capable of withstanding overspeeds of 115% percent maximum allowable steady state speed at maximum allowable measured gas temp for 5 minutes. The engine is capable of withstanding gas temperatures 75 degrees F in excess of the maximum allowable measured gas temperature and at maximum allowable steady state speed for 5 minutes.

3. Gyroscopic moments: The engine can operate satisfactorily at maximum allowable steady state engine speed when subjected to rotational velocities and accelerations within the flight envelope and gyroscopic moment conditions. Two conditions must be assessed: 3.5 radians per second for a period of 15 seconds with a 1 g maneuver load, and 1.4 radians per second for 10E7 cycles at all load factor conditions within the flight envelope.

4. Disk burst speed: The minimum disk burst speed is at least 115% of the maximum steady state speed (with a target of 122% which represents a factor of safety of 1.5) or 5 percent above the worst transient speed, whichever is higher. Worst case thermal conditions should be applied.5. Blade and disk deflection: Blades and disks do not contact any static parts of the engine other than seals and shrouds when operating at all points within the flight and ground envelope. Seals and clearances remain effective under all internal and external loads, manufacturing tolerances, cold and hot day operation including transient thermal conditions.

6. Blade out: Subsequent to blade failure at maximum allowable steady state speed, the engine does not experience uncontained fire, catastrophic rotor, bearing support or mount failures, overspeed conditions, leakage of flammable fluid, or loss of ability to shut down the engine. Blade loss loads for conventional blades are based on the imbalance equivalent to fracture in the blade attachment at the minimum neck section above the outermost retention feature. Blade loss loads for integrally bladed rotors are based on the imbalance equivalent

to liberation of the airfoils including the fillet material down to the rotor rim diameter. Additional imbalance due to secondary damage is included.

7. Engine mounts can withstand limit load conditions without permanent deformation and ultimate loads without fracture.

8. Ground handling mounts support the weight of the engine (including all engine mounted equipment and accessories, components and operating fluids) under a 4g axial, 2g lateral, and 3g vertical load acting in combination at the engine center of gravity.

9. Engine cases and each gas pressure loaded component of the engine is capable of withstanding maximum operational pressure loads that occur within the flight and ground envelope including safety factors.

10. Engine pressure balance provides thrust loading to assure bearing operation without skid damage at all power settings throughout the flight and ground envelope.

11. Containment: The engine can completely contain a fan, compressor or turbine blade failure. No fires result and the engine contains all parts damaged and released by the failure of a single blade.

12. Ingestion: The engine meets all requirements of the specification during and after the sand and dust ingestion test specified. The engine operates and performs during and after ingestion of hailstones and sheet ice at the take-off, cruise, and descent aircraft speeds. The engine can not be damaged beyond field repair capability after ingesting the hailstones and ice. The engine continues to operate and perform during and after impact of birds as specified in JSSG 2007.

Compliance: 1. Factor of safety: The requirements are evaluated by analyses and tests. Strain gauges and other instrumentation are used during tests to validate analysis methods. It is recommended that tests be conducted progressively to ultimate load conditions.

2. Rotor integrity: Analysis confirms the overspeed and overtemperature capability of the engine. Engine testing validates analytical predictions.

3. Gyroscopic moments: Analysis verifies that component deflections under gyroscopic loading conditions do not impair operation of the engine under ultimate loading levels and meet life requirements under limit load conditions.

4. Disk burst speed: Disk burst testing is conducted on the most limiting rotor (disk with the minimum burst capability) of each module. Maximum test speed should be sufficient to demonstrate that a minimum tensile strength component (–3 Sigma) can meet the burst margin requirement based on the specific ultimate strength capability of the test component. These conditions should be maintained for a minimum of 30 to 60 seconds. The test is considered successfully completed if there is no evidence of imminent failure.

5. Blade and disk deflection: Analysis verifies that positive clearances, both axial and radial, exist under all operational and maneuver load conditions.

6. Blade out: Evaluation of blade out requirements include analyses of the fan, compressor, and turbine sections of the engine. Evaluation of the most critical rotors is accomplished by an engine test. Failure is assumed to occur at the maximum transient rotor speed.

7. Engine mounts: Engine-mount requirements are evaluated by analysis of the worst-case engine-mount failures and their consequences. Testing of mount capability to limit and ultimate load conditions is accomplished for qualification. Testing is taken to mount failure to validate analytical models.

8.Ground handling mounts: Tests should be conducted to load levels sufficient to evaluate limit load and ultimate load operational requirements and to evaluate that minimum strength components can meet the load requirements, assuming the test components have average strength capability.

9. Pressure vessel/case design: The analyses should show that all pressure-loaded parts

and components can meet the limit and ultimate load conditions when constructed with minimum-strength materials. The analyses should be substantiated/correlated with pressure vessel/case testing. All pressure-loaded parts and components should be tested to at least two times (2 X) the maximum operating pressure in combination with the external ultimate loads based on the external loads encountered during engine operation. These tests should be conducted at the maximum allowable temperature or at a test pressure adjusted to account for the differences between operating and test temperatures.

10. Engine pressure balance: Analysis results indicate that loads imposed on the engine bearings are of sufficient magnitude to ensure adequate bearing operation without skid damage. The analysis is validated with suitably instrumented engine testing. This test should be conducted in an altitude test cell to simulate altitude and ram conditions representative of operational use.

11. Containment: The engine contractor shall perform a blade containment analysis which relates the released blade kinetic energy to the energy required for containment. The analysis is substantiated/correlated with rig or engine containment tests.

12. Verification is accomplished via analyses, component, and full-up engine tests.

DoD/MIL Doc: MIL-HDBK-1783B: para A.4.10/A.5.10 through A.4.10.14/A.5.10.14, A.4.5.3, A.5.5.3

FAA Doc: 14CFR references: 33.75, 33.91, 33.23

**7.2.3.2** Verify that the engine has positive durability margins over the defined operational interval and duty cycle to preclude adverse safety, economic, or operational impacts.

Standard: 1. Positive low cycle fatigue life margins have been used for component design.

2. Vibratory stresses are kept below 60% of the minimum Goodman allowable limit for one billion cycles.

3. Material corrosion does not degrade the engine function, integrity or maintenance for the design service life.

4. Parts cannot creep to the extent that acceptable field engine operations is impaired for the operating conditions, operating interval and design usage.

5. Maximum engine mechanical vibration limits are established as a function of frequency, engine order, and location and direction of measurement. Maximum engine mechanical vibration limits should be based on an acceptable margin of safety for structural capability. Damaging rotor critical speeds have probabilistic margin over the operating speed range to account for variation in influence parameters. When there is insufficient confidence in probabilistic solutions, a deterministic margin of at least 20% should be specified for rotor critical speeds that exist above maximum operating speed or below idle speed.

6. The engine meets the design service life requirements in the presence of the noise environment produced during installed and uninstalled operation at flight and ground conditions consistent with the design usage.

7. Foreign object/domestic object damage (FOD/DOD): The engine is capable of operating for one inspection interval after ingestion of foreign or domestic objects which produce damage equivalent to a minimum fatigue notch factor (Kf) of 3. If probabilistic methods are used, a failure threshold of one failure in 10 million engine flight hours is met.

Compliance: 1. LCF Margin: Low cycle fatigue analyses and testing is accomplished. Testing consist of component and AMT testing. Rotating components have cyclic life demonstrated by spin pit testing with thermal gradients applied, where appropriate. The testing is continued until crack initiation or five times (5X) the design service life.

2. HCF: Aeromechanical stress surveys are conducted using final configuration hardware and control schedules. Testing is conducted over the range of operating pressures and temperatures to clear the design flight envelope. Sensitivity testing over the expected range of influence parameters is part of the test program to demonstrate robustness to expected

variations. Analytical models are validated using the HCF Test Protocol defined in MIL-HDBK-1783B CN2.

3. Corrosion: A corrosion prevention and control plan is prepared. Corrosion resistance is verified through engine testing in a corrosive environment as defined in JSSG 2007.

4. Creep: Analytical prediction of creep and component growth and percent stress rupture life, as a function of design life, is accomplished on each creep-critical component. Design operating stresses is established based on past experience that indicates a high probability that satisfactory creep and stress rupture life can be achieved (e.g.; 0.2% plastic creep life, 0.005-inch diametrical rim growth, 50% stress rupture life, etc.). Component and engine AMT testing validates analytical predictions.

5. Vibration: Engine AMT testing is accomplished at allowable field levels of vibration for the duration of the test to validate structural integrity of components and assemblies. Instrumented engine tests confirm rotor critical margins.

6. Noise: The capability of the engine to meet the strength and durability requirements in the presence of the noise environment generated during engine operation is verified by test. Acoustic measurements should be made during operation in the test cell at various conditions. Analysis of the data should be made to establish if pressure levels are of sufficient magnitude to cause structural cracking. Inspection of AMT engines should be used to verify resistance to component structural cracking.

7. FOD/DOD: Analysis of aeromechanical test results validates that airfoils stresses remain under the 100% Goodman allowable for a Kt=3 notch or probabilistic analysis verifies a failure rate of < 1e-7. Simulated foreign object damage is applied to three (3) airfoils of the most critical stage of both the fan and compressor. The damage is located at the most critical areas susceptible to foreign object/domestic object damage. The applied damage produces a minimum fatigue notch factor (Kf) of 3. The engine test is conducted to an equivalent depot inspection interval which simulates the design duty cycle.

DoD/MIL Doc: MIL-HDBK-1783B: para A.4.9/A.5.9 through A.4.9.3/A.5.9.3 for LCF/durability/economic life design and compliance methods

MIL-HDBK-1783B: para A.4.13/A.5.13 through A.4.13.3.3/A.5.13.3.3 for high cycle fatigue/vibration guidance

MIL-HDBK-1783B: para A.4.12/A.5.12 for creep guidance

MIL-HDBK-1783B: para A.4.11/A.5.11 for deterioration guidance

MIL-HDBK-1783B: para A.4.14/A.5.14 for noise guidance

MIL-HDBK-1783B: para A.4.15/A.5.15 for foreign object damage/domestic object damage (FOD/DOD) guidance

MIL-HDBK-1783B: para A.4.16/A.5.16a and b, for durability and compliance criteria for repaired components

FAA Doc: 14CFR references: 33.14, 33.5, 33.63, 33.83, 33.19

### 7.2.3.3 Verify that all safety- and mission-critical parts are designed to be damage tolerant over the defined operational interval and duty cycle.

Standard: 1. Safety and mission critical engine parts maintain damage tolerance for two times the inspection interval in the presence of material, manufacturing, processing, and handling defects.

2. Assumed initial surface flaw sizes are based on the NDI methods to be used during manufacture and depot maintenance. Assumed initial imbedded flaw sizes are based on the intrinsic material defect distribution or the NDI methods to be used during manufacture. Flaw size detection reliability is verified to have a probability of detection and confidence level of 90%/95% for manual inspections or 90%/50% for fully automated inspection

methods.

3. The residual strength is equal to the maximum stress that occurs during the design service life to the required design usage conditions.

4. Safety and mission critical parts are serialized, properly marked, and subjected to the required process control and NDI procedures.

Compliance: 1. Fracture critical component: Damage tolerance analysis is conducted on each component classified as safety or mission critical. Damage tolerance analysis that addresses imbedded defects can be based on probabilistic methods that account for the distribution of variables. Analyses demonstrates that the assumed initial flaws will not grow to critical size for the usage, environment, and required damage tolerance operational period. The analyses account for repeated and sustained stresses, environments, and temperatures, and include the effects of load interactions. Analysis methods are verified by test, utilizing engine or spin pit testing.

2. Initial flaw size: Controls and inspection methods are established through the damage tolerance control plan. Demonstration programs, in the absence of existing data, is performed to ensure flaws greater than the assumed design flaws will not occur in finished components. Subsequent to successful completion of these demonstration programs, the selected inspection methods and processes become part of the production requirements and may not be changed without approval of the Procuring Activity.

3. Residual strength: Analyses verifies that at the end of the required damage tolerance operational period, the strength requirement can be met for the flaw configuration and the required load.

4. Damage tolerance controls: Inspection of drawings, specifications, and damage tolerance control plan verifies parts are serialized, marked and comply with process and NDI controls.

DoD/MIL Doc: MIL-HDBK-1783B: A.4.7/A.5.7 through A.4.8.6/A.5.8.6 for application of damage tolerance and inspection methods

FAA Doc: 14CFR references: 33.75

**7.2.3.4** Verify that the allowables for materials are minimums and are established considering statistical variability, the expected environments, fabrication processes, repair techniques, and quality assurance procedures. Verify that conditions and properties for material repairs satisfy design requirements.

Standard: Structural properties used in design are based on minimum material capability. All material properties except fracture toughness and crack growth are based on minus three sigma values with a 50% confidence level or minus two Sigma values with a 95% confidence level. Another option is to state that material properties will be based on B0.1 probability values. The confidence level for B0.1 is 50%. B50 properties may be used to characterize fracture toughness and crack growth rate.

Compliance: Test and modeling programs have been used to establish material structural properties. Anticipated properties under damage states (e.g.; fretting, etc.) have been verified through combinations of laboratory specimen, sub-element and component testing, material damage models which have been validated against databases and supplemented with historical data which cover the range of potential damage states, or databases which cover the properties under damage states. Material properties established by test have been based on specimens fabricated from "as produced" parts, from parts produced by equivalent practices, or from parts sufficiently similar in processing and size, since critical structural properties are dependent upon the manufacturing processes. Damage states in the parts which may occur during field usage have been verified for their potential impact on high cycle fatigue life.

DoD/MIL Doc: MIL-HDBK-1783B: para A.4.6/A.5.6 for material characterization guidance

FAA Doc: 14CFR references: 33.15

**7.2.3.5** Verify that the engine is designed such that pertinent environmental variables and all sources of repeated loads are considered and these considerations are included in the development of the design duty cycle.

Standard: The design usage includes missions and mission mix, usage parameters, externally applied forces, operating envelope, engine attitude limits, ambient temperature distribution, icing environment conditions, corrosive atmosphere conditions, noise environment, customer bleed air extraction, loaded accessory pads and power takeoff usage, and engine performance retention characteristics. Sensitivity analysis is conducted on critical components to identify the effect of probable ranges in usage variables on engine life limits. The results of the sensitivity analysis are used to condense the design service life and design usage into a minimum number of design duty cycles. The design duty cycle equivalent damage content is equal to or greater than the damage content of the full mission set.

Compliance: Inspection of design duty cycle details and life analyses as documented in the strength and life report.

DoD/MIL Doc: MIL-HDBK-1783B: para A.4.3/A.5.3 through A.4.5.3/A.5.5.3, for design service life and usage

FAA Doc: 14CFR references: 33.4

**7.2.3.6** Verify that all inspection intervals and life-limited components are identified in the technical manuals and a process to track life consumption is operational and current.

Standard: Required maintenance actions (component inspection, repair, or replacement requirements) has been defined to ensure adequate structural integrity and operational readiness for the design service life. Required maintenance actions are based on duty cycles defined by operational usage of the airframe/engine. Individual component maintenance times are based on the parameter that causes life degradation. The critical component tracking system has been established and defines the analysis procedures, serialization, data collection, and computer programs necessary to establish maintenance times of individual components based on accrual of parameter events.

Compliance: Verification by inspection of the Engine Life Management Plan, applicable Technical Orders and maintenance manuals and parts life tracking program.

DoD/MIL Doc: MIL-HDBK-1783B: para A.4.19/A.5.19 for component life management guidance.

MIL-HDBK-1783B: para A.5.9.1.1 through A.5.9.1.6 for accelerated mission testing concepts

**7.2.4** Engine subsystems, components, computer resources and software.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.4.2, A.3.11, A.4.11, A.3.12, A.4.12, A.3.2.2, A.4.2.2.

FAA Doc: 14CFR references: 33.5, 33.7

AC 33-2B

**7.2.4.1** Subsystems.

**7.2.4.1.1** Verify that the engine control system maintains safe engine operation under all required conditions.

Standard: The control system maintains adequate levels of engine thrust/power and surge/stall margin while not allowing it to operate outside its maximum specified parameters of speed, temperature and pressure. The control system is sized and the architecture able to accommodate all required inputs, computations and outputs. Auxiliary engine control functions, such as engine limiting (contingency or emergency power), backup (or reversionary) engine control modes, control anticipation features, and cruise fuel flow optimization provide backup or emergency operation to all critical engine functions.

Compliance: A Failure Modes and Effects Criticality Analysis (FMECA) of the control system establishes a list of all known potential failure modes, their associated probabilities and an analysis of engine impacts. Closed loop bench testing, using production qualified components, ensures the system can properly interact with all other systems and components on the engine. Engine sea level and altitude testing demonstrate the control system's ability to maintain required levels of speed, temperature, pressure and fuel flow throughout the flight envelope. Closed loop fault injection bench testing ensures the control system can correctly identify and accommodate known critical failures. Engine sea level and altitude testing provide an opportunity to inject faults into the control system and evaluate the engine's ability to respond within specification limits. Flight testing ensures the engine performs as required and there are no unaccounted for installation effects. Alternative compliance approaches include similarity to other systems or previous FAA airworthiness certification support documentation.

DoD/MIL Doc: JSSG-2007A: para A.3.7.2/A.4.7.2, control systems design and verification.

FAA Doc: 14CFR references: 33.27, 33.28, 33.91

**7.2.4.1.2** Verify that multiple propulsion subsystems are physically, systemically, and operationally isolated from each other to prevent the failure of more than one propulsion subsystem due to any single or common cause.

Standard: Subsystem components are physically isolated and protected to minimize collateral or secondary damage in the event of failure.

Subsystems are systemically and operationally isolated to avoid possible cascading failures.

Compliance: Inspection of design review and test data, drawings and installed hardware provide information to evaluate adequate physical isolation of engine subsystem components. Mock-ups can be used if they adequately represent fielded systems.

A Failure Modes Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities. The FMECA is used to conduct a system analysis of engine impacts resulting from propulsion system failures.

DoD/MIL Doc: JSSG-2007A: para A.3.7.2/A.4.7.2, control systems guidance..

FAA Doc: 14CFR references: 33.27, 33.28, 33.91

**7.2.4.1.3** Verify that the control system maintains both stable engine operation and response during all steady state and transient conditions.

Standard: All engine control loops demonstrate a minimum of 6 db gain margin and 45 degrees of phase margin. The engine provides safe and stable thrust levels in response to all pilot commands.

Compliance: Phase and gain stability margins are verified through analysis, closed loop modeling, bench testing (wet rig) and full-up engine testing. These verification methods are conducted using the entire range of expected PLA inputs and transients. Closed loop models are validated using closed loop bench and full-up engine testing. Ground and flight testing demonstrate the engine's ability to respond to all pilot commands.

DoD/MIL Doc: JSSG-2007A: para A.3.7.2/A.4.7.2, control systems guidance.

MIL-HDBK-516 criteria 7.2.2.2.

FAA Doc: 14CFR references: 33.27, 33.28, 33.91

**7.2.4.1.4** Verify that any failure of the engine controls and associated subsystems results in a fail-operational or fail-safe condition.

Standard: Fail-operational capability provides full-up engine performance.

Fail-safe capability allows continued engine operation at a degraded level of performance sufficient to

sustain safe air vehicle operation.

Compliance: Failure Modes Effects and Criticality Analysis (FMECA) establishes a list of all known potential failure modes and their associated probabilities. Closed loop and fault injection bench testing ensures the control system can correctly identify and accommodate all known failures that can affect safe operation of the air vehicle. During engine sea level and altitude testing, faults are injected into the control system and the engine responds to them within specification limits.

DoD/MIL Doc: JSSG-2007A: para A.3.7.2/A.4.7.2, control systems guidance.

FAA Doc: 14CFR references: 33.27, 33.28, 33.91

**7.2.4.1.5** Verify that the engine control system failures do not cause unexpected engine transients; or result in unacceptable controllability, stability, or handling qualities; or require any urgent or excessive pilot action.

Standard: Unexpected engine responses to control system failures do not distract or increase the workload of the pilot or impact continued safe operation of the air vehicle.

Critical failures that could affect continued safe operation of the air vehicle are recorded in the engine health monitoring (EHM) system and the pilot is notified via cockpit alarms or warnings.

Non-critical failures are recorded in the EHM system and are available to the pilot and maintenance personnel when the system is queried.

Compliance: A Failure Modes Effects and Criticality Analysis (FMECA) of the control system details all known potential failure modes, their associated probabilities and an analysis of engine impacts.

Closed loop bench and fault injection testing ensures the control system correctly identifies and accommodates all known critical failures and the appropriate level of information is provided to the pilot and maintenance personnel.

During engine sea level and altitude testing, faults are injected into the control system and the engine responds to them within specification limits.

DoD/MIL Doc: JSSG-2007A: para A.3.7.2, A.4.7.2, A.3.7.6, A.4.7.6.

FAA Doc: 14CFR references: 33.27, 33.28, 33.91

**7.2.4.1.6** Verify that the engine fuel system safely provides the required fuel supply to the combustor, augmentor, and fueldraulics subsystems under all required conditions.

Standard: Fuel system components such as pumps, regulators, carburetors, flow metering valves, check valves, nozzles, spray bars, tubing and wiring are adequately sized to provide the necessary fuel flows, pressures and temperatures to simultaneously satisfy the requirements of the main combustor, augmenter, heat exchangers/cooling systems and all variable geometry fueldraulic subsystems. An in-line filtration system includes cleaning, replacement and a bypass indication (manual or electronic) provisions.

The fuel system can safely perform under severe operating conditions such as high vapor/liquid ratios, temperature ranges, contamination, and dry lift for specification, alternate, and emergency fuels.

Fuel system pressure vessels and lines can withstand 1.5X (proof) normal operating pressures (without performance degradation or leakage) and 2X (burst) maximum operating pressures (without permanent deformation or leakage).

All fuel carrying components and lines are fire resistant.

Compliance: A complete analysis of fuel system requirements versus capabilities, using worse case flight conditions, establishes the system design parameters.

Bench (wet rig) testing demonstrates the fuel systems ability to produce required flows, pressures and temperatures.

Ground engine testing demonstrates the fuel system's ability to provide properly conditioned fuel to the engine.

A fuel filter flow and contamination test ensures it adequately cleans debris from the fuel, maintains acceptable flow and pressure and activates bypass when needed. Inspection of the fuel filter determines its capabilities for required maintenance.

Applicable fuel system performance testing (dry lift, cavitation, V/L, lubricity, etc.) ensures the engine can safely operate under anticipated worse case conditions.

Proof and burst pressure component testing ensures adequate safety margin across the entire flight envelope.

Testing verifies fire resistance where a 2000 degrees F flame is applied for 5 minutes with no fire propagation.

Comm'l Doc: SAE-AS1055B, Fire Testing

DoD/MIL Doc: JSSG-2007A: para A.3.7.3.2/A.4.7.3.2, Fuel Systems Performance, engine fuel system design and verification testing

JSSG-2007A: para A.3.1.8.1/A.4.1.8.1, Flammable Fluid Systems - fire resistance testing requirements and procedures.

FAA Doc: 14CFR references: 33.17, 33.67, 33.87(a)(7), 33.89

**7.2.4.1.7** Verify that the engine ignition system provides a safe ignition source for the main combustor and augmentor.

Standard: Operation of the ignition exciters, igniters and cables ensures safe and reliable light-off of the main combustor and augmenter throughout the ground and air start envelopes.

The engine control system detects a flameout and activates the ignition system (auto-relight) without pilot/operator involvement or the pilot/operator can manually activate the main and augmenter ignition systems.

Compliance: The ignition system ability to provide adequate spark energies to the main combustor and augmenter is verified by bench testing and full-up engine and flight testing.

The control system ability to correctly identify an engine flameout and automatically activate the ignition system without pilot action is verified by full-up engine and flight testing. All ignition system functions are fully exercised by pilot command with the engine installed in the air vehicle.

DoD/MIL Doc: JSSG-2007A: para A.3.2.2.3.5/A.4.2.2.3.5, Auto-Relight and A.3.7.5/A.4.7.5, Ignition Systems

FAA Doc: 14CFR references: 33.89, 33.69

**7.2.4.1.8** Verify that the engine anti-ice/de-ice system prevents damaging ice buildup or provides safe and non-damaging ice removal at all engine speeds/power levels and will not result in heat-induced damage to the engine's front frame structure.

Standard: Anti-ice systems prevent ice from accumulating on the engine structure that could result in ingestion and subsequent mechanical damage to internal rotating components.

De-ice systems remove existing ice accumulations before they can be ingested and cause mechanical damage to internal rotating components.

The engine control system is capable of automatically operating the anti-ice and de-ice systems without pilot or operator action. The pilot or operator can override the engine control system and operate the anti-ice or de-ice system.

Anti-ice and de-ice system operational temperatures are monitored and the systems are automatically turned off in the event engine front frame damage is likely to occur. Moisture cannot accumulate and freeze in areas (sensors, lines, etc.) that could result in control system malfunctions.

Compliance: Analysis of the air vehicle mission defines the engine's icing environment.

Bench testing of the anti-ice or de-ice plumbing, valves and sensors demonstrates the system's ability to prevent or remove ice prior to it damaging the engine.

Bench testing of the control system demonstrates it can identify the existence of icing conditions and turn on the anti-ice or de-ice system.

All anti-ice and de-ice system controls are tested to ensure the pilot or operator can override the control system and manually operate the anti-ice or de-ice system.

Fault injection testing of the anti-ice and de-ice systems demonstrate the ability to properly recognize temperature exceedances and initiate system function shutdown.

Analysis and inspection of all critical control system components verifies resistance to moisture collection and freezing.

DoD/MIL Doc: JSSG-2007A: para A.3.7.1/A.4.7.1, Anti-ice and De-ice Systems

FAA Doc: 14CFR references: 25.1419

**7.2.4.1.9** Verify that engine cooling and thermal management systems safely remove excess heat from the engine and its subsystems (see 8.2.16).

Standard: Cooling and thermal management systems function properly during ground and flight operation, under all atmospheric conditions and for all flight conditions/attitudes in the air vehicle operating envelope.

Cooling and thermal management systems are properly sized to remove heat from those components (electronic controls, sensors, lubrication system, etc.) which could become damaged or operate erratically when exposed to excessive thermal loads.

Engine and air vehicle cooling and thermal management systems function together to ensure adequate thermal load dissipation for the entire air vehicle.

Compliance: Analysis and modeling of engine components determine their thermal loading and heat rejection characteristics. Results from this analysis and modeling are used to verify the engine components' ability to continue operation when exposed to engine induced thermal loads. Analysis and modeling of the combined air vehicle and engine thermal management systems ensures there are no conditions that result in exceedance of established loss of aircraft (LOA) rates.

DoD/MIL Doc: JSSG-2007A: para A.3.2.2.13/A.4.2.2.13.

FAA Doc: 14CFR references: 27.1121

**7.2.4.1.10** Verify that the engine variable geometry systems safely operate under all engine operating conditions.

Standard: Variable geometry system components such as pumps, actuators, bleed valves, plumbing and mechanical cables that are powered by electric, air, oil, fuel or mechanical means, operate with a full range of motion and adequate force margins to properly operate the engine variable geometry systems.

Variable geometry system components maintain full functional capability when exposed to the maximum static and dynamic loads, temperatures and flows throughout the operating envelope.All variable geometry components and lines that carry fuel are fire resistant and those that carry oil are fire proof.

Compliance: Analysis and bench testing of each variable geometry system component demonstrates the

system's ability to meet engine specification requirements.

Engine and flight testing of the variable geometry system demonstrates its ability to meet engine specification requirements.

Fire resistance is demonstrated by testing with a 2000 degree F flame for 5 minutes without flame propagation. Fire proof is demonstrated by testing with a 2000 degree F flame for 15 minutes without flame propagation.

Comm'l Doc: SAE-AS1055B, Fire Testing

DoD/MIL Doc: JSSG-2007A: para A.3.7/A.4.7, variable geometry system design and verification testing.

JSSG-2007A: para A.3.1.8.1/A.4.1.8.1, Flammable Fluid Systems - fire resistance and fire proof testing.

FAA Doc: 14CFR references: 25.671, 27.695, 29.695, 33.17, 33.72, 43.1

**7.2.4.1.11** Verify that the engine lubrication system safely operates under all engine operating conditions.

Standard: Engine lubrication systems provide safe and reliable oil supply, scavenge, cooling, filtration and de-aeration under all engine operating conditions.

The engine safely operates in a low or no lubrication condition for specified periods.

An in-line filtration system includes cleaning, replacement and a bypass indication (manual or electronic) provisions.

Lubrication system temperature, pressure and quantity information is monitored by an appropriate sensor, gage or manual means (dipstick) and has features for overfill protection.

Lubrication system debris is monitored (e.g., magnetic chip detectors, quantity debris monitors and the Joint Oil Analysis Program (JOAP)).

All oil carrying components, lines and manifolds are fire proof.

Compliance: Analysis of the lubrication supply and scavenge system requirements versus capabilities identifies conditions to be tested. Lubrication system bench, engine and flight testing demonstrate its ability to provide the operating pressures, temperatures and flows required in the engine specification.

An oil deaeration test ensures the system deaerator removes entrained air from the oil. An oil filter flow and contamination test demonstrates its ability to clean debris, maintain acceptable flow and pressure and activate bypass. Inspection of the oil filter determines its capabilities for required maintenance.

Analysis, bench and engine testing of all monitored lubrication system information ensures the pilot and maintainers are provided the information to determine the lubrication system is operating properly.

Fireproof is verified by testing with a 2000 degree F flame applied to the component or line for 15 minutes with no flame propagation.

DoD/MIL Doc: JSSG-2007A: para A.3.7.8/A.4.7.8, Lubrication System

FAA Doc: 14CFR references: 33.5, 33.71, 33.87, 33.89

**7.2.4.1.12** Verify that the lubrication system is free from excessive discharge at the breather.

Standard: Lubrication system breather exhaust does not pose a health risk or inhibit ground maintenance personnel from performing tasks around and underneath the installed engine. The location and orientation of the breather exhaust port minimizes ground personnel's exposure.

Breather system exhaust particle limits do not exceed the OSHA health and safety Threshold Limit Values (TLV) (5 mg/cubic meter per current American Conference of

Governmental Industrial Hygienists (ACGIH) requirements.

Compliance: Analysis of breather emissions establishes test parameters.

Instrumented engine testing measures breather emissions and ensures they do not exceed OSHA requirements.

DoD/MIL Doc: JSSG-2007A: paraA.3.7.8.3/A.4.7.8.3, Breather Mist - engine breather exhaust emissions design and verification testing.

**7.2.4.1.13** Verify that the lubrication system and bearing compartments do not support combustion.

Standard: Lubrication and bearing compartments such as tanks, lines, gearboxes and sumps do not allow the collection or buildup of materials that initiates or supports combustion.

Components that are exposed to both fuel and oil (heat exchangers, fuel lubricated oil pumps, etc.) do not allow engine fuel flow to enter the lubrication system, bearing compartments or gearboxes.

All oil carrying components, lines and manifolds are fire proof.

Compliance: Analysis of bearing compartments, tanks, lines, gearboxes and sumps establish the system design parameters.

Analysis and bench testing verifies fuel and oil carrying component failures do not allow mixing of the two systems.

Fireproof is verified by testing where a 2000 degrees F flame is applied to the component or line for 15 minutes with no flame propagation.

Comm'l Doc: SAE-AS1055B, Fire Testing

DoD/MIL Doc: JSSG-2007A: para A.3.7.8/A.4.7.8, Lubrication System

JSSG-2007A: para A.3.1.8.1/A.4.1.8.1, Flammable Fluid Systems - fire resistance and fireproof testing.

**7.2.4.1.14** Verify that the engine health monitoring and prognostics systems provide adequate warnings in a timely manner to reduce occurrences of in-flight shutdowns and power losses.

Standard: All safety/mission-critical faults and warnings are supplied to the pilot/maintainers and provide a clear interpretation of any identified engine problems.

The engine monitoring and prognostics systems detect, isolate and record all engine faults that affect continued safe operation of the air vehicle or require maintenance before next flight. Critical fault detection is at least 95% of all known possible failures and critical fault isolation is at least 90% of detected faults.

Critical faults, affecting continued safe operation of the air vehicle, result in immediate notification to the pilot via visual or audible alarms.

All faults requiring maintenance action are recorded for post-flight download.

Critical engine information such as speed, control operating mode and fluid quantities and pressures, if provided to the pilot, are displayed in a clear and concise format, consistent with their training and technical data.

The engine monitoring and control systems provide accurate information and do not allow false positive faults from occurring.

Compliance: Analysis and fault injection bench testing verifies the capability of the monitoring system to detect and isolate all failures that affect safe operation of the air vehicle. Engine/air vehicle testing provides assurance that the pilot is provided clear notification of any critical failure.

Engine fault download testing verifies the maintainers have full access to failure data.

Analysis of all cockpit engine data demonstrates the pilot can receive and properly interpret the information necessary to safely operate the air vehicle. Inspection of the Interface Control Document (ICD) and pilot manual ensures they match what engine information is being provided to the pilot.

DoD/MIL Doc: JSSG-2007A: para A.3.7.6/A.4.7.6, Engine Health Monitoring Systems (EHMS), the Interface Control Document (ICD) and the pilot's operating manual

FAA Doc: 14CFR references: 33.28

**7.2.4.2** Components: mechanical and electrical.

**7.2.4.2.1** Verify that any uncontained failure of an engine control or subsystem component with rotating parts does not adversely affect the continued safe operation of the air vehicle.

Standard: Containment of failed components with rotating parts (i.e., pumps, turbochargers, etc.) provides protection against damage to neighboring critical systems or components.

Protection of critical systems and components from the uncontained failure of neighboring components minimizes their exposure to secondary failure.

Non-rotating parts with sharp edges cannot come into contact with rotating parts and result in an uncontained failure.

Compliance: Analysis of components' damage tolerance design characteristics, location and orientation demonstrates their ability to continue to meet specification requirements when exposed to an uncontained failure of a neighboring system or component. Analysis of components' protections (shields, locations, orientations, etc.) demonstrate they are protected and can continue to meet specification requirements when exposed to an uncontained failure of a neighboring components.

DoD/MIL Doc: JSSG-2007A: para A.3.7/A.4.7, Subsystems, engine subsystem component design and verification.

JSSG-2007A: para A.3.4.1.7/A.4.4.1.7, Damage Tolerance.

JSSG-2007A: para A.3.4.1.6.3/A.4.4.1.6.3, Containment, component containment design requirements.

FAA Doc: 14CFR references: 33.19, 33.94

**7.2.4.2.2** Verify that changes in bearing thrust balance do not result in the bearing operating in failure prone regions of operation.

Standard: Engine bearings can withstand the maximum expected changes in load and load direction (crossover) across the entire operating envelope.

Compliance: Analysis followed by full-up instrumented engine testing ensures engine bearing radial and thrust loading is within design limitations.

DoD/MIL Doc: JSSG-2007A: A.3.4.1.6.9/A.4.4.1.6.9, Bearing Load.

FAA Doc: 14CFR references: 33.93

**7.2.4.2.3** Verify that all engine mounted tubing, manifolds and clamps are safely affixed and routed on the engine.

Standard: External hardware is mounted/routed such that there is no interference or contact with neighboring components or the engine structure and that no wear or chaffing conditions exist. Typical clearances are 1 inch and are usually documented in the engine specification and Interface Control Document.

The orientation and routing of fuel and oil tubes/lines meet engine specification requirements by providing separation from all potential sources of extreme temperatures or ignition such

as electrical components, cables and hot air bleed lines.

Compliance: Inspection and analysis of engine externals drawings and hardware, mock-ups and an engine installation demonstration verify that there are no interferences, chaffing conditions or ignition sources.

Comm'l Doc: ARP 994, Tubing/Plumbing Routing

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.3/A.4.1.1.3, Interface Loads, A.3.11/A.4.11, Controls and Externals Verification, the Interface Control Document (ICD).

FAA Doc: 14CFR references: 33.5

**7.2.4.2.4** Verify that all engine mounted tubing, manifolds and clamps do not contain natural frequencies within the engine and subsystems operating ranges.

Standard: Engine mounted tubing, manifolds and clamps do not contain natural (resonant) frequencies within the engine or air vehicle drive operating range or have adequate damping provisions to prevent resonances, damage or failure.

Engine mounted tubing, manifolds and clamps withstand a full blade out vibration excitation without failure.

Compliance: Analysis and vibration surveys (ping testing) and vibration (shaker table) testing on external components, tubes/manifolds and lines ensures natural frequencies are outside the engine and air vehicle drive system operating range or are sufficiently damped to prevent damage or failure.

Analysis and engine testing results confirms the externals capability to withstand excitations resulting from a blade out condition.

DoD/MIL Doc: JSSG-2007A: para A.3.11/A.4.11, Controls and Externals Verification.

FAA Doc: 14CFR references: 29.993

**7.2.4.2.5** Verify that all pressure vessels, tubes and manifolds have design margin for their maximum operating conditions.

Standard: Pressure vessels and lines withstand 1.5X (proof) normal operating pressures (without performance degradation or leakage) and 2X (burst) maximum operating pressures (without permanent deformation or leakage).

All pressure vessels and fluid carrying tubes/manifolds withstand the maximum amount of pressure cycles encountered during normal engine operation.

All fuel components and lines are fire resistant and all oil carrying components and lines are fireproof.

All critical connections include visually verifiable redundant locking features.

Tubing and lines meet damage tolerance/leak before burst criteria.

Compliance: Analysis and bench top (1.5X) proof and (2X) burst pressure component testing ensures adequate safety margin across the entire flight envelope.

Analysis and bench top pressure cycle testing ensures the components and lines do not leak or rupture during operation.

Fire resistance is demonstrated by testing with a 2000 degree F flame for 5 minutes with no flame propagation.

Fireproof is demonstrated by testing with a 2000 degree F flame for 15 minutes with no flame propagation.

Inspection and analysis of engine externals drawings and hardware, mock-ups and an engine installation demonstration verify the existence of redundant locking features for critical connections. Analysis of design review information ensures a damage tolerant/leak

before burst capability.

Comm'l Doc: SAE-AS1055B, Fire Testing

DoD/MIL Doc: JSSG-2007A: para A.3.4.1.6 to A.4.4.1.6, A.3.7.3.2, A.4.7.3.2 and A.3.7.8, A.4.7.8, pressure vessel proof and burst testing.

JSSG-2007A: para A.3.1.8.1, A.4.1.8.1, Flammable Fluid Systems, fire resistance and fire proof testing.

**7.2.4.2.6** Verify that engine gearboxes have design margin for their maximum operating conditions.

Standard: The gearbox provides sufficient mechanical speed, power and torque to all mounted components.

All internal gears are free from damaging resonance at all speeds up to the maximum overspeed condition.

Compliance: Analysis, bench and engine testing verify the gearbox ability to support all mounted components.

Analysis and vibration testing identify and evaluate any internal gearing resonances.

DoD/MIL Doc:JSSG-2007A: para A.3.7.16/A.4.7.16, Gearbox.

**7.2.4.2.7** Verify that failure of any gearbox mounted component (oil pumps, fuel pumps, starters, generators, etc.) does not result in failure of the gearbox itself.

Standard: The gearbox and mounted components allow disengagement (shear sections) prior to causing secondary damage to the gearbox or other components.

Components whose continued operation is required to maintain safe air vehicle operation, do not contain shear sections.

Compliance: Analysis and inspection of the gearbox and mounted components ensures adequate disengagement provisions have been incorporated into the design.

DoD/MIL Doc: JSSG-2007A: para A.3.7.16/A.4.7.16, Gearbox.

**7.2.4.2.8** Verify that failure of the engine power take-off (PTO) coupling assembly does not adversely affect safe operation of the air vehicle.

Standard: The PTO coupling assembly prevents a post-failure PTO shaft from damaging surrounding hardware (anti-flail design).

Compliance: Analysis and inspection of the PTO drawings and hardware ensures a failed coupling cannot damage surrounding hardware.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.10/A.4.1.1.10, Power Take-Off and A.3.7.16/A.4.7.16, Gearbox.

MIL-HDBK-516 criteria 7.2.5.1.3.

**7.2.4.2.9** Verify that all engine mounted electrical components and cabling are safely affixed and routed on the engine.

Standard: Minimum specified clearances (typically 1 inch) are maintained with adjacent components and engine and air vehicle structure and that no wear or chaffing conditions exist.

The separation between combustible fluids and potential ignition sources meets engine specification requirements.

Safety critical electrical connectors contain visually verifiable redundant locking features.

Dielectric strength and explosion proof capability exists.

Compliance: Inspection and analysis verifies adequate clearances, no wear or chaffing conditions exist,

adequate separation between combustible fluids and ignition sources and safety critical connectors contain visually verifiable redundant locking features.

Bench testing verifies dielectric and explosion proof capability.

Comm'l Doc: SAE-AS-50881, for required clearances for electrical cables, and requirements for appropriate selection and installation of wiring and wiring devices.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.3/A.4.1.1.3, Interface Loads and A.3.7.4/A.4.7.4, Electrical System.

MIL-STD-464A, for requirements for proper bonding and grounding

FAA Doc: 14CFR references: 33.5

**7.2.4.2.10** Verify that all engine mounted electrical components and cabling can safely operate in the lightning and electromagnetic effects environment of the air vehicle.

Standard: All engine mounted electrical components (i.e., electronic controls, alternators/generators, cables, wires, sensors, etc.) can safely operate when exposed to the worse case expected electromagnetic (EMI), nuclear (EMP) or lightning induced energy environments.

All engine mounted electrical components do not generate or emit EMI that could affect the continued safe operation of any engine or aircraft mounted electronic system or component.

Compliance: Analysis of the air vehicle EMI, EMP and lightning threat/exposure environment and the engine EMI generation characteristics determines the types and levels of verification testing to be accomplished. Control and electrical subsystem closed loop bench testing verifies the engine EMI, EMP and lightning operational capabilities meet engine specification requirements.

Safety of Flight Testing (SOFT) evaluates the engine's ability to meet specification requirements when installed inside the air vehicle.

DoD/MIL Doc: For guidance on engine EMI, EMP, and Lightning design and verification testing:

JSSG-2007A: para A.3.3.3/A.4.3.3

MIL-STD-461E

MIL-STD-464A.

FAA Doc: 14CFR references: 33.28

**7.2.4.2.11** Verify that all engine mounted electrical components and associated cabling do not react to engine or air vehicle induced vibratory and acoustic excitations.

Standard: All components and cabling are designed such that their natural frequencies are outside the engine and air vehicle operating range or have adequate damping provisions to prevent resonances, damage or failure.

Compliance: Analysis of vibration surveys and vibration (shaker table) testing on components and cabling verifies capability to operate in the expected vibratory environment and that natural frequencies are outside the engine operating range.

Full-up engine testing, with vibration measuring instrumentation, provides assurance that electrical components and cabling can safely operate within the engine operating envelope.

DoD/MIL Doc: JSSG-2007A: para A.3.11/A.4.11, Controls and Externals Verification and A.3.7.4/A.4.7.4, Electrical System.

FAA Doc: 14CFR references: 29.993, 33.5

**7.2.4.2.12** Verify that electrical power is supplied to all safety critical engine systems under all flight conditions.

Standard: The engine driven alternator/generator is adequately sized to provide safe and reliable

electrical power at all specified engine speeds.

Back-up power is supplied by the air vehicle for all engine safety critical systems and components.

Compliance: Analysis of the engine's total power consumption establishes the power required to be generated by the alternator, generator and air vehicle.

Analysis, bench and engine testing demonstrate the ability to meet the electrical power generation requirements of the engine specification, when not installed in the air vehicle.

Flight testing demonstrates the engine's ability to meet the electrical power generation requirements of the engine specification, when installed in the air vehicle.

Inspection and test of the air vehicle's power generation and battery systems demonstrate their ability to meet the back up power requirements of the engine specification.

DoD/MIL Doc: JSSG-2007A: para A.3.7.4/A.4.7.4, Electrical System.

FAA Doc: 14CFR references: 29.993, 33.5

### **7.2.4.3** Computer resources and software.

*See section 15.*

Standard: Engine controls and monitoring devices that use computers and software meet all applicable criteria of Section 15.

Compliance: Engine controls and monitoring devices that use computers and software meet all applicable criteria of Section 15.

Comm'l Doc: IEEE/EIA 12207.0, IEEE/EIA 12207.1, IEEE/EIA 12207.2 and RTCA DO 178.

DoD/MIL Doc: JSSG-2007A: para 3.8/4.8 Software Resources.

FAA Doc: 14 CFR reference: 33.28

### **7.2.5** Installations.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.4.2, A.3.3.2, A.4.3.2.

FAA Doc: 14CFR reference: 23.901-23.1203, 25.901-25.1207, 23.1305, 25.1305, H25,

AC 20-128

(Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.)

### **7.2.5.1** Physical Installation.

#### **7.2.5.1.1** Verify that all engine/air vehicle physical interfaces such as mechanical, fluid, and electrical connections are safe.

Standard: All engine to air vehicle interfaces meet all safety related requirements as defined in the Interface Control Document (ICD).

All engine to air vehicle interfaces remain securely connected and do not leak when subjected to the operating conditions (vibration, temperature, etc.) of the air vehicle.

All engine to air vehicle interfaces are free of any contact with neighboring components that result in a wear or chaffing condition.

All engine to air vehicle interfaces can withstand the maximum combination of static and dynamic loading throughout the defined flight and ground envelopes and environments. All safety critical engine to air vehicle interfaces are fault tolerant or fail safe with no single failure or combination of failures having a loss of air vehicle probability greater than one in ten million.

Compliance: Inspection of the hardware and a demonstration of installing the engine ensures ICD requirements are met.

Analysis, full-up engine and flight tests ensure interface loads are within design limitations.

Analysis and inspection of the interfaces, with the engine installed in the air vehicle, verifies the absence of wear or chaffing conditions.

Engine/Air Vehicle physical interface requirements are verified by inspection of program documentation such as interface control and design documents. System interfaces are analyzed to withstand maximum loading at worst case single failure operating and loading conditions (bending/torsional loads, pressures, temperatures, vibratory, etc.).

System interface critical analysis assumptions are verified by stress, thermal, pressure or vibration surveys during ground and flight tests as appropriate.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.3, A.4.1.1.3, Interface Loads.

FAA Doc: 14CFR references: 33.5

**7.2.5.1.2** Verify that the aircraft/engine mounts contain adequate design margin to secure the engine properly under all operating conditions and failure modes.

Standard: The engine is securely retained in the air vehicle at all flight, takeoff, landing, and ground operating conditions.

The engine mounts withstand all limit loads, resulting from air vehicle maneuvers and engine failures, without permanent deformation.

The engine mounts withstand all ultimate tensile strength loads without complete fracture.

The engine mounts keep the engine from entering the flight deck or passenger compartments in the event of a crash landing. The engine mounts meet established durability, strength and damage tolerance design requirements.

Compliance: Analysis, full-up engine and flight testing ensures the mounts retain the engine under all operation and known failure conditions.

Engine mount testing ensures adequate design safety margins.

Analysis of the engine mount design review data and drawings ensure a damage tolerant design.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.4, A.4.1.1.4, Mounts, A.4.10.12, A.5.10.12:

MIL-HDBK-1783B, Engine Structural Integrity.

FAA Doc: 14CFR references: 33.5, 33.23

**7.2.5.1.3** Verify that, when applicable, the installed power-take-off (PTO) shaft system is free of any potentially damaging resonant conditions (refer to section 8.6 for additional details) for all loads and modes of operation.

Standard: Installed power-take-off (PTO) system withstands vibratory induced loads from startup to maximum operating speed under any combined expected torsional (power extraction) and air vehicle maneuver induced loading. System contains no natural (resonant) frequencies within the normal operating range or has adequate damping provisions to prevent resonances, damage or failure.

Compliance: Inspection of design criteria establishes suitable critical speed margins that accommodate manufacturing variation, wear and unknown system dynamics. Analysis (e.g., dynamic model) of end to end system predicts compliance with the speed margin goal. Analysis results evaluate the capability of the system components to withstand excitations. Component tests validate response, stiffness and other characteristics used in the analysis. Installed system vibratory response testing verifies critical speed margin and is consistent with the analysis. (A static type test typically shows lower margins due to lack of dynamic

stiffening effects, whereas a dynamic test with a shaker is typically more definitive and desirable but not always possible due to installation constraints.) System run up tests reveal no actual or impending resonance conditions throughout the operating speed range.

**7.2.5.1.4** Verify that the probability of failure due to uncontained rotating parts damaging air vehicle safety of flight (SOF)/critical safety items (CSIs) is acceptable.

Standard: The severity of all hazards associated with uncontained failures are reduced to an acceptable level or have residual risk accepted IAW MIL-STD-882.

Compliance: Inspection of the safety analyses documentation verifies that hazards associated with uncontained failures are reduced to an acceptable level.

**7.2.5.1.5** Verify that clearance between the air vehicle and engine (including associated components, plumbing, and harnesses) is maintained under all operating conditions within the ground and flight envelopes.

Standard: Except at controlled interfaces, Engine/Air Vehicle physical separation is maintained under all operating conditions within the ground and flight envelopes. Static clearances of no less that one (1) inch is provided unless positive clearance is validated under operational loading.

Compliance: Engine/Air Vehicle clearance requirements are verified by inspection of design documentation. System clearances are validated by inspection of system design analysis and simulation which properly accounts for flight loads and thermal growth. System design analysis and simulations are validated by first article inspections and flight tests.

**7.2.5.1.6** Verify that drain systems have sufficient capacity, operate throughout required ground and flight attitudes and regimes, and expel/store the fluids in a safe manner.

Standard: Propulsion system drain and vent system accommodates the combined maximum engine leakage and ventilation flow rates. No flight conditions inhibit the function to the extent that engine operation is impacted or a hazardous condition is created. Storage or expulsion of the fluids and vapor do not create a hazardous condition to the air vehicle, personnel or environment.

The drain systems provide isolation to the source of the leak.

Compliance: Propulsion drain and ventilation system sizing is validated by inspection of design documents and analysis identifying flow requirements and volume capacities for projected missions. System operation under ground attitudes and flight conditions are validated by analysis of in-flight pressure gradients and attitudes. Analysis assumptions (e.g., pressure gradients, attitudes, etc) are validated by ground and flight test. Storage or expulsion hazards of fluids are validated by inspection of System Safety documentation.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.8, A.4.1.1.8, for design and verification guidance for drains.

**7.2.5.1.7** Verify the engine air inlet components have adequate structural margin to withstand the over-pressures generated by inlet/compressor anomalies.

Standard: Engine air inlet components withstand proof pressure of 1.5 X max over-pressure (inlet stall) without degradation in performance or permanent deformation.

Note: The inlet structure design is governed by section 5 requirements.

Compliance: Engine air inlet components requirements are verified by inspection of design documents. Maximum induced inlet stall pressures generated by inlet/engine anomalies are validated by inspection of analyses and/or test. Capability of the components to withstand 1.5X inlet stall pressure is verified through component proof analysis and test.

**7.2.5.1.8** Verify accessibility to propulsion-system-related equipment for the performance of required servicing, inspections, and maintenance.

Standard: Required installed propulsion system servicing, inspections, and maintenance activities can

be accomplished by the multivariate maintainer population. Access accommodates the maintainer's anthropometric dimensions and strength limitations, taking into consideration all environmental conditions, and any required mission equipment (chemical protective gear, gloves, etc.).

Compliance: Inspection of design criteria (to include Interface Control Document data) establish required servicing, inspections and maintenance requirements. Analysis of virtual models or physical mock-ups verify accessibility to required servicing, inspection and maintenance areas. Technical Order verification demonstrates ability to accomplish and verify required tasks.

**7.2.5.1.9** Verify that airframe and propulsion systems eliminate sources of self-induced foreign/domestic object damage (FOD/DOD) to engines.

Standard: Airframe equipment, fasteners, etc., upstream of the installed propulsion system are properly secured to prevent damaging ingestion or functional loss of the engine.

Compliance: Inspection and analysis of documentation (e.g., FMEA, FMECA, SHA, SSHA) of systems within or upstream of the inlet verifies the absence of FOD generating failure modes. Inspection verifies that manufacturing and maintenance procedures contain FOD control practices.

**7.2.5.2** Functional installation.

**7.2.5.2.1** Verify that functional compatibility of the integrated system is safe.

Standard: Engine/Air Vehicle interfaces maintain functional compatibility throughout all normal operating and flight conditions. Hazardous conditions to interfacing subsystems do not result from normal or abnormal operation of the associated subsystem. Critical functional interfaces are fault tolerant or fail safe to the extent that no single failure or combination of failures result with probability greater than one in ten million result in loss of air vehicle.

Compliance: Engine/Air Vehicle functional interface requirements are verified by inspection of program documentation such as interface control and design documents. Integrated system functional compatibility is verified by simulation, test and demonstration of system functionality at integration test facilities and on the air vehicle during ground and flight test. Engine/Air Vehicle functional hazards and probability of air vehicle loss are verified by inspection of System Safety documentation.

**7.2.5.2.2** Verify that the engine can safely supply all customer extractions (bleed air, horsepower, electrical power, etc.) under all operating conditions.

Standard: Air vehicle bleed airflow requirements are met across the entire flight envelope.

The engine does not introduce foreign matter or contaminants into the air vehicle environmental control system that could damage its operation.

Air vehicle horsepower extraction requirements are met across the entire flight envelope.

Air vehicle electrical power demands are met across the entire flight envelope.

Compliance: Bleed air interface airflow and quality is verified by demonstration and test. Power takeoff horsepower extraction is verified by demonstration and test. Gearbox horsepower extraction is verified by analysis and test. Electrical power demands is verified by analysis, demonstration, and test.

DoD/MIL Doc: JSSG-2007A: para A.3.2, A.4.2 and A.3.7, A.4.7, engine performance and operability impacts of customer extractions.

JSSG-2007A: para A.3.1.1.7, A.4.1.1.7, bleed air interface design and verification.

JSSG-2007A: para A.3.1.1.10, A.4.1.1.10 and A.3.7.16, A.4.7.16, PTO horsepower extraction.

JSSG-2007A: para A.3.7.4.1, A.4.7.4.1, electrical power design and verification

requirements.

**7.2.5.2.3** Verify customer bleed air contamination does not exceed safe limits.

Standard: The engine does not introduce foreign matter or contaminants into the air vehicle environmental control system that could result in contaminating the pilot's breathable air supply.

Compliance: Customer bleed air contamination is verified by analysis and tests.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.7.1, A.4.1.1.7.1, customer bleed air contaminants guidance

**7.2.5.3** Inlet compatibility.

**7.2.5.3.1** Verify that the air induction system(s) functions under all expected ground, flight, and environmental (including ice, sand, and dust, as applicable) conditions without adversely affecting engine operation or resulting in engine damage.

Standard: All environmental conditions (e.g., Inlet ice accretion and separation, distortion, sand and dust ingestion, water ingestion, etc.) do not adversely impact engine performance and operability.

Compliance: Analysis and installed engine testing verifies inlet performance for all expected environmental conditions. For icing environments, analysis, icing tunnel or ground icing tests and/or flight tests reveal acceptable icing build up and/or levels of shedding that are compatible with the engine(s).

DoD/MIL Doc: JSSG-2007A: para A.3.3.2.4, A.4.3.2.4, for sand and dust design and verification; A.3.3.2.3, A.4.3.2.3, for ice ingestion guidance; A.3.2.2.11, A.4.2.2.11, distortion guidance; and A.3.3.2.5, A.4.3.2.5, for atmospheric liquid water ingestion guidance.

**7.2.5.4** Exhaust system compatibility.

**7.2.5.4.1** Verify that exhaust systems direct exhaust gases to the atmosphere clear of the flight crew, boarding or discharging passengers, externally mounted equipment, fluid drains, air intakes, and stores.

Standard: Exhaust plume(s) do(es) not: impinge on aircraft structure or equipment to the extent that their maximum temperatures are exceeded, impinge on or mix (except when designed) with any flammable fluid drainage or vapor discharge to the extent that the fluid/vapor auto ignition temperature is achieved or exceeded, impose an unavoidable hazard to flight/ground crew or impede a pre-flight/launch activity.

Compliance: Exhaust plume interaction with structure, fluid/vapor discharge, and flight/passenger/ground crew is validated by inspection of plume and thermal analysis and models. Acceptability of hazards is validated by inspection of system safety documentation.

DoD/MIL Doc: JSSG-2007A: para A.3.7.10, A.4.7.10, engine exhaust nozzle system design and verification.

JSSG-2007A: para A.3.1.8.2, A.4.1.8.2, A.3.1.8.5, A.4.1.8.5 and A.3.1.8.7, A.4.1.8.7, fire prevention, air and gas leakage and jet wake.

**7.2.5.4.2** Verify that thrust reverser/thrust vectoring systems are fail-safe and compatible with engine and air vehicle systems.

Standard: Thrust reverser/thrust vectoring operation does not adversely impact engine performance, operability or aircraft structure. No single failure or combination of failures with probability greater than one in ten million result in loss of air vehicle.

Forces and moments and dynamic response from the thrust vector are quantified and compatible with aircraft flying qualities.

Compliance: Analyses (e.g., Failure Modes Effects and Criticality Analysis, System Safety Hazard Analysis) verify the design is free from single or combined failures modes that would create an unacceptable risk hazard. Analysis of reverser flow field patterns verifies acceptable conditions relative to impingement, inlet ingestion (propulsive, environmental control system, ventilation, auxiliary power system, etc), and FOD/Sand & Dust generation. Ground tests demonstrate reverser safety features and compatibility with engines and airframe. Flight tests demonstrate safe reverser deployment and operation.

DoD/MIL Doc: JSSG-2007A: para A.3.1.1.12 to A.4.1.1.13, for exhaust system and thrust reverser interfaces design and verification guidance.

JSSG-2007A: para A.3.7.10, A.4.7.10, Exhaust Nozzle System and A.3.7.10.2, A.4.7.10.2, Vectored Nozzle.

**7.2.5.5** Environmental compatibility.

**7.2.5.5.1** Verify that engine bay/nacelle cooling and ventilation provisions are adequate to maintain the temperatures of power plant components, engine fluids, other bay/nacelle equipment and structure within the temperature limits established for these components and fluids, under ground and flight operating conditions, and after normal engine shutdown. (These provisions should be compatible with the fire protection certification criteria of 8.4.)

Standard: Criteria is self-explanatory.

Compliance: Temperature limit requirements are verified by inspection of design documentation. System thermal performance is verified by inspection of design analysis, thermal models and simulations. Engine bay/nacelle environments are verified by thermal surveys during ground and flight tests.

**7.2.5.5.2** Verify the installed vibratory compatibility of the engine/airframe system.

Standard: Airframe induced engine vibration does not exceed engine limits within the aircraft and engine operational envelope

Compliance: Airframe induced engine vibration is established by analysis, and ground and flight vibration tests which identify the response characteristics of the aircraft/engine to forced vibrations and impulses. Inspection of vibration response to demonstrated engine capability verify that limits are not exceeded.

DoD/MIL Doc: JSSG-2001B: para 3.3.1.1.2/4.3.1.1, exhaust integration design and verification requirements.

**7.2.5.5.3** Verify compatibility with shipboard jet blast deflectors.

Standard: Areas hazardous to personnel and equipment are appropriately defined and included in technical data. Any special restrictions on engine power setting or nozzle vector positions are defined and included in pilot instructions. Appropriate modifications to jet blast deflectors have been incorporated consistent with propulsion system jet wake characteristics and operating limitations.

Compliance: Propulsion system jet wake temperature and velocity characteristics for various power settings and nozzle vector angles are verified by analysis and test. Any modifications made to jet blast deflectors to ensure compatibility with the propulsion system are verified by analysis and test.

DoD/MIL Doc: JSSG-2007A: para A.3.1.8.7, A.4.1.8.7.

**7.2.5.6** Installation other.

**7.2.5.6.1** Verify that the air vehicle propulsion controls and crew station information are adequate for proper crew control and operation of the propulsion system.

Standard: Crew/operator station provides capability to reliably do the following: start and stop each engine independently, independently control/set thrust for each engine, assess engine operating condition to the extent necessary for flight safety. The system provides warnings, cautions and advisories to operators and maintainers for hazardous failure conditions.

Compliance: Crew/operator station propulsion control capabilities are validated by inspection of design documentation, analysis (FMEA, FMECA, Sneak circuit, common cause, software etc.) that reveal reliable control, and tests (software and hardware) in integration facilities and on the air vehicle demonstrating proper functionality. Warnings, cautions and advisories to operators and maintainers for hazardous failure conditions are validated by inspection of design and system safety documentation, tests (software and hardware) in integration facilities and demonstration at the air vehicle level.

DoD/MIL Doc: JSSG-2001B: para 3.4.3.1.6/4.4.3.1.6 and MIL-STD-411.

## 7.3 Alternate propulsion systems.

**7.3.1** Propeller driven systems.

DoD/MIL Doc: JSSG-2007: para A.3.3, A.4.3, A.3.4, A.4.4, A.3.11, A.4.11, A.3.12, A.4.12

FAA Doc: 14CFR references: 33.14, 33.19, 33.63, 33.75, 33.76, 33.77, 33.90, 33.94, 33.97

AC 33.1B, AC 33.3, AC 33.4, AC 33.4-2, AC 33.5

**7.3.1.1** Verify that adequate margins exist for the performance, strength, and durability of the following: propeller and propeller system components, including the propeller drive shaft, reduction gearbox, torque measurement system, negative torque system, propeller brake, and mechanical over-speed governor.

Standard: Propellers provide sufficient performance to ensure the capability of the weapon system to accomplish established missions. The propeller steady state performance is defined by a steady-state performance computer program.

During all permissible power transients and times of accomplishment of such transients established for the engine, the propeller response is compatible with the transient engine performance requirements stated in the engine model specification. Transient response of the propeller system is defined by a transient performance computer program.

All propeller steady-state and transient operating limits (maximum, minimum) are specified for all modes of operation. The limits are predicated on the most critical tolerances of the propeller. The propeller system operates satisfactorily in all thrust modes up to these limits.

Engine negative torque signal input is provided.

Structural design considerations include the application of appropriate limit and ultimate load factors.

Compliance: Compliance of each standard is demonstrated through a combination of component, stand and systems tests as follows:

Component Testing

Propeller components including the blades and barrel, pitch changing mechanism, pitch lock, negative torque signal, control unit, and ice control system are durability tested to establish their capability to perform their function for the period established in the model specification or 1,500 hours between overhaul. A complete teardown inspection has been conducted at the conclusion of the test.

Whirl Stand Testing

Stand testing is conducted to calibrate sea level performance characteristics, demonstrate durability, overspeed capability and feathering.

DoD/MIL Doc: JSSG-2009: para L.3.4.12/L.4.4.12 and L.3.4.12.4/L.4.4.12.4, performance and structural design and compliance methods.

**7.3.1.2** Verify that any critical propeller speeds (e.g., speeds that excite resonant frequencies and cause detrimental blade stresses) are outside the engine operating range or identified limitations are placed in the appropriate operators and maintenance technical manuals (T.O.'s).

Standard: The propeller system is free of destructive vibrations at all steady state and transient operating conditions and is capable of balancing to remove vibration that could cause equipment to operate below specified requirements or cause excessive crew discomfort. The propeller is free from flutter in both forward and reverse thrust modes under conditions up to 120 percent of maximum rated engine speed and at powers up to the standard day maximum take-off power rating of the engine. Propeller critical speeds existing below the operating range are at least 20 percent below the minimum steady state operating speed.

Compliance: Compliance is demonstrated through a combination of stand, system ground tests and flight testing as follows:

Whirl Stand Tests

A vibration stress survey conducted on the whirl stand establishes the stress characteristics of the hub and blade and the flutter characteristics of the blade. The data obtained in this survey defines the test operational limitations for subsequent testing of the propeller on the whirl rig. Blade angle settings for the test are selected so that, if flutter is present, a flutter boundary can be determined for the propeller.

Propeller and Engine Test Stand Tests

A vibration stress survey of the propeller covering all appropriate conditions of engine operation on the test stand defines the stress characteristics of the engine and propeller system. Measured stresses for any vibratory modes within the operating range are within the allowable material limits (reference 7.3.2, 7.3.7).

Flight Vibratory Stress Survey

A flight vibratory stress survey of the propeller on all nacelles of the air vehicle establishes the stress characteristics of the propeller when operated in the air vehicle environment. Measured stresses for any vibratory modes within the operating range are within the allowable material limits (reference 7.3.2, 7.3.7). Safe operation is demonstrated in all modes of use.

DoD/MIL Doc: JSSG-2009: para L.3.4.12/L.4.4.12 and L.3.4.12.6/L.4.4.12.6, propeller vibration and flutter criteria and compliance methods.

FAA Doc: 14CFR references: 33.43, 33.83, 33.63

**7.3.1.3** Verify the safety and functionality of the hardware and software components of propeller reversing systems and pitch controls for all steady state, transient, and emergency operating conditions.

Standard: Risk levels must meet established safety thresholds for safe operation (example: < 0.5/1MEFH non-recoverable in-flight shutdown and < 0.5 Class As prior to next inspection opportunity). All identified single point failures have acceptable risk mitigation procedures in place.

Overspeed during propeller reversal is compatible with engine overspeed limits. The primary features of the self-contained type propeller control systems function independently of the engine oil system or the air vehicle electrical system insofar as flight safety features

are concerned. The propeller control system includes an adequate mechanical pitch lock that engages in the event of overspeeding or loss of hydraulic pressure or similar failure.

Manual and automatic feathering systems are operational for all steady state, transient, and emergency operating conditions.

Compliance: A Failure Modes, Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities. Risk levels meet the safety thresholds.

Demonstration of satisfactory control of the propeller is accomplished through the control response test, the steady state check, the transient check and miscellaneous checks conducted as part of the engine and propeller test stand and air vehicle flight testing.

DoD/MIL Doc: JSSG-2009: para L.3.4.12/L.4.3.12.

FAA Doc: 14CFR references: 35.21

**7.3.1.4** Verify the safety of all physical and functional interfaces between the propeller and any system that drives the propeller.

Standard: The interfaces between the airframe and the propeller is established and controlled to ensure compatibility. The propeller and airframe contractors control the interface to ensure the propeller will work properly when installed in the air vehicle.

The allowable range of characteristics of the propeller at the engine interface is specified. No resonant frequency is transmitted to or from the engine through the propeller.

The propeller and engine control systems are compatible under all steady state, transient, and emergency operating conditions

Compliance: A Failure Modes Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities.

Testing: The propeller and engine system endures a 150 hr ground test. The system and hardware passes a variety of conditions and transients. A complete teardown check is performed afterward. Air vehicle flight tests demonstrate no detrimental interaction between the engine, propeller and air vehicle.

DoD/MIL Doc: JSSG-2009: para L.3.4.12/L.4.3.12.

FAA Doc: 14CFR references: 35.21, 35.39, 35.41

**7.3.1.5** Verify that the manual and automatic feathering systems are operational for all steady state, transient, and emergency operating conditions.

Standard: TBD

Compliance: TBD

DoD/MIL Doc: JSSG-2009: para L.3.4.12.1, L.4.4.12.1, feathering systems.

**7.3.1.6** Verify the compatibility of the propeller and engine control systems under all steady state, transient, and emergency operating conditions.

Standard: TBD

Compliance: TBD

DoD/MIL Doc: JSSG-2009: para L.3.4.12.5, L.4.4.12.5, control system compatibility.

**7.3.1.7** Verify that the propeller system is free of destructive vibrations at all steady state and transient operating conditions and is capable of balancing to remove vibration that could cause equipment to operate below specified requirements or cause excessive crew discomfort.

Standard: TBD; Synchrophasing

Compliance: TBD

DoD/MIL Doc: JSSG-2009: para L.3.4.12.6, L.4.4.12.6, guidance on vibration and balance.

**7.3.1.8** Verify that the propeller ice control system prevents the dangerous accumulation of ice during all operating conditions.

Standard: When required by operational and environmental usage, the propeller incorporates an ice control system for the blades, cuffs, and spinner. Either electrical, fluid, gas, compound, or mechanical ice control systems are used when approved by the procuring activity. The ice control system(s) are specified in the model specification. The type of ice control is continuous, cyclic, or a combination of both as specified in the model specification. Unless continuous ice control is provided, operation of the ice control system is accomplished either automatically or manually as specified in the model specification. Continuous operation of the ice control system in flight does not damage the propeller system.

Compliance: Analysis, component and rig testing verifies that the ice control system provides the necessary level of protection against ice formation throughout the required icing envelope.

DoD/MIL Doc: JSSG-2009: para L.6.3.1, for guidance on propeller anti-icing systems.

**7.3.1.9** Verify that the propeller can tolerate bird strikes.

Standard: The propeller blades and spinner are capable of withstanding the impact of a four-pound bird at the critical location(s) and critical flight condition(s) of the intended aircraft without causing a major or hazardous propeller effect.

Compliance: Component/rig tests or analysis based on tests verify the structural integrity of the propeller & spinner under bird ingestion conditions.

FAA Doc: 14CFR references: 35.36

**7.3.2** Rotary wing systems.

DoD/MIL Doc: JSSG-2007A: para A.3.3, A.4.3, A.3.4, A.4.4, A.3.11, A.4.11, A.3.12, A.4.12.

FAA Doc: 14CFR references: 33.15, 33.19

AC 33.3, AC 33.15-1

**7.3.2.1** Verify that the rotary wing and all associated components and systems (drive shaft, reduction gearbox, torque measurement system, negative torque system, brake system, and mechanical overspeed governor) provide sufficient power, torque, strength, and durability for safe operation at sea level hover and margin for vertical climb and hover throughout the flight envelope.

Standard: The rotary wing and all associated components and systems provide sufficient power to ensure safe operation of the air vehicle throughout its envelope. The steady state performance (horsepower and torque) described in the flight manual is consistent with delivered production engine performance and all installation effects.

The rotary wing and all its associated components and systems safely operate throughout the air vehicle and engine envelopes without any degradation in structural strength or durability. Strength and durability limitations include the application of appropriate limit and ultimate load factors.

The power drive subsystem is of a robust design capable of operating beyond its maximum rated condition for those instances where excursions may occur such as autorotation, other emergency conditions and defined transients. Excursion capabilities is defined as:

a. An input torque of at least 20 percent greater than the input for the subsystem maximum rating.

b. An output shaft speed of at least 20 percent greater than the maximum operating speed

of the power absorber.

System load limits are established.

Each gearbox of the power drive subsystem and associated components is rated at the most severe input power condition (torque and speed) for all allowed operating modes exclusive of transient conditions. Transient capability of the power drive subsystem is defined by the contractor relative to the specific application. The rating is based on the durability, dynamic response and structural integrity requirements specified.

Compliance: Analysis verifies the expected levels of power produced by the rotary wing and its associated components and systems. Rig testing verifies the rotary wing's ability to provide adequate power. Instrumented air vehicle/engine testing verifies the rotary wing and all associated components and systems provide the levels of power required to safely operate the air vehicle throughout its envelop.

Analysis verifies the expected strength and durability of the rotary wing and its associated components and systems for the expected life of the air vehicle. Rig testing verifies the rotary wing, its components and systems strength and durability limitations. Instrumented air vehicle/engine testing verifies the rotary wing and all associated components and systems operate safely as an integrated system.

Verification is performed incrementally by analysis and a series of bench and system level tests, to ensure structural integrity, endurance, performance, and capability to withstand all specified transient excursions, operational and environmental conditions, including emergency conditions and autorotation.

Typical drive system tests include:

a. Integrity / Overstress

b. 200 hr Production Configuration

c. System Level Pre-Flight Acceptance

d. 200 hr Verification (MQT)

DoD/MIL Doc: JSSG-2007A: para A.3.7.16, A.4.7.16.

JSSG-2009: para K.4.4.11, for drive system bench and system level testing.

FAA Doc: 29.1309

**7.3.2.2** Verify that the rotor system provides safe controllability of the air vehicle under all expected operating conditions.

Standard: The rotor system provides the required power response to maintain safe control of the air vehicle under all operating conditions, including loss of lubricant and OEI and autorotations.

Compliance: Analysis verifies the power response levels required to maintain safe air vehicle operation. Rig testing verifies that the rotary wing provides the expected power response. Instrumented air vehicle/engine testing verifies that the rotary wing properly responds to maintain safe control of the air vehicle.

DoD/MIL Doc: JSSG-2007A: para A.3.7.16, A.4.7.16.

FAA Doc: 14CFR references: 27.1143

**7.3.2.3** Verify that, for rotary wing air vehicles, the effects of high-energy, low-frequency vibrations, generated by main rotor blade passage (fundamental and harmonic) frequencies at all engine and related component operating speeds and powers, do not adversely affect the operation of the engine and the drive system.

Standard: Airframe induced engine vibration do not exceed engine limits within the aircraft and engine operational envelope.

High frequency vibration modes generated by the engine do not cause potentially damaging vibration to the propulsion subsystems or other parts of the aircraft

The engine - drive train system is free from potentially damaging vibration levels.

Compliance: Verification is by engine test. Vibration levels of engine and drive train components are monitored throughout the operating range of the helicopter, over the entire operational range of aircraft and rotor speeds, aircraft gross weights, and center of gravity limits.

DoD/MIL Doc: JSSG-2007A: para A.3.4.1.8, A.4.4.1.8, for engine vibration and dynamic response.

FAA Doc: 14CFR references: 29.907

**7.3.2.4** Verify, for rotary wing air vehicles, that a satisfactory interface is achieved between the engine (including subsystems/accessories) and the airframe relative to both high-frequency engine-excited and low-frequency air vehicle rotor(s) excited vibrations.

Standard: TBD

Compliance: TBD

DoD/MIL Doc: JSSG-2007A: para A.3.4.1.8, A.4.4.1.8, for engine vibration and dynamic response.

FAA Doc: 14CFR references: 29.907

**7.3.2.5** Verify that the transmission/gearbox lubrication system safely operates under all air vehicle operating conditions.

Standard: The system used to lubricate the drive subsystem gearboxes and associated accessories is independent from that used for other components and power plants and accomplishes the following:

a. Avoids contamination from other systems.

b. Allows the use of lubricants optimized for gearbox operation provided substantiating data verifies its benefits and logistics impact to the field.

c. Minimizes exposure of vulnerable areas. Precautions are taken to prevent cross contamination of the lubricant, the gearbox, and associated accessories.

The maximum allowable static and dynamic oil loss is specified.

Essential functional elements of the lubrication system include:

a. Gearbox Breathers

b. Lubrication Filtering

c. Filling Provisions

d. Gearbox Oil Drain

e. Lubricant Selection

f. Cooling System

g. Valves and Pressure Pumps

h. Oil Level Indication

i. Oil Leakage

Compliance: Verification is by analysis and testing at the element, component, and system levels. Analysis includes a functional description of the lubrication system indicating the limits of the lubrication system with respect to environments (high and low temperature) and air vehicle flight envelope limits (attitude and altitude) and associated schematics showing all components and indicating minimum flow rates to each oil jet. The design of the cooling system for all transmissions and gearboxes is substantiated by applicable schematics, analysis and pertinent testing. The cooling system or heat balance analysis includes

consideration of the highest ambient air condition specified herein, the minimum gearbox oil flow, the maximum allowable oil temperatures and the minimum cooling airflow as a basis for sizing the cooling system.

DoD/MIL Doc: JSSG-2007A: para A.3.7.8, A.4.7.8, Lubrication System.

JSSG-2009: para K.4.4.11.4, for lubrication element, component, and system level testing.

**7.3.2.6** Verify that unfavorable dynamic coupling modes do not occur when the engine, engine accessories, rotor system, and all dynamic transmission components are operated as a combined dynamic system.

Standard: The minimum margin from critical speeds is in the range of 20 to 30% above applicable speed. For super critical shaft operation, the margin is both above and below critical speed.

If supercritical shafting is used during transient operation, damping is provided to the extent necessary to prevent stress and deflection amplitudes from exceeding design allowables.

Range of vibratory characteristics at the power drive system interfaces are defined.

Vibration limits are defined.

The engine control system ensures adequate gain and phase margins to avoid torsional instabilities. It may be necessary to limit torsional spring rate within the power drive subsystem.

Compliance: Verification is through similarity analysis or a combination of analyses, static (such as rap testing of components to confirm modal prediction) and dynamic testing. Analysis shows all critical speeds in relation to operational speeds throughout the range of possible shaft misalignments. The critical speeds of all shafting are determined by demonstration. Demonstration of critical speeds on supercritical shafts include measurement of stresses at the critical speed to ensure they are within design limits. Data is provided to show the absence of dynamic coupling modes that are destructive or limit the use of the air vehicle for all permitted ground and flight modes. Data defines all power drive subsystem spring constants, inertia and damping coefficients for use in torsional stability assessments.

The power drive subsystem dynamic analysis consider engine control system interfaces to avoid torsional instabilities in the power drive subsystem.

Resonance frequencies and mode shapes are determined for each gear. For the gear resonance test, the dynamic stress levels in each gear are measured in locations sensitive to all significant vibratory modes. A speed scan from 0 to the speed of maximum overspeed is performed with:

a. Minimum load

b. Approximately 50-percent load

c. Maximum load

**7.3.2.7** Verify that the engine's control/rotor system torsional stability has required gain and phase margins and main rotor torque damping during steady-state and transient operation.

Standard: Note: In military helicopters engine/rotor transient requirements often lead to large power changes over short periods of time. An engine control that can respond rapidly to power changes is generally more susceptible to transient torsional oscillations than one with slow response.

The engine responds rapidly to low frequency signals such as pilot demanded power changes, while showing little or no response to high frequency signals, such as excitations at the natural frequency of the drive system. The system is designed to prevent amplification of drive train resonant modes.

The engine control is stable throughout the operational envelope of the helicopter and over

the operating range of the engine.

Control system gain margin is a minimum of 6dB for both single engine and multi-engine operation.

Drive train resonant peaks are attenuated by at least 6dB below unity gain.

Control system phase margin is between 30 degrees and 60 degrees for both single engine and multi-engine operation.

Compliance: Verification is by simulation, analysis, and test.

The analysis includes linearized models of the engine control loops and the rotor system. The control design is verified throughout the operational envelope of the helicopter, including ambient conditions, engine power level, airspeed, and degraded lag damper operation, etc. Open and closed loop bench testing of the control with a simulation of the engines and helicopter shows stable operation and compliance with the design goals of the engine control system.

Engine control system stability is evaluated by flight test. The pilot's controls (collective and/or cyclic) are cycled at the frequency of interest to demonstrate stable control response. Other methods that excite drive train torsional modes are also acceptable, such fuel flow interrupts or pedal inputs. Testing is conducted at multiple power levels and rotor speeds as necessary to show stable response throughout the operational envelope of the helicopter.

FAA Doc: 14CFR references:29.939

**7.3.2.8** Verify that the torque and misalignment capabilities of drive shaft couplings are suitable for all possible combinations of torque and speed when installed in the aircraft at the maximum permissible misalignment.

Standard: Replacement of coupling mechanisms do require realignment of the associated shafting.

Coupling mechanisms are identified as being subject to the damage tolerant requirements of "Durability" and its subparagraphs in this appendix.

Couplings are the dry type to avoid the necessity of doing maintenance checks before every flight. Couplings are fail-safe. Replacement of couplings do not cause realignment of the associated shafting.

Compliance: To substantiate compliance with the requirements, the following test as a minimum is completed on a coupling that is representative of the production units.

a. Two couplings undergo an endurance fatigue test run at the maximum permissible misalignment and at 110% of the maximum torque seen by the coupling in service.

b. One of the above couplings is run until inspection reveals the coupling has become unserviceable. The test continues until three times the normal inspection period for the coupling has elapsed. The coupling does not fail to transmit torque within that time interval. If the coupling is so designed as to not become unserviceable within an acceptable period of testing, then a determination as to the safe inspection interval is made at that time.

**7.3.2.9** Verify that the rotors can be held from rotating in winds at specified velocities and directions, during engine nonoperation, power up, and ground idle conditions.

Standard: A means of preventing rotation of the rotor in winds up to 45 knots is provided. The system is capable of being operated from the cockpit, and capable of 1000 engagements without failure of any of the parts.

Compliance: Analyses include heat generation, provisions for isolation from flammable materials or fluids, energy absorption rate and effects on the dynamic response of the transmission. Component bench and system level testing demonstrate the capability to keep the rotors from rotating when exposed to the specified conditions. The brake's ability to perform the specified repeated single engine startup cycles at the specified power without failure is

demonstrated by component endurance tests and a limited demonstration at the system level.

The system level test demonstrates the ability of the engine interlock safeguard system to prevent actuation during specified periods.

**7.3.2.10** Verify that the normal and emergency braking systems (consisting of aerodynamic rotor drag and subsequent mechanical braking) are capable of stopping the rotor, from 100% speed, within specified times after engine shutdown.

Standard: The rotor brake system is capable of stopping the rotor 400 times, without replacement of any part, from 100% speed within the specified duration after engine shutdown.

The minimum stopping time is based on a structural analysis to protect power drive subsystem gears and components from overloads due to sudden stops.

Engine control interlock safeguards are provided to prevent inadvertent actuation of the system. The brake cannot be applied if the control is forward of the ground idle position.

When the rotor brake is applied, slippage of air vehicles under various ground conditions is prevented.

Compliance: Analyses verifies margins against heat generation limits, provisions for isolation from flammable materials or fluids, transmission energy absorption rate limit. Component bench and system level testing demonstrate the capability to keep the rotors from rotating when exposed to the specified conditions. Component bench and system level testing demonstrate the ability of the brake to stop the rotor within the specified stop time (at the specified engagement speed) and number of braking cycles from the specified speed for both normal and emergency operation.

The brake's ability to perform the specified repeated single engine startup cycles at the specified power without failure is demonstrated in component endurance tests and a limited demonstration at the system level.

The system level test demonstrates the ability of the engine interlock safeguard system to prevent actuation during specified periods.

**7.3.2.11** Verify that rotor system condition monitoring provides warning of impending failure that could result in loss of the air vehicle or prevent a safe landing.

Standard: Applicable elements of the rotor system condition monitor, listed below, are configured for incorporation with other subsystems into any planned integrated diagnostic system.

a. Debris monitoring. Debris monitors capable of detecting oil borne particles for the purpose of identifying an impending failure are used on all gearboxes and transmissions. The monitors are capable of isolating faults to each gearbox or module. The monitors are insensitive to normal wear debris.

b. Lubrication System- Oil Pressure and Temperature. The oil operating temperature and pressure (for pressurized systems) provide continuous real time indications of out-of-control limits to cockpit instrumentation.

c. Health monitoring. Sensor number and location are selected to isolate the condition of critical rotating

components including drive shafts, heat exchanger blowers and internal gearbox components. Sensor mounting positions are provided as an integral part of the gearbox and drive shaft system design.

d. Usage monitoring. A system is provided for accurate in-flight monitoring of the power drive subsystem operational usage (power and time) for life management of specified components.

Compliance: Inspection and analysis of designs, schematics and functional descriptions of the monitoring

systems verifies compliance with requirements.

The following tests apply to the elements of the rotor system monitor functions:

a. Debris monitor. Debris monitor testing demonstrates the ability to detect debris of the size, shape and material specified, the characteristic of debris considered abnormal and its insensitivity to normal wear. Component level testing demonstrates capture efficiency.

b. Lubrication System - Oil Pressure and temperature. Full up rig, engine and flight testing demonstrates the required monitoring capability of the lubrication system.

c. Health monitoring. Testing identifies a characteristic normal baseline for applying diagnostic indicators to isolate mechanical component faults. Data is recorded in a manner that can be used for incorporation into any planned integrated diagnostic system. The number of sensors, tachometer frequency, recorder specifications and record length are selected so as to adequately isolate the characteristics of the dynamic components in each gearbox.

d. Usage Monitoring. Testing demonstrates acceptable and accurate in-flight monitoring of the power drive subsystem operational usage (power and time).

**7.3.2.12** Verify that the drive system permits engagement and disengagement of the engines from the load absorbers as required for all applicable modes of air vehicle operation.

Standard: For rotary-wing air vehicles in autorotation mode, the engine(s) not supplying torque is immediately and automatically disengaged from the power drive subsystem. For multi-engine air vehicles conducting single engine operations, the engines not supplying torque are similarly disengaged to permit continued operation of the rotor system and accessory drive for 2 hours without damage to the overrunning mechanism.

The number of engagements without losing the ability to transmit the required power (torque and speed) are consistent with operations.

Compliance: The following bench tests demonstrate compliance:

a. Static torque test. During the static torque check, the torsional spring rate (angular deflection of the outer race relative to the inner race) of the clutch is determined. Static torque is gradually increased until the occurrence of slip such that further torque increase is not possible. The torque transmitted is based on the limit of system dynamic loads as determined by test or equal to 200 percent maximum rated torque.

b. Cyclic fatigue (stroking) test. Stroking tests are performed to define the clutch's fatigue characteristics.

c. Overrunning test. The overrunning clutch test is conducted in two parts for two hours each. The first is a differential overrunning test at 100 percent differential speed (the clutch driving member stationary and the driven member at 100 percent speed). The second overrun test is to the worst case engagement element pressure velocity (PV).

d. Cold temperature engagement test. The clutch is subjected to cold temperature engagement tests, using specified lubricants.

e. Clutch durability test. A minimum of 2,400 clutch engagements is conducted on two of each clutch configuration of the power drive subsystem. In each engagement, the clutch is loaded to rated torque and speed after engagement. The clutch engagements include a minimum of 1500 dynamic engagements, for example second engine starts, practice autorotation (for engine clutches), in percentages that estimates usage. A dynamic engagement is defined as a condition where the clutch engages a rotating shaft in a manner that simulates how it will be used in service. The time between engagements represents the minimum time expected in usage. After completion of the 2400 engagements, the static torque test is conducted to verify component condition.

**7.3.2.13** Verify that, during a loss of the primary lubrication system, the gearboxes continue to function and transmit required power until appropriate pilot action can be accomplished.

Standard: Gearboxes function for at least 30 minutes after complete loss of the lubricant from the primary lubrication system and are in a condition such that the gearbox is still capable of transmitting the required power and that no components are in a state of imminent failure. The operational conditions are such that the loss of lubricant occurs at the most severe power condition and that the air vehicle can transition to cruise and land vertically at the end of the thirty minute period. The power drive subsystem is capable of safe operation in the overrunning mode for at least 30 minutes with complete loss of gearbox lubricant. If an emergency lubrication system is used, any resulting attitude limitations during loss of lubricant operation are defined.

Compliance: Two thirty minute tests are conducted with teardown inspections. Testing is conducted after completion of the system level verification test described in criteria 7.3.2.1d. Transmission and gearbox lubrication systems are starved at the system's supply side (downstream from the pump) and continue to scavenge. Operation is demonstrated for a thirty minute period, as follows:

a. Two minutes at rated power to simulate hover.

b. Twenty six minutes at a power condition to simulate cruise.

c. Two minutes at a power condition simulating vertical landing.

Creditable run time starts at the point at which the cockpit low oil pressure warning would be displayed. For non-pressurized gearboxes, creditable run time starts when the oil being drained from the gearboxes ceases to flow in a steady stream. The transmission is configured in an air vehicle attitude simulating the cruise power condition. For a VTOL air vehicle, the test spectrum and attitudes are commensurate with expected field use. A thirty minute loss-of-lubrication overrunning test consistent with the loss-of-lubricant test spectrum above demonstrates the ability of continued safe operation.

**7.3.2.14** Verify that inadvertent operation of externally phased intermeshing-rotor systems cannot occur if the rotors become dephased and that cockpit indications are provided to the pilot.

Standard: Dephasing devices are provided with positive mechanical interlocks to prevent operation of rotors unless they are locked in phase.

Compliance: Verification is by analysis and demonstration. Analysis and demonstration is accomplished during system level verification in compliance section of criteria 7.3.2.1d.

**7.3.2.15** Verify that failure or seizure of any individual accessory does not cause damage to any power drive subsystem components during all phases of air vehicle operation.

Standard: For rotary-wing air vehicles, accessories are driven whenever the rotor system is rotating including during autorotation.

Accessory drive splines are protected from wear with non-metallic inserts or are positively lubricated with oil when functioning.

Compliance: Testing and inspection is accomplished during system level verification of power drive subsystem performance in the compliance section of criteria 7.3.2.1.d.

**7.3.3** Reciprocating engines.

DoD/MIL Doc: JSSG-2007A: para A.3.3, A.4.3, A.3.4, A.4.4, A.3.11, A.4.11, A.3.12, A.4.12.

FAA Doc: 14CFR references: 33.83

**7.3.3.1** Verify that reciprocating engines meet 14 Code of Federal Regulation (CFR) certification as used for the military mission.

Standard: Criteria is self-explanatory.

Compliance: Comparison of the 14 Code of Federal Regulation (CFR) for reciprocating engines against the engine specification, mission requirements and verification results, provides assurance that the engine can maintain safe operation under all conditions.

FAA Doc: 14CFR reference 33 subpart C for design requirements for commercial applications.

14CFR reference 33 subpart D for verification requirements for commercial applications.

# 8. AIR VEHICLE SUBSYSTEMS

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Functional operations test results
3. Performance test results
4. Failure modes, effects, and criticality analyses (FMECA)
5. Hazard analysis
6. Component and system SOF certifications/qualifications
7. Design studies and analysis
8. Installation and operational characteristics
9. Flight manual and limitations
10. Electromagnetic environmental effects analysis and test results
11. Diminishing manufacturing sources plan
12. Obsolete parts plan

CERTIFICATION CRITERIA

(Note: For subsystems that use computer resources, see section 15 for additional, specific criteria.)

DoD/MIL Doc: JSSG-2000: Air System, JSSG-2001 Air Vehicle, JSSG-2009 Air Vehicle Subsystems, and their associated Appendices.

## 8.1 Hydraulic and pneumatic systems.

DoD/MIL Doc: JSSG-2009: Appendix B and Appendix M.

FAA Doc: 14CFR references: 23.1435, 23.1438

**8.1.1** If there is more than one hydraulic system or pneumatic system, verify that safe operation can be continued if any one hydraulic or pneumatic system fails.

Standard: A single failure in a hydraulic power system component or a total hydraulic system failure does not result loss of aircraft or unacceptable flying qualities. The platform is capable of safe flight and safe landing after a single failure. The hydraulic systems are configured such that any one system failure due to combat or other damage, which cause loss of fluid or pressure, does not result in complete loss of flight control. Systems are separated as far as possible (i.e., on opposite sides of the fuselage or the wing spar) to obtain maximum advantage of the dual system.

When two or more using functions are pressurized by a common pressure source, the non-essential function is isolated from the essential function (e.g., landing gear is isolated in flight from flight controls to limit exposer of the hydraulic system to battle damage).

Compliance: System characteristics are verified by analysis. Inspection of drawings, subsystem tests, ground demonstration, and flight tests verify failure operation.

DoD/MIL Doc: JSSG-2009: para B.3.4.2, B.4.4.2, B.3.4.2.1.10, B.4.4.2.1.10, B.3.4.2.1.16, B.4.4.2.1.16, Emergency Operation and Appendix M: M.3.4.13/M.4.4.13, Pneumatic Subsystems.

FAA Doc: 14CFR references: 25.1435 b4

**8.1.1.1** Verify that any single-point failure locations are identified and their consequences of failure are acceptable, eliminated, or mitigated.

Standard: All single point failures are identified and the risks accepted by the appropriate decision maker per MIL-STD-882.

If the hydraulic system is configured such that any one single-point failure causes loss of fluid pressure in multiple hydraulic systems, the system architecture is such that it does not result in complete loss of flight control.

If there are points on the platform where two or more hydraulic systems come together (e.g., valves, switching valves) and a single failure will result in the loss of two hydraulic systems, the design of the platform's hydraulic systems minimizes the impact of this failure to the platform's performance.

Compliance: The FMECA addresses safe operation of the air vehicle following hydraulic/pneumatic system failures. All safety risks are accepted by the appropriate decision maker per MIL-STD-882.

DoD/MIL Doc: JSSG-2009: para B.3.4.2/B.4.4.2 Hydraulic Power Subsystem; and Appendix M: M.3.4.13/M.4.4.13 Pneumatic Subsystem.

**8.1.2** Verify that interfaces and redundancies with the flight control, electrical, and avionics systems are evaluated and verified to be safe.

Standard: Interface and redundancy requirements with the flight controls, electrical and avionic systems are defined in program documentation such as ICDs and specifications.

Compliance: Inspection of ICDs and specifications verify that the interfaces are defined.

Analysis of steady state and dynamic performance, component qualification tests, full-scale functional hydraulic system mockup/simulator testing, ground and flight tests verify hydraulic/pneumatic system interfaces. Failure mode testing in the simulator and aircraft verify adequacy of redundant systems.

DoD/MIL Doc: JSSG-2009: para B.3.4.2, B.4.4.2, B.3.4.2.1.10/ B.4.4.2.1.10 Emergency Operation; B.3.4.2.1.9/B.4.4.2.1.9 Leakage Control; B.3.4.2.2/B.4.4.2.2 Interface requirements; B.3.4.2/B.4.4.2 Hydraulic power subsystem; and Appendix M: M.3.4.13/M.4.4.13 Pneumatic Subsystem.

**8.1.3** Verify normal, back-up, and emergency hydraulic or pneumatic system operation.

Standard: The hydraulic/pneumatic systems have sufficient power to maintain safe operation during normal, back-up and emergency operation for all conditions. Transition of power from the primary to the backup and emergency system is smooth - i.e., minimal sag in power, no detrimental pressure spikes.

Compliance: Analysis, coupled with simulator, ground and flight tests, verify safe operation during normal, backup and emergency conditions. Actual operational conditions of the air vehicle are used for the test verifications. Start up, take off, flight, weapons delivery, return to base, and landing conditions are included.

DoD/MIL Doc: JSSG-2009 Appendix B: B.3.4.2.1.2/B.4.4.2.1.2 System Fluid Capacity; B.3.4.2.1.10/B.4.4.2.1.10 Emergency Operation; and Appendix M: M.3.4.13, M.4.4.13

**8.1.4** Verify that hydraulic fluid temperatures do not exceed the maximum allowable temperature.

Standard: High temperature operating conditions are defined to ascertain fluid cooling needs.

High temperature conditions are controlled to prevent degradation of pressure seals and to prevent overpressurization or leakage due to thermal expansion which creates a fire hazard condition.

Compliance: Analysis of steady state and dynamic performance, component tests and full-scale

functional hydraulic power subsystem mockup/simulator testing, ground and flight tests verify hydraulic power subsystem do not exceed maximum allowable temperatures.

Analysis and inspection of drawings and/or tests verify protection features.

DoD/MIL Doc: JSSG-2009: para B.3.4.2.1.14/B.4.4.2.1.14 High Temperature Operation; B.3.4.2.1.14.1/B.4.4.2.1.14.1 Thermal Relief; B.3.4.2.1.15/B.4.4.2.1.15 Fire and Explosion Proofing

**8.1.5** Verify that adequate crew station information is available to notify the flight crew of the hydraulic and pneumatic systems' operating conditions.

Standard: Means are provided to monitor hydraulic/pneumatic system fluid quantity and pressure to prevent system failure due to fluid loss. Warnings Cautions and Advisories are provided to operators and maintainers when a hydraulic/pneumatic power subsystem fails and the air vehicle no longer has hydraulic power subsystem redundancy.

Compliance: The hydraulic/pneumatic fluid quantity monitoring and pressure indication systems are verified by inspection and air vehicle ground and flight tests. The visibility and accuracy of the gage readout is verified during the air vehicle ground and flight test program. The low-pressure warning device is verified by conducting ground and flight tests.

DoD/MIL Doc: JSSG-2009 Appendix B: B.3.4.2.1.3/B.4.4.2.1.3 System Fluid Monitoring; B.3.4.2.1.4.3/B.4.4.2.1.4.3 System Pressure Indication; B.3.4.2.1.4.4/B.4.4.2.1.4.4 System Low-Pressure Warning; B.3.4.2.2.3/B.4.4.2.2.3 Instrumentation interface(s); and Appendix M: M.3.4.13.3/M.4.4.13.3 Status Indication.

FAA Doc: 14CFR references: 23.1435 a2, 25.1435 b1

**8.1.6** Verify that flight and maintenance manuals include normal, back-up and emergency operating procedures, limitations, restrictions, servicing, and maintenance information.

Standard: Criteria is self-explanatory

Compliance: Verification is by demonstration, analyses and review of T.O.s. Engineering data validated during ground and flight testing. Ground testing, flight testing, and validation and verification of T.O.s verify compliance with criteria.

DoD/MIL Doc: JSSG-2000: para 3.6.2

FAA Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**8.1.7** Verify that the plumbing installation and component installations are safe for flight.

Standard: The installation of the system components, tubing and component/tubing mounts account for internal and external environmental conditions. These include vibration, thermal expansion, platform bending, etc. Sufficient clearances between moving system components and structure or other components are maintained to ensure that no possible combinations of temperature effects, airloads, wear or structural deflections cause binding, rubbing or jamming. Hydraulic system tubing are not used to support other tubing or wiring. Multiple systems are physically separated as much as possible to increase survivability due to wartime damage. For platforms with multiple systems, more than one system powers the flight controls.

Compliance: Analysis, component SOF qualification tests, demonstration/simulator programs and ground/flight tests verify system performance, system separation and fluid compatibility for all internal and external environmental conditions. Operational conditions of the air vehicle ( i.e., start up, take off, flight, weapons delivery, return to base, and landing) are used for the test verifications.

DoD/MIL Doc: JSSG-2009: para B.3.4.2.1.1/B4.4.2.1.1 Fluid Selection; B.3.4.2.1.2/4.4.2.1.2 System fluid capacity; B.3.4.2.1.4/B.4.4.2.1.4 System Pressure; B.3.4.2.1.5/B.4.4.2.1.5 Pressure Control; B.3.4.2.1.14.1/B.4.4.2.1.14.1 Thermal Relief; B.3.4.2.1.15/B.4.4.2.1.15 Fire and Explosion Proofing; B.3.4.2.1.17/B.4.4.2.1.17 Clearances, M.3.4.13.2/M.4.4.13.3 Pressure,

M.3.4.13.4/M.4.4.13.4 Moisture Content, M.6.4 Component Information

FAA Doc: 14CFR references: 23.1435 a1, a3, c1, c2, 25.1435 a2, a4, a5

**8.1.8** Verify that the air vehicle hydraulic and pneumatic systems' size/power meets demand.

Standard: The hydraulic/pneumatic power subsystem(s) is sized and configured to supply hydraulic/pneumatic power, as required at sufficient flow rates and pressure to the using systems and utility functions in all modes of ground and flight operation (including backup and emergency). The total fluid volume, including reserves is optimized to provide for system fluid exchanges, compressibility, thermal effects and leakage.

Compliance: Analysis of steady state and dynamic performance, component SOF qualification tests, full-scale mockup/simulator testing and ground/flight tests verify hydraulic system power requirements. A hydraulic simulator capable of performing all normal, back-up and emergency functions demonstrates adequate system fluid capacity. Acceptable fluid loss levels from the system overboard relief valves are verified in the simulator. Operational conditions of the air vehicle (i.e., start up, take off, flight, weapons delivery, return to base, and landing) are used for the test verifications.

DoD/MIL Doc: JSSG-2009 Appendix B: B.3.4.2/B.4.4.2 Hydraulic Power Subsystem; B.3.4.2.1.2/B.4.4.2.1.2 System Fluid Capacity; and Appendix M: M.3.4.13/M.4.4.13 Pneumatic Subsystems.

FAA Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**8.1.9** Verify that undesirable pressure fluctuations are precluded from the system.

Standard: The hydraulic systems have been designed to withstand pressure spikes of 135 percent of system pressure. Pressure spikes above 135 percent are precluded from the system. System pressure relief valves and thermal relief valves are provided to prevent sustained excessive pressures which may cause component structural failures. Pressure relief for hydraulic/pneumatic fluid thermal expansion shall be provided for all components in hot locations and closed plumbing segments. Pressure ripple generated by high-speed rotating fluid equipment do not result in subsystem instabilities.

Compliance: The performance of the hydraulic/pneumatic power subsystem pressure control devices is verified by analyses, inspections, laboratory tests, and ground tests.

Peak pressures are predicted by computer analysis. Component, iron bird, and air vehicle tests are used to verify the transient pressure characteristics.

DoD/MIL Doc: JSSG-2009 Appendix B: B.3.4.2.1.5/B.4.4.2.1.5 Pressure Control; B.3.4.2.1.5.1/B.4.4.2.1.5.1 Peak Pressure; and B.3.4.2.1.5.2/B.4.4.2.1.5.2 Pressure Ripple; and Appendix M: M.3.4.13.2/M.4.4.13.2 Pressure.

FAA Doc: 14CFR references: 23.1435 a3, 25.1435 b2

**8.1.10** Verify that methods and procedures exist for controlling and purging impurities from the hydraulic and pneumatic systems and that the systems' level of contamination is acceptable.

Standard: Means are provided to remove solid particulate contaminants from hydraulic/pneumatic power subsystem fluid during flight, ground and filling operations in order to prevent component wear and contaminant-induced component malfunctions. Provisions are provided for bleeding air from the hydraulic fluid at critical points for maintenance purposes. System design restricts the ingestion and collection of moisture which causes malfunctions from corrosion, shorts in electrical devices and freezing.

Compliance: Verify by inspection of drawings, and laboratory test data. Entrained air phenomena is evaluated in functional test rigs (iron bird). The provisions for air removal are verified by inspection, demonstration, and tests.

DoD/MIL Doc: JSSG-2009: para B.3.4.2.1.6/B.4.4.2.1.6 System Level Contamination Prevention;

B.3.4.2.1.7/B.4.4.2.1.7 System Air Removal; and B.3.4.2.1.8/B.4.4.2.1.8 Moisture Removal; M.3.4.13/M.4.4.13 Pneumatic Subsystem.

## 8.2 Environmental control system (ECS).

FAA Doc: Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

### 8.2.1 Verify that the design incorporates system safety requirements of the air vehicle.

Standard: The design approach provides weapon system level integrity for safety of flight. System safety program requirements are incorporated into the functional baseline and operating procedures of the ECS. ECS design integrates into the overall air vehicle design approach philosophy. System safety requirements, analyses, time lines and other milestones are in synchronization with the rest of the program schedules.

Compliance: Installed air vehicle level testing validates and verifies performance for the ECS and other interlinked systems involving thermal stability for SOF.

Review of operational procedures and appropriate documents validate the incorporation of the system safety program.

Note: This compliance is integral to the air vehicle performance and functionality activities required for overall air vehicle SOF.

DoD/MIL Doc: JSSG-2009: para 3.3.3, 4.3.3

FAA Doc: 14CFR reference: 23 Miscellaneous & Cooling paragraphs

### 8.2.2 Verify that the ECS meets safety requirements when operating under installed conditions over the design envelope and maintains integration integrity to ensure the weapon system's SOF.

Standard: The components and the ECS are designed to insure an integrated/installed ECS in the air vehicle that meets safety requirements and weapons system environment profiles.

Compliance: ECS SOF and safety requirements are verified by the following activities:

A. Component level SOF testing demonstrates safe operation under all environments and loadings

B. ECS level integrated testing verifies safe operation of the air vehicle (bleed subsystem, environmental protection subsystem, and thermal conditioning function for flight control system).

C. Simulator and/or air vehicle ground testing demonstrates safe operation under all conditions including failure

D. Flight test data from ECS flight test profile(s) validates analysis results and predictions of critical design envelope points

E. FMECA and hazard analysis of the ECS including the ground station system verifies that the ECS does not

DoD/MIL Doc: JSSG-2009: para 3.3.6, 4.3.6,

JSSG-2001: para 3.3.10, 3.3.10.1

### 8.2.3 Verify the availability of alternate means of cooling of safety-critical avionics and sufficient cockpit ventilation when the primary ECS is nonoperational.

Standard: Criteria is self-explanatory.

Compliance: Acceptable performance of alternate cooling methods is verified by the following:

A. CFD or similar analysis predicts acceptable performance of alternate methodology and technology employed to provide thermal stability to air vehicle during primary EMS system

loss.

B. Test performed both inflight and ground level to verify flowpath and ensure thermal balance exist to sustain safe operation conditions for the air vehicle and personnel.

DoD/MIL Doc: JSSG-2009 Appendix D: D.3.4.4.5.2/D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.5.3/D.4.4.4.5.3 Avionic equipment and equipment compartment emergency cooling

FAA Doc: 14CFR references: 23.831, 25.831

**8.2.4** Verify that normal and emergency pressurization requirements are met in the air vehicle and, as appropriate, are indicated or monitored at the ground station to ensure SOF.

Standard: System design (including emergency equipment and/or auxiliary methods) provides an acceptable pressure environment for crew survival and equipment affecting safety of flight.

Compliance: The standard is verified by the following activities:

A. Analyses and/or simulation determines the severity of the environment that drives pressurization needs for the air vehicle

B. Capability analysis and test verify the adequacy of pressurization subsystem mechanisms required for air vehicle SOF profile.

C. Critical functional test verifies the adequacy of pressurization subsystem based on the formulated and projected threats for the air vehicle.

D. Analyses and flight tests verify pressure schedule and tolerance requirements for occupied compartments.

DoD/MIL Doc:JSSG-2009 Appendix D: D.3.4.4.1, D.4.4.4.1

FAA Doc: 14CFR references: 23.365, 25.841

**8.2.5** Verify that the effects of loss of some or all ECS functions on air vehicle safety, on air vehicle performance, or on the safety and performance of other air vehicle systems are understood and acceptable.

Standard: Safety-critical items such as flight controls, avionics and communications function long enough to safely land the aircraft if ECS function is lost and ram air or alternate methods are not available to insure airworthy operations.

Compliance: The standard is verified by the following activities:

A. FMECA and System Hazard Analysis indicate safe operation

B. ECS system level analyses indicate safe operation of the air vehicle after loss of some or all ECS functions

C. Simulator and/or air vehicle ground testing verifies safe operation

D. Flight test data from ECS flight test profile validates FMECA and system level analyses

DoD/MIL Doc: JSSG-2009: para 3.2.4, 3.2.5, 3.2.7.4.4, 3.2.7.6, 3.3.3, 4.2.4, 4.2.5, 4.2.7.4.4, 4.2.7.6, 4.3.3; Appendix D: D.3.4.4.3, D.3.4.4.5, D.3.4.4.12, D.4.4.3.3, D.4.4.4.5, D.4.4.4.12, D.3.4.4.5.2/D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.5.3/D.4.4.4.5.3 Avionic equipment and equipment compartment emergency cooling; D.3.4.4.12.2/D.4.4.4.12.2 Bleed air source shut off; D.3.4.4.5.2/D.4.4.4.14.1 Proof pressure; D.3.4.4.14.2/D.4.4.4.14.2 Burst pressure; D.3.4.4.14.3/D.4.4.4.14.3 Rotating equipment structural integrity

**8.2.6** Verify that normal and emergency procedures are included in the flight manual and training curriculum for the air vehicle.

Standard: Criteria is self-explanatory.

Compliance: Review of flight and maintenance manuals verify that proper instructions are provided for procedures required to ensure SOF operations under both normal and emergency operation conditions.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: 14CFR references: 23.1581

**8.2.7** Verify that adequate controls and displays for the ECS are installed in the crew station/ground segment control station or other appropriate locations to allow the ECS to function as intended.

Standard: Adequate provisions exist from a controls and display perspective to insure the functional integrity of the design for safety of flight operations. Sufficient cautions, warnings, and advisories are provided to alert the crew to problems in time for corrective action to be taken from a safety of flight perspective.

Compliance: Inspection of drawings and the air vehicle verifies the incorporation of the required controls, warning, cautions, and advisories. Analysis and test demonstrate functionality of all controls, sensors, and warning devices.

DoD/MIL Doc: JSSG-2009: para D.3.4.4.3/D.4.4.4.3 ECS crew station interface

**8.2.8** Verify that the ECS meets the requirements for personnel atmosphere including adequate crew/occupant ventilation and protective flight garment supply systems (oxygen equipment, pressure suits, and anti-g garments or ventilation garments).

Standard: The ECS supplies air at the pressure, flow, temperature, moisture, and contamination levels compatible with the respective equipment and suits.

Compliance: Analysis and laboratory tests verify suit or other ventilation equipment requirements are met. Flight testing verifies complete installed function. FMECA and hazard analysis of the ECS including the ground station system verifies acceptability of personnel thermal conditioning impact on SOF activities for the air vehicle.

DoD/MIL Doc: JSSG-2009 Appendix D: D.3.4.4.3, D.4.4.3.3, D.3.4.4.5.4/D.4.4.4.5.4 ECS Suit ventilation and pressurization

**8.2.9** Verify that subsystems used for environmental protection (e.g., windshield rain/snow/ice removal, ice protection and defog) provide for safe operation of the air vehicle in the specified environment.

Standard: No single environmental protection subsystem failure (including ground station functions that are critical to air vehicle flight safety) results in flying qualities less than level three or loss of aircraft.

Compliance: The standard is verified by the following activities:

A. Analysis and/or simulation determines the severity of the environment that drives protection needs for the air vehicle

B. Capability analysis and test verify the adequacy of environmental protection system mechanisms required for air vehicle SOF profile.

C. FMECA and hazard analysis including the ground station system verifies that the ECS does not prevent the safe operation of the air vehicle.

DoD/MIL Doc: JSSG-2009: para D.3.4.4.8/D.4.4.4.8 Transparent area fog and frost protection; D.3.4.4.9/D.4.4.4.9 Rain removal; D.3.4.4.10/D.4.4.4.10 Transparency cleaning; D.3.4.4.11/D.4.4.4.11 Ice protection

FAA Doc: 14CFR references: 23.1419, 25.1419, 23 Miscellaneous (Safe Operations Certification)

**8.2.10** Verify that the crewmember's breathing air is protected from contamination in all forms, including oil leakage in the engine and nuclear-chemical-biological warfare conditions.

Standard: A method to shut off all air flow to occupied compartments is incorporated to prevent introduction of smoke, fumes, toxic gases or other such contaminants, into the occupied compartments (when the source of the contaminant is the ECS). Nuclear, biological and chemical (NBC) protection provisions are provided to remove deadly or incapacitating agents from the ECS air to provide for the safety of the crew and to improve the survivability of the air vehicle.

Compliance: Inspection of drawings and air vehicle demonstrations verify ability to shut off air flow. Laboratory testing with simulants and live agent testing verifies the NBC system performs as required.

DoD/MIL Doc: JSSG-2009: para D.3.4.4.2.8/D.4.4.4.2.8 Occupied compartment flow shutoff; D.3.4.4.5.1/D.4.4.4.5.1 Occupied compartment normal ventilation; D.3.4.4.5.2/D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.6.1/D.4.4.4.6.1 Occupied compartment; D.3.4.4.6.3/D.4.4.4.6.3 Nuclear, biological, and chemical contamination

FAA Doc: 14CFR references: 23.1109, 23.1111, 25.832

**8.2.11** Verify that the bleed air or other compressed air duct system is monitored for leaks and structural integrity. Verify that hot air leaking from damaged ducting does not cause ignition of any flammable fluids or other materials or cause damage to SOF items/CSIs.

Standard: Verify a leak monitoring system or methodology/process is employed to insure safety of flight when using bleed air or compressed air sources on an air vehicle. Shutdown capability, with a crew station advisory or a crew station warning, is provided when a potentially damaging or fire-producing leak occurs. The sensors for the leak detection system recover their required leak detection function following exposure to a leak.

Compliance: The standard is verified by the following activities:

A. Perform assessment study to establish the set point for leak detection system based upon impact of leak on installed environment conditions. The study includes the impact assessment on the propulsion system.

B. Analysis determines the required performance parameters.

C. Component and system testing verifies SOF performance with special focus on ensuring auto-ignition temperature limits are established for the installation environment and the fluids in this area.

D. Fire hardening and fire protection criteria for AWCC are coordinated with the aforementioned compliance methods for this criteria.

DoD/MIL Doc: JSSG-2009 Appendix D: D. 3.4.4.12, D.4.4.4.12, D.3.4.4.12.8/D.4.4.4.12.8 Bleed air leak detection

MIL-HDBK-221: para 2.8

FAA Doc: 14CFR references: 23.1109, 23.1111

**8.2.12** Verify that bleed air shut-off provisions are available at, or as close as possible to, the bleed source.

Standard: Provisions exist for bleed air shut off that provide the air vehicle with secure means for isolating bleed air from creating any adverse conditions jeopardizing safety of flight. No single point bleed air system failure causes an uncontrollable flow of high temperature bleed air into interior of the aircraft.

Compliance: Inspection of installation drawings, FMECA, hazard analyses, and air vehicle testing verifies redundant shut-off provisions. Simulation and testing demonstrates the timing and

mechanisms used to ensure SOF operations in the event of bleed system failure.

DoD/MIL Doc: JSSG-2009: para D.3.4.4.12.2/D.4.4.4.12.2 Bleed source shut off; D.3.4.4.12.3/D.4.4.4.12.3 Bleed distribution control; D.3.4.4.12.4/D.4.4.4.12.4 Isolation and crossover control; D.3.4.4.12.10/D.4.4.4.12.10 Uncontrolled bleed air

FAA Doc: 14CFR references: 23.1109, 23.1111

**8.2.13** Verify that pressurization rate control is available to preclude pressure surges in the cockpit.

Standard: Pressure schedules defined for the air vehicle minimize discomfort to the crew and passengers and prevent hypoxia. Pressurization system reacts quickly to changes in flight conditions and air conditioning flow rates are maintained at the required pressure schedule to insure safe operations. Protection from excessive pressure differentials and partial decompression is provided for crew safety and to prevent air vehicle structural damage. If aircraft is pressurized in flight, pressure is relieved prior to crew exit to prevent personal injury or structural damage.

Compliance: A. Analysis and flight tests verify pressure schedule and tolerance requirements for occupied compartments.

B. Ground test is performed to show relief methods for adverse pressurization conditions.

DoD/MIL Doc: JSSG-2009: para D.3.4.4.1.1/D.4.4.4.1.1 Occupied compartment pressure schedule; D.3.4.4.1.4/D.4.4.4.1.4 Compartment positive and negative pressure relief; D.3.4.4.1.5/D.4.4.4.1.5 Occupied compartment pressure release; D.3.4.4.1.6/D.4.4.4.1.6 Occupied compartment leakage rate; D.3.4.4.1.7/D.4.4.4.1.7 Occupied compartment pressure source

FAA Doc: 14CFR references: 23.841, 23.843, 25.841, 25.843

**8.2.14** Verify that nuclear, biological, and chemical (NBC) equipment and/or procedures are provided for protecting or maintaining ECS cooling air free from contaminants.

Standard: Nuclear, biological and chemical (NBC) protection provisions are provided to remove deadly or incapacitating agents from the ECS air to provide for the safety of the crew and to improve the survivability of the air vehicle.

Compliance: Laboratory testing with simulants and live agent testing verifies the NBC system performs as required. Inspection of training curriculum, flight and maintenance manuals verifies proper instructions are provided for procedures required to ensure SOF operations under both normal and emergency operation conditions.

DoD/MIL Doc: JSSG-2009: para D.3.4.4.2.8/D.4.4.4.2.8 Occupied compartment flow shutoff; D.3.4.4.5.1/D.4.4.4.5.1 Occupied compartment normal ventilation; D.3.4.4.5.2/D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.6.1/D.4.4.4.6.1 Occupied compartment; D.3.4.4.6.3/D.4.4.4.6.3 Nuclear, biological, and chemical contamination

**8.2.15** Verify that the air vehicle's thermal management system is stable for all flight conditions and environments.

Standard: Mass flow and delivery temperature of cooling medium are sufficient for the air vehicle heat loads and provide the necessary thermal stability to ensure SOF conditions for the air vehicle. Thermal conditioning ensures there is no loss of critical function.

Compliance: The standard is verified by the following activities:

A. Analysis/simulation establishes the energy balance requirements for the air vehicle.

B. Dynamic control system analysis verifies that system stability exists to ensure SOF.

C. Simulation profiles the system stability critical envelope points. This study is performed

to bound the limitations of the ECS responsibility for thermal stability of the air vehicle.

D. Ground-based thermal survey of air vehicle validates the thermal analyses and system stability projections.

E. Thermal survey conducted during air vehicle flight testing validates the fidelity of model projections and viability of the design.

DoD/MIL Doc: JSSG-2009 Appendix D: D.3.4.4.2, D.3.4.4.18, D.4.4.4.2, D.4.4.4.18

JSSG-2001: para 3.3.10, 3.3.10.1

**8.2.16** Verify adequate smoke clearance is available to ensure safe operation with or without an operational ECS.

Standard: Rapid means for smoke removal from cockpit and passenger-occupied cargo compartments is provided to allow crew visibility and prevent nausea or asphyxiation.

Compliance: Analysis, inspection of drawings and flight demonstrations verify emergency smoke removal for occupied compartments.

DoD/MIL Doc: JSSG-2009 Appendix D: D.3.4.4.5, D.4.4.4.5, D.3.4.4.5.1/D.4.4.4.5.1 Occupied compartment normal ventilation; D.3.4.4.5.2/D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal

FAA Doc: 14CFR references: 23.831, 25.831

**8.2.17** Verify that all surface touch temperatures remain within required limits to preclude any operational limitations to safety of flight operations of the air vehicle.

Standard: Criteria is self-explanatory.

Compliance: The standard is verified by the following activities:

A. Analysis, component testing, and flight-testing verify that surface temperatures are adequate for human tolerance and interaction.

B. Temperature measurement activities are performed during flight and ground testing to verify and validate the analyses used in assessing the ECS.

DoD/MIL Doc: JSSG-2009 Appendix D: D.3.4.4.4, D.4.4.4.4 Surface touch temperatures

## 8.3 Fuel system.

(Refuel, defuel, feed, transfer, pressurization, vent, quantity gauging, dump, and inerting, including external and auxiliary fuel systems (tanks, plumbing, and pumps))

FAA Doc: 14CFR references: 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001

(Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.)

**8.3.1** Verify that the fuel system is safely compatible with other system interfaces.

Standard: The fuel system design requirements, including interfaces, are functionally and physically compatible with other air vehicle systems, e.g., engine, tankage, vent system, scavenge, Warnings, Cautions and Advisories, displays, gauging, refueling, aerial refueling and other unique interfaces.

Compliance: Interface requirements are documented and verified through design analysis, component qualification tests, system functional checkout tests, and ground/flight tests.

DoD/MIL Doc: JSSG-2009: para 3.4.4.1/4.4.4.1; Appendix E: E.3.4.5.1.1, E.4.4.5.1.1, E.3.4.5.1.2, E.4.4.5.1.2, E.3.4.5.1.3, E.4.4.5.1.3, E.3.4.5.1.3.11, E.4.4.5.1.3.11, E.3.4.5.2.1, E.4.4.5.2.1, E.3.4.5.2.2, E.4.4.5.2.2, E.3.4.5.3, E.4.4.5.3

FAA Doc: 14CFR references: 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001

**8.3.1.1** Verify that all components, either individually or as part of a subsystem, have passed all safety-related qualification tests (e.g., proof, burst, vibration, containment, over-speed, acceleration, explosive atmosphere, pressure cycling, and temperature cycling as required for airworthy performance).

Standard: Components require analysis, component level testing or ground based simulator testing to confirm sufficient safety verification. Safety of Flight (SOF) testing is considered if a limited amount of verification to permit initial flight test without fully qualified hardware is required. Life limits and restrictions defined as required.

Compliance: Fuel system components are verified for expected usage and environmental conditions using analyses, simulator tests, component test, and ground/flight tests.

**8.3.1.2** Verify that adequate crew station information is available to notify the flight crew of the system operating conditions.

Standard: Fuel system information and status are monitored and reported to the flight crew, ground and maintenance crew as appropriate.

Compliance: Verify by analysis, ground tests and flight tests that safety of flight information is reported to the appropriate crew - e.g., fuel quantity, pump status, CG of fuel in tanks, leak detection, etc.

**8.3.2** Verify that the fuel system functions under all probable conditions with the approved fuels.

Standard: Primary fuels use allows full fuel system functionality without any restrictions to aircraft envelope performance. Alternate fuels use is utilized on a continuous basis without fuel system damage, but has possible aircraft performance restrictions. Emergency fuels use is on a limited basis to support emergency or combat conditions, with aircraft restrictions and possible fuel system degradation. Aircraft operating restrictions and additional maintenance actions are defined for each alternate and emergency fuel.

Compliance: Fuel system compatibility with specified air vehicle fuels and performance under all probable flight and environmental conditions are verified using analyses, simulator tests, component test, and ground/flight tests.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.1, E.4.4.5.1.1, E.3.4.5.1.2, E.4.4.5.1.2, E.3.4.5.1.3, E.4.4.5.1.3, E.3.4.5.1.4, E.4.4.5.1.4, E.3.4.5.2.1, E.4.4.5.2.1, E.3.4.5.2.2, E.4.4.5.2.2

FAA Doc: 14CFR references: 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001

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**8.3.3** Verify that all fuel system critical failure modes and hazards have acceptable risk levels.

Standard: When using any specified fuel, no single failure of the fuel system results in loss of aircraft or fuel delivered to the engine outside prescribed pressure, flow and temperature.

Compliance: FMECA addresses safe operation of the air vehicle following fuel system failures. Safety Hazard Analysis addresses all fuel system related failures, including single point failure and realistic multiple failures, and have acceptable risk levels. Failure mode tests conducted during component tests verify performance necessary for single failure operation. Fuel system simulator and/or aircraft ground testing verify redundancy of the system critical functions.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.12, E.4.4.5.1.12

FAA Doc: 14CFR references: 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001

**8.3.4** Verify the safe installation of the fuel system and components.

Standard: Fuel components and tubing withstands expected loading conditions for all phases of flight for static and durability related loads as well as internal pressure loads. Adequate brackets

and clamps are provided for the expected conditions.

Compliance: Component performance validated through qualification testing. System performance validated through simulator and air vehicle testing. Inspection of specific tubing and component installation after air vehicle operation confirms appropriate clearance and support. Installation integrity confirmed by on aircraft system level proof pressure test.

DoD/MIL Doc: JSSG-2009: para 3.3.3.1, 4.3.3.1, 3.3.8, 4.3.8

FAA Doc: 14CFR references: 23.963, 23.993, 23.994, 25.963, 25.993, 25.994

**8.3.5** Verify that the plumbing and components in the fuel system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit for the subsystem without resulting in fuel leakage, critical system performance degradation or critical life limited durability.

Standard: All components, lines and connections are capable of withstanding a proof pressure of twice maximum operating pressure without degradation in performance, permanent deformation or leakage. The engine feed line is capable of withstanding a negative pressure of one atmosphere (14.7 psi) without permanent deformation. The installed fuel system withstands proof pressure without leakage.

Compliance: Component-level proof pressure testing verifies capability of components to withstand specified proof pressure. Bench testing verifies the capability of the engine feed line to withstand required pressure. Proof pressure testing of the installed system verifies capability of plumbing to withstand specified proof pressure.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.5, E.4.4.5.1.5, E.3.4.5.1.6, E.4.4.5.1.6, E.3.4.5.1.7, E.4.4.5.1.7, E.3.4.5.1.8, E.4.4.5.1.8, E.3.4.5.6.1, E.4.4.5.6.1

FAA Doc: 14CFR references: 23.993, 25.993

**8.3.6** Verify that the fuel feed system provides a continuous supply of fuel to the engine at sufficient pressure throughout the flight and ground operation envelopes, including starting and all flight maneuvers.

Standard: The fuel system supplies pressure and flow to the engines within the temperature limits during all phases of the mission.

Compliance: Fuel feed system analysis and engineering development test model verify continuous fuel supply under all probable conditions. Ground and flight tests verify the performance parameters of the fuel feed system.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.2.1, E.4.4.5.2.1, E.3.4.5.2.2, E.4.4.5.2.2, E.3.4.5.2.4, E.4.4.5.2.4, E.3.4.5.2.5, E.4.4.5.2.5

FAA Doc: 14CFR references: 23.951, 23.953, 23.955, 23.959, 25.951, 25.953, 25.955, 25.959

**8.3.7** Verify that fuel transfer flow rates meet the operational ground and flight envelope requirements.

Standard: The fuel system meets transfer requirements for all functions including c.g. management, thermal management, and engine feed.

Compliance: Analyses, ground tests and flight demonstrations verify the availability of fuel in the transfer tanks under all operational conditions. Ground and flight tests verify the performance of the fuel transfer subsystem.

Analyses, fuel system simulator tests and flight tests verify that the fuel transfer subsystem is not affected by operation of fuel jettison system.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.2.3, E.4.4.5.2.3, E.3.4.5.4, E.4.4.5.4, E.3.4.5.4.1, E.4.4.5.4.1

FAA Doc: 14CFR references: 23.951, 23.952, 23.953, 23.955, 23.961, 25.951, 25.952, 25.953,

25.955, 25.961

**8.3.8** Verify that the air vehicle center-of-gravity limits are not exceeded during all fuel system and air vehicle functions, including release of stores, aerial refueling (if applicable), fuel transfer, fuel dumping operations, wing sweep operations, and engine feed.

Standard: The fuel system pressure/flow performance, control software and crew system manual control maintains aircraft c.g. requirements for all mission phases.

Compliance: Analysis indicates that c.g. limits are not exceeded for all fuel loading and flight conditions. Ground calibration tests verify fuel gauging system accuracy at those conditions critical to the air vehicle operation (e.g., stores release, fuel dump, aerial refueling). Ground and flight tests verify the performance of the air vehicle computer management system and cockpit interfaces.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.5, E.4.4.5.5

FAA Doc: 14CFR references: 23.1001, 25.1001

**8.3.9** Verify that the fuel system is designed to prevent pressures from exceeding the system's proof pressure limits (both minimum and maximum) during refueling (aerial and ground), defueling, transfer, fuel feed, fuel dump operations and engine feed.

Standard: Valve closing, deadend legs, refuel, transfer, engine feed, fuel dump or pump start up/shut down do not create high pressure transients in the fuel system that exceed proof pressure limits (2X max operating pressure). Negative pressure does not exceed one atmosphere.

Compliance: System analysis verifies that proof pressure limits are not exceeded throughout air vehicle operation. Simulator and/or ground air vehicle testing verifies that proof pressure limits are not exceeded during normal and failure conditions. Flight testing verifies analysis and previous testing. Fuel system simulator, ground and flight tests verify that a negative pressure of one atmosphere is never exceeded in the engine feed line.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.7, E.4.4.5.1.7, E.3.4.5.1.8, E.4.4.5.1.8, E.3.4.5.8, E.4.4.5.8

FAA Doc: 14CFR references: 23.963, 23.979, 25.963, 25.979

**8.3.10** Verify that the flight and maintenance manuals include normal and emergency operating procedures, limitations, restrictions, servicing, and maintenance information.

Standard: Engineering data, e.g., system parameters, normal and emergency operational limitations, and fuel system maintenance requirements, have been developed as input to flight and maintenance manuals. Flight manual addresses fuel system normal and emergency procedures, warnings and cautions, and aircraft operating limitations. Maintenance manuals address fuel system servicing and maintenance procedures.

Compliance: Engineering data validated during ground and flight testing. Ground testing, flight testing, and validation and verification of T.O.s verify compliance with criteria.

DoD/MIL Doc: JSSG-2009: para 3.2.6, 4.2.6

**8.3.11** Verify that the design and procedures are adequate for controlling and purging impurities from the fuel system and that the fuel system's level of contamination is acceptable at all times.

Standard: The fuel system components are qualified to a contaminated fuel condition that reflects the presumed contamination over the expected usage. The fuel system has provisions to drain water from sump areas in the tanks or provide in-flight scavenge capability. Procedures for controlling and purging impurities are included in the Maintenance T.O.s.

Compliance: Component qualification testing indicates capability of components to operate at contamination levels specified in the engine ICD. Ground tests verify compliance with

engine ICD fuel quality requirements. Bench and ground testing verifies performance of water scavenging system. Fluid samples taken prior to first flight are within system level contamination limits. Maintenance T.O.s are validated and verified.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.6.2, E.4.4.5.6.2, E.3.4.5.6.3, E.4.4.5.6.3, E.3.4.5.1.3, E.4.4.5.1.3

MIL-F-8615

FAA Doc: 14CFR references: 23.971, 23.973, 23.977, 23.997, 25.971, 25.973, 25.977, 25.997

AC 20-119

**8.3.12** Verify that the system is designed to withstand the hazards associated with lightning, static electricity, fuel leaks, and the introduction of electrical power into fuel tanks.

Standard: The fuel system prevents ignition as a result of a lightning strike or failure of a component (e.g., overvoltage) from a lightning strike for the defined lightning zones and electrostatic discharges. All components inside of a fuel tank have energy levels low enough to prevent an ignition source and prevent introduction of an ignition source through the wiring or components. Fuel tank and component sealing design criteria are developed at the outset of the program.

Compliance: Air vehicle inspection and measurements verify compliance with the air vehicle bonding and lightning protection requirements. Components qualification and drawing inspections verify compliance with the bonding and lightning protection requirements. Lightning ground tests verify adequacy of the protection designs. Fuel tank and component sealing are analyzed and tested at the component/simulator level to confirm sealant integrity. On aircraft leak checks are conducted to confirm final assembly.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.9, E.4.4.5.1.9, E.3.4.5.1.11, E.4.4.5.1.11, E.3.4.5.7, E.4.4.5.7, E.3.4.5.8.12, E.4.4.5.8.12,

FAA Doc: 14CFR references: 23.863, 23.954, 23.971, 23.975, 25.863, 25.954, 25.971, 25.975, 25.981

AC 20-53A, AC 20-136, AC 25.981-2, AC 25.981-1B, AC 25-16

**8.3.12.1** Verify that the fuel system is designed and arranged to prevent the ignition of fuel vapor within the system.

Standard: Fuel components located in a fire zone are fire hardened. Fuel components located in fuel tanks are qualified as intrinsically safe. Fuel components located in a flammable leakage zone are qualified as explosion-proof.

Compliance: System Safety Hazard Analysis verifies ability of the fuel systems components to operate, including fail-safe condition, in flammable vapor-laden environment. Analyses and ground tests demonstrate that fuel tank surface temperatures do not exceed the auto-ignition temperature of the fuel. On-aircraft fuel system component bonding measurements demonstrate compliance with bonding requirements. Component tests verify ability of fuel system components to operate safely in a flammable vapor-laden environment.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.9, E.4.4.5.1.9, E3.4.5.1.11 & E4.4.5.1.11; Appendix G: 3.4.7, G4.4.7

FAA Doc: 14CFR references: 23.954, 23.975, 25.954, 25.975, 25.981

AC 20-53A, AC 20-136, AC 25-16, AC 25.981-1B, AC 25.981-2

**8.3.12.2** Verify that secondary fuel and vapor tight barriers is provided between fuel tanks, fire hazard areas, and inhabited areas.

Standard: Vapor and liquid-proof barriers are installed between fuel tanks and other zones on the aircraft that contain ignition sources, e.g., avionics bays, sensor bays, etc.

Compliance: Analysis and component tests verify performance of the primary and secondary fuel and

vapor tight barriers. Engineering test models verify performance of the fault isolation provisions to detect a failure of the primary fuel barrier. Ground demonstration verifies adequacy of the secondary barrier design to isolate and remove flammable vapors to a safe location.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.6.11, E.4.4.5.6.11

FAA Doc: 14CFR references: 23.863, 23.967, 23.1185, 25.863, 25.967, 25.1185, 25.981

AC 25-981-2, AC 25-981-1B

**8.3.12.3** Verify that drainage provisions are provided to remove all normal and accidental fuel leakage to a safe location outside of the air vehicle.

Standard: Drainage and vent outlets are located such that normal or accidental leakage is routed to a safe location outside of the air vehicle and that the fuel does not re-enter the aircraft.

Compliance: Drawing inspections verify that all areas surrounding fuel tanks or containing fuel system components are properly drained to remove fuel leakage to a safe location. Analysis and on-aircraft tests verify that the drain rates are in compliance with the air vehicle design requirements.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.6.2, E.4.4.5.6.2, E.3.4.5.1.10, E.4.4.5.1.10

FAA Doc: 14CFR references: 23.977, 23,997, 23.999, 25.977, 25.997, 25.999

**8.3.12.4** Verify that fuel jettison, fuel venting, fuel leaks, or fuel spills can not be ingested by the engine, flow into hazardous ignition areas, onto the environmental management system, or become reingested into the air vehicle.

Standard: Drainage and vent outlets are located such that normal or accidental leakage is routed to a safe location outside of the air vehicle and that the fuel is not reingested into the engines, hazardous ignition areas or the Environmental Management System.

Compliance: Ground and flight tests verify performance of the fuel jettison subsystem. Design analysis and ground demonstration verifies the safe location of the fuel jettison in relation to potential ignition sources (hot brakes, bleed air ducts, engine, APU, etc). Ground and flight demonstrations verify that fuel does not re-enter the air vehicle after fuel jettison. Ground and flight tests verify that no drained flammable fluid impinges on potential ignition sources.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.2.6, E.4.4.5.2.6

FAA Doc: 14CFR references: 23.971, 23.999, 23.1001, 25.971, 25.999, 25.1001

**8.3.13** Verify that fuel tanks are capable of withstanding, without failure, the vibration, inertia, fluid, and structural loads that they may be subject to in operation.

Standard: Fuel tanks are designed to the expected operational usage and natural and induced environments such as slosh (delta moment loads), vibration, tubing misalignment, deflection loads, thermal loads, flight loads, pressure changes from rapid altitude changes, and other.

Compliance: Structural analyses and tests verify that the fuel tanks are capable of withstanding all ground and flight conditions and environments.

Fuel system functional checks verify that the fuel tanks are designed to withstand fluid and structural loads during transfer, refueling and defueling operations. Analysis and system ground tests verify that adequate fuel expansion space have been provided.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.6, E.4.4.5.6, E.3.4.5.6.13, E.4.4.5.6.13

FAA Doc: 14CFR references: 23.963, 23.965, 23.993, 25.963, 25.965, 25.993

AC 25.963-1

**8.3.14** Verify that tank pressure does not exceed tank structural limits due to a single failure under normal operation.

Standard: The fuel vent system maintains internal tank pressure within limits during single failure operations, e.g., rapid descent with empty tanks, failed open fuel control valve during refueling, tank to tank transfer, etc.

Compliance: Analysis and tests verify that the fuel tanks withstand the maximum pressure likely to occur on the ground or in flight due to a fuel system failure. Component tests, structural analysis and fuel system analysis verify that a fuel system failure during refueling operations does not result in fuel tank pressures exceeding limit loads of the fuel tanks.

DoD/MIL Doc: JSSG-2009: para 3.2.9.1, 4.2.9.1, and Appendix E: E.3.4.5.1.7, E.4.4.5.1.7, E.3.4.5.1.8, E.4.4.5.1.8, E.3.4.5.1.12, E.4.4.5.1.12

FAA Doc: 14CFR references: 23.957, 23.963, 23.965, 25.957, 25.963, 25.965

AC 25.963-1

**8.3.15** Verify that the air vehicle can be safely refueled and defueled.

Standard: The refuel system, vent system and tank system accommodate maximum refueling rates during normal and single failure conditions without causing hazardous conditions, e.g., tank overpressure, LRU rupture or injury to personnel.

Compliance: Demonstration verifies the capability to safely refuel the internal tanks from 10% full to high level shut off at maximum refueling servicing pressure without venting fuel. Analysis and demonstration verify aircraft hot pit refueling requirements. Component demonstration and ground testing verify that there is freedom from static discharge inside the tanks during refueling operations. Inspections verify the absence of external leakage during ground refueling operations. Gravity refueling, if applicable, is demonstrated by analysis, full scale simulator and/or on aircraft tests.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.12, E.4.4.5.1.12, E.3.4.5.8.1, E.4.4.5.8.1, E.3.4.5.8.4, E.4.4.5.8.4, E.3.4.5.8.5, E.4.4.5.8.5, E.3.4.5.8.6, E.4.4.5.8.6, E.3.4.5.8.7, E.4.4.5.8.7, E.3.4.5.8.8, E.4.4.5.8.8

FAA Doc: 14CFR references: 23.863, 23.973, 23.975, 23.979, 25.863, 25.973, 25.975, 25.979,

**8.3.16** Verify that the fuel system has been designed to prevent fuel spills during refuel operations.

Standard: The refuel system provides backup valve closure (e.g., mechanical shutoff) or procedures to identify a failed condition to prevent fuel spills.

Compliance: Demonstration verifies the capability to safely refuel the internal tanks from 10% full to high level shut off at maximum refueling servicing pressure without venting fuel. Component demonstration and ground testing verify that there is freedom from static discharge inside the tanks during refueling operations. Inspections verify the absence of external leakage during ground refueling operations. On-aircraft ground testing verifies capability to defuel the internal fuel tanks from the maximum capacity to the unpumpable level. Fuel volume thermal expansion is demonstrated by analysis and aircraft hot day operations.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.12, E.4.4.5.1.12, E.3.4.5.6.1, E.4.4.5.6.1, E.3.4.5.8.1, E.4.4.5.8.1, E.3.4.5.8.11, E.4.4.5.8.11, E.3.4.5.8.14, E.4.4.5.8.14, E.3.4.5.9, E.4.4.5.9

FAA Doc: 14CFR references: 23.969, 23.975, 25.969, 25.975

**8.3.17** Verify that adequate controls and displays for the fuel system functions are provided for the appropriate crewmember(s) to indicate the necessary fuel system functions and warn of hazardous conditions.

Standard: Warnings, Cautions and Advisories are provided to operators and maintainers for hazardous failure conditions in the fuel system.

Compliance: Flight simulator, inspection and ground demonstration verify the adequacy of the refueling subsystem controls and displays. Flight simulator, ground tests and flight demonstration verify that the required fuel system tracked parameters (fuel pressure, fuel temperature, low level fuel, c.g. monitoring, etc.) are properly displayed and available to the flight crew.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.1.12, E.4.4.5.1.12, E.3.4.5.8.11, E.4.4.5.8.11, E.3.4.5.12, E.4.4.5.12, E.3.4.5.12.1, E.4.4.5.12.1, E.3.4.5.12.2, E.4.4.5.12.2, E.3.4.5.12.3, E.4.4.5.12.3, E.3.4.5.12.4, E.4.4.5.12.4, E.3.4.5.12.5, E.4.4.5.12.5

**8.3.18** Verify that built-in-test (BIT) and fault isolation provisions are available to ensure safe fuel system operations.

Standard: The fuel system provides BIT and fault isolation to identify safety critical failure modes to the operators & maintainers.

Compliance: Analysis of the design verifies that the necessary BIT and fault isolation provisions are provided. Fuel system simulator testing verifies performance of the fault isolation provisions. Ground demonstration verifies performance of the BIT and fault isolation provisions.

DoD/MIL Doc: JSSG-2009: para 3.2.9, 4.2.9 and Appendix E: E.3.4.5.8.11, E.4.4.5.8.11, E.3.4.5.12.5, E.4.4.5.12.5

FAA Doc: 14CFR references: 23.979, 25.979

**8.3.19** Verify that jettisoned fuel does not impinge on air vehicle surfaces or become re-ingested into the air vehicle.

Standard: Fuel jettison (dump) outlets are located such that jettisoned fuel is not reingested into the engines, hazardous ignition areas or the Environmental Management System.

Compliance: Ground and flight tests verify performance of the fuel jettison subsystem. Design analysis and ground demonstration verifies the safe location of the fuel jettison in relation to potential ignition sources (hot brakes, bleed air ducts, engine, APU, etc). Ground and flight demonstrations verify that fuel does not re-enter the air vehicle after fuel jettison. Ground and flight tests verify that no drained flammable fluid impinges on air vehicle surfaces.

## 8.4 Fire and hazard protection.

Includes prevention, detection, and extinguishing and explosion suppression provisions.

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

(Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.)

**8.4.1** Verify that the fire protection system safely integrates within the air vehicle, both physically and functionally.

Standard: Fire protection, prevention and control requirements are included in program design and documentation. Fire protection equipment is capable of withstanding the hazards they are designed to control. A means of controlling the fire protection system is provided.

Compliance: Inspection of documentation verifies that appropriate requirements have been flowed down to the different systems/elements of the air vehicle. Design analysis indicates air vehicle compliance. Component acceptance tests and system functional checkout tests verify functional compatibility of all elements of the installed system. Flight tests verify functional and physical compatibility with other air vehicle systems.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7, G.4.4.7, G.3.4.7.1, G.4.4.7.1, G.3.4.7.2, G.4.4.7.2, G.3.4.7.29, G.4.4.7.29

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.1.1** Verify that any single-point failure conditions are identified and their consequences of failure are acceptable, eliminated or mitigated.

**8.4.1.2** Verify that all components, either individually or as part of a subsystem, have passed all safety-related qualification tests (e.g., proof, burst, vibration, containment, over-speed, acceleration, explosive atmosphere, pressure cycling, and temperature cycling as required for airworthy performance).

Standard: Components require analysis, component level testing or ground based simulator testing to confirm sufficient safety verification. Safety of Flight (SOF) testing demonstrates minimum safety verification to permit initial flight test without fully qualified hardware. Life limits and restrictions are defined as required.

Compliance: Fire Protection components are verified for expected usage and environmental conditions using analyses, simulator tests, component test, and ground/flight tests.

**8.4.1.3** Verify that adequate crew station information is available to notify the flight crew of the system operating conditions.

Standard: Warnings, Cautions, Advisories and other fire protection system information is defined and provided to appropriate crew and maintenance personnel.

Compliance: Verify by analysis, demonstration, inspection, ground tests and flight tests that information is defined and reported to the appropriate crew.

**8.4.2** Verify that each component of the air vehicle is properly zoned according to the fire and explosion hazards and that protection is provided to counter the hazards such that no fire or explosion hazards exist under normal operating conditions.

Standard: Each aircraft zone is identified as one of the following categories: Fire Zone, Flammable Leakage Zone, Flammable Zone, Ignition Zone, or Support Equipment Zone. Fire protection criteria is defined for each zone.

Compliance: Analyses identify which zones in the air vehicle contain flammable fluids or ignition sources, and documentation appropriately classifies those zones as a fire zone, flammable leakage zone, flammable zone, ignition zone or support equipment zone. Analysis of the air vehicle zones verify separation of flammable leakage sources and ignition sources. Analysis indicates that flammable fluids and vapor systems are isolated from engines, engine compartments and other designated fire zones. Analysis identifies the potential leak sources and control measures for each zone of the air vehicle. Single point failures and dual failures are analyzed for risk and mitigation for each fire protection zone.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7, G.4.4.7

MIL-HDBK-221: para 2.11

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.3** Verify that the design of subsystems other than fire protection have taken into consideration any potential for fire hazards.

Standard: Fire protection criteria are applied to all systems on the aircraft, e.g., explosion-proof qualified (MIL-STD-810), leakage control, ventilation, drainage, low surface temperatures.

Compliance: Fire and explosion hazard analysis determines the fire and explosion protection features for the air vehicle. Components testing and inspections verify incorporation of the safety features for the fire protection zones.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.1, G.4.4.7.1,

MIL-HDBK-221: para 2.1, 2.2.1.2, 2.2.1.4, 2.2.1.5, 2.2.1.6, 2.2.1.7, 2.2.1.8, 2.2.2 through 2.2.9, 2.5, 2.6, 2.7.3, 2.7.11, 2.7.13, 2.10.2 though 2.10.8.

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.3.1** Verify that, in areas where a fluid system might leak flammable fluids or vapors, there is a means to minimize the probability of ignition of the fluids and vapors and to minimize the resultant hazards if ignition does occur.

Standard: Ignition sources are separated from flammable vapors to prevent fire/explosion. Ventilation, drainage, containment, detection and suppression are provided as required for each fire protection zone.

Compliance: Analyses verify that provisions are implemented to provide separation of combustible and ignition sources. Air vehicle inspections verify that appropriate clearances are provided between the electrical wiring and flammable fluid carrying lines under all operational conditions. Review of component and air vehicle design verifies that adequate drainage, ventilation and hardening control measures are implemented. Bench testing and ground testing of components verify that the subsystem designs are free of potential ignition arcing or friction ignition sources and have maximum surface temperature that does not cause auto ignition of flammable vapors within the zone.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.3, G.4.4.7.3, G.3.4.7.6, G.4.4.7.6

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.3.2** Verify that provisions exist for air vehicle safety-critical components to withstand fire and heat to a predetermined safe level.

Standard: Safety critical components withstand a 2000 deg F fire with a heat flux of 10 Btu/sec/ft^2.

Compliance: Analysis identifies the appropriate level of containment capability and the time duration that the air vehicle components must meet to maintain the necessary level of performance under a fire condition. Analysis demonstrates material and component compliance with the established fireproof or fire-resistance air vehicle requirements. Laboratory component tests demonstrate compliance to the fire protection requirements when exposed to the required flame temperature and heat flux density for the required time (15 minutes for fireproof and 5 minutes for fire resistance).

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.6, G.4.4.7.6, G.3.4.7.21, G.4.4.7.21

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.4** Verify that provisions for drainage and ventilation of combustible fluids or vapors are adequate to preclude the occurrence of fire or explosion hazards.

Standard: Drains are provided that operate in flight and provide active ventilation of 1 volumetric air change per minute for flammable leakage zones. Drainage collections systems are fire hardened and provide 2 to 3 volumetric air changes per minute ventilation flow for fire zones. Drains and vent systems for flammable zones are separated from other systems. Drains and vent systems for ignition zones are separated from other systems.

Compliance: Analysis for flight and ground conditions verify that ventilation is provided to minimize flammability. T.O.s identify necessary procedures for ground operations, e.g., requirement for opening bay doors when ventilation to a bay is no longer available under ground operation.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.3, G.4.4.7.3, G.3.4.7.4, G.4.4.7.4, G.3.4.7.5, G.4.4.7.5, G.3.4.7.18, G.4.4.7.18,

MIL-HDBK-221: para 2.4

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207,

23.1411, 25.1411

**8.4.4.1** Verify that drainage and ventilation provisions are located so that combustibles are removed from the air vehicle to a safe location on the ground and can not reenter the air vehicle in flight or ground operations.

Standard: Criteria is self-explanatory.

Compliance: Analysis demonstrates that the location of the drained fluid does not reenter the air vehicle or impinge on potential ignition sources under all operational conditions. Manufacturing and inspection processes and procedures are in place to assure there are no blockages of drainage paths. Ground and flight tests demonstrate the removal of flammable fluids to a safe location.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.3, G.4.4.7.3, G.3.4.7.4, G.4.4.7.4, G.3.4.7.17, G.4.4.7.17, G.3.4.7.18, G.4.4.7.18, G.3.4.7.22, G.4.4.7.22

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.5** Verify that drains and vents from areas that might carry flammable fluids are not manifolded with drains from areas that do not carry a potentially flammable fluid.

Standard: Criteria is self-explanatory.

Compliance: Inspection of the air vehicle drain system verifies that flammable fluid drains are independent from non-flammable fluid drains.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.3, G.4.4.7.3, G.3.4.7.5, G.4.4.7.5

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.6** Verify that engine nacelle cooling and ventilation provisions are adequate to provide required heat rejection and maintain nacelle conditions necessary to avoid both hot surface ignition sources and collection of flammable fluids or vapors.

Standard: Engine bays/nacelles are ventilated with between 2-3 volumetric air changes per minute or the minimum required flow to keep hot surfaces less than autoignition temperature of the fuel or other flammable fluid in or near the engine bay.

Compliance: Design analysis and thermal models establish heat rejection and cooling requirements for components for normal and worst case operations and environments. Component tests verify heat rejection models. Ground and flight tests verify cooling capability to eliminate the presence of hot surface ignition during all expected flight and ground conditions. Installed ground and flight tests verify ventilation capability to remove hazardous fluids and vapors to a safe location during all expected flight and ground conditions.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.4, G.4.4.7.4, G.3.4.7.18, G.4.4.7.18

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.7** Verify that all potential fire zones (e.g., engine, auxiliary power unit (APU) and other compartments, such as engine-driven airframe accessory area) are designated as such and that suitable fire warnings and protection are provided.

Standard: Appropriate warning and fire prevention methods such as isolation, elimination of ignition sources, ventilation, drainage, fire detection, fire hardening of components and fire containment have been used for fire zones.

Compliance: Analysis identifies all potential fire zones. Thermal analysis establishes the performance requirements of the fire detection systems - e.g., activation temp, activation time, clearance signal time, repeatability etc. Component tests verify that the alarm activation time meets

the air vehicle response time criteria. Laboratory testing supports analysis and verifies performance of the fire detection systems under vibration, inertia, and other loads to which it is subjected in operation. Aircraft ground test verifies the operation of the fire detection, suppression and containment systems and its warnings.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.19, G.4.4.7.19, G.3.4.7.20, G.4.4.7.20, G.3.4.7.24, G.4.4.7.24, G.3.4.7.27, G.4.4.7.27

MIL-HDBK-221: para 2.12, 2.13 (All except any reference to Halon), 2.17

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.8** Verify that essential flight controls, engine mounts, and other flight structures located in designated fire zones or adjacent areas are qualified to withstand the effects of fire.

Standard: All flammable fluid lines and components as well as safety critical components located in the fire zone have been fire proof tested to 15 minutes at 2000 deg F with a heat flux of 10 Btu/sec/ft^2.

Compliance: Hazard analysis determines the level of protection required for the safety critical components. Analysis of potential fire scenarios establishes the appropriate fire test criteria (fire proof or fire resistance). Analysis and inspection indicates at least 1/2 inch of clear airspace between a fuel tank and a fire wall. Fire testing simulates the fire environment and proves that the materials and components provides the appropriate fire containment.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.20, G.4.4.7.20, G.3.4.7.21, G.4.4.7.21,

MIL-HDBK-221: para 2.7.4

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.9** Verify that each electrically powered fire protection subsystem (e.g., fire detection, extinguishing, and explosion suppression) is provided power at all times during air vehicle operations, including engine start and battery operations.

Standard: Power is provided to all fire protection equipment during all phases of operation.

Compliance: Analysis demonstrates that electrical power is provided to the fire protection system under all phases of operation. Component laboratory tests and simulation tests verify the ability of the fire protection system to operate at all times including electrical power failure conditions. Ground and flight tests verify the ability of the fire protection system to operate at all flight and ground conditions including electrical power system failure conditions.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.10, G.4.4.7.10

FAA Doc: 214CFR references: 3.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.10** Verify that the air vehicle explosion suppression system meets performance requirements for fire and hazard protection.

Standard: Passive explosion suppression is provided for all fire protection zones, e.g., ventilation, drainage, containment, detection, suppression and isolation, as appropriate. Active fire suppression is provided for zones where passive protection is not adequate, e.g., fire zones, flammable leakage zones or flammable zones.

Compliance: Hazard analysis and survivability/vulnerability analysis identify the level of protection required for the explosion suppression system. Component tests verify the safety provisions (oxygen dilution, flame quenching devices, etc). Analysis and component tests verify that the explosion suppression system limits the overpressure to levels that do not result in loss of aircraft. Ground and flight tests verify the explosion suppression system performance under actual or simulated flight conditions.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.8, G.4.4.7.8, G.3.4.7.9, G.4.4.7.9, G.3.4.7.26, G.4.4.7.26, G.3.4.7.27, G.4.4.7.27, G.3.4.7.28, G.4.4.7.28

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.11** Verify that the fire detection system is designed to preclude false warnings.

Standard: Redundancy is provided in the fire detection system to avoid a false detection. All failures of the fire detection system are flagged and reported to maintenance.

Compliance: Analysis demonstrates avoidance of false warnings. Component tests verify performance of the failure indication systems. Component tests verify the alarm set points to avoid false alarm. Ground and flight tests verify there are no false alarms at all ground and flight conditions.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.9, G.4.4.7.9, G.3.4.7.10, G.4.4.7.10, G.3.4.7.11, G.4.4.7.11, G.3.4.7.12, G.4.4.7.12, G.3.4.7.13, G.4.4.7.13, G.3.4.7.14, G.4.4.7.14, G.3.4.7.15, G.4.4.7.15

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.12** Verify the performance of the fire suppression system.

Standard: Criteria is self-explanatory.

Compliance: Hazard analysis and survivability/vulnerability analysis determines the need for a fire extinguishing system for each designated fire zone. Analysis establishes agent concentrations and duration levels that extinguish a fire. Ground testing verifies that the appropriate agent concentrations are present under all ground and flight conditions.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.24, G.4.4.7.24, G.3.4.7.25, G.4.4.7.25, G.3.4.7.26, G.4.4.7.26

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.13** Verify that fireproof protective devices are provided to isolate a fire within a defined fire zone from any portion of the air vehicle where a fire could create a hazard.

Standard: Containment is provided for all fire zones to prevent the fire from spreading to other bays. Barriers are provided to withstand burn through from a 2000 deg F, 10 Btu/sec/ft^2 fire for the time required to safely land the aircraft. All other flammable fluid components in the fire zone withstand this fire condition.

Compliance: Analysis of potential fire scenarios establishes the appropriate fire test criteria. Component level testing demonstrates firewall compliance with the fireproof requirements. Fire testing simulates a fire environment and proves that the firewall components provides the appropriate fire containment and isolation.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.20, G.4.4.7.20,

MIL-HDBK-221: para 2.7.8, 2.11,

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.14** Verify that air vehicle interior finishes and materials deter combustion and that any toxic by-products of combustion are at acceptable levels.

Standard: Use of combustible materials is avoided in any of the fire protection zones.

Compliance: Analysis establishes the design criteria for flammability properties and quantities of toxic by-products. Design analyses and thermal models adequately represent system's materials

and predict suitable performance during a fire. Component analysis and/or tests validate flammability and toxicity requirements. Testing verifies the properties of uncharacterized materials.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.7, G.4.4.7.7, G.3.4.7.22, G.4.4.7.22,

MIL-HDBK-221: para 2.7.9

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

AC 25.853-1, AC 25.869-1

**8.4.15** Verify that hazardous quantities of smoke, flames, or extinguishing agents are prevented from entering inhabited areas, UAV/ROA control station, or UAV/ROA flight-critical sensor bays.

Standard: Provisions are provided to prevent smoke, vapors or fumes from creating a Safety-Of-Flight condition for the aircraft by adversely affecting flight critical sensors. The UAV/ROA control station is protected to National Fire Protection Agency (NFPA) standards.

Compliance: Analysis of the air vehicle verifies that provisions are provided for the protection of the crew and passengers from smoke and other hazardous vapors. Ground and flight demonstrations verify that the crew and passengers are protected from smoke and extinguishing agents.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.22, G.4.4.7.22

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

AC 25-9

**8.4.16** Verify that proper separation is provided between oxidizers and flammable fluid systems or electrical components.

Standard: Flammable fluids and oxidizers are separated from electrical wiring by at least 1/2". Electrical wiring is routed above flammable fluid lines so that leakage does not impinge on the wiring.

Compliance: Hazard analysis of the air vehicle verifies that provisions are implemented to provide for separation of combustible, oxidizers and ignition sources. Air vehicle inspections verify that appropriate clearances are provided between the electrical wiring and flammable fluid carrying lines under all operational conditions (minimum of 1/2" under worst case). Air vehicle inspections verify that oxygen equipment is not installed in a fire zone and that flammable fluid lines and oxygen lines are not routed together or in proximity to each other without proper isolation design. Ground and flight tests show that clearance requirements are met under all ground and flight conditions. Inspections indicate proper separation between a fuel tank and an ignition zone.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.16, G.4.4.7.16, G.3.4.7.17, G.4.4.7.17,

MIL-HDBK-221: para 2.7.2, 2.7.10, 2.10.4.2, 2.10.2.1

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.17** Verify that provisions are available to shut off flammable fluids and de-energize all electrical ignition sources in the identified fire zone(s) for all mission phases including ground operations.

Standard: Main engine shutoff valve is provided that can be closed during a fire. All electrical equipment in a fire zone can be de-energized to prevent further ignition of flammable fluids.

Compliance: Ground tests demonstrate that the closing of any of the fuel shutoff valves does not affect

fuel availability to the remaining propulsion system. Drawing inspections and component tests verify that each flammable fluid shut-off means and controls are fireproof or protected from a fire or fire zone.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.17, G.4.4.7.17, G.3.4.7.19, G.4.4.7.19

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.18** Verify that ground fire-fighting access provisions are compatible with standard ground fire-fighting systems and that fire suppression can be accomplished through this access provision.

Standard: Access to the engine bay and other fire zones is provided to permit ground fire fighting crews to extinguish a fire on the ground.

Compliance: Analysis verifies the location and interface requirements of ground fire fighting provisions. Demonstration on the aircraft verifies that ground fire fighting access provisions are compatible with standard ground fire fighting systems.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.7, G.4.4.7.7, G.3.4.7.13, G.4.4.7.13, G.3.4.7.31, G.4.4.7.31

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

AC 20-42C

**8.4.19** Verify that the air vehicle provides safety features for post-crash fire and explosion hazards.

Standard: Flammable fluids are contained during a post-crash condition to avoid further explosions or feeding a ground fire. Ignition sources are reduced, e.g., hot surfaces during a wheels up landing, in close proximity to a flammable fluid.

Compliance: Fire and explosion hazard analysis determines the fire and explosion protection features for the air vehicle. Component testing and inspections verify the safety features for a post-crash fire.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.7, G.4.4.7.7,

MIL-HDBK-221: para 2.15

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

AC 25-17, AC 25.994.1

**8.4.20** Verify that the air vehicle has provisions to detect and control overheat conditions that are potential fire and explosion hazards.

Standard: Overheat detection for bleed air lines meets the expected usage and environments in the installed condition while providing adequate detection, activation and reset time as well as avoiding false signals.

Compliance: Thermal analysis establishes the performance requirements of the overheat protection systems, e.g., set temperature, activation time, clearance signal time, repeatability, etc. Component tests verify that the alarm activation time meets the air vehicle response time criteria. Laboratory testing verifies the performance requirements of the overheat protection systems under vibration, inertia, and other loads to which it is subjected in operation. Aircraft functional checkouts demonstrate the operation of the overheat protection system and its warnings.

DoD/MIL Doc: JSSG-2009 Appendix G: G.3.4.7.23, G.4.4.7.23, G.3.4.7.28, G.4.4.7.28

FAA Doc: 14CFR references: 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

**8.4.21** Verify, if unoccupied cargo holds are present, that fire protection, fire detection/ suppression, and smoke detector requirements are met.

Standard: Unoccupied cargo holds meet fire protection zone definition and criteria.

Compliance: Hazard analysis and survivability/vulnerability analysis determines the need for fire detection, suppression and smoke detection for an unoccupied cargo hold. Analysis and testing verify requirements are met for ventilation and drainage.

DoD/MIL Doc: JSSG-2010-7: para 3.7.3.4

JSSG-2009-Appendix G: 3.4.7, 3.4.7.22, 3.4.7.25, 3.4.7.28

FAA Doc: 14CFR references: 25.855, 25.857, 25.858, 25.859

## 8.5 Landing gear and deceleration systems.

DoD/MIL Doc: AFGS-87139;

JSSG-2009 Appendix A

FAA Doc: 14CFR references: 23.721-23.745, 25.721-25.737

(Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.)

**8.5.1** Verify safe ground flotation capability of the landing gear systems.

Standard: Landing gear system applies loads to the airfield surface which do not exceed the bearing strength of the airfield surface for all types of airfields called out in the Operational Requirements.

Compliance: Flotation analysis verifies compliance with the flotation requirements for the given tire sizes, tire pressures and specified mission weights.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.1, A.4.4.1.2.1, Ground Flotation

AFGS-87139: para 3.2.1.1.b Ground Flotation.

**8.5.2** Arrangement, dynamics, and clearances.

DoD/MIL Doc: AFGS-87139: para 3.2.1.1, 3.2.1.2

FAA Doc: 14CFR reference: 23.721-23.745, 25.721-25.737 -Covers dynamics and some of arrangements, no clearances

**8.5.2.1** Verify that the landing gear arrangement and servicing criteria prevents ground contact (including servicing equipment, arresting cables, runway lights, etc.) at all weapons loading configurations, engine runs, and for flat gear, flat tire, flat gear and flat tire situations.

Standard: The design provides sufficient clearance between the movable landing gear parts and all of the air vehicle structure and other systems. Minimum clearances are maintained at all times and for all operational conditions.

Compliance: Clearance analysis verifies ground clearance for all possible operations. Ground taxi and turning tests verify values used in the analysis.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.1.1, A.4.1.1.1, A.3.4.1.1.6, A.4.4.1.1.6, A.3.4.1.1.3, A.4.4.1.1.3, Appendix A: A.3.4.1.1.1/A.4.4.1.1.1 Gear arrangement; A.3.4.1.1.3/A.4.4.1.1.3 Extended Clearances; and A.3.4.1.1.6/A.4.4.1.1.6 Clearance with flat tire and flat strut.

AFGS-87139: para 3.2.1.2 Arrangement and 3.2.1.3.a Clearances.

FAA Doc: 14CFR reference: 13.1-13.2.4, 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

**8.5.2.2** Verify that, for all ground operations, the air vehicle maintains operational control and stability such that no part of the air vehicle or its weapons contacts the ground or other permanent ground structures (servicing equipment, arresting cables, runway lights, etc.).

Standard: The air vehicle maintains an acceptable level of dynamic stability and control for all mission operations on the ground and during the transition to and from flight. There are no adverse dynamics occurring at any time, such as shimmy, porpoising.

Compliance: Stability analysis, shimmy analysis and dynamic analysis verifies ground operation of the air vehicle for all phases of operation. Instrumented ground taxi and turning tests verify operational control and no contact with the ground.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.1.2/A.4.4.1.1.2 Pitch Stability; and A.3.4.1.1.7/A.4.4.1.1.7 Gear Stability.

AFGS-87139: para 3.2.1.2 Arrangement and 3.2.5.1 General.

FAA Doc: 14CFR reference: 25.233

**8.5.2.3** For retractable gears, verify that sufficient clearance exists within the wheel well under all ground and flight conditions so that no part of the gear contacts the airframe or becomes stuck in the up position due to interference with any air vehicle structure.

Standard: Sufficient clearance is maintained between all landing gear components and air vehicle structure. Rotating parts do not unintentionally contact other components and systems over the landing gear's life including adverse wear effects. Loads from rotating parts do not exceed design requirements.

Compliance: Clearance analysis, system inspection and system checkouts on the air vehicle verify clearance between landing gear and structure. Simulator testing verifies clearances under air loads. Flight testing verifies suitable clearances for all takeoff and landing operations, both for normal and emergency operations. Lab testing verifies that rotating parts, including grown tires, do not exceed design requirements and clearances. Clearances due to wear effects are verified by simulation or inspection of lead the fleet aircraft.

DoD/MIL Doc:JSSG-2009 Appendix A: A.3.4.1.1.4/A.4.4.1.1.4 Retraction Clearances.

AFGS-87139: para 3.2.1.2 Arrangement and 3.2.1.3.b Clearances (retractable landing gears).

FAA Doc: 14CFR references: 23.745

**8.5.2.4** Verify that the design of the landing gear system prevents the occurrence of unsafe dynamics, vibrations, or pitching motions for all operational phases of the air vehicle on the ground and in the transition to air.

Standard: The air vehicle maintains an acceptable level of dynamic stability for all mission operations on the ground and during the transition to and from flight. There are no adverse dynamics occurring at any time, such as shimmy, porpoising, yaw skids.

Compliance: Dynamic and Stability analyses verify landing gear damping and stability for all ground operations and are validated using component characterization, air vehicle ground vibration and taxi tests. Flight testing verifies that all transitional operations (air-to-ground and visa-versa) have no adverse vibration or instability

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.1.2/A.4.4.1.1.2 Pitch Stability; A.3.4.1.1.7/A.4.4.1.1.7 Gear Stability; A.3.4.1.4.2/A.4.4.1.4.2 Directional Control; A.3.4.1.4.3/A.4.4.1.4.3 Emergency directional control; A.3.4.1.4.5.1/A.4.4.1.4.5.1 Steering characteristics.

AFGS-87139: para 3.2.1.2.b Arrangement; and 3.2.1.4 Damping.

FAA Doc: 14CFR references: 23.721-23.745, 25.721-25.737

**8.5.2.5** Verify that the air vehicle does not tip back when reverse braking or towing is done at the specified conditions.

Standard: Tip back of the air vehicle on its aft sections does not occur when maximum braking (either air vehicle or tow vehicle) is applied with the air vehicle traveling in the aft direction at a speed of 5 miles per hour on a 3 degree slope.

Compliance: The reverse braking and towing capability of the air vehicle for all aircraft configurations, adverse CG locations and weapon loadings is verified by analysis and ground test.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.3.1.14/A.4.4.1.3.1.14 Empennage protection; and A.3.4.1.2.2.1.3/A.4.4.1.2.2.1.3 Landing gear towing.

FAA Doc: 14CFR references: 23.509, 25.507, 25.509

**8.5.2.6** Verify the landing gear kneeling capability allows for safe kneeling of the air vehicle.

Standard: For air vehicles that have kneeling capability, lowering and raising of the air vehicle is accomplished in a predictable and controllable manner, with no sudden or adverse movements.

Compliance: Design analysis verifies kneeling system operation and limits of operation. Air Vehicle demonstrations verify the design and the analysis for all operations and environmental conditions. Ground operational tests verify suitability of the kneeling system to operators requirements.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.10/A.4.4.1.10 Specialized subsystems

AFGS-87139: para 3.1.9 Specialized subsystems.

**8.5.2.6.1** Verify the servicing procedures for landing gear kneeling and unkneeling are safe and properly sequenced.

Standard: Servicing interfaces and kneeling system control are accessible to ground personnel and/or the pilot as required by the design. All air vehicle movements are controllable at all times from the kneeling control station.

Compliance: Design analysis verifies kneeling system operation, servicing and controls. Air Vehicle demonstrations verify the design and the analysis for all operations and controls. Ground operational tests verify suitability of the kneeling system to the operators requirements.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.10/A.4.4.1.10 Specialized subsystems;

AFGS-87139: para 3.1.9 Specialized subsystems.

**8.5.3** Landing gear structure.

DoD/MIL Doc: AFGS-87139: para 3.2.2;

JSSG-2009 Appendix A: A.1.2

FAA Doc: 14CFR reference: 23.721-23.745, 25.721-25.737

**8.5.3.1** Verify that any structural failure of the gear does not result in penetration of the crew station (for manned air vehicles), fuel tanks, or any other bay that may explode.

Standard: Landing gear structural failure modes do not result in catastrophic failure modes such as cockpit or cabin penetration, severed hydraulic lines or electrical cables, or fuel spillage.

Compliance: FMECA shows all expected structural failures of the landing gear do not result in catastrophic failures. Functional checkouts and inspection of gear design, location and alignment verifies that all expected structural failures of the landing gear do not result in

catastrophic failures.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.3.1.3/A.4.4.1.3.1.3 Failure Tolerance;

AFGS-87139: para 3.2.2.1.e General (limits on structural failure modes).

FAA Doc: 14CFR reference: 23.721 & 25.721 cover fuel spillage

**8.5.3.2** Verify the functionality of the shock strut to perform all its required energy absorption for all ground operations, landing, and takeoffs with normal servicing and with acceptable levels of misservicing.

Standard: Landing gear energy absorption capability supports the air vehicle at all times for all the design missions. Static and dynamic loads generated during taxi, takeoff and landing under all air vehicle operational weights and environments with properly serviced and misserviced strut are considered and included.

Compliance: Shock Strut Energy analysis verifies that air vehicle loads are not exceeded for all strut pressure levels and all air vehicle operational weights, including misserviced struts and is validated by component test results. Checkout/inspection verifies that the gear can be serviced properly. Ground demonstration verifies that the gear performs as designed when serviced at the specified pressure levels. Flight testing validates the analysis and verifies the operation suitability of the strut.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.3.1.8/A.4.4.1.3.1.8 Energy Absorption; 3.4.1.3.1.11/4.4.1.3.1.11 Repeated Operation

AFGS-87139: para 3.2.2.1 General and 3.2.2.2 Shock absorption;

MIL-T-6053 - presently inactive for new designs, plan to be converted into an SAE document

MIL-L-8552

FAA Doc: 14CFR reference: 23.721-23.745, 13.1-13.2.4, 23.1501, 23.1529, 25.721-25.737, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

**8.5.3.3** Verify that a misserviced gear safely supports all weapons loading, fueling and defueling, does not compromise takeoff and landings nor result in ground resonance.

Standard: Misserviced landing gear will not adversely effect dynamic energy absorption nor adversely effect air vehicle structure. Sudden and adverse movements of the strut does not occur during weapons, fuel, and other loading events. During takeoff, landing and taxi events no damage occurs to the landing gear system nor to the air vehicle structure as long as the pressure within the strut stays within the misservicing range.

Compliance: Shock Strut Energy analysis verifies that air vehicle loads are not exceeded for misserviced strut pressures and at all air vehicle operational weights. Ground demonstrations and inspection verifies that the gears maintain satisfactory attitudes during ground operations such as fueling, weapons loading, etc. Component testing verifies that the gear performs as designed when misserviced within the specified range of pressures. Flight and ground air vehicle testing validates the analysis and verifies the operation suitability of the strut.

DoD/MIL Doc: AFGS-87139: para 3.2.1.3 Clearances;

MIL-T-6053 Tests, Impact, Shock Absorber, Landing Gear, Aircraft; presently inactive for new designs – an SAE replacement document is forthcoming;

MIL-L-8552 Landing Gear, Aircraft Shock Absorbers (Air-Oil Type)

FAA Doc: 14CFR reference: 13.1-13.2.4, 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

**8.5.3.4** Verify that, for both main and nose/tail landing gear, landing conditions (normal and emergency) are within the safe operating limits.

Standard: For all expected air vehicle operations, the sink rates and landing weights do not cause overloads of aircraft structures and systems. Landing gear rebound and gear dynamic characteristics are within safe operating limits.

Compliance: Energy Analysis verifies the landing gear capability to handle all air vehicle landing weights and conditions, both normal and emergency including flat strut and flat tire operations. Drop Testing verifies that design loads are not exceeded for all operational conditions (normal and emergency) and verifies load predictions for both static and fatigue conditions. The energy absorption curves verify that metering pin and orifice design are acceptable.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.3.1.7/A.4.4.1.3.1.7 Flat tire and flat strut operation; A.3.4.1.3.1.8/A.4.4.1.3.1.8 Energy absorption; A.3.4.1.3.1.11/A.4.4.1.3.1.11 Repeated operation.

AFGS-87139: para 3.6 Environmental Conditions, 3.2.2.1 General and 3.2.2.2 Shock absorption.

FAA Doc: 14CFR references: 23.721-23.731, 23.473, 23.477, 23.479, 23.481, 23.483, 23.485, 25.721-25.731, 25.101, 25.511, 25.1583

**8.5.3.5** Verify that dynamic stability is adequate and landing gear shimmy is not evident.

Standard: Verify that the landing gear design parameters for new and worn conditions suppress all divergent loads and forces at all operational ground speeds. Divergent loads and forces are controlled by either active or passive means in order to prevent detrimental oscillations induced by runway roughness, tire imbalance or design, brake vibrations or gear natural responses. The oscillations modes to be evaluated includes fore and aft, torsional and vertical displacements.

Compliance: Shimmy analysis verifies sufficient shimmy damping at all ground operations. Ground vibrational tests verify the natural frequency sensitivities of the gear and air vehicle. Ground (taxi) and flight testing verify that all air vehicle operations meet vibrational requirements and are within prescribed shimmy and stability limits.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.1.7/A.4.4.1.1.7 Gear Stability; and A.3.4.1.4.5.1/A.3.4.1.4.5.1 Steering Characteristics.

AFGS-87139: para 3.2.1.2 Arrangement and 3.2.1.4 Damping.

FAA Doc: 14CFR reference: 23.721-23.745, 25.721-25.737- shimmy is not covered, the rest of the paragraphs imply coverage

**8.5.4** Verify that all mission and all ground handling conditions, including maximum air vehicle deceleration at the most critical C.G. and gross weight, have a maximum expected tire load and speed below that demonstrated for the selected tire at its rated inflation pressure and maximum wear limit (MWL).

Standard: The tire design characteristics are compatible with all air vehicle performance during taxi, turns, takeoff, and landing operations. The tire design parameters account for all critical gross weights and velocities such that the loads do not exceed aircraft structural or operational limits.

Compliance: Performance analysis determines the maximum expected tire load and speed profiles for all missions and ground handling conditions. Laboratory tests verify the structural and performance capability of the tire when tested at maximum expected tire load and speeds. Tests include material, strength, roll distance, service life, overload operations and speed/load/time that represents air vehicle performance. Flight test verifies tire carcass integrity and simulated loads used for qualification are not exceeded in the field operations. Operational tests verify tire life and tread design (wet and dry stopping performance).

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.2/A.4.4.1.2.2 Ground handling; A.3.4.1.3.1.4/A.4.4.1.3.1.4 Strength; and A.3.4.1.11.1.1/A.4.4.1.11.1.1 Air vehicle tire performance.

AFGS-87139: para 3.1.8 Ground handling (operations), 3.2.4.1 Tires

MIL-PRF-5041.

FAA Doc: 14CFR reference: 23.473, 23.726, 23.733, 25.473, 25.726, & 25.733

**8.5.5** Verify that the worst-case loads expected during operational missions on the nose/tail wheels and main gear wheels are not exceeded.

Standard: Tire/wheel combination supports all expected normal and emergency ground operations at all design mission condition, including operation at hot and cold climates, altitudes, wet and dry as well as all air vehicle gross weights and flight configurations.

Compliance: Air Vehicle performance analysis predicts the worst case loads. Laboratory tests verify the structural and performance capability of the wheel/tire combination. Tests include material selection, strength, roll distance, service life, overload operation and speed/load/time profiles supports the air vehicle performance and operations. Flight test and operational tests validate the analysis and component tests.

Comm'l Doc: SAE ARP-1493.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.2/A.4.4.1.2.2 Ground handling; A.3.4.1.3.1.4/A.4.4.1.3.1.4 Strength; A.3.4.1.11.2.1/A.4.4.1.11.2.1 Air vehicle wheel performance; and A.3.4.1.11.2.4/A.4.4.1.11.2.4 Nonfrangibility criteria (flat tire operation).

AFGS-87139: para 3.1.8 Ground handling (operations) and 3.2.4.2 Wheels

MIL-B-8584,

MIL-W-5013 Wheel and Brakes - presently inactive for new designs

FAA Doc: 14CFR reference: 23.721-23.732, 25.721-25.732, 23.471-23.511 & 25.471-25.511, 25.101 (see 13.1-13.2.4)

**8.5.6** Verify that protection is incorporated to preclude wheel overheating and overpressurization.

Standard: The overheat/overpressurization device must release "contain" tire pressure whenever the material in the wheel and or tire is degraded or contained pressure reaches unsafe levels. Overheating and/or over pressurization will cause explosive failure of the wheel and or tire, which represents a safety hazard to personnel and the air vehicle.

Compliance: Thermal analysis and inspection confirms overheat/over-pressurization protection, i.e., the fuse plug releases before the wheel is softened by brake temperature and that the fuse plug releases before overpressure exceeds explosive levels. Component testing verifies the capabilities and consistency of pressure release device(s) and the applicability for the particular design. Laboratory testing validates analysis and verifies performance of fuse plugs and over pressurization devices.

Comm'l Doc: SAE ARP-1493

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.11.2.3/A.4.4.1.11.2.3 Brake Overheat Capability; and A.3.4.1.11.2.6/A.3.4.1.11.2.6 Pressure-release criteria; A.3.4.1.11.3.1/A.4.4.1.11.3.1 Air vehicle stopping and turn-around performance; and A.3.4.1.11.3.7/A.4.4.1.11.3.7 Temperature interface criteria.

AFGS-87139: para 3.2.4.2.c Wheel overheat capability;

MIL-W-5013 Wheel and Brakes - presently inactive for new designs.

FAA Doc: 14CFR reference: 11.2.2 & 11.2.2.1 Included in each specific 14CFR reference per section.

**8.5.7** Brake.

Comm'l Doc: SAE ARP-1493

DoD/MIL Doc: AFGS-87139: para 3.2.3 & 3.2.4.3;

JSSG-2009: A.3.4.1.4.1,4.4.1.4.1; A.3.4.1.11.3, A.4.4.1.11.3;

MIL-W-5013 Wheel and Brakes - presently inactive for new designs

FAA Doc: 14CFR reference: 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, 25.735, 25.101

**8.5.7.1** Verify that the energy, torque, and distance performance are at least equal to the levels required for the air vehicle when it is operated within its design limits.

Standard: The deceleration system stops the air vehicle within operational requirements, on all specified runways and lengths, etc. Brake performance meets defined dry and wet runway requirements.

Compliance: Air vehicle performance analyses determine system size and energy characteristics. Laboratory tests verify brake performance levels at all critical weights and speeds. Flight testing verifies compliance with the brake performance on various runway surfaces and conditions.

Comm'l Doc: ARP-1493

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.11.3.1/A.4.4.1.11.3.1 Air vehicle stopping and turn-around performance.

AFGS-87139: para 3.2.3.1.a & b Brake system (General)

MIL-W-5013 Wheel and Brakes - presently inactive for new designs

FAA Doc: 14CFR reference: 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, 25.735, 25.101

**8.5.7.2** Verify that failure of any brake (structural or control system) does not prevent the air vehicle from stopping within the runway length needed to conduct the missions.

Standard: An alternate means of stopping is provided that is compatible with the air vehicle system requirements including operational runway lengths if any brake component (structural or control system) fails. Alternate brake performance meets dry and wet runway operation criteria for all specified distances and surfaces.

Compliance: FMECA indicates safe and unsafe modes of operation in the brake and control system. Component testing supports the FMECA and the design concept (redundancy). Air vehicle checkout procedures verify design functionality and integration. Flight test demonstrates performance of the deceleration systems both for normal and emergency or alternate modes.

Comm'l Doc: SAE ARP-1493

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.11.2.4/A.4.4.1.11.2.4 Nonfrangibility criteria (flat tire operation); A.3.4.1.11.3.3/A.4.4.1.11.3.3 Structural failure criteria; and A.3.4.1.11.3.4/A.4.4.1.11.3.4 Secondary braking capability (fail-safe).

AFGS-87139: para 3.2.3.1.c Brake system, General and 3.2.4.3 Brakes;

MIL-W-5013 Wheel and Brakes - presently inactive for new designs

FAA Doc: 14CFR reference: 11.2.2.1

**8.5.7.3** Verify that the brakes provides sufficient torque to hold the air vehicle still with engine thrust at least equal to normal preflight test levels.

Standard: Brake sizing is sufficient to provide static holding torque that prevents wheel rotation when end of runway run-up thrust is applied to the air vehicle.

Compliance: Laboratory tests establish brake holding torque capabilities. Air vehicle demonstrations at

the design and operational levels verify the brake prevents wheel rotation.

Comm'l Doc: SAE ARP-1493

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.7/A.4.4.1.7 Restraint capability.

AFGS-87139: para 3.2.3.1.b Brake System, General, and 3.2.4.3 Brakes;

MIL-W-5013 Wheels and Brakes - presently inactive for new designs,

MIL-B-8584 Design of Brake Systems

FAA Doc: 14CFR references: 23.735, 25.735

### 8.5.7.4 Verify that an appropriate device is installed to release tire pressure if the brakes overheat.

Standard: Because brakes are surrounded with materials (rubber and aluminum) that loose strength and fail when heated over 350 to 400 deg F, temperature sensitive pressure relief devices must be incorporated to prevent explosive deflation or failure of the tire and/or the wheel, for all operational conditions. The overheat device must release "contained" tire pressure before the material strength within the wheel and/or tire is degraded or contained pressure reaches unsafe levels. Material degradation due to overheating will cause explosive failure of the wheel and/or tire, which represents a safety hazard to personnel and the air vehicle.

Compliance: Brake system thermal analysis establishes the energy and temperature design requirements. Laboratory testing validates the analysis and pressure release function on over temperature conditions. Air vehicle braking tests verify that energy and temperature levels are the same as the analysis and laboratory test.

Comm'l Doc: ARP-1493

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.11.2.3/A.4.4.1.11.2.3 Brake Overheat Capability; A.3.4.1.11.2.6/A.4.4.1.11.2.6 Pressure-release criteria; and A.3.4.1.11.3.7/A.4.4.1.11.3.7 Temperature interface criteria.

AFGS-87139: para 3.2.3.1 General and 3.2.4.3.a Brakes;

MIL-W-5013 Wheel and Brakes - presently in active for new designs.

FAA Doc: 14CFR reference: 11.2.2 & 11.2.2.1

### 8.5.8 Brake control and anti-skid control.

Comm'l Doc: SAE ARP-1493

DoD/MIL Doc: AFGS-87139: para 3.2.3 & 3.2.4.3;

JSSG-2009: A.3.4.1.4.1, 4.4.1.4.1; A.3.4.1.11.3, A.4.4.1.11.3;

MIL-W-5013 Wheel and Brakes - presently inactive for new designs.

FAA Doc: 14CFR reference: 25.101, inferred in 23.45, 23.55, 23.493, & 23.735 &25.45, 25.55, 25.493 & 25.735

### 8.5.8.1 Verify that there is a separate and independent method of stopping the air vehicle within the required distance when the primary stopping method is unavailable.

Standard: An alternate and independent means of stopping and controlling the air vehicle is provided when the primary means is unavailable. This lowers the risk of air vehicle loss, and provides improved safety and reliability. The level of control and stopping performance should be equal to that provided by the normal system; if not equal, then as specified for reduced stopping performance.

Compliance: Ensure the FMECA addresses all modes of brake control system failure. Design analysis verifies the availability of a redundant and/or alternate means to provide stopping power. Brake system simulator testing confirms that there is a separate and independent method of

stopping the air vehicle when the primary means is not available. Laboratory braking test verifies the performance of the secondary braking system. Air vehicle checkouts and ground testing verifies system performance and proper functioning of the secondary system.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.4.2/A.4.4.1.4.4.2 Alternate independent braking;

AFGS-87139: para 3.2.3.2.a Brake actuation system and 3.2.4.3 Brakes;

MIL-B-8584 Design of Brake Systems

FAA Doc: 14CFR reference: 11.2.2 & 11.2.2.1

**8.5.8.2** Verify that the braking function can be maintained from the pilot's station in a smooth and controllable manner for all normal and emergency operations.

Standard: Brake actuation forces can be applied in a predictable and proportional manner. The pilot is able to apply varying input commands and achieve the expected output braking force from the commanded input. The following system parameters need to be considered for cockpit design: rudder pedal design, feel spring characteristics, and pedal force versus pedal travel. Non-cockpit designs include preprogrammed command conditions, switching commands, design logic, etc. System feedback requirements are established to determine varying brake operation commands.

Compliance: Simulators and mockups provide system force, travel and response assessments for the specified size range of pilots. Air vehicle checkouts verify controllability and suitability of braking system function and command integration. Air vehicle ground and flight tests verify controllability and suitability of braking system for all required operations.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.2/A.4.4.1.4.2 Directional Control; and A.3.4.1.4.4.1/A.4.4.1.4.4.1 Braking control interface.

AFGS-87139: para 3.2.3.1 General, 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; and 3.2.4.3 Brakes;

MIL-B-8584 Design of Brake Systems

FAA Doc: 14CFR reference: inferred in 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, 25.735 & 25.101

**8.5.8.3** If a parking brake is required, verify that it provides holding power for the required time and conditions.

Standard: Criteria is self-explanatory.

Compliance: Simulator tests verify system design logic and functionality of the parking brake. Air vehicle demonstrations and tests verify performance of the parking brake.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.9.5/4.4.1.9.5 Parking Brake;

AFGS-87139: para 3.2.3.2.d Brake actuation system;

MIL-B-8584 Design of Brake Systems.

**8.5.8.4** Verify safe stopping performance for all expected runway conditions (dry, wet, snow, ice, etc.) over all mission speed ranges and for all ground maneuvering conditions.

Standard: Criteria is self-explanatory.

Compliance: Air vehicle performance analysis determines stopping performance capability for all specified operations and locations. Laboratory testing and simulation that uses all system hardware and software as incorporated in the air vehicle and under specified environmental design conditions verifies the stopping performance. Air vehicle checkouts verify proper

functioning of the brake system with and without failures as integrated within the air vehicle control systems. Ground braking tests verify system operation for the specified runway conditions.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.4.3/A.4.4.1.4.4.3 Skid control; and A.3.4.1.11.3.1/A.4.4.1.11.3.1 Air vehicle stopping and turn-around performance;

AFGS-87139: para 3.2.3.1 General, 3.2.3.3 Anti-skid brake control and 3.2.4.3 Brakes;

MIL-B-8584 Design of Brake Systems

FAA Doc: 14CFR reference: 23.45, 23.55, 23.493, 23.735, 25.187, 25.45, 25.55, 25.493, & 25.735.

**8.5.8.5** Verify that anti-skid system design can respond to any power interruptions or system malfunctions without compromising the ability of the pilot to control the air vehicle.

Standard: The braking and deceleration system responds to an internal anti-skid malfunction or to external power interruption. The anti-skid self correcting features switch to alternate braking mode in a safe and controllable manner. The change in controlling function is designed to provide for safe recovery of the air vehicle from any failure state.

Compliance: The FMECA indicates safe operation and switching for all anti-skid malfunctions. Simulator testing verifies the modes of operation shown in the FMECA results. Air vehicle checkout verifies proper functioning of the anti-skid system as integrated within the brake control system. Flight and ground testing demonstrates the successful operation of the brake control/anti-skid systems and warnings/indications.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.4.4/A.4.4.1.4.4.4 skid control with power interruption; and A.3.4.1.4.4.5/A.4.4.1.4.4.5 anti-skid engagement and disengagement;

AFGS-87139: para 3.2.3.3 Anti-skid brake control and 3.2.4.3 Brakes;

MIL-B-8584 Design of Brake Systems

**8.5.8.6** Verify that the anti-skid system precludes locked wheel/tire occurrences for all normal operating conditions.

Standard: The anti-skid control system prevents locked wheel conditions from occurring from touchdown to taxi speeds. The system controls braking forces to the extent that the tire is not flat spotted and the anti-skid and air vehicle deceleration performance requirements are still met.

Compliance: The brake design analysis indicates sufficient locked wheel protection for all braking operations. Braking simulator testing verifies locked wheel protection for all modes of air vehicle operations. Air vehicle system checkout verifies proper functioning of the anti-skid system with and without failures. Ground and flight testing verifies installed aircraft performance.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.4.3/A.4.4.1.4.4.3 Skid Control;

AFGS-87139: para 3.2.3.3 Anti-skid brake control and 3.2.4.3 Brakes;

MIL-B-8584 Design of Brake Systems

FAA Doc: 14CFR reference: 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, & 25.735

**8.5.8.7** Verify that brake control power is equal and proportional to brake pedal movement.

Standard: To produce repeatable and predictable braking actuation forces, input commands are proportional to output commands.

Compliance: Laboratory testing verifies that input commands and output braking force are proportional as designed and brake release and running clearances are maintained. Air vehicle checkout verifies that air vehicle system operation and integration matches that which was tested. Ground and flight braking tests validates all the previous testing and checkouts.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.4.1/A.4.4.1.4.4.1 Braking Control Interface;

MIL-B-8584 Design of Brake Systems

**8.5.8.8** Verify that when pedal pressure is removed, pedals return to brakes-off position and that brake control power is not trapped or slow to release at any brake.

Standard: When the input braking command is removed, the brake actuation system returns to a free-wheeling position to prevent any dragging brake events from occurring. Brake heat stack running clearances and consistent brake on pressure levels are maintained.

Compliance: Laboratory testing verifies brake is released and running clearances are maintained when input commands are removed. Air vehicle checkout verifies system operation and integration. Ground and flight braking tests validate all previous testing and checkouts.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.4.1/A.4.4.1.4.4.1 Braking control interface;

MIL-B-8584 Design of Brake Systems;

AFGS-87139: para 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; and 3.2.4.3 Brakes.

**8.5.8.9** Verify that all modes of brake operation are safe.

Standard: Brake system disconnect, switching or disengaging does not cause locked wheels/tire conditions. System failures or control changes are predictable and default to a state that is controllable by the pilot. Single point failures have been identified and their consequences of failure have been eliminated or mitigated.

Compliance: Ensure the FMECA indicates the ability to achieve safe deceleration operations for all braking system malfunctions and failures. Hardware and software simulator testing addresses all predicted modes of failure and malfunction. Air vehicle checkouts verify deceleration system performance with and without failures. Ground and flight tests validate analysis and previous testing.

Comm'l Doc: SAE ARP-1070

DoD/MIL Doc: JSSG-2009: para 3.2.7.4.4.2/4.2.7.4.4.2 Damage tolerant-fail safe evident subsystems and components; and Appendix A: A.3.4.1.4.3/A.4.4.1.4.3 Emergency directional control; and A.3.4.1.4.4.2/A.4.4.1.4.4.2 Alternative independent braking;

MIL-B-8584 Design of Brake Systems;

AFGS-87139: para 3.2.3.1 General; 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; and 3.2.4.3 Brakes.

FAA Doc: 14CFR reference: 11.1-11.2.6

**8.5.8.10** Verify that the anti-skid control system is compatible with and continues to function in the installed environment and that heat buildup does not cause locked wheels on touchdown or during the landing roll.

Standard: Brake control system and anti-skid are integrated with the brake hardware and provide the required air vehicle and landing gear deceleration performance. The methods for the pilot and internal system controls for switch on/off and to alternate controls do not cause:

A. Locked wheels/tire conditions

B. Inadvertent operation without anti-skid

Compliance: Laboratory and simulation testing verifies that all anti-skid operations are sufficient for all specified environmental conditions. Ground and flight testing verifies anti-skid operations and validates previous test results at all operational energy levels and conditions.

Comm'l Doc: SAE ARP-1070.

DoD/MIL Doc: JSSG-2009: para 3.2.7.2/4.2.7.2 Environment;

MIL-B-8584 Design of Brake Systems;

AFGS-87139: para 3.2.3.1 General; 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; and 3.2.4.3 Brakes.

**8.5.8.11** Verify that there is no anti-skid coupling into the landing gear structure.

Standard: Normal, alternate and emergency braking does not induce any undesirable dynamics. Brake operations in each of the designed control systems including switching between systems do not induce any undesirable dynamics.

Compliance: Dynamic analysis shows no adverse gear loadings and undesirable dynamics due to anti-skid operations during all phases of brake operations. Laboratory testing validates values used in the analysis. Air vehicle ground and flight testing shows no adverse loadings due to anti-skid operations during all phases of brake operations.

DoD/MIL Doc: JSSG-2006: para 3.4.2.7 Dynamic response during ground/ship-based operations and 4.4.2 Ground loading conditions;

JSSG-2009 Appendix A: A.3.4.1.4.4.3/A.4.4.1.4.4.3 Skid Control;

AFGS-87139: para 3.2.1.4 Damping and 3.2.3.3 Anti-skid brake control.

**8.5.9** Directional control.

DoD/MIL Doc: AFGS-87139: para 3.2.5;

JSSG-2009: A.3.4.1.4.2, A.4.4.1.4.2, A.3.4.1.4.5, A.4.4.1.4.5.

FAA Doc: 14CFR reference: 23.45, 23.497, 23.499, 23.745, 25.233, 25.45, 25.497, 25.499, & 25.745

**8.5.9.1** Verify that there is a primary and emergency method to provide directional control during ground operations of the air vehicle for all the operational missions and flight configurations.

Standard: Control of the air vehicle is maintained at all times during all phases of ground and flight operations. Systems that affect directional control of the air vehicle include steering, brakes, flight control surfaces, propulsion, etc.

Compliance: Ensure the FMECA indicates safe air vehicle operation for all modes of directional control with various component failures. Air vehicle checkouts indicate proper functioning of the primary, secondary and emergency directional control systems. Air vehicle ground and flight testing verifies safe operation of the primary, secondary and emergency directional control systems.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.2/A.4.4.1.4.2 Directional control; and A.3.4.1.4.3/A.4.4.1.4.3 Emergency directional control;

AFGS-87139: para 3.2.5.1 General; 3.2.5.2 Nose gear steering system;

MIL-S-8812.

FAA Doc: 14CFR reference: 23.45, 23.497, 23.499, & 23.745

**8.5.9.2** Verify that the steering control system protects against steering failures and that system failures does not cause loss of control of the air vehicle.

Standard: All uncommanded steering events and hard-over commands are negated. The system disengages or corrects the command to the extent that the aircraft remains in its original commanded direction or goes to a controllable configuration.

Compliance: FMECA indicates safe operation for all steering and directional control failures (including hard-overs and uncommanded events). Component failure mode testing indicates acceptable performance of all components and switching logic within the steering system. Air vehicle checkouts verify proper functioning of the steering control system with and without failures. Ground and flight testing verifies safe operation for all steering and directional control failures.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.5.2/A.4.4.1.4.5.2 Response to nose wheel steering failure; and A.3.4.1.4.5.3/A.4.4.1.4.5.3 Emergency steering;

AFGS-87139: para 3.2.5.1 General, 3.2.5.2 Nose gear steering system;

MIL-S-8812.

**8.5.9.3** Verify that control of the air vehicle can be maintained during engagement or disengagement of the steering throughout all the operational speed ranges and conditions, even if it occurs from a pilot commanded or a system uncommanded action.

Standard: The air vehicle maintains its directional headings as previously commanded or defaults to a controllable configuration during engaging and disengaging of the steering control function.

Compliance: Design and failure analysis verifies performance of the steering engage and disengage system. Simulator testing verifies control for the expected modes of operation and engagements. Air vehicle checkout and ground and flight testing of the normal, backup and emergency steering systems verifies proper control of the aircraft during engagements and disengagements.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.5.1/A.4.4.1.4.5.1 Steering Characteristics;

MIL-S-8812;

AFGS-87139: para 3.2.5.1 General and 3.2.5.2 Nose gear steering system.

**8.5.9.4** Verify that the steering control system can detect and correct steering hardovers.

Standard: The internal fault detections and heading monitoring system are able to detect any steering system movements that do not match the commanded positions. The time to detect and respond allows the air vehicle to maintain its commanded direction.

Compliance: System design analysis verifies the performance of the steering control system. Modeling and simulator testing verifies performance of the steering control system during failures, uncommanded and hardover events. Air vehicle checkout verifies appropriate response to unacceptable steering actions.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.5.2/A.4.4.1.4.5.2 Response to nose wheel steering failure;

MIL-S-8812.

**8.5.9.5** Verify that steering system operation during taxi, takeoff, and landing is sufficient to accomplish all the required ground maneuvering and parking, and is not sensitive to high-speed, ground rolling effects on directional control.

Standard: Criteria is self-explanatory

Compliance: Ground, taxi and flight testing verifies steering and directional control system performance.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.4.5.1/A.4.4.1.4.5.1 Steering Characteristics;

MIL-S-8812;

AFGS-87139: para 3.2.5.1 General and 3.2.5.2 Nose gear steering system.

FAA Doc: 14CFR reference: 23.45, 23.497, 23.499, 23.745, 25.233, 25.45, 25.497, 25.499, & 25.745

**8.5.10** Landing gear actuation control.

DoD/MIL Doc: AFGS-87139: para 3.2.6;

JSSG-2009: para A.3.4.1.5, A.4.4.1.5

FAA Doc: 14CFR reference: 23.729 & 25.729

**8.5.10.1** Verify safe operation of landing gear retraction, extension, and emergency extension; and verify that there are adequate clearances and suitable geometry for components having relative motion.

Standard: The motion relationship and mechanical interface of the gear and door actuation and locking system are established for all modes of operation. Door sequencing during normal and emergency operations maintains all specified clearances and ensures that the gear can be extended for any expected set of adverse conditions.

Compliance: Solid modeling and/or inspection verifies adequate clearances for various combinations of free play, installation tolerances, rigging, misalignment, etc. Mock-up or simulators validate adequate clearances are maintained under the full range of motion and under all loading conditions. Air vehicle checkouts verify proper functioning of the gear through the gear's full range of motion. Flight testing verifies operation under air loads and ensures no contact with air vehicle structure and other components within the wheel well.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.1.3/A.4.4.1.1.3 Extended clearances; A.3.4.1.1.4/A.4.4.1.1.4 Retraction Clearances; and A.3.4.1.5.1/A.4.4.1.5.1 Retraction and extension actuation interface;

AFGS-87139: para 3.2.6.1 Retraction-extension system and 3.2.6.2 Actuation system indication.

FAA Doc: 14CFR reference: 23.729 & 25.729

**8.5.10.2** Verify that loss of doors, reversal of commands, or any other single failures in the air vehicle power does not prevent gear extension. Verify that the emergency extension system is independent of the landing gear primary power source(s).

Standard: Loss of doors or fairings do not prevent extension of the gear. Gear extension capability is not lost due to failure of door or its actuation. Changes in gear position command while in transit do not cause the gear system to jam, nor prevent the successful extension of the gears. The emergency extension system is independent of the landing gear primary power source(s).

Compliance: Ensure the FMECA indicates safe operation for all failure and operational events that prevent extension. Design analysis shows sufficient capability to extend the gear, either by normal or emergency means. Air vehicle checkout verifies proper operation with the different methods of extending the gear. Flight testing validates previous testing and analysis.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.3/A.4.4.1.5.3 Single failure criteria; A.3.4.1.5.4/A.4.4.1.5.4 Actuation reversal; A.3.4.1.5.6/A.4.4.1.5.6 Operation with loss of door; and A.3.4.1.5.7/A.4.4.1.5.7 Emergency extension;

AFGS-87139: para 3.2.6.1 Retraction-extension system; and 3.2.6.2 Actuation system indication.

FAA Doc: 14CFR reference: 23.729 & 25.729

**8.5.10.3** Verify that proper gear position indications are given to the flight crew for all gear sequencing events during any phase of mission operations.

Standard: The pilot or the operator has sufficient indications that the landing gear is in the last commanded position.

Compliance: Design analysis verifies all modes of operation and position indications are properly annunciated. Analysis addresses all normal and emergency conditions, and addresses all failure events as defined by the FMECA. Simulators/mock-ups verify sequencing events and gear position indications. Air vehicle checkouts verify that proper gear position indications are given to the air crew or ground controller. Flight testing validates the previous design analysis and tests.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.8.1/A.4.4.1.5.8.1 Gear position status indicators; and A.3.4.1.5.4/A.4.4.1.5.4 Actuation reversal;

AFGS-87139: para 3.2.6.1 Retraction-extension system; and 3.2.6.2 Actuation system indication.

FAA Doc: 14CFR reference: 23.729 & 25.729

**8.5.10.4** Verify that the gear position warning system operates properly and allows the crew to override the warning systems.

Standard: Visual and audible warnings are provided to the pilot/operator indicating when the air vehicle is close to the ground and close to landing speeds without gear down. The pilot/operator has time to extend the gear before landing, and indications are given that the gear is in a safe position to land.

Compliance: Design analysis verifies that appropriate ICAWs are provided that address all normal and emergency conditions, and for all failure events as defined by the FMECA. Simulators/mock-ups confirm the logic analysis and validate the warnings and indication. Air vehicle checkouts verify proper installation and integration of the warning and indication system. Flight testing verifies correct functioning of the warning and indication system.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.8.1/A.4.4.1.5.8.1 Gear position status indication;

AFGS-87139: para 3.2.6.1 Retraction-extension system; and 3.2.6.2 Actuation system indication.

FAA Doc: 14CFR reference: 23.729 & 25.729

**8.5.10.5** Verify that the time to move the gear to the command positions is compatible with air vehicle performance requirements for takeoff, landing, and go-around.

Standard: For takeoff conditions, the gear is retracted before its design limit speeds are reached under maximum performance acceleration. Prior to landing, the gear has sufficient time to extend and lock.

Compliance: Design analysis establishes gear retract/extend times in relation to air vehicle performance. Simulator mock-up testing supports analysis and gear times. Air vehicle checkout demonstrations and flight testing verifies retract/extend times for all operational performance speeds and accelerations.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.5.1/A.4.4.1.5.5.1 Retraction; and A.3.4.1.5.5.2/A.4.4.1.5.5.2 Extension;

AFGS-87139: para 3.2.6.3 Retraction-extension time.

FAA Doc: 14CFR references: 23.729, 25.729, 25.1515, 25.1583

**8.5.10.6** Verify that the emergency extension times are compatible with emergency landing requirements.

Standard: When the alternate method of extension is used, such as freefall or battery power, the gear

achieves its final down and locked position before limit speeds are reached or power is lost or interrupted.

Compliance: Ensure the FMECA indicates safe emergency operation for all expected emergency conditions. For the emergency conditions defined by the analysis, the emergency extension times are compatible with emergency air vehicle landing requirements. Simulator testing identifies emergency extend times and operation. Air vehicle checkouts verify installation and emergency extension performance. Flight testing validates the extend times and extension performance.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.7/A.4.4.1.5.7 Emergency extension;

AFGS-87139: para 3.2.6.3 Retraction-extension time.

FAA Doc: 14CFR reference: 23.729, 25.729, 25.1515, 25.1583

**8.5.10.7** Verify that the gear is restrained in the final commanded positions for all ground and flight conditions required by all mission profiles.

Standard: A positive passive means is provided to maintain the gear in the final commanded position without the primary power source. Typical positive passive means include: over center locking mechanism, pins or locking detents, such that gears do not unlock due to power failure, leakage, or excessive deflection.

Compliance: Design analysis verifies gear locking mechanism maintains position under all expected loads resulting from any expected maneuver. Simulator tests and ground demonstrations verify gear position holding capability. Ground and flight testing under all expected mission loading and maneuvering verifies position holding capability.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.9.1/A.4.4.1.5.9.1 Gear position restraint and A.3.4.1.5.1/A.4.4.1.5.1 Retraction and extension actuation interface;

AFGS-87139: para 3.2.6.4 Position restraint.

FAA Doc: 14CFR reference: 23.729, 25.729

**8.5.10.8** Verify that a positive means is provided to lock the gear and doors during ground operations to prevent retraction on the ground. Also verify that visual indicators are provided so the ground retention devices are removed prior to flight.

Standard: Positive means is provided to prevent inadvertent gear retraction while the air vehicle is on the ground, or during any maintenance event. The locking device holds the gear in position for all expected ground configurations and ground operations.

Compliance: Design analysis determines the suitability of the ground locking features of the gear. Ground demonstration and testing under all expected loads and conditions verify position restraints and load carrying capability. The ground demonstration validates the visual indication when the lock mechanism is installed

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.9.1/A.4.4.1.5.9.1 Gear position restraint and A.3.4.1.5.1/A.4.4.1.5.1 Retraction and extension actuation interface;

AFGS-87139: para 3.2.6.4 Position restraint.

**8.5.10.9** Verify that no damage to airframe or gear structure results if power is supplied to retract the gears when ground retention devices are installed.

Standard: Locking devices and the structure used to retain the devices can take the full retraction power and load without damage to and without any detrimental effects to the air vehicle.

Compliance: Design analysis verifies load capability. Air vehicle checkout validates functionality and structural integrity of the restraining device. Ground demonstration during flight testing validates the analysis and previous testing.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.5.10/A.4.4.1.5.10 Ground safety restraint; and

A.3.4.1.5.1/A.4.4.1.5.1 Retraction and extension actuation interface;

AFGS-87139: para 3.2.6.4 Position restraint.

**8.5.10.10** Verify the downlocking and uplocking fail-safe provisions of the landing gear.

Standard: If the doors or lock mechanisms fail or jam, the links and locks allow the gear to be maintained in its final commanded position and to be extended prior to landing. These provisions limit the possibility of having inadvertent gear extensions.

Compliance: The design analysis and the FMECA verifies the performance of the locks with and without failures. Simulator/mock-up testing verifies strength and functionality of the locks. Flight testing verifies the gear position locking design.

DoD/MIL Doc: JSSG-2009: para 3.2.7.4.4.2/4.2.7.4.4.2 Damage tolerant-fail safe evident subsystems and components; and Appendix A: A.3.4.1.5.3/A.4.4.1.5.3 Single failure criteria;

AFGS-87139: para 3.2.6.1 Retraction-extension system and 3.2.6.2 Actuation system indication.

FAA Doc: 14CFR reference: 23.729, 25.729

**8.5.11** Auxiliary deceleration devices.

DoD/MIL Doc: AFGS-87139: para 3.2.7 Auxiliary deceleration devices;

JSSG-2009: A.3.4.1.8, A.4.4.1.8

**8.5.11.1** Verify that the arresting system is capable of stopping the air vehicle at all the required design conditions (refused takeoffs (RTOs), fly-in engagements, brake overruns, etc.) without any damage to either the air vehicle or the arresting systems.

Standard: The arresting system is capable of stopping the air vehicle at all specified design conditions. Barrier engagements are defined by energy level, hook loads, air vehicle speeds and weights. The engagement limits are defined for on-center and off-center engagements. The engagement limits are set either by the air vehicle or the type of barrier; these limits are defined and documented.

Compliance: Design analysis verifies the barrier engagement capability under all specified conditions. Flight testing supports the design analysis and verifies the installation, functionality and performance capability of the arresting system and the barrier engagement limits.

Comm'l Doc: SAE ARP-1538.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.8.1.1 thru A.3.4.1.8.1.8/A.4.4.1.8.1.1 thru A.4.4.1.8.1.8 Hook/Arresting system information;

MIL-A-18717

MIL-A-83136.

**8.5.11.2** Verify the safety of the following: hook load, hold-down, and damping forces; engagement probabilities; off-center engagement capabilities; lateral run-outs; barrier compatibility; and any other specific engagement provisions.

Standard: The arresting hook design minimizes the occurrence of the hook skipping over the cable and improves the ability of engaging the cable at the various air vehicle positions. Arrestments often cause violent hook and cable movements which can contact air frame structures. The system provides sufficient damping and protection to minimize any damage to the air vehicle.

Compliance: Design analysis indicates compliance at all the specified arrestment conditions. Air vehicle demonstrations determine the operability of the system and hold down forces. Flight testing supports the design analysis and verifies the installation, functionality and performance capability of the arresting system not only to stop the air vehicle, but to minimize air vehicle

damage.

Comm'l Doc: SAE ARP-1538.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.8.1.1 thru A.3.4.1.8.1.8/A.4.4.1.8.1.1 thru A.4.4.1.8.1.8 Hook/Arresting system information;

MIL-A-18717;

MIL-A-83136;

AFGS-87139: para 3.2.7.1 Arresting hook system.

**8.5.11.3** Verify that the hook can be deployed from the crew station in a timely manner and that a means is provided in the crew station to determine the position of the hook.

Standard: The pilot or the operator can deploy the hook from his station. Indications confirm that the arresting hook is in the last commanded position. The hook is deployed to the proper position in a timely manner necessary to meet all normal and emergency conditions.

Compliance: FMECA determines the situations that require deployment of the hook and time to deploy. Design analysis indicates compliance with operational conditions. Flight testing supports the design analysis and verifies the installation, functionality and performance capability of the arresting system and its indications.

Comm'l Doc: SAE ARP-1538

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.8.5 thru A.3.4.1.8.8/A.4.4.1.8.5 thru A.4.4.1.8.8;

MIL-A-18717

MIL-A-83136

AFGS-87139: para 3.2.7.1 Arresting hook system.

**8.5.11.4** Verify that no part of the landing gear, air vehicle, or stores snags the arresting cable when the air vehicle is rolling on rims after a tire failure.

Standard: Nose and main gear rims diameters are large enough to preclude snagging cable (stable or dynamic conditions). Projections in front of the rims do not snag the cable or cause the barrier cable to travel over the top of the wheel and snag the strut(s).

Compliance: Design analysis and component inspection indicates cable roll-over capability at all operational conditions. Flight testing and demonstration supports the design analysis and performance of the arresting system.

Comm'l Doc: SAE ARP-1538

DoD/MIL Doc: MIL-A-18717

MIL-A-83136

AFGS-87139: para 3.2.7.1 Arresting hook system.

**8.5.11.5** Verify that the performance of drag chutes meets the specified deceleration requirements without any adverse loading or damage to air vehicle structure.

Standard: Design of the chute and its attachments and deployments meets all specified operational conditions within specified failure rates. The speeds for deployment and the drag performance of the chute are defined. Method for releasing the chute is compatible with system operations.

Compliance: Design analysis indicates compliance at all specified operational conditions. Flight testing supports the design analysis and verifies the installation, functionality and performance capability of the drag chute system.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.8.2/A.4.4.1.8.2 Drag Chutes; and AFGS-87139 3.2.7.2

Drag Chutes.

**8.5.11.6** As applicable to the air vehicle, verify the performance of thrust reversers, speed brakes, and/or other auxiliary deceleration systems; and verify that there is no adverse loading or structural damage to the air vehicle when these devices are used.

Standard: Auxiliary deceleration devices (alone or in combination with other deceleration devices) do not cause unacceptable air vehicle loadings or dynamics. Directional control of the air vehicle is maintained when these devices are in use for all specified operations and expected environments.

Compliance: Design analysis verifies compliance at all operational and environmental conditions. Flight testing supports the design analysis and verifies the installation, functionality and performance capability of the thrust reversers and/or speed brakes and any other deceleration devices. Flight testing and demonstrations verify absence of adverse impact on air vehicle control.

DoD/MIL Doc: AFGS-87139: para 3.2.7.1 Arresting hook system; and 3.2.7.2 Drag chutes.

**8.5.12** Ground handling.

DoD/MIL Doc: AFGS-87139: para 3.2.7;

JSSG-2009: para A.3.4.1.2.2, A.4.4.1.2.2

FAA Doc: 14CFR reference: 23.471-23.511, 25.471-25.519

**8.5.12.1** Verify that safe jacking provisions are provided and that they satisfy all specified air vehicle gross weight conditions and environmental conditions.

Standard: Jacking provisions are provided on each gear so various maintenance actions can be accomplished. The provisions are capable of supporting the air vehicle such that the maintainers can accomplish all required tasks within all required environmental conditions.

Compliance: Design analysis verifies jacking location and capability for all expected conditions, including wind gusts and wind direction. Air vehicle ground testing validates the analysis and verifies suitability for all environmental and maintenance conditions.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.2.1.1/A.4.4.1.2.2.1.1 Axle jacking; and A.3.4.1.2.2.1.2/A.4.4.1.2.2.1.2 Fuselage jacking;

AFGS-87139: para 3.2.8.1 Jacking;

NATO STANAG 3098

FAA Doc: 14CFR reference: 23.507

**8.5.12.2** Verify that the jacking interface meets the defined standards, including appropriate international standards.

Standard: STANAGS are typically the primary military standard.

Compliance: Design analysis shows compliance with all international interfaces and operational requirements. Air vehicle demonstration verifies compliance with international ground equipment.

DoD/MIL Doc: NATO STANAG;

AFGS-87139: para 3.2.8.1 Jacking

FAA Doc: 14CFR reference: 23.507, 25.519

**8.5.12.3** Verify that the air vehicle is capable of being safely towed in all specified directions, at all mission weights, under the required environmental conditions, on expected operational surfaces.

Standard: Towing provisions on the gears allow towing of the air vehicle at its maximum gross weight. The design accommodates all required tow vehicles/bars and the tow interface conforms to all service/international standards. Towing is limited by the capability of the powered steering system. Operational procedures for towing outside of powered steering limits are defined. Steering disconnects prevent damage to the steering system when operated outside the powered steering limits.

Compliance: Design analysis verifies towing capability and the towing interface at all specified conditions. Air vehicle ground testing and operational tests validates the analysis and verifies suitability for all environmental conditions and surfaces.

DoD/MIL Doc: NATO STANAG 3278;

NATO STANAG 4101;

MIL-STD-805;

JSSG-2009 Appendix A: A.3.4.1.2.2.1.3/A.4.4.1.2.2.1.3 Landing gear towing; A.3.4.1.2.2.1.5/A.4.4.1.2.2.1.5 Towing interface;

AFGS-87139: para 3.2.8.2 Towing

FAA Doc: 14CFR reference: 23.509 & 25.509

**8.5.12.4** Verify emergency towing capability of the air vehicle to the maximum weight and load requirements.

Standard: When emergency towing provisions are provided on the gear, the towing loads and limits are defined. The attachment methods, interface and limitations are specified.

Compliance: Design analysis verifies emergency towing methods, interfaces and capability for all expected conditions. Air vehicle ground demonstrations and testing validates the analysis and verifies suitability for all environmental conditions and surfaces.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.2.1.4/A.4.4.1.2.2.1.4 Emergency towing;

AFGS-87139: para 3.2.8.2 Towing

FAA Doc: 14CFR reference: 23.509 & 25.519

**8.5.12.5** Verify that all mooring requirements are met for all mission weights and environmental conditions, and that these requirements address the defined standard arrangements and interface for mooring to ensure safety.

Standard: Mooring provisions accommodate all mooring conditions that the vehicle encounters. The interface conforms to all specified interfaces and international standards.

Compliance: Design analysis verifies mooring capability and mooring interface for all expected conditions including wind gust and wind direction. Air vehicle ground demonstration and testing validate the analysis and verify mooring provisions for all environmental conditions and surfaces.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.2.1.6/A.4.4.1.2.2.1.6 Mooring provisions;

AFGS-87139: para 3.2.8.3. Mooring

FAA Doc: 14CFR reference: 25.519, 23.519

**8.5.12.6** Verify that the specialized systems requirements and functional characteristics are safe for the operational mission conditions. (Examples of specialized systems are skis, skids, kneeling, crosswind positioning, and in-flight pressure control systems.)

Standard: The design criteria for any specialized systems that affect ground operation or control of the air vehicle are defined. Requirements for mission operation are consistent with specialized systems/equipment .

Compliance: Design analysis verifies specialized system performance and operations for all expected missions including all specified environments. Air vehicle ground testing validates the analysis and verifies suitability for all environmental conditions and surfaces.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.10.1 thru A.3.4.1.10.2/A.4.4.1.10.1 thru A.4.4.1.10.2 Flotation and snow ski gear;

AFGS-87139: para 3.2.9.1 General.

FAA Doc: 14CFR reference: 23.737, 25.737

**8.5.12.7** Verify all known potential single-point failures are identified and are acceptable.

Standard: No single component or function failure results in loss of any one of the following: extend system, deceleration function, air vehicle support or directional control on the ground. Loss of primary landing gear functions/performance due to single-point failure is mitigated by an alternate means of accomplishing the function (preferably independent from the primary power and control).

Compliance: Design analysis and FMECA determine safe operation for all possible failure events and list the alternate operational capability. Simulator, ground and flight testing validates the analysis and verifies the acceptable alternate operation.

DoD/MIL Doc: JSSG-2009: para 3.2.7.4.4.1/4.2.7.4.4.1 Safety and mission critical functions; and Appendix A: A.3.4.1.3.1.3/A.4.4.1.3.1.3 Failure tolerance;

AFGS-87139: para 3.5 System safety.

FAA Doc: 14CFR reference: 23.471-23.511, 25.471-25.519, 25.1309

**8.5.12.8** Verify that the air vehicle does not turnover or ground loop for all mission conditions that produce side-load. All taxi and turn conditions at all gross weights are evaluated for all possible strut/tire conditions and for adversely sloped taxiways and runways.

Standard: The turnover loads do not exceed a 0.5g load at the CG location for all possible gear configurations. Taxi and turn conditions include all expected turning speeds and turn radius at all air vehicle weights and ground configurations including crowned and sloped runways.

Compliance: Design analysis and dimensional inspections verifies the air vehicle turnover angle and turn radius at turn off speeds. Air vehicle ground operations and test validate the analysis.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.1.1/A.4.4.1.1.1 Gear Arrangement; and A.3.4.1.1.2/A.4.4.1.1.2 Pitch Stability;

AFGS-87139: para 3.2.1.2 Arrangement.

FAA Doc: 14CFR reference: 23.473, 23.477, 23.485, 25.473, 25.477, 25.485

**8.5.12.9** Verify the landing gear and engine inlet geometry are designed to prevent possible FOD to engines.

Standard: The location of the main and nose gear tires minimizes the probability of throwing FOD, water, snow, slush into the engine inlet. Design limits inlet exposure by establishing spray pattern and thrown object trajectories.

Compliance: Design analysis indicates compliance of gear and inlet locations, and projected spray patterns for various environmental elements. Air vehicle demonstrations and ground testing

validate the analysis.

DoD/MIL Doc: JSSG-2009 Appendix A: A.3.4.1.2.3/A.4.4.1.2.3 Ground FOD

AFGS-87139: para 3.2.1.1 General, 3.2.1.2 Arrangement; and 3.2.1.3 Clearances.

**8.5.12.10** Verify that the landing gear systems are compatible with air vehicle structure, weight, and balance, and with any other subsystems that interface with the landing gear system.

Standard: The arrangement and location of the gear and its attach points support air vehicle weight and balances for specified mission operations and within specified environmental conditions. All interfaces with other systems are defined and controlled.

Compliance: Design analysis indicates the gear supports the air vehicle at all weight and balance conditions, and interfaces with all other air vehicle systems as needed to complete specified missions. Laboratory testing validates the analysis. Simulator testing verifies interface compatibility. Air vehicle ground and flight testing verifies compatibility with all interfaced systems.

Comm'l Doc: Level II Interface and Functional Requirements as stated in contractual interface documentation.

DoD/MIL Doc: AFGS-87139: para. 3.2.1.1 General; 3.2.1.2 Arrangement; and 3.2.1.3 Clearances.

FAA Doc: 14CFR reference: 23.471-23.511, 25.471-25.519

**8.5.12.11** Verify landing gear system's integrity in preventing uncommanded or unsafe effects in the event of single-point failures, dormant failures, or primary system loss. Ensure that the consequences of the failure are eliminated, mitigated, or evaluated to be at a risk level acceptable to the procuring activity.

Standard: Single-point failures of interfacing systems do not adversely affect landing gear systems and components. The analysis and logic incorporated within the control system design prevents loss of critical function due to a single point failure of any landing gear function or component. Failure of externally provided power or governing control logic (for example electrical, hydraulic, etc) does not prevent the air vehicle from safely landing or stopping within the designated runways.

Compliance: Design analysis and FMECA indicates safe operation for all possible failure events and documents solutions to all unsafe conditions including dormant states of non-indicated failures. All levels of testing support the FMECA and verify the acceptability of alternate systems operation.

Comm'l Doc: Level II single point/redundancy requirements.

DoD/MIL Doc: AFGS-87139: Appendix B

FAA Doc: 14CFR reference: 23.471-23.511, 25.471-25.519, 25.1309, 11.1-11.2.6

**8.5.12.12** Verify that the system and system components have damage tolerance capability to sustain partial failure or leakage before failure without jeopardizing safety.

Standard: Structure or components that have fail safe design criteria fail in a safe and predictable manner. The design limits undesirable failures and controls the method of failure and provides maintenance procedures for detecting failures for fail safe components.

Compliance: Design analysis shows damage tolerance capability of individual components, and FMECA shows primary failure modes for the system and components. Static, fatigue and system tests validate the analysis.

Comm'l Doc: Level II Damage Tolerance requirements.

DoD/MIL Doc: AFGS-87139: para. 3.2.2.1 General; 3.2.2.2 Shock absorption; and 3.2.2.3 Tail bumpers.

FAA Doc: 14CFR reference: 25.1309, 25.571

**8.5.12.13** Verify that failures and leakage are evident in flight and/or during routine ground maintenance.

Standard: The landing gear system and its components are designed to an agreed to maintenance concept. Components (tire, wheels, brakes, gear structure, locks, latches, doors, etc.) fail in an inspectable manner or shows an indication that prevents the air vehicle from being operated unsafely.

Compliance: Design analysis indicates that acceptable fail safe criteria is applied, and that sufficient indications are provided. Laboratory testing validates the analysis. Air vehicle checkout verifies the installation and application of design logic. Air vehicle flight testing validates failure and leak criteria.

Comm'l Doc: Level II Damage Tolerance requirements and Maintainability requirements.

DoD/MIL Doc: AFGS-87139: para. 3.2.2.1 General; 3.2.2.2 Shock absorption; and 3.2.2.3 Tail bumpers.

FAA Doc: 14CFR reference: 25.1309, 25.571

**8.5.12.14** Verify that adequate and safe lift points are provided for air vehicles that require routine external ground crew movement utilizing hands, mechanical lifts, hoists, etc.

Standard: Proper air vehicle moving and lifting operations are indicated and documented. Areas where the air vehicle is not to be pushed, towed or otherwise stressed are highlighted.

Compliance: Design analysis establishes proper air vehicle moving or lifting operations. Design analysis identifies where the air vehicle is not to be loaded while on the ground or during ground maintenance events. Air vehicle demonstration validates movement, lifting and maintenance operations.

DoD/MIL Doc: JSSG-2001: para 3.4.3.2.1.6.1.3, 4.4.3.2.1.6.1.3

**8.5.12.15** Verify that adequate crew station information is available to notify the flight crew of the landing and deceleration system operational conditions and state of functionality.

Standard: Crew/operator station provides means to assess landing and deceleration systems operating condition to the extent necessary for flight safety. The system provides warnings, cautions and advisories to operators and maintainers for hazardous failure conditions of equipment and controls of the landing and deceleration systems.

Compliance: Inspection of design verifies provisions for the necessary monitoring of the system's operation and health. Integration tests, to include Failure Modes and Effects Tests (FMET), verify compatibility of landing and deceleration systems with cockpit control and monitoring system. Ground tests of installed systems verify operating performance.

**8.5.12.16** Verify that flight and maintenance manuals include normal, back-up, and emergency operating procedures, limitations, restrictions, servicing, and maintenance information for all landing gear and deceleration systems.

Standard: Technical data describes the installed landing and deceleration systems, normal and emergency operation, operating procedures and limitations, servicing, and maintenance requirements.

Compliance: Technical data is validated by inspection of design documentation and technical manuals and demonstration of technical manual procedures.

**8.5.12.17** Verify that all components, either individually or as part of a landing gear and deceleration subsystem, have passed all safety-related qualification tests (e.g., proof, burst, vibration, acceleration, explosive atmosphere, pressure cycling, and temperature cycling as required for airworthy performance).

Standard: Component analysis, component level testing and ground based simulator testing confirm sufficient safety verification. Safety of Flight (SOF) testing may be a limited amount of verification to permit initial flight test without fully qualified hardware. Life limits and restrictions may be required.

Compliance: Landing gear and deceleration components are verified for expected usage and environmental conditions using analyses, simulator tests, component test, and ground/flight tests. Inspection of design criteria documents establish usage and environment (natural and induced) requirements (the following criteria should be considered: life, temperature, ambient pressure, shock, vibration, acoustics, explosive atmosphere, proof & burst pressure, acceleration, gyroscopic moments, humidity & moisture, sand & dust, rain, salt fog, fungus, attitude, EM environments, material compatibility, FOD, steam & gun gas ingestion and others as derived from the air vehicle requirements that could affect safe usage of the equipment). Component Safety Of Flight (SOF) and qualification analyses and tests validate requirements, capabilities and limitations.

**8.5.12.18** Verify the safe installation of the landing gear and deceleration system and their components.

Standard: The on air vehicle installation meets all interface, functions, form, fit, and performance criteria as designed. Appropriate system and component checkout procedures are in place to determine form, fit and functions are as designed and perform as expected.

Compliance: Air Vehicle checkout and acceptance procedures are developed and performed. The landing gear system demonstrations and tests exercise the hardware and software to the maximum extent possible on the air vehicle. Systems installation and checkout procedures are further substantiated during taxi testing and subsequent flight test.

## 8.6 Auxiliary/emergency power system(s) (APS/EPS).

This covers auxiliary power units (both ground and in flight use applications), airframe accessory gearboxes, engine starting system components, power-take-off (PTO) shafts, emergency power systems, and ram air turbines (RATs).

DoD/MIL Doc: JSSG-2009 Appendix C

FAA Doc: 14CFR references: 23.901-23.1203, 25.901-25.1207,

TSO C77b,

AC 20-128, AC 120-42A (Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.)

**8.6.1** Verify that system components are safe for the intended use and environment.

Standard: Component design and performance requirements, capabilities and limitations are established and substantiated.

Compliance: Inspection of design criteria documents establish usage and environment (natural and induced) requirements for life, temperature, ambient pressure, shock, vibration, acoustics, explosive atmosphere, proof & burst pressure, acceleration, gyroscopic moments, humidity & moisture, sand & dust, rain, salt fog, fungus, attitude, EM environments, material compatibility, FOD, steam & gun gas ingestion and others as derived from the air vehicle requirements that could affect safe usage of the equipment). Component Safety Of Flight (SOF) and qualification analyses and tests validate requirements, capabilities and limitations.

DoD/MIL Doc: JSSG-2009: para 3.2.7 - 3.2.7.6.5, 4.2.7 - 4.3.7.6.5

FAA Doc: TSO C77b

**8.6.2** Verify that the APS/EPS operates safely under installed operating conditions over the design envelope.

Standard: Control system ensures stable operation. Power, torque, bleed pressure and temperature provided by APS/EPS are within specified limits.

Compliance: Inspection of control system design analysis verifies phase and gain margins exist between all control loops to provide stable operation. FMECA verifies safe system operation or termination following any combination of failures that have a probability of occurrence greater than one in ten million, or single control system failure. Inspection of performance model verifies operability margins throughout intended ground and flight envelopes as applicable. Software verification and validation testing, control system integration tests, and Vehicle Integration tests verify proper operation. Aircraft ground tests and flight tests of the installed system and interfacing systems demonstrate intended operation.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3, C.4.4

FAA Doc: 14CFR reference: 23.901, 25.901, 25.903 (f),

TSO C77b 4.4.1 - 4.5.2

**8.6.2.1** Verify that protective safety features (auto shutdown, etc.) are available and effective in protecting the equipment against hazardous malfunctions and conditions such as over-speed, over-temperature and inadvertent activation.

Standard: Criteria is self-explanatory.

Compliance: Inspection of system safety documentation (FMECA) verifies safe system operation or termination following any combination of failures that have a probability of occurrence greater than one in ten million, or single control system failure. Software verification and validation testing, control system integration tests, and Vehicle Integration tests verify intended operation. All protective shutdown features are verified by test at the controller (via simulated inputs) and system levels.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.12.1, C.4.4.3.12.1

FAA Doc: TSO C77b 4.6.2

**8.6.3** Verify that the functional and physical compatibility of the integrated system is safe.

Standard: The integrated APS/EPS system maintains functional compatibility throughout all normal operating and flight conditions. Hazardous conditions to interfacing subsystems do not result from normal or abnormal operation of the APS/EPS system. Physical interfaces withstand the maximum combination of static and dynamic loading throughout defined flight and ground envelopes and environments. Safety critical interfaces are fault tolerant or fail safe. No single failure or combination of failures with probability greater than one in ten million results in loss of air vehicle.

Compliance: APS/EPS physical and functional interface requirements are verified by inspection of program documentation such as interface control and design documents. System interfaces are verified to be safe by analyses of worst case single failure operating and loading conditions (bending, torsional and gyroscopic loads, pressures, temperatures, vibratory, etc.). System interface critical analysis assumptions are verified by stress, thermal, pressure or vibration surveys during ground and flight tests as appropriate. Integrated system functional compatibility is verified by simulation, test and demonstration of system functionality at integration test facilities and on the air vehicle during ground and flight test. System physical and functional compatibility hazards and probability of air vehicle loss are verified by inspection of System Safety documentation.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3, C.4.4.3

FAA Doc: 14CFR references: 23.901, 25.901, 25.903 (f),

TSO C77b 4.4.1 - 4.5.2, Sections 6 and 7

**8.6.4** Verify that high-speed rotating components are designed to be damage tolerant, or that there are provisions for containment of failed parts. Also, verify that any potentially uncontained fragments do not damage SOF components or CSIs or injure personnel.

Standard: High-speed rotating components maintain damage tolerance for two times the inspection interval, in the presence of material, manufacturing, processing, and handling defects for the design service life and design usage specified in the model specification. In the absence of damage tolerant design, containment prevents SOF component damage due to liberated parts.

Compliance: For damage tolerance approach: Inspection of material characterization data validates material properties used in failure mechanics analysis. Component development tests validate thermal and stress models. Design analysis of rotating components verify adequate strength and fatigue life margins using minimum material properties. FMECA verifies control system ability to prevent overspeed following any single or likely combination of failures. Disk burst and durability testing demonstrates adequate strength and life. Material and component manufacturing processes are validated by inspection. Trajectory and size analysis in an installed configuration verifies that loss of safety critical systems are extremely remote or less in the event of an uncontained failure.

For containment approach: Analysis of maximum energy burst verifies containment of fragments and includes assessment of failure modes that may result in axial movement of the rotating group. Containment tests verify containment of hazardous fragments.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.10.1, C.4.4.3.10.1

FAA Doc: 14CFR reference: 23.903 (b), 23.1461, 25.901(c), 25.1461,

AC 20-128, TSO C77b: 5.9, 6.6, 6.7, 6.8

**8.6.4.1** Verify that containment or other provisions preclude a failed power-take-off (PTO) system from causing secondary damage, due to flailing or whipping, to critical safety items (CSI) or to nearby safety of flight component/systems, including fuel and hydraulic lines.

Standard: Criteria is self-explanatory and applies to all components of the installed PTO system including flex couplings, shear sections, clutches and interfacing AMAD/EMAD stub shafts.

Compliance: Inspection of design criteria verifies containment, duration and operating parameters. Containment tests (generally component level) validate specified capability. For a non-containment solution, safety and other supporting analyses and tests verify that personnel and safety critical systems are safe in event of a flailing or whipping shaft.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.10.1, C.4.4.3.10.1

FAA Doc: 14CFR reference: 25.901 (c), 25.1167 (a), (c),

**8.6.5** Verify that APS/EPS equipment in the installed configuration is free of damaging vibrations at all operating conditions throughout the APS/EPS operational envelope.

Standard: Installed equipment withstands vibratory induced loads from startup to maximum operating speed under any combined expected torsional and air vehicle maneuver induced loading. System contains no natural (resonant) frequencies within the normal operating range or has damping provisions to prevent resonances, damage or failure.

Compliance: Inspection of design and models verify that the system (compressor, turbine, shafts, gear trains and other highly stressed parts) is free from vibration stresses that damage the system or other air vehicle systems throughout the operating envelope. Development tests validate analyses and models. Durability tests demonstrate the ability to withstand the vibratory stresses for the intended life.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.10.2, C.4.4.3.10.2

FAA Doc: 14CFR reference: 25.901 (c), 25.903 (f),

TSO C77b 5.10

**8.6.5.1** Verify, when applicable, that the PTO system is capable of operating safely when installed at the maximum allowable conditions of misalignment and imbalance.

Standard: Operating the PTO system (shaft, clutch, flex coupling, interfacing AMAD/EMAD stub shafts, etc.) with the maximum shaft imbalance and installation misalignment does not induce excess vibration or accelerated wear of system components.

Compliance: Inspection of design criteria verifies that requirements for balance and alignment of the PTO shaft are addressed and tolerances established. Endurance testing in a suitable test fixture verifies safe operation at the maximum allowable imbalance and misalignment.

DoD/MIL Doc:JSSG-2009 Appendix C: C.3.4.3.10.2, C.4.4.3.10.2

FAA Doc:14CFR reference: 25.1167 (a), (c),

**8.6.6** Verify that the emergency power system (including the APU or jet fuel starter (JFS) when deemed flight essential) is capable of responding to failures and providing adequate levels of bleed air, shaft, electrical and/or hydraulic power in sufficient time to meet design requirements.

Standard: Criteria is self-explanatory.

Compliance: Inspection of program documentation and design analysis identifies the APS/EPS sizing and performance requirements. Component tests verify the ability to start, operate, and endure the natural and induced environmental conditions (ambient temperature extremes, pressure, humidity, rain, sand & dust, etc) and flight conditions (maneuvers, attitudes, negative "g", shock, etc). Base level and simulated altitude chamber tests verify uninstalled performance and operability. Analysis and/or wind tunnel tests verify inlet and exhaust performance. Performance analysis (model) verifies installed performance throughout the operating and flight envelope. Integration tests (e.g., Vehicle Integration Facility) verify APS/EPS controller hardware/software compatibility with the air vehicle. Installed system ground test verify proper operation and performance with Air Vehicle systems. Flight test results including those of the inlet and exhaust system verify system starting, operability and performance and validate installed performance model.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.4, C.4.4.3.4

FAA Doc: 14CFR reference: 23.943, 25.901 (f), 25.943,

TSO C77b: 4.1, 4.4.1, 4.4.2, 4.4.3, 4.7

**8.6.7** Verify that provisions for the following adequately address safety: (for criteria 8.6.7.1 through 8.6.7.6)

**8.6.7.1** (was 8.6.7.a) Structural mounting

Standard: Mounts withstand maximum combination of static and dynamic loading throughout defined flight and ground envelopes and environments. Structural mounts are corrosion resistant and fireproof (as governed by section 8.4).

Compliance: Inspection of design criteria verifies maximum static and dynamic mount loads including flight loads and loads that result from APU/EPU seizure, imbalance under a failed blade condition, and the critical vibration amplitudes and frequencies transmitted by the APU/EPU from the mounting points to the airframe through the normal operating range of the APU. Structural analysis verifies the ability to withstand specified limit loads without permanent deformation and ultimate loads without failure. Critical analysis assumptions are verified by stress, thermal, pressure or vibration surveys during ground and flight tests.

DoD/MIL Doc: JSSG-2009: para 3.2.7, 4.2.7, 3.2.7.4.4, 4.2.7.4.4, 3.2.7.5, 4.2.7.5

FAA Doc: 14CFR reference: 25.901 (c), (d); and TSO C77b: 4.8, 5.1.3, 5.2.5

### 8.6.7.2 (was 8.6.7.b) Wiring and plumbing support, routing, and clearances

Standard: APS system wiring and plumbing is mounted/routed such that there is no interference or contact with neighboring components or the system and that no wear or chaffing conditions exist. Positive clearances are maintained under all operational loadings. Electrical wiring is routed above flammable fluid lines to preclude leak impingement on wiring. Flammable fluids and oxidizers are separated from wiring by at least 1/2". Wiring (including connectors) and plumbing do not contain natural (resonant) frequencies within the system operating range or have adequate damping provisions to prevent resonances, damage or failure.

Compliance: Inspection of design criteria verifies suitable support and clearance requirements. Inspection of drawings verify proper installation that provides for adequate routing, support and clearance to preclude contact and chafing. Tests (vibration response) and analysis verify that plumbing lines are adequately dampened. Unit durability tests verify life. Visual inspection of installed system verifies required support and clearance.

Comm'l Doc: ARP994, Tubing/Plumbing Routing - tubing and line support, routing and clearance requirements;

SAE AS50881A, Wiring, Aerospace Vehicle - wiring support and routing requirements.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8

FAA Doc: 14CFR reference: 23.993, 23.1017, 25.901 (c), 25.993, 25.1017

### 8.6.7.3 (was 8.6.7.c) System/component and compartment drainage.

Standard: APS/EPS drain and vent system accommodates the combined maximum system leakage and ventilation flow rates. No allowable flight conditions inhibit the function to the extent that APS/EPS operation is impacted or a hazardous condition created. Storage or expulsion of the fluids and vapor do not create a hazardous condition. These provisions are compatible with applicable fire protection certification criteria of section 8.4.

Compliance: Inspection of design verifies existence of provisions for drainage of flammable fluids and vapors within the APU which may occur during normal operation or abnormal events such as a false start. Aircraft manufacturing or system operational tests verify functional capability.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8

FAA Doc: 14CFR reference: 25.1187; and TSO C77b: 5.27, 5.42, 5.52

### 8.6.7.4 (was 8.6.7.d) System/component and compartment cooling and ventilation.

Standard: APS/EPS compartment cooling and ventilation provisions maintain the temperatures of system components, fluids, and structure within the temperature limits established for these components and fluids, under ground and flight operating conditions, and after normal system shutdown. These provisions are compatible with applicable fire protection certification criteria of section 8.4.

Compliance: Temperature limit requirements are verified by inspection of design documentation. System thermal performance is verified by inspection of design analysis, thermal models and simulations. APS/EPS compartment environments are verified by thermal surveys during ground and flight tests.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8

FAA Doc: 14CFR reference: 23.1041 - 23.1045, 23.1103 (a), 25.1041 - 25.1045, 25.1103 (a); and TSO C77b (5.3)

**8.6.7.5** (was 8.6.7.e) System/components designed for appropriate level of fire hardening.

Standard: Safety critical components withstand a 2000 deg F fire with a heat flux of 10 Btu/sec/ft^2. These provisions are compatible with applicable fire protection certification criteria of section 8.4.

Compliance: Analysis demonstrates material and component compliance with the established fireproof or fire-resistance air vehicle requirements. Laboratory component tests demonstrate compliance to the fire protection requirements when exposed to the required flame temperature and heat flux density for the required time (15 minutes for fireproof and 5 minutes for fire resistance).

DoD/MIL Doc: JSSG-2009: para 3.3.3, 4.3.3, 3.3.8, 4.3.8; and Appendix G: G.3.4.7, G.4.4.7

FAA Doc: 14CFR reference: 23.1181 - 23.1203, 25.1181 - 25.1207; and TSO C77b (5.2)

**8.6.7.6** (was 8.6.7.f) Accessibility to all required inspection and servicing features and areas

Standard: Required installed APS/EPS system servicing, inspections, and maintenance activities can be accomplished and verified by the multivariate maintainer population. This includes access necessary to accomplish pre or post maintenance leak checks of high pressure fluid and pneumatic system. Access accommodates the maintainer's anthropometric dimensions and strength limitations, taking into consideration all environmental conditions, and any required mission equipment (chemical protective gear, gloves, etc.).

Compliance: Access for required servicing, inspections and maintenance requirements are verified by inspection of design documentation and virtual models that provide evidence that clearances, reach and weight are within the capability of the maintainer population. Physical mock-ups and Technical Order verification demonstrations verify ability to accomplish and verify required tasks.

DoD/MIL Doc: JSSG-2009: para 3.2.6, 4.2.6

FAA Doc: 14CFR reference: 23.901, 23.1021, 25.901, 25.1021

**8.6.8** Verify that the inlet and exhaust hazards (i.e., velocities, temperatures, acoustics, exhaust by-products, etc.) to the ground/flight/passenger personnel, air vehicle subsystems, and air vehicle structure are acceptable.

Standard: APS/EPS is not susceptible to leakage from flammable fluid lines, fitting, or components entering the inlet air stream. Exhaust gases are transported off the air vehicle. Exhaust plume does not:

A. Impinge on aircraft structure or equipment to the extent that maximum temperatures are exceeded

B. Impinge on or mix (except when designed) with any flammable fluid drainage or vapor discharge to the extent that the fluid/vapor auto ignition temperature is achieved or exceeded

C. Impose an unavoidable hazard to flight/ground crew or impede a pre-flight/launch activity.

Acoustic emissions do not exceed established levels.

Compliance: Inspection of design verifies that leakage from flammable fluid lines, fittings, or components cannot enter the intake air stream. Component and ground tests verify that the exhaust system prevents leakage of exhaust gas into the aircraft. Exhaust plume interaction with structure, fluid/vapor discharge, and flight/passenger/ground crew is validated by inspection of plume and thermal analysis and models. Design analysis verifies there is no plume attachment to the aircraft during in-flight operation. Flight tests validate the design analysis. Ground tests verify acoustical emission levels. Hazards are validated by inspection of system safety documentation.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.11, C.4.4.3.11

FAA Doc: 14CFR reference: 23.1091, 23.1103, 23.1121, 23.1123, 25.1091, 25.1103, 25.1121, 25.1123,

TSO C77b: 5.3.1, 5.3.3, 5.6

**8.6.9** Verify that personnel hazards are properly documented in the appropriate flight/operator and maintenance manuals (T.O.) with warnings and precautions.

Standard: Technical data accurately describes hazards (exhaust plumes, overspeed, over temperature, etc) and associated cautions, warnings and advisories, and procedures.

Compliance: Review of the Operating and Support Hazard Analyses verifies that the potential hazards are identified. Inspection of Operator's and Maintenance Technical manuals verifies that they contain the appropriate hazards and warnings.

DoD/MIL Doc: JSSG-2009: para 3.3.3, 4.3.3

FAA Doc: 14CFR reference: 23.1541, 23.1581 (a) (2), 25.1541, 25.1581 (a) (2)

**8.6.10** Verify that compatibility of the accessory drive system with the air vehicle accessories and engine drive system is adequately evaluated for torsional vibrations and loads as well as possible misalignments.

Standard: Criteria is self-explanatory.

Compliance: Design analysis verifies strength margins throughout drivetrain and absence of torsional modes within the operating range. Tolerance and flight load analysis establishes maximum misalignment. Accessory Drive Integration Lab tests and system alignment measurements verify installed performance. Installed ground tests verify operating performance.

DoD/MIL Doc: JSSG-2009: para 3.2.7, 4.2.7, 3.2.7.4.4, 4.2.7.4.4, 3.2.7.5, 4.2.7.5

FAA Doc: 14CFR reference: 25.1167

**8.6.11** Verify that all critical failure modes and hazards have acceptable risk levels.

Standard: No single failure or combination of failures with probability greater than one in ten million result in loss of air vehicle. The severity of all hazards associated with the APS/EPS are reduced to an acceptable level or have risk accepted in accordance with MIL-STD-882D

Compliance: APS/EPS critical failures modes, hazards and acceptability of risk are verified by inspection of System Safety documentation.

DoD/MIL Doc: JSSG-2009: para 3.3.3, 4.3.3

FAA Doc: 14CFR reference: 25.901 (c),

TSO C77b (5.1)

**8.6.12** Verify that the crew station provides for adequate control and monitoring of the system.

Standard: Crew/operator station provides means to control and assess APS/EPS operating condition to the extent necessary for flight safety. The system provides warnings, cautions and advisories to operators and maintainers for hazardous failure conditions of APS/EPS.

Compliance: Inspection of design verifies provisions for the necessary control and monitoring of the system operation and health. Integration tests, to include Failure Modes and Effects Tests (FMET), verify compatibility of APS/EPS system with cockpit control and monitoring system. Ground tests of installed system verify operating performance.

DoD/MIL Doc: JSSG-2009 Appendix C: C.3.4.3.8, C4.4.3.8

FAA Doc: 14CFR reference: 23.1141 - 23.1142, 23.1549, 25.1141 - 25.1142, 25.1549

**8.6.13** Verify that equipment service life, overhaul, and operating limits are safe and that life-limited components have a reliable means of tracking the limiting parameter.

Standard: Required maintenance actions are defined to ensure safe operation over the design service life. Component maintenance times are based on the parameter(s) that causes life degradation. A critical component tracking system has been established and defines the analysis procedures, serialization, data collection, and computer programs necessary to establish maintenance times of individual components based on accrual or parameter events.

Compliance: Established lives and limits are verified by design analyses. Development tests validate critical calculated/modeled parameters such as stress and temperature spectrums. Durability/Accelerated Mission Testing validates established limits. Inspection of design and maintenance system verifies that provisions exist for tracking of critical components.

DoD/MIL Doc: JSSG-2009: para 3.2.7.4.4, 4.2.7.4.4, 3.2.7.6, 4.2.7.6

FAA Doc: 14CFR reference: 23.1522, 23.1549, G23.3, 25.1522, 25.1549, H25.3,

TSO C77b: 4.3, 4.4.1, 4.6.1, 5.7

**8.6.14** Verify that the flight/operator and maintenance manuals include normal and emergency operating procedures, limitations, servicing, and maintenance information.

Standard: Technical data describes the installed APS/EPS, normal and emergency operation, operating procedures and limitations, servicing, and maintenance requirements.

Compliance: Technical data is validated by inspection of design documentation and technical manuals and demonstration of technical manual procedures.

DoD/MIL Doc: JSSG-2000: para 3.6.2

FAA Doc: 14CFR reference: 23.1581 - 23.1585, G23.3 - G23.4, 25.1581 - 25.1585, H25.3 - H25.4

## 8.7 Aerial refueling system.

DoD/MIL Doc: MIL-A-87166(USAF) aerial refueling technical guidance (canceled document)

FAA Doc: Note: 14CFR reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

**8.7.1** Verify that aerial refueling operations can be safely and successfully accomplished with the targeted tanker/receiver aerial refueling subsystem(s).

Standard: All applicable factors involved in aerial refueling operation are addressed including but not limited to: handling qualities, developed loads, electrical compatibility, visual cues, communication capabilities, formation awareness, material compatibility, fuel pressures, flow rates, lighting, flammability hazards, fuel spray hazards, types of fuel to be carried/transferred, and technical data.

"Targeted" clarification: The other vehicles that will interface with the subject air vehicle during the aerial refueling process are referred to as "targeted".

Compliance: Systems engineering and system safety analyses verify aerial refueling capability and safety. Additionally, all criteria listed in 8.7.1 subparagraphs have been verified by methods defined for each respective subparagraph. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

Comm'l Doc: ATP-56

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2

**8.7.1.1** Verify that the operator and maintenance manuals for the air vehicle and the targeted tanker(s)/receiver(s) document safe aerial refueling procedures. The manuals should identify the proper instructions/information and placards noting restrictions

and limitations in the use of the air vehicle's aerial refueling system(s) under all operating conditions (ground/in flight; normal/emergency).

Standard: Procedures address all applicable factors involved in aerial refueling operation including but not limited to: day vs. night, with and without NVG, rendezvous methods, formation techniques, envelope restrictions, single vs. multiple aircraft operations, and reverse aerial refueling.

Compliance: Aerial refueling procedures are identified and confirmed through inspection of the technical manuals.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2, 3.6.2

FAA Doc: Note: Use 14CFR reference sections corresponding to Structural and Installation requirements. Use all systems 14CFR references as applicable, i.e., Electrical.

**8.7.1.2** Verify that there is dimensional, physical, electrical, and material compatibility between each aerial refueling interface and the targeted tanker's/receiver's aerial refueling interface to permit safe engagement.

Standard: Engagements can be conducted in accordance with standard aerial refueling operations associated with targeted tanker/receiver. Aerial refueling system designed meets physical and dimensional tolerances as well as electrical and material compatibilities associated with targeted tanker/receiver.

Compliance: Verification of dimensional and physical interface characteristics is achieved by inspection of drawings, analysis of envelope, and both ground and flight demonstration of engagement throughout the contact envelope. Verification of electrical and material interface compatibility is achieved by laboratory tests and analyses of aerial refueling interface(s) and interface(s) of targeted aerial refueling counterpart(s). Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2

NATO STANAG 3447 for probe or drogue equipped receivers dimensional guidance;

NATO STANAG 7191.

UARRSI technical exhibit, for boom or receptacle equipped receivers dimensional guidance

**8.7.1.2.1** Verify that all structural fastener heads around the receptacle are flush with the surrounding structural surface.

Standard: There are no raised fasteners to be damaged by or cause damage to the boom. Raised fasteners present a FOD hazard as a broken fastener could enter the fuel system through the receptacle.

Compliance: Inspection of drawings and aircraft surface surrounding receptacle verifies structural fasteners are flush. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2006: para 3.3.11, 4.3.11JSSG-2010: 3.5.3.3, 4.5.3.3

**8.7.1.3** Verify that the aerial refueling system interface, its attachment to airframe structure, and the structure surrounding the interface can withstand the loads experienced during the aerial refueling process (engagement, disengagement, and fuel transfer) with the tanker/receiver interface(s) without being damaged or creating FOD.

Standard: The aerial refueling system interface, its attachment to airframe structure, and the structure surrounding the interface can withstand the loads experienced during the aerial refueling process (engagement, disengagement, and fuel transfer) with the tanker/receiver interface(s) without being damaged or creating FOD.

There are different sets of loads associated with the method of aerial refueling. Specific loads to be

considered include:

A) For boom and receptacle aerial refueling subsystems, loads expected during normal engagements within the defined contact envelope and normal disengagements within the disconnect envelope; loads experienced when a single failure occurs in the latching mechanism of the receptacle and the boom nozzle must be forcibly pulled out of the receptacle at flight conditions.

B) For probe and drogue aerial refueling subsystems, loads expected during normal engagements/disengagements at the most severe receiver closure/fallback rates, those experienced due to inadvertent/off-center engagements/disengagements, and those experienced when a single failure occurs in the latching mechanism of the aerial refueling coupling and the probe nozzle must be forcibly pulled out of the receptacle at flight conditions.

Compliance: Critical points in the aerial refueling envelope have been defined based on the mission profiles and system design. Analysis verifies aerial refueling system and interfacing structure can withstand expected loads without being damaged or creating FOD. Flight testing of select critical points of the aerial refueling envelope validates the analysis. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2;

JSSG-2009 Appendix F: F.3.4.6.2.2.5, F.4.4.6.2.2.5, F.3.4.6.2.3.5, F.4.4.6.2.3.5;

JSSG-2006: para 3.4.1.7, 4.4.1.7;

AFGS 87154A (inactive), load guidance

MIL-A-8865A: para 3.9.1.3.1and 3.9.2.2. load guidance.

**8.7.1.4** Verify that cues (visual or equivalent) are provided on the air vehicle to assist the crewmember(s)/operator(s)/automated system(s) of the targeted tanker(s)/ receiver(s) and the crewmember(s)/operator(s)/automated system(s) of the air vehicle during the aerial refueling process under mission-defined environmental conditions. Likewise, verify that cues (visual or equivalent) provided on the targeted tanker/receiver air vehicle(s) can be viewed/received as intended by the appropriate air vehicle crewmember(s)/operator(s)/automated system(s), during the aerial refueling process under mission-defined environmental conditions.

Standard: Cues (visual or equivalent) are provided on the air vehicle to assist the crewmember(s)/operator(s)/automated system(s) of the targeted tanker(s)/ receiver(s) and the crewmember(s)/operator(s)/automated system(s) of the air vehicle during the aerial refueling process under mission-defined environmental conditions. Cues (visual or equivalent) provided on the targeted tanker/receiver air vehicle(s) can be viewed/received as intended by the appropriate air vehicle crewmember(s)/operator(s)/automated system(s), during the aerial refueling process under mission-defined environmental conditions. Critical areas depend on the type of aerial refueling system and are identified below:

A) For boom subsystems, receiver positioning markings, aerial refueling boom markings showing inner/outer receiver contact limit and inner/outer fuel transfer limit positions, size and movement indicators (including lighting of) such as: wing tips, engine nacelle, horizontal/vertical stabilizers, etc.

B) For receptacle subsystems, boom lead-in markings in front of the receptacle, markings on objects which are located near the receptacle (e.g., antennae), size and movement indicators (including lighting of) such as: wing leading edge, engine nacelle, canopy, horizontal/vertical stabilizers, etc.

C) For drogue subsystems, receiver positioning markings and aerial refueling hose markings showing full trail, inner and outer fuel transfer range, inner clearance limit positions.

D) For probe subsystems probe illumination

Compliance: Crewmember(s)/operator(s)/automated system(s) evaluation/analyses during flight test/demonstration and/or ground simulation verify cues (visual or equivalent) provided on the targeted tanker/receiver air vehicle(s) can be viewed/received as intended by the appropriate air vehicle crewmember(s)/operator(s)/automated system(s), during the aerial refueling process under mission-defined environmental conditions. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2;

AFGS 87154A (inactive)

**8.7.1.4.1** Verify that all markings used for aerial refueling are compatible with the expected environmental conditions and fluid exposures (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.).

Standard: The aerial refueling markings do not degrade to the point of hindering the aerial refueling process or causing a hazard to flight/ground crews under any expected environmental conditions or fluid exposure (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.).

Compliance: Criteria is verified by analyses and laboratory tests of material compatibilities prior to flight. Inspection of lights throughout aircraft testing regime confirms analyses and lab test accuracy.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2

**8.7.1.4.2** Verify that exterior aerial refueling lights are provided on the air vehicle to assist the targeted tanker/receiver crewmember(s)/operator(s)/automated system(s) and the air vehicle crewmember(s)/operator(s)/automated system(s) during the aerial refueling process.

Standard: Exterior aerial refueling lights are provided on the air vehicle to assist the targeted tanker/receiver crewmember(s)/operator(s)/automated system(s) and the air vehicle crewmember(s)/operator(s)/automated system(s) during the aerial refueling process.

Lighting required vary depending on the systems being used for aerial refueling. Lighting includes:

A) For receiver receptacle subsystems, receptacle/slipway illumination, illumination of the surface area immediately aft of the receptacle, wing leading edge illumination, and illumination of surface features possibly in the path of the boom.

B) For tanker boom subsystems, boom nozzle illumination, flood light illumination, wing and underbody illumination, wing pod and engine nacelle illumination, and receiver pilot director lights.

C) For receiver probe subsystems, probe illumination.

D) For tanker drogue subsystems, drogue illumination, flood light illumination, wing and underbody illumination, wing pod and engine nacelle illumination, and drogue subsystem status lights.

Compliance: Inspection of drawings and/or air vehicle verifies exterior aerial refueling lights are provided. Ground/flight demonstration verifies exterior aerial refueling lights assist the aerial refueling process as intended. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2, JSSG-2010: 3.5.3.3, 4.5.3.3;

AFGS 87154A (inactive).

**8.7.1.4.3** Verify that the appropriate air vehicle crewmember(s)/operator(s)/automated system(s) can view/receive exterior aerial refueling lights provided on the targeted tanker/receiver air vehicle(s) , as intended, during the aerial refueling process.

Standard: Receiver(s) can view/receive information from targeted tanker(s) as presented through the use of aerial refueling lights. Tanker(s) can view/receive information on the location of the reciever(s) as well as location of equipment and obstructions on the receiver.

Compliance: Criteria is verified by evaluation and analysis of crewmember(s)/operator(s)/automated system(s) observations/data during flight test(s)/demonstration(s) and/or ground simulation. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2, JSSG-2010: 3.5.3.3, 4.5.3.3;

AFGS 87154A (inactive)

**8.7.1.4.4** Verify that the intensity of each exterior aerial refueling light, or light group, can be independently varied to accommodate the needs of the targeted tanker/receiver crewmember(s)/operator(s)/automated system(s)and the air vehicle crewmember(s)/operator(s)/automated system(s).

Standard: Lighting intensity is variable in response to the differing requirements depending on environmental lighting conditions as well as tanker/receiver orientation. Variability of lighting provides optimum illumination of appropriate systems.

The following lighting systems are controllable: receptacle/slipway illumination, probe illumination, boom nozzle illumination, flood light illumination, wing and underbody illumination, wing pod and engine nacelle illumination, receiver pilot director lights, and tanker subsystem status lights.

Compliance: Criteria is verified by evaluation and analysis of crewmember(s)/operator(s)/automated system(s) observations/data during ground and flight demonstration. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2010: para 3.5.3.3.1, 4.5.3.3.1, 3.5.3.5, 4.5.3.5;

**8.7.1.4.5** Verify that the appropriate exterior aerial refueling lights are compatible with night vision imaging systems (NVIS) or automated systems.

Standard: Appropriate exterior aerial refueling lights are compatible with night vision imaging systems (NVIS) or automated systems.

Compliance: Analysis, ground and flight test/demonstration verify compatibility of all appropriate lights with NVIS and/or automated systems. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2010: para 3.5.3.2.1, 4.5.3.2.1, 3.5.3.3, 4.5.3.3

FAA Doc: 14CFR reference: 23.951-23.1001, 25.951-25.1001

**8.7.1.4.6** Verify that all exterior aerial refueling lights are compatible with the expected environmental conditions and fluid exposures (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.).

Standard: The aerial refueling lights do not degrade to the point of hindering the aerial refueling process or causing a hazard to flight/ground crews under any expected environmental conditions or fluid exposure (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.).

Compliance: Criteria is verified by analyses and laboratory tests of material compatibilities prior to flight. Inspection of lights throughout aircraft testing regime confirms analyses and lab test accuracy.

DoD/MIL Doc: JSSG-2009: para 3.2.7.2, 4.2.7.2

FAA Doc: 14CFR reference: 25.1381 (Note: Use 14CFR reference sections corresponding to structural and installation requirements. Use all systems 14CFR reference's as applicable, i.e., electrical.)

**8.7.1.5** Verify that a communication system is provided which permits the timely exchange of all identified data/information between the crewmember(s)/operator(s)/ automated system(s) of the air vehicle and the crewmember(s)/operator(s)/automated system(s) of the targeted tanker/receiver air vehicle(s) during the aerial refueling process.

Standard: Communication system is provided which permits the timely exchange of all identified data/information between the crewmember(s)/operator(s)/automated system(s) of the air vehicle and the crewmember(s)/operator(s)/automated system(s) of the targeted tanker/receiver air vehicle(s) during the aerial refueling process. Communication system is compliant with appropriate classified information transfer requirements.

Data/information includes but is not limited to: relative positioning, fuel offload amount, "breakaway" command, boom operator guidance, call sign, tail number, etc.

Compliance: Adequate communication is verified by demonstration/test of communication system under operational restrictions/conditions. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2;

NAVAIR 00-80T-110 section 2.4.4 and 3.6.5.

**8.7.1.6** Verify that the types of fuels to be transferred/received and any allowed deviations are identified.

Standard: Criteria is self-explanatory.

Compliance: Identification of types of fuels to be transferred and allowable deviations is verified by inspection of program documentation. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc:JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2

**8.7.1.7** Verify that the delivery pressure and flow rate of the transferred/received fuel are identified and are within all applicable tanker/receiver design limits.

Standard: Delivery pressure and flow rate of the transferred/received fuel have been identified and are within all applicable tanker/receiver design limits. Values are established that keep the maximum delivery pressures including transients within aerial refueling, vent, and fuel system proof pressure limits. Other considerations include: maximum flow capability of the vent and fuel system, flow induced static buildup, and any other limiting factors.

Compliance: Design analysis, ground tests, and flight tests verify delivery pressure and flow rate of the transferred/received fuel are within tanker/receiver design limits. Analysis of ground and flight test data identifies maximum delivery pressure and flow rate. Inspection of the technical data verifies delivery pressure and flow rate of the transferred/received fuel have been properly identified. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

Comm'l Doc: ARSAG International, Doc. no. 00-03-01, "Pressure Defs & Terms, Mar '03.doc" (para 4.7),

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2;

MIL-A-19736: para 3.5.2.1 and 3.8.7;

MIL-STD-87166: para 3.1.1 and 4.1.1)

**8.7.1.8** Verify that surge pressures generated during the aerial refueling process do not exceed proof pressure limits for the aerial refueling system(s) of any air vehicle involved in the aerial refueling process.

Standard: Proof pressure is defined as: a minimum pressure in which the fuel system may function satisfactorily including pressure transients (surges) up to a value in which the aircraft can continually sustain throughout the life of the aircraft without any external leakage, failure and/or malfunction, or permanent deformation.

Surge pressures generated during the aerial refueling process do not exceed proof pressure limits for the aerial refueling system(s) of any air vehicle involved in the aerial refueling process.

Compliance: Design analysis, ground tests, and flight tests verify surge pressure of the transferred/received fuel are within tanker/receiver design limits. Analysis of ground and flight test data identifies maximum delivery pressure and flow rate. Inspection of the technical data verifies surge pressure of the transferred/received fuel have been properly identified. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

Comm'l Doc: ARSAG 00-03-01, "Pressure Defs & Terms, Mar '03.doc" (para 3.5 and 4.7)

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2;

MIL-A-19736A: para 3.5.2.3

**8.7.1.8.1** Verify that surge pressure conditions are safe, including, but not limited to:

a. With and without a single failure in the tanker system's pressure regulation feature(s),
b. Pump start-up surges (no flow to receiver),
c. All possible receiver valve closures (manually or automatically activated) which could terminate flow into the receiver,
d. Flowing disconnects.

Standard: Surge pressure conditions do not generate hazards to air vehicle or personnel, including such conditions as (1) with and without a single failure in the tanker system's pressure regulation feature(s), (2) pump start-up surges (no flow to receiver), (3) all possible receiver valve closures (manually or automatically activated) which could terminate flow into the receiver, and (4) flowing disconnects.

Pressure transients occur as a result of an interruption of fuel flow, a perturbation of fuel flow or an abrupt change in flow velocity. Pressure transients do not exceed limit (proof) pressure in the aircraft. When exceptions do occur, a potential exists for system fatigue damage depending on the magnitude of the transient frequency and the duration of the transient. Evaluation of those pressure transients is important for determining whether system fatigue and/or system damage/leakage has occurred.

Compliance: Design analysis, ground tests, and flight tests verify surge pressures are within tanker/receiver design limits under the following conditions: (1) with and without a single failure in the tanker system's pressure regulation feature(s), (2) pump start-up surges (no flow to receiver), (3) all possible receiver valve closures (manually or automatically activated) which could terminate flow into the receiver, and (4) flowing disconnects.

Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

Comm'l Doc: ARSAG 00-03-01, "Pressure Definitions & Terms, Mar '03.doc", para 3.7 and 4.7

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2;

MIL-A-19736A: para 3.5.2.3.

**8.7.1.9** Verify that any spray resultant of the aerial refueling process does not negatively affect the safe operation of the air vehicle(s). (Fuel spray is typically created during the engagement and disengagement of the aerial refueling interfaces.)

Standard: Any spray resultant of the aerial refueling process does not cause hazards for the air vehicle(s) or personnel. (Fuel spray is typically created during the engagement and disengagement of the aerial refueling interfaces). Areas addressed include but are not limited to: engine inlet, ventilation inlets/outlets, air data sensors, antennae masts, low observable coatings/material, mission equipment, canopy, etc.

Compliance: Analysis of system design and review of flight test data verifies no hazards are caused by fuel spray resultant of the aerial refueling process. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.2.3

**8.7.1.9.1** Verify that any fuel spray entering receiver engine(s), hazardous ignition areas, environmental management systems, and air data systems does not compromise safety.

Standard: Limitation on the amount of allowable fuel spray/leakage upon engagement and disconnect of the aerial refueling interfaces is identified. Spray ingested into the engine(s) of the receiver, into hazardous ignition areas on the tanker/receiver, or into the environmental control system of the tanker/receiver does not cause hazards for the air vehicle(s) or personnel.

Compliance: Analysis of system design and review of flight test data verifies no hazards (related to receiver engine(s), hazardous ignition areas, environmental management systems, and/or air data systems) are caused by fuel spray resultant of the aerial refueling process. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.2.3, 3.3.10

JSSG-2009 Appendix F: F.3.4.6.2.2.2, F.4.4.6.2.2.2, F.3.4.6.2.3.2, F.4.4.6.2.3.2

**8.7.1.9.2** Verify that any fuel spray that covers or contacts lights, optical windows, antennae, and any other sensitive device does not compromise safety.

Standard: Limitation on the amount of allowable fuel spray/leakage upon engagement and disconnect of the aerial refueling interfaces is identified. Any fuel spray contacting lights, optical windows, antennae, and any other sensitive device does not cause hazards for air vehicle(s) or personnel.

Compliance: Analysis of system design and review of flight test data verifies no hazards (related to lights, optical windows, antennae, and any other sensitive device) are caused by fuel spray resultant of the aerial refueling process. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.2.3, 3.3.10

JSSG-2009 Appendix F: F.3.4.6.2.2.2, F.4.4.6.2.2.2, F.3.4.6.2.3.2, F.4.4.6.2.3.2

**8.7.1.10** Verify that satisfactory flight stability and handling qualities are achievable for the tanker/receiver aerial refueling interface within the specified aerial refueling envelope.

Standard: Satisfactory flight stability and handling qualities are achievable for the tanker/receiver aerial refueling interface within the specified aerial refueling envelope to accomplish the mission without significant increased crew member(s) workload (acceptable Cooper-Harper rating or equivalent as defined by program). All flight conditions are addressed including but not limited to: altitudes, airspeed, night and weather.

Compliance: Satisfactory flight stability and handling qualities are verified by design and/or simulation analysis and flight test data including crewmember evaluations. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.1.1.1.1, 3.3.11.1.1.

**8.7.2** Verify that each aerial refueling system can be installed and operated (normal and single-failure conditions) without causing loss of the air vehicle or creating a potential hazard to personnel in the identified environment (induced and natural).

Standard: Normal operation or single failure conditions of the aerial refueling systems do not cause loss of the air vehicle or create potential hazards to personnel in identified environments including all flight and ground conditions. Areas addressed include but are not limited to: the hydraulic, environmental control, structure, fuel, and vehicle management systems.

Compliance: Analysis of the system, FMECA, inspection of drawings and ground/flight tests verify aerial refueling systems do not cause loss of the air vehicle or create potential hazards to personnel. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.2.7.4.4.1, 4.2.7.4.4.1, 3.2.7.4.4.2, 4.2.7.4.4.2, 3.3.8, 4.3.8;

MIL-STD-87166: para 3.1.3 and 4.1.3 guidance on expected environments

**8.7.2.1** Verify that the system has been designed to minimize the hazards from lightning, static electricity, fuel leaks, ignition sources, and ground potential.

Standard: Criteria is self-explanatory.

Compliance: Analysis of design, Safety Hazard Analysis, inspection of drawings, and laboratory tests verify risks are within defined acceptable limits.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.7, F.4.4.6.1.7

**8.7.2.1.1** Verify that the receptacle installation has a fuel- and vapor-proof pressure box below it to collect the fuel spray that may occur during aerial refueling.

Standard: Criteria is self-explanatory.

Compliance: Criteria is verified by inspection of drawings and/or air vehicle for receptacle fuel- and vapor-proof pressure box. Fuel- and vapor proof characteristics of pressure box are verified by analysis, lab tests and/or certification. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8; and Appendix F: F.3.4.6.2.2.4, F.4.4.6.2.2.4

**8.7.2.1.2** Verify that all fluids that collect within the pressure box are capable of being drained safely.

Standard: Fluids that collect within the pressure box are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel.

Compliance: Analysis, drainage demonstration, and flight test verify fluids which collect within the pressure box are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8; and Appendix F: F.3.4.6.2.2.3, F.4.4.6.2.2.3

**8.7.2.1.3** For probe installations (retractable), verify that the probe compartment is fuel- and vapor-proof such that any fuel spray that may collect in this compartment does not migrate.

Standard: Criteria is self-explanatory.

Compliance: Analysis, ground and flight demonstration verify probe compartment is fuel- and vapor-proof such that any fuel spray collecting in this compartment does not migrate. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8; and Appendix F: F.3.4.6.2.3.3, F.4.4.6.2.3.3

**8.7.2.1.4** Verify that the collected fluids within the probe compartment are capable of being drained safely.

Standard: Collected fluids within the probe compartment are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel.

Compliance: Analysis and drainage demonstration verify collected fluids within the probe compartment are capable of being drained safely. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8;and Appendix F: F.3.4.6.2.3.3, F.4.4.6.2.3.3

**8.7.2.1.5** For aerial refueling pods, verify that there is adequate air flow/exchange within the pod to preclude the buildup of a flammable vapor within the pod.

Standard: Drains are provided that operate in flight and provide active ventilation of 1 volumetric air change per minute for flammable leakage zones. Drainage collections systems are fire hardened and provide 2 to 3 volumetric air changes per minute ventilation flow for fire zones.

Compliance: Analysis for flight and ground conditions verify that ventilation is provided to minimize flammability. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8

**8.7.2.1.6** Verify that all fluids that can be collected within the pod are capable of being drained safely.

Standard: Collected fluids within the aerial refueling pod are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel.

Compliance: Analysis, drainage demonstration and flight test verifies collected fluids within the aerial refueling pod are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter is required prior to conducting aerial refueling operations.

DoD/MIL Doc: JSSG-2009: para 3.3.8, 4.3.8

**8.7.2.1.7** Verify that a dry-run condition with an aerial refueling pump does not create a potential ignition source.

Standard: Criteria is self-explanatory.

Compliance: Analysis of design, inspection of installation, and laboratory/ground/flight test verify that a dry-run condition with an aerial refueling pump does not create a potential ignition source. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter is required prior to conducting aerial refueling operations.

DoD/MIL Doc: JSSG-2009: para 3.3.3, 4.3.3,Appendix F: 3.4.6.1.7, 4.4.6.1.7, Appendix G: 3.4.7.23, 4.4.7.23

**8.7.2.1.8** Verify that there is a secondary liquid- and vapor-tight barrier between the aerial refueling fuel tanks and identified fire hazard areas/inhabited areas.

Standard: Criteria is self-explanatory.

Compliance: Analysis, ground and flight demonstration verify there is a secondary liquid- and vapor-tight barrier between the aerial refueling fuel tanks and identified fire hazard areas/inhabited areas. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009 Appendix E: E.3.4.5.6.11, E.4.4.5.6.11; and Appendix F: F.3.4.6.1.6, F.4.4.6.1.6, F.3.4.6.1.7, F.4.4.6.1.7

**8.7.2.1.9** Verify that each aerial refueling system can withstand the static discharge typically encountered during the engagement of tanker and receiver interfaces.

Standard: Each aerial refueling system involved in an engagement is designed to accommodate/dissipate the static discharge resultant of the electrical potential difference of the two aircraft.

Compliance: Analysis of design, Safety Hazard Analysis, inspection of drawings, and laboratory tests verify each aerial refueling system can withstand the static discharge encountered during the engagement of tanker and receiver interfaces. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.2.3

**8.7.2.1.10** Verify that each aerial refueling system, in the open/deployed position and in the closed/retracted position, is designed to withstand the appropriate lightning strike criteria.

Standard: Each aerial refueling system, in the open/deployed position and in the closed/retracted position, is designed to withstand lightning strikes without causing damage to air vehicle as appropriate, loss of air vehicle, or creating hazards to personnel.

Compliance: Analysis of design, Safety Hazard Analysis, inspection of drawings, and laboratory tests verify each aerial refueling system, in the open/deployed position and in the closed/retracted position, is designed to withstand lightning strikes without causing damage to air vehicle or creating hazards to personnel. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.2.1, 3.3.10.1.1

JSSG-2009 Appendix G: 3.4.7.6, 4.4.7.6

FAA Doc: 14CFR reference: 23.954, 25.954

**8.7.2.2** Verify that the flight control/handling qualities of the air vehicle are not negatively impacted when the aerial refueling system is installed or operating under normal aerial refueling and single-failure conditions.

Standard: The flight control/handling qualities of the air vehicle are not negatively impacted when the aerial refueling system is installed or operating under normal aerial refueling and single-failure conditions. Areas addressed include but are not limited to:A) Receiver receptacle installations: the opening/closing of receptacle/slipway doors or the transition of roll-over installations during opening and closing.

B) Tanker boom subsystems: moving the boom from the “stowed” position and moving it throughout its control envelope (prior to receiver engagement and after a contact has been made).

C) Receiver probe installations: all positions and transitions between the “stowed” and “fully extended” positions.

D) Tanker drogue subsystems: all positions and transitions between the “stowed” and “fully extended” positions (with and without fuel in the hose).

Compliance: Analysis of system design, ground and flight demonstration verify the flight control/handling qualities of the air vehicle are not negatively impacted when the aerial refueling system is

installed or operating under normal aerial refueling and single-failure conditions. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1.1.1

**8.7.2.2.1** Verify that the flight control/handling qualities of the air vehicle are not degraded below safe limits, and the air vehicle can safely land when the system interface cannot be returned to its fully stowed configuration.

Standard: Flight control/handling qualities of the air vehicle are not degraded to the point of causing loss of air vehicle or creating hazards to personnel. The air vehicle can land when the system interface cannot be returned to its fully stowed configuration without causing loss of air vehicle or creating hazards to personnel.

Compliance: System design analysis, FEMCA, and flight demonstration verify flight control/handling qualities of the air vehicle are not degraded to the point of causing loss of air vehicle or creating hazards to personnel when the system interface cannot be returned to its fully stowed configuration. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1.1.1

**8.7.2.2.2** For aerial refueling pods, verify that any ram air turbine (RAT) failure mode does not degrade flight control/handling qualities of the air vehicle below acceptable limits.

Standard: Any RAT failure mode does not degrade flight control/handling qualities of the air vehicle to the point of causing loss of air vehicle or creating hazards to personnel. All phases of flight operation are addressed including landing.

Compliance: System design analyses, FMECA, and flight tests verify any RAT failure mode does not degrade flight control/handling qualities of the air vehicle to the point of causing loss of air vehicle or creating hazards to personnel. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc:JSSG-2009 Appendix F: 3.4.6.1.1, 4.4.6.1.1, 3.4.6.1.2, 4.4.6.1.2

FAA Doc: 14CFR reference: 25.1309

**8.7.2.3** Verify that in-flight egress, ground emergency egress, and assisted egress of any crewmember are not affected when the system interface cannot be returned to its fully stowed configuration.

Standard: In-flight egress, ground emergency egress, and assisted egress of any crewmember are not hindered when the system interface cannot be returned to its fully stowed configuration.

Compliance: Analyses and demonstration verify in-flight egress, ground emergency egress, and assisted egress of any crewmember are not hindered when the system interface cannot be returned to its fully stowed configuration.

DoD/MIL Doc:JSSG-2009 Appendix F: F.3.4.6.2.2.2, F.4.4.6.2.2.2, F.3.4.6.2.3.2, F.4.4.6.2.3.2

**8.7.2.4** Verify that built-in-test (BIT) and fault isolation provisions are available to appropriate crewmember(s)/operator(s)/maintenance personnel to ensure safe ground or in-flight operations under all configuration options.

Standard: Built-in-test (BIT) and fault isolation provisions are available to appropriate crewmember(s)/operator(s)/maintenance personnel during ground or in-flight operations under all configuration options without causing loss of air vehicle or creating hazards to personnel.

Compliance: Inspection of technical data verifies BIT and fault isolation capabilities are provided. Demonstration verifies BIT and fault isolation provisions are available/accessible to

appropriate personnel. Testing verifies proper operation and indication of BIT and fault isolation capabilities.

DoD/MIL Doc: JSSG-2009: para 3.2.9, 4.2.9

**8.7.3** Verify that the flight control/handling qualities of the air vehicle are not negatively impacted by the removal of hardware associated with an aerial refueling system. For tankers, this may include pods, palletized systems, and fuel tanks that must be removed to reconfigure the tanker for another mission. For receivers, this may include probe installations that are not permanent.

Standard: Flight control/handling qualities of the air vehicle are not negatively impacted by the removal of hardware associated with an aerial refueling system. Areas that are addressed include but are not limited to: pods, palletized systems, removable fuel tanks, boom to drogue adapters and non-permanent probe installations.

Compliance: Analysis of system design, ground and flight demonstration verify the flight control/handling qualities of the air vehicle are not negatively impacted by the removal of hardware associated with aerial refueling systems.

DoD/MIL Doc: JSSG-2001: para 3.3.11.1.1.1

**8.7.3.1** When aerial refueling hardware is removed, verify that interfaces with other systems (e.g., electrical, hydraulic, and fuel system) are properly covered, sealed, isolated, etc., to preclude providing a new leak or ignition source in the air vehicle.

Standard: Criteria is self-explanatory.

Compliance: Analysis of technical data verifies interfaces have proper coverage, sealant and/or isolation. Inspection of the air vehicle verifies coverage, sealant and/or isolation prevents new leaks or ignition sources.

DoD/MIL Doc:JSSG-2009 Appendix F: F.3.4.6.1.5, F.4.4.6.1.5

**8.7.4** Verify that each aerial refueling system, as installed, can meet its design and performance requirements when operated within the specified parameters.

Standard: Criteria is self-explanatory.

Compliance: Analysis, functional ground tests, and flight test verifies the aerial refueling system operates as required. Flight and ground testing includes operation of the system on the aircraft itself and the system coupled aircraft representative of intended aerial refueling parings. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009: para 3.1, 4.1; and Appendix F: F.3.4.6, F.4.4.6

**8.7.4.1** Verify that the plumbing/components in each aerial refueling system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit without resulting in fuel leakage and system performance degradation.

Standard: Plumbing/components in each aerial refueling system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit without resulting in fuel leakage and system performance degradation.

Proof pressure is defined as: a minimum pressure in which the fuel system may function satisfactorily including pressure transients (surges) up to a value in which the aircraft can continually sustain throughout the life of the aircraft without any external leakage, failure and/or malfunction, or permanent deformation.

Compliance: Analysis and ground tests verify plumbing/components in each aerial refueling system (as completely assembled and installed within the air vehicle) can withstand exposure to the

specified proof pressure limit without resulting in fuel leakage and system performance degradation. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

Comm'l Doc: ARSAG 00-03-01, "Pressure Defs & Terms, Mar '03.doc" para 3.5 and 4.7

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.3, F.4.4.6.1.3

**8.7.4.2** Verify that critical operational functions and functional modes are provided in the aerial refueling system to ensure the aerial refueling process can be conducted safely.

Standard: Critical operational functions and functional modes are provided in the aerial refueling system to conduct the aerial refueling process without causing loss of aircraft or creating hazards to personnel.

Receivers:

A) Receptacle subsystems have the operational modes of DISCONNECT (initiates a disconnect from the boom subsystem), RESET of the mode of the receptacle (from DISCONNECT to READY), and door open/close.

B) Probe subsystems have probe extension/retraction function and a "PRE-CHECK" function (verifies all valves are functional).

Tankers:

A) Boom subsystems have fuel transfer control, fuel pressure regulation, boom control, tanker internal fuel management, manual/automatic DISCONNECT function, etc.

B) Drogue subsystems have fuel transfer control, fuel pressure regulation, hose extension/retraction function, hose response capability, tanker internal fuel management, hose jettison capability, pod jettison capability (pod installations only), etc.

Compliance: Analysis of technical data verifies functional modes have been provided. Ground and flight demonstration verify aerial refueling can be conducted without causing loss of aircraft or creating hazards to personnel. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.2.2.7, F.4.4.6.2.2.7, F.3.4.6.2.3.1.2, F.4.4.6.2.3.1.2

**8.7.4.3** Verify that controls are provided and properly located for the appropriate crewmember(s)/operator(s) to activate and control the identified functions of the aerial refueling system.

Standard: Controls are provided and properly located for the appropriate crewmember(s)/operator(s) to activate and control the identified functions of the aerial refueling system.

Receivers:

A) Receiver receptacle subsystems have the following: Press-to-Test (verify mode indicators properly working), DISCONNECT (initiates a disconnect from the boom subsystem), RESET of the mode of the receptacle (from DISCONNECT to READY), the ability to open and close receptacle doors, etc.

B) Probe subsystems with a retractable probe have extension/retraction control.

Tankers:

A) Boom subsystems have the following: aerial refueling pump activation, fuel transfer control, boom deployment/stowage, boom control, tanker internal fuel management, boom nozzle/receptacle DISCONNECT, system RESET, etc.

B) Drogue subsystems have the following: aerial refueling pump activation, fuel transfer control, hose extension/retraction, tanker internal fuel management, hose jettison capability, pod jettison capability (pod installations only), etc.

Compliance: Analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation and flight demonstration verifies controls are provided and properly located. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2010: para 3.2.14, 4.2.14

**8.7.4.4** Verify that displays are provided and properly located for the appropriate crewmember(s)/operator(s) to indicate the necessary information to conduct the aerial refueling operation safely.

Standard: Displays are provided and properly located for the appropriate crewmember(s)/operator(s) to indicate the necessary information to conduct the aerial refueling operation safely.

Receivers:

A) Receptacle subsystems have the standard refueling status mode indicators with the standard color code of lights; i.e., READY (Aviation white/light blue), CONTACT and/or LATCHED (Green), and DISCONNECT (Amber). Receptacle subsystem have an indicator for receptacle position (OPEN/CLOSED) and functional mode (NORMAL/OVERRIDE).

B) Probe subsystems have an indicator for probe position (EXTENDED/RETRACTED).

Tankers:

A) Boom subsystems have an indicator for fuel transfer, boom position, functional mode (NORMAL/OVERRIDE), and status mode (READY, CONTACT, LATCHED, DISCONNECT).

B) Drogue subsystems have indicators for subsystem operational status; i.e., ON/OFF, EXTEND, TRAIL, REWIND, STOWED. They also have an indicator for fuel transfer.

Compliance: Analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation and flight demonstration verifies displays are provided and properly located. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2010: para 3.2.13, 4.2.13

**8.7.4.5** Verify that display lights are variable intensity and, if appropriate, NVIS compatible.

Standard: Criteria is self-explanatory.

Compliance: Analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation and flight demonstration verifies display lights are variable intensity. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2010: para 3.5.2.1.2, 4.5.2.1.2

**8.7.5** Verify that the installation and operation of each aerial refueling system (normal/single-failure conditions) does not negatively impact the operation of other systems on the air vehicle or on the targeted tanker(s)/receiver(s) throughout the mission(s) of the air vehicle or the targeted tanker(s)/receiver(s).

Standard: Installation and operation of each aerial refueling system (normal/single-failure conditions) does not negatively impact the operation of other systems on the air vehicle or on the targeted tanker(s)/receiver(s) throughout the mission(s) of the air vehicle or the targeted tanker(s)/receiver(s). Examples include but are not limited to: proper release of offensive weapons, release of defensive countermeasures, jettisoning of external stores, crew escape, etc.

Compliance: Analysis of drawings and technical data, ground tests and flight tests verify installation

and/or operation of each aerial refueling system does not negatively impact operation of other systems. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.1, F.4.4.6.1.1

**8.7.5.1** Verify that the vent system of any fuel tank that contains aerial refueling plumbing can accommodate the maximum refuel/transfer rate and pressures associated with aerial refueling transfer rates encountered during normal aerial refueling operations and single-failure conditions.

Standard: Fuel tanks that contain aerial refueling lines are able to accommodate the resultant flow rate and pressures associated with loss of integrity of aerial refueling lines. Conditions include those with a failure in the tanker's pressure regulation system, a tank overfill condition in the receiver due to a failure of a valve to close, and a tank overfill condition due to a separation of an aerial refueling line within the tank. Fuel tank pressures do not exceed tank structural limitations.

Compliance: Analysis of technical data, FMECA, and ground testing verify the vent system of any fuel tank containing aerial refueling plumbing can accommodate the maximum refuel/transfer rate and pressures associated with aerial refueling transfer rates encountered during normal aerial refueling operations and single-failure conditions. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc:JSSG-2009 Appendix F: F.3.4.6.1.6, F.4.4.6.1.6

**8.7.5.2** Verify that no ground or flight hazards are created if leakage occurs in the air vehicle fuel system and/or other aerial refueling system plumbing during aerial refueling operations. Consider leakage due to a failure of the sealing mechanism at the single-point refueling adapter, at the pressure defueling adapter, or at the other aerial refueling system interface(s).

Standard: Criteria is self-explanatory.

Compliance: Analysis of technical data, FMECA, and ground testing verifies no ground or flight hazards are created if leakage occurs in the air vehicle fuel system and/or other aerial refueling system plumbing during aerial refueling operations. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.6, F.4.4.6.1.6

**8.7.5.3** For tankers carrying a unique fuel for the designated receiver air vehicle(s), which cannot be utilized by the tanker's propulsion system(s), verify that there is adequate isolation of the aerial refueling system from the tanker's fuel system.

Standard: Criteria is self-explanatory.

Compliance: Analysis of technical data, inspection, and ground testing verifies proper isolation of aerial refueling system from the tanker's fuel system. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.6, F.4.4.6.1.6

**8.7.5.4** Verify that any data communication system provided on the air vehicle is compatible with (1) the flight control system on the air vehicle, (2) other electrical systems on the air vehicle, and (3) the flight control and electrical systems on the targeted tanker(s)/receiver(s).

Standard: Data communication system provided on the air vehicle does not negatively impact the function of (1) the flight control system on the air vehicle, (2) other electrical systems on the air vehicle, and (3) the flight control and electrical systems on the targeted tanker(s)/receiver(s).

Compliance: Analysis of technical data, ground and flight testing verifies data communication system does not negatively impact the function of (1) the flight control system on the air vehicle, (2) other electrical systems on the air vehicle, and (3) the flight control and electrical systems on the targeted tanker(s)/receiver(s). Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc: JSSG-2001: para 3.4.7.2.1, 3.4.7.2.2

**8.7.5.5** Verify that the field of view of the crew member(s)/operator(s)/automated system(s) is adequate during landing and during other critical flight phases when an aerial refueling system is installed, is operating, or fails to return to the fully stowed configuration.

Standard: Field of view is not obstructed by the following conditions: retractable probes remaining extended, receptacle doors remaining open, hoses extended, booms remaining extended and/or unstowed, fixed probes, stowed boom, etc.

Compliance: Analysis of models/simulation, ground and flight demonstration verify field of view of the crew member(s)/operator(s)/automated system(s) is adequate during landing or other critical flight phases when an aerial refueling system is installed, is operating, or fails to return to the fully stowed configuration. Aerial Refueling Performance Interface Survey and ASC/ENFA Aerial Refueling Clearance letter has been obtained.

DoD/MIL Doc:JSSG-2010: para 3.3.2.1, 4.3.2.1

**8.7.5.6** When the plumbing of the aerial refueling system interfaces with the fuel system plumbing of the air vehicle or of other aerial refueling systems, verify that a leak in the aerial refueling system plumbing does not impact the fuel system's fuel management functions (engine feed, thermal management, center of gravity control, etc.).

Standard: Criteria is self-explanatory.

Compliance: Analysis of technical data combined with ground test verifies when the plumbing of the aerial refueling system interfaces with the fuel system plumbing of the air vehicle or of other aerial refueling systems, a leak in the aerial refueling system plumbing does not negatively impact the fuel system's fuel management functions.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.1, F.4.4.6.1.1, F.3.4.6.1.5, F.4.4.6.1.5

**8.7.5.7** Verify that electrical failures within the aerial refueling system do not adversely affect the air vehicle electrical system.

Standard: Criteria is self-explanatory.

Compliance: Inspection of drawings, analysis, FMECA and ground test verify electrical failures within the aerial refueling system do not adversely affect the air vehicle electrical system.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.1, F.4.4.6.1.1

**8.7.5.8** When aerial refueling components interface with the fuel or hydraulic system, verify that pressures and temperatures within the fuel/hydraulic system remain within safe limits under normal aerial refueling operations and single-failure conditions. Typical components for consideration are RAT-driven pumps in aerial refueling pods, aerial refueling pumps, probe door actuation/retraction mechanisms, probe extension/retraction mechanisms, and receptacle door/toggle latch mechanisms.

Standard: Criteria is self-explanatory.

Compliance: Analysis of technical data, FMECA, and ground test verify fuel/hydraulic system components that interface with the aerial refueling system operate within defined safe limits under normal aerial refueling operations and single-failure conditions.

DoD/MIL Doc: JSSG-2009 Appendix F: F.3.4.6.1.1, F.4.4.6.1.1

## 8.8 Deleted - Propulsion installations moved to section 7.2.5

## 8.9 Mechanisms.

(Equipment involved in the securing, fastening, and mechanizing of air vehicle doors, hatches, ramps, weapon launchers, etc.; includes items such as locks, latches, bearings, hinges, linkages, indicators, and actuators.) Mechanical actuation subsystems that provide motion and position locking functions for stowable and deployable surfaces such as folding wing panels, folding rotor blade systems, folding tail rotors/pylons, air scoops, air vents, and weapons bay doors in ground and air applications for both operational and maintenance purposes. Equipment that is mechanical in form, fit, and function, but not covered by any other system-level requirements should be included herein.

DoD/MIL Doc: MIL-87222 Mechanical Systems for Aircraft Doors and Canopies (presently in a cancelled status)

**8.9.1** Verify that all SOF critical mechanisms perform their allocated air vehicle functions under their specified operating environments and conditions.

Standard: Self-explanatory

Compliance: 1.The component sizing and operating characteristics are determined analytically based on specified missions.

2.Test selection, test methods and test conditions reflect the expected operating environment(s) for individual components and subsystems. Mechanical systems are designed for safe and durable operation in accordance with the damage tolerance and durability requirements of the cited aircraft structures specification.

3.Full scale functional test mock-up duplicating the air vehicle installation and interfaces, and system control verify system performance, rigging, installation and indication requirements at the expected loads and structural attachments.

4.System components are laboratory tested to life and performance requirements.

5.Checkouts on the air vehicle verify installation, rigging, normal and emergency functionality, and performance.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies (presently in a cancelled status)

**8.9.2** Verify that damage or permanent deformation to any mechanism or support structure does not result in a critical jam load condition.

Standard: Latches, locks, linkages and the rigging of have sufficient strength and rigidity to withstand all actuator stall loads resulting from a jam load condition, without adverse deflection or deformation. The system is designed to prevent jamming or blocking by cargo, baggage, or foreign objects in the open or closed position. The design prevents system damage that causes subsequent improper operation. When the system function is linked to the lock system, no damage to the system actuation linkage or support structure causes the system and locks to lose their related synchronization.

Compliance: 1. The sizing and operating characteristics are determined analytically. Analysis is used to determine conditions where the mechanical linkage exerts the greatest force due to the available mechanical advantage on the critical parts of the system.

2. Integration of the mechanical systems is demonstrated and tested in a mock-up simulating the expected loads and structural attachments. Testing validates the integrity and durability of the mechanisms. Demonstrations verify that the system cannot be jammed

or blocked by cargo, baggage, or foreign objects in the open or closed position. Demonstration verifies that the system will withstand jam loads at any point in the system without detrimental deformation. All jam load tests are conducted on the full scale article in conjunction with the latch and lock jam load tests. Jam load tests are accomplished on every critical part of the system.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.4.9; 3.1.5.9; 4.1.4.9; 4.1.5.9. (presently in a cancelled status)

**8.9.3** Verify that the failure of any mechanism does not cause the loss of control of the air vehicle or prevent continued safe flight and landing.

Standard: Loss of a door or mechanical system component does not rupture hydraulic lines or tear electrical cables and thereby disable additional systems which makes the aircraft unsafe for continued flight or landing.

Compliance: Review of the aircraft drawings and analysis of the trajectory of a loose door verify that damage will not occur to the flight control surfaces or engines. FMECA predicts the consequence of hydraulic, electrical or mechanical failures or loss upon door separation or mechanical failure.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.2.4; 4.1.2.4 (presently in a cancelled status)

**8.9.4** Verify that inadvertent loosening or opening of air vehicle doors, door latches, locks, or fasteners does not restrict the operation of any flight control system.

Standard: In flight operation of any mechanical system and/or doors will not interfere or impact the operation of any flight control surface, nor compromise the flying qualities to maintain safe flight. The integrity of the flight controls is maintained at all time to avoid compromising the aircraft flight safety regardless of the state of the mechanical mechanisms and it components.

Compliance: Design analysis and a review of the aircraft drawings ensure the independence of flight controls from the mechanical systems. Failure modes and effects analysis predicts the consequences of inadvertent loosening or opening or departing of the mechanical components.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1.3, 3.4.9.4, 3.4.9.3;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.2.6; 4.1.2.6 (presently in a cancelled status)

**8.9.5** Verify that no single failure allows any latch to open inadvertently.

Standard: The latching system employed is designed to hold the doors closed in the event of a single failure within the system. The latching system is fail-safe. Maximum possible relative deflection between the aircraft structure, doors, and the latching system do not cause unlatching under any ultimate design loading condition. Locking and latching systems are separated so that a single malfunction cannot cause the hazardous actuation of both the locking and latching actuators.

Compliance: Failure modes of the latching system is determined by analysis. Critical loading conditions are identified by structural analysis. Structural tests and demonstrations are conducted to ascertain that no door opening will occur subsequent to a single latch system failure.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1.3, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.5.1; 4.1.4.2 (presently in a cancelled status)

**8.9.6** Verify that any locking system is incapable of locking or indicating it is locked unless all the latches are properly latched in the fully secured position.

Standard: The latching system is independent of the locking system so that any inadvertent unlatching attempt shall not cause unlocking. There is no possibility of an out of sequence door locking action producing a false indication of a locked door. Neither is there any indication of a lock condition other than when the locking action is fully completed.

Compliance: Verify by analysis and demonstration that the latching system is independent of the locking system so that any inadvertent unlatching attempt will not cause unlocking. Verify by demonstration that the locking system is incapable of locking or indicating it is locked unless the latches are in the fully secured position and the locking action is completed. Verify by analysis and demonstration that the locking system is independent of the latching system and that inadvertent unlocking shall not cause unlatching. Verify by analysis and demonstration that inadvertent latching system activation shall not cause unlocking or unlatching with the locking system engaged.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 4.1.5.7 (presently in a cancelled status)

**8.9.7** Verify that all air vehicle doors, whose inadvertent opening would present a probable hazard to continued safe flight and landing, have provisions to prevent depressurization of the air vehicle to an unsafe level if the doors are not fully closed, latched, and locked.

Standard: The door latches cannot be unlocked unless the air vehicle has been depressurized. The latching system cannot overpower the lock system. The latching system incorporates an interlock that senses fuselage air pressure differential to prevent unsafe unlocking. The system not only gives positive evidence of an improperly locked and latched door, but also guards against unsafe pressurization before it is latched and completely locked.

Compliance: Verify by analysis and demonstration that the locking system is incapable of unlocking at unsafe pressurization levels. Verify by testing on a full scale test model that a completely assembled lock and latching system will not unlock under unsafe pressurization levels, even when the locking system receives a command to unlock. Demonstration verifies that the system prevents depressurization when all doors are secured. All probable failure modes are tested on a full scale test article. Testing ensures that the pressurization prevention system will hold the locks in the closed position when the fuselage is pressurized and the locks are energized to open.

DoD/MIL Doc:JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.5.8; 4.1.5.8 (presently in a cancelled status)

**8.9.8** Verify that the indication system continuously monitors and provides an unsafe indication when the door, latching, or locking system is unsecured, and provides a safe indication when the system is secured.

Standard: The safe or unsafe status of the doors is continuously presented to the aircrew/ground operators. The system also assists in trouble shooting in the event of a malfunction. Sensors only respond to the system components and not to sensor targets which could hang up and give a false indication. Mechanical indicators use positive mechanical linkage for extension and retraction. The indication system is designed such that the deflection of the aircraft structure under all ground and flight load conditions do not cause false indications.

Compliance: Analysis and demonstration verify that each indication system will continuously monitor and provide an unsafe indication when either the door, latching or locking system is unsecured and will provide a safe indication when the systems are secured. Included are all the malfunctions that could give a false indication. Particular emphasis is placed on those

malfunctions that could give a safe indication for an unsafe condition. Analysis of aircraft drawings and demonstration on a full scale article verify that the sensors will only respond to actual door system components position. Flight and ground test verify that the indication system will not report false indications due to the deflection of the aircraft structure under all ground and flight load conditions.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.7.1; 4.1.7.1 (presently in a cancelled status)

**8.9.9** Verify that the door control systems are designed for emergency operation by means of manual actuation of the door/drive sequence.

Standard: The door system can be manually operated by actuating the sequence valves in the event of an electrical power system failure provided the hydraulic system is still intact.

Compliance: Analysis and test on the full scale test article or production aircraft demonstrates that the system can be manually sequenced in an emergency. Tests include the event where normal system operation opens the doors partially and manual operation is required to complete the operating cycle.

DoD/MIL Doc: JSSG-2009: Appendix I, 3.4.9.1, 3.4.9.4.11;

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.9.4; 4.1.9.4 (presently in a cancelled status)

**8.9.10** Verify that all door seals prevent rain or water leakage into the air vehicle during all flight and ground operations and while the air vehicle is parked and depressurized under storm conditions.

Standard: All seals are air tight when pressurized and protect against water when the aircraft is unpressurized. The seals exclude water at all times with the doors or canopy closed.

Compliance: Analysis and seal life testing verifies that the seals will have adequate life expectancy and a satisfactory performance when pressurized and unpressurized. Rain storm tests do not reveal any leaks in the aircraft.

DoD/MIL Doc: JSSG-2009: Appendix I: 3.4.9.1.10; 3.4.9.4

MIL-87222 Mechanical Systems for Aircraft Doors and Canopies: para 3.1.10.2; 4.1.10.2 (presently in a cancelled status)

**8.9.11** Verify that all actuation subsystems are able to be locked and unlocked, provide for folding, unfolding, and deploying, and can be folded, unfolded, and deployed within a wind environment that encompasses atmospheric and weather-induced conditions, wind-over-deck from carrier vessel movement, and downwash and jetwash conditions caused by other vehicles expected in the operational ground/deck environment.

Standard: The mechanical subsystem is able to operate and complete all its functional actions under all expected mission and environmental conditions. Worst case conditions include operations in the air and on the ground.

Compliance: The design is substantiated by analysis. Component and system load testing verifies operation at worst case conditions. Testing up to design limits are conducted on the ground and in flight as applicable.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; I.4.4.9.4.1

**8.9.12** Verify that mechanisms that provide a structural load path incorporate redundant means of locking the mechanism in position.

Standard: Mechanical systems are designed for safe and durable operation in accordance with the damage tolerance and durability requirements of the cited aircraft structures specification.

Particular attention is paid to safety of flight and critical single load path systems. These items are designed to have redundant means of locking the mechanism in position.

Compliance: The verification methods are consistent with the approach taken with respect to the airframe structure specification and are integrated within the air vehicle structural test programs. Where fail-safe criteria is used, inspection and maintenance procedures detect unsafe conditions.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.2; 4.4.9.4.2

**8.9.13** Verify that, for UAV/ROAs, the locked-or-unlocked condition of mechanisms with position sensors are displayed on the aircraft and at the ground control station during ground operation.

Standard: Safe or unsafe status of the mechanisms are continuously presented to the aircrew/ground operators. The system also assists in trouble shooting in the event of a malfunction.

Compliance: Testing on the full scale article and ground station as applicable verifies that the condition of mechanisms with position sensors are properly displayed. Tests, such as the life cycle tests, include all the malfunctions that could give a false indication as determined by the analyses. Particular emphasis is placed on those malfunctions that could give a safe indication for an unsafe condition. FMECA substantiates probable failures and system indications associated with the failures.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.4; 3.4.9.4.3; 4.4.9.4.3

**8.9.14** Verify that, when applicable, a means is provided for controlling utility actuation. Where possible, include a separate means for "motion" and "locking" control.

Standard: The actuation power and control for moving the mechanism to its commanded position is independent from the power and control used to hold the mechanism in its initial and final commanded state.

Compliance: The design and operating characteristic are substantiated by analysis. System components are laboratory tested to the performance requirements. Full scale functional tests duplicating the system power and system control verify system performance, rigging, installation and indication requirements. Checkout on the air vehicle validates mechanical system installation, rigging, functionality, and performance. Normal and emergency functions are demonstrated and verified.

DoD/MIL Doc:JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.4; 4.4.9.4.4

**8.9.15** Verify that actuation subsystems that have a provision for manual operation include safety devices to prevent injury to maintainers in case of inadvertent application of power during a manually powered operation.

Standard: The design for deployment of mechanisms is safe when air vehicle power is off. Safety devices provide retention capability to keep mechanism in the locked and hold position for all cases when power or forces are applied to unlock and move the mechanism.

Compliance: The design is substantiated by analysis. Component and system load testing verifies safe operation with locking/hold devices installed. Ground checkouts on the air vehicle up to design limits validate the safe operation.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.5; 4.4.9.4.5

**8.9.16** Verify that utility actuation subsystems are capable of operating from the ground power supplied to the air vehicle as well as air vehicle supplied power.

Standard: Control, actuation, indication and functional performance parameters are the same when either ground power or air vehicle power is used to activate the mechanical system. There is no change in how the system responds, nor in how the controls or indication logic acts.

Compliance: Testing verifies that the mechanical system operates correctly with either air vehicle power or with ground station power as applicable. System tests, such as the life cycle tests, regression tests, and performance tests, include all the malfunctions that could give a false indication as determined by the analyses. Particular emphasis is placed on those malfunctions that could give a safe indication for an unsafe condition. FEMECA substantiates probable failures and system indications associated with the failures

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.6; 4.4.9.4.6

**8.9.17** Verify that all actuation subsystems are able to perform their specified function within the specified safe time and cycle. Also specify allowable intervals between actuation cycles as well as total cycles expected during the application lifetime.

Standard: The system actuation cycle is compatible with the air vehicle operational requirements. The time between initiation of the command to the completion of the action is within the design allowable. The time between successive operations of the same cycle is not degraded and can be consistently repeated, for the design service life.

Compliance: The design is substantiated by analysis of components and systems. Component and system tests verify actuation rates and times to be completed as required. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, control, and functional performance. Air vehicle flight and ground tests demonstrate compatibility with air vehicle performance requirements.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.7; 4.4.9.4.7

**8.9.18** Verify that utility actuation subsystems incorporate some means to prevent damage to adjacent movable surfaces (for example, flaps) during folding and unfolding operations.

Standard: The mechanical system control has interlocks or logic that will prevent actuation power/movement when other mechanical surfaces or flight control surfaces are in a position to be damaged or compromised.

Compliance: The design is substantiated by analysis of components and systems. Component and full scale system tests verify actuation logic and control to the extend no power or damage occurs when other components are in the way. Full scale checkouts on the air vehicle verify system interlock and control logic meet design requirements

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.8; 4.4.9.4.8

**8.9.19** Verify that the actuation subsystem attachment is not an integral part of the air vehicle structure, such as a wing rib, but is a replaceable attachment designed so that, in case of an overload or fatigue failure, the attachment fails in lieu of a structural component failure on the primary air vehicle.

Standard: No structural failure of the mechanical system actuation system and its attachment fitting cause damage to air vehicle structure. Replacement of mechanical system attachment does not require the replacement of major structure such as bulk head, keel beams, etc.

Compliance: Analysis and inspection of drawings verify that mounting and attachment fittings are designed to be replaceable without major structural effects. The design loads and ultimate loads are substantiated by analysis. System components pass laboratory testing to design limit loads and ultimate loads.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.9; 4.4.9.4.9

**8.9.20** Verify that clearance is provided in the deployed or stowed position and during the deployment operation to prevent damage to the surface, attached equipment, and to other areas of the air vehicle.

Standard: When stationary or in motion, adequate clearance is maintained between the mechanism and all other air vehicle and ground equipment for all expected operational conditions

including all air vehicle maintenance. There should be no contact between the mechanism and air vehicle structure or ground systems.

Compliance: The design is substantiated by analysis of components and systems, and accounts for worn states of various components. Component and system tests verify clearances between air vehicle structure and systems. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, and clearances. Air vehicle flight and ground tests demonstrate compatibility with air vehicle and ground equipment clearance requirements.

DoD/MIL Doc: JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.10; 4.4.9.4.10

**8.9.21** Verify that utility actuation mechanisms used during ground operations have a purely manual backup available for motive power and locking/unlocking purposes if the primary mode of operation is automatic or powered (or both). And verify that subsystems used for purely in-flight applications also have means incorporated to allow on aircraft activation for ground maintenance actions.

Standard: There are means to provide accessibility to mechanism by the maintainers. There can be an alternate non-power means to open doors or access to the mechanisms on the air vehicle, while on the ground and when in in servicing by the maintainers.

Compliance: Review and inspection of design drawings and maintenance documentation verify the ability to open/operate mechanism without power for maintenance action. Non-power access is demonstrated on the air vehicle.

DoD/MIL Doc:JSSG-2009, Appendix I: 3.4.9.1.10; 3.4.9.4; 3.4.9.4.11; 4.4.9.4.11

**8.9.22** Verify that the locked-unlocked condition of mechanisms used during ground operations is displayed visually, externally, by purely mechanical, nonelectric means.

Standard: A visual or a mechanical means is provided to confirm the status of doors and is readily visible to the maintainers. The system is a backup for the primary indicating system.

Compliance: The design and operating characteristic are verified by analysis. Full scale functional test mock-up duplicating the air vehicle installation and interfaces, and system control verifies system performance, rigging, installation and indication requirements. Checkout on the air vehicle verifies installation, rigging, functionality, and performance. Demonstration verifies normal and emergency functions.

DoD/MIL Doc: JSSG-2009 para I: 3.4.9.4.13; 4.4.9.4.13

## 8.10 External cargo hook systems (rotary wing).

**8.10.1** Verify that the cargo hook system operation in normal, automatic, and emergency modes does not adversely affect safety of the air vehicle system.

Standard: The air vehicle maintains an acceptable level of dynamic stability for all mission operations on the ground and during flight whenever the cargo hook system is in operation. There are no adverse effects that damage the air vehicle or harm personnel at any time the cargo hook system is used.

Compliance: Dynamic and Stability analyses verify that the cargo hook system operation does not adversely affect all ground and flight operations and are validated using component characterization and air vehicle ground demonstrations tests. Flight testing verifies that all transitional operations (air-to-ground and visa-versa) and inflight operations have no adverse vibration or instability effects.

DoD/MIL Doc:Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: 14CFR reference Parts 27 and 29

**8.10.2** Verify that the cargo hook system cockpit switches and indicators provide for normal, automatic, and emergency release of cargo.

Standard: The pilot or the operator has sufficient control and indications of the cargo hook system operation. Control and indication provisions allow release of the cargo as commanded for normal and emergency operations. The indications provide an accurate representation of the status of the cargo and of any malfunctions. Safe or unsafe status of the cargo is continuously presented to the aircrew/ground operators. The system also assists in trouble shooting in the event of a malfunction. The sensors only respond to the system components and not to sensor targets which could hang up and give a false indication. Mechanical indicators use positive mechanical linkage for hold or release, and deflection of the aircraft structure under all ground and flight load conditions does not cause false indications.

Compliance: Analysis and demonstration verifies that the cargo hook system operates correctly and provides proper status indication with air vehicle power and/or ground station power. Testing, such as the life cycle tests, regression tests and performance tests are conducted to include all malfunctions that could give a false indication. Test verify all malfunctions that could give a safe indication for an unsafe condition. FEMECA substantiates probable failures and system indications associated with the failures

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: 14CFR references: 133 Amendment No. 133-11, 133 Amendment No. 133-9 (Rotorcraft External-Load Operations)

**8.10.3** Verify that the cargo can be hooked safely to the hook and that the manuals contain the maximum and minimum loads for safe movement of cargo.

Standard: The cargo hook system and the associated structure used to retain the cargo can take the full ground and flight loads without damage to and without any detrimental effects to the air vehicle and the cargo. Sufficient documentation and instructions to properly retain the cargo in position and to release it is provided so as not to cause and overloads throughout the operational missions

Compliance: Air Vehicle performance analysis predicts the worst case loads. Laboratory tests verify the structural and performance capability of the cargo hook system and structural attachment combination. This includes material selection, strength, service life, overload operation and cargo release profiles that supports the air vehicle performance and operations. Flight test and operational tests validate the analysis and component tests.

DoD/MIL Doc:Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: 14CFR references: 133 Rotorcraft External-Load Operations, subpart D-Airworthiness Requirements, sec.133.45

**8.10.4** Verify that the electromagnetic environment of the air vehicle is compatible with safe loading and release of cargo.

Standard: Cargo hook operation is able to complete all its functional actions under all expected mission and electromagnetic conditions. Worst case conditions are to be designed for operations in the air and on the ground.

Compliance: The design is substantiated by analysis. Component and system load testing is conducted at worst case conditions. Ground and air vehicle flight testing up to design limits are conducted on the ground and in flight as applicable.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: 14CFR references: 27.865 (Part 27 Airworthiness Standards: Normal Category Rotorcraft, subpart D-Design and Construction);

14CFR references: 29.865 (Part 29 Airworthiness Standards: Transport Category Rotorcraft, Subpart D-Design and Construction).

**8.10.5** Verify that the air vehicle structure can support all loads imposed by the external transport of cargo during operational usage.

Standard: The Operational Concept dictates the structural requirements based on a defined external loads envelope and worst-case flight conditions. The aircraft's structural limits for flight operations will exceed external loads envelope by an acceptable margin.

Compliance: Analysis and structural testing of subsystems or complete structures will be performed as necessary. Structural testing verifies analytical results such that an acceptable margin of safety is attained for the design condition.

DoD/MIL Doc: Refer to the technical point of contact for this discipline (listed in section A.2)

FAA Doc: 14CFR references: 27.865, 29.865

**8.10.6** Verify that the external cargo hook and supporting structure limits are defined and are published in all applicable operator and maintenance manuals.

Standard: Unless otherwise specified the cargo hook and supporting structure shall have a limit load factor of 2.5 times the rated or working load capacity. The hook support structure shall be capable of withstanding the rated capacity to 15 degrees with the vertical forward and lateral and 30 degrees with the vertical to the rear.

Compliance: The rated capacity of the cargo hook and support structure throughout their defined range of movement will be verified through analysis and testing.

DoD/MIL Doc: Refer to the technical point of contact for this discipline (listed in section A.2)

FAA Doc: 14CFR references: 27.865, 29.865

**8.10.7** Verify that air vehicle flight performance/control is not adversely affected by load movement experienced during external load operations and the emergency jettison of external cargo.

Standard: The air vehicle can perform external load operations and emergency jettisons throughout the defined external cargo envelope at the required airspeeds without adverse effects on performance/control or the airframe.

Compliance: Aircraft stability shall be verified through analysis and testing with a range of loads and airspeeds.

DoD/MIL Doc: Refer to the technical point of contact for this discipline (listed in section A.2)

FAA Doc: 14CFR references: 27.865, 29.865

## 8.11 External rescue hoist (rotary wing).

**8.11.1** Verify that the external rescue hoist system does not adversely affect safety to personnel or to the air vehicle system.

Standard: The air vehicle maintains an acceptable level of dynamic stability for all mission operations on the ground and during flight whenever the hoist system is in operation. There are no adverse effects that would damage the air vehicle or harm personnel at any time the hoist system is used.

Compliance: Dynamic and Stability analyses verify that the hoist system operation does not adversely affect all ground and flight operations and are validated using component characterization and air vehicle ground demonstrations tests. Flight testing verifies that all transitional operations (air-to-ground and visa-versa) and inflight operations have no adverse vibration or instability effects.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**8.11.2** Verify that the hoist system operates safely under rated and emergency loading conditions.

Standard: The design of the hoist system allows for safe operation at its maximum and minimum loading conditions, as specified for normal and emergency missions.

Compliance: The design is substantiated by analysis of components and systems. Component and system tests verify operation, loads and times to be completed as required. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, control, and functional performance. Air vehicle flight and ground tests demonstrate compatibility with air vehicle performance requirements.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**8.11.3** Verify that the electromagnetic environment of the air vehicle is compatible with safe operation of the rescue hoist.

Standard: The hoist operation is able to complete all its functional actions under all expected mission and electromagnetic conditions. Worst case conditions are to be designed for operations in the air and on the ground.

Compliance: The design is substantiated by analysis. Component and system load testing is conducted at worst case conditions. Ground and air vehicle flight testing up to design limits are conducted on the ground and in flight as applicable.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

## 8.12 Fast rope insertion/extraction system (FRIES) (rotary wing).

**8.12.1** Verify that H-bar and FRIES bar provides for the safe insertion and extraction of personnel into and out of the air vehicle.

Standard: The design of the H-bar and FRIES bar system allows for safe operation at its maximum and minimum loading conditions, as specified for normal and emergency missions. The system allows for the safe insertion and extraction of personnel for all expected mission profiles.

Compliance: The design is substantiated by analysis of components and systems. Component and system tests verify operation, loads and times to be completed as required. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, control, and functional performance. Air vehicle flight and ground tests demonstrate compatibility inserting and extracting personnel within air vehicle performance requirements.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**8.12.2** Verify that the back-up structure possesses adequate structural margins of safety for the safe insertion and extraction of personnel.

Standard: The design of the air vehicle back-up structure has the capability to support the FRIES at all times for all the design missions. Static and dynamic loads generated during taxi, takeoff, flight and landing under all air vehicle operational weights and operational environments are considered.

Compliance: Air Vehicle performance analysis predicts the worst case loads. Laboratory tests verify the structural and performance capability of the FRIES system and back-up structure. This includes material selection, strength, service life, overload operation and speed/load/time to insert/extract profiles that support the air vehicle performance and operations. Flight test and operational tests validate the analysis and component tests.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

# 9. CREW SYSTEMS

The crew systems area consists of the following elements: pilot-vehicle interface, aircrew station (accommodations, lighting, furnishings, and equipment), human-machine interface, UAV/ROA control station (operator accommodations, lighting, and equipment), the life support system, the emergency escape and survival system, the transparency system, crash survivability, and air transportability.

TYPICAL CERTIFICATION SOURCE DATA

1. Escape system requirements and validation
2. Crew station layout/geometry review
3. Human factors
4. Failure modes, effects, and criticality analysis (FMECA)
5. Life support system requirements and validation
6. Crash survivability requirements and validation
7. Lighting system design, analysis, test reports
8. Transparency integration
9. Air transportability, cargo, and airdrop systems
10. Load analyses
11. Aeroservoelastic analyses
12. Test plans
13. Test reports
14. Proof test results
15. Simulation test, modeling and results

CERTIFICATION CRITERIA

DoD/MIL Doc: JSSG-2010 Crew Systems

FAA Doc: AC 20-41A, AC 20-60

## 9.1 Escape and egress system.

This element provides the means whereby the occupant(s) can leave the air vehicle during inflight, water, and ground emergencies. It may include the following equipment and devices: the ejection seat (if equipped), restraint system, escape sequencing system, cartridge actuated or pyrotechnic actuated devices (CAD/PAD), canopy jettison (including thrusters and rockets), escape path clearance, parachute(s), provisions for survival equipment (flares, medicine, radio, sustenance, arms, emergency oxygen, flotation equipment), manual bailout, emergency escape exits, escape paths, life rafts, slides, emergency ground egress provisions, and aeromedical evacuation.

**9.1.1** Verify that the escape system is safe for human use and compatible with the aircraft.

Standard: An escape system or means to affect emergency escape is incorporated within the air vehicle for both ground and ditching conditions, and in flight conditions if specified. (An escape system may include ejection seats, escape capsules, escape path clearance systems, emergency exits, and ground egress aids used to perform the functions of escape, survival, and recovery of air vehicle occupants.) Automated ejection seats, escape capsules or modules function to separate the aircrew from the aircraft and recover them to the earth. Escape system functionality, including operation of escape path clearance systems, does not induce a probability of incapacitating major injury greater than 5% throughout the

required performance envelope. Means of emergency egress (e.g., use of explosive components for egress, sharp edges, hot metal percussion, etc.) does not cause serious injury or hinder required procedures for evacuation. For systems that allow one or a portion of the aircrew to eject independently, the ability to sustain flight and for remaining aircrew to subsequently eject is not precluded.

Applied and inertial forces during escape do not exceed a 5% human incapacitating injury probability for speeds up to at least 350 KEAS for legacy aircraft and 450 KEAS for aircraft in development unless otherwise specified or limited by air vehicle speed capability.

Recovery decent rates with oscillation dampening devices deployed do not exceed a total velocity of 24ft/sec at SL on a standard day. The maximum resultant deceleration, stabilization, and recovery opening loads experienced by the aircrew during escape do not exceed;

25g at 450 KEAS or less and 8000 ft MSL and below

35g above 450 KEAS and 8000 ft MSL and below

20g at 450 KEAS or less and 8000 to 18000 ft MSL

30g above 450 KEAS and 8000 to 18000 ft MSL

Canopies and hatches do not present a risk of collision with any ejectee of the aircraft during the escape and recovery sequence from straight and level flight conditions.

Head and Neck loads (neck tension, compression, shear force and combined neck moment and loads) that may be experienced during escape do not exceed injury level criteria for the anthropometric range of aircrew.

Accelerations imposed on an ejection seat occupant do not exceed limits indicated below for the Dynamic Response Index (DRI), Multi-Axis Dynamic Response Criteria (MDRC), and Dynamic Response Radical (DRR) criteria as defined in JSSG-2010 paragraphs 3.11.4.1, and B.4.1.1.5.2. (Note: MRDC is referred to as the Biodynamic Response Index in B.4.1.1.5.2.b.).

Criteria Limits unless otherwise specified:

The +gz direction (parallel to the spinal column) accelerations imposed by the ejection catapult does not exceed a DRI of 18 at 70F and a DRI of 22 at 165F if the acceleration vector is within 5 degrees of the z axis (towards the head parallel with the spine). If the acceleration vector is not within 5 degrees of the z axis, the DRI does not exceed 16 at 70F and 21.9 at 165F. Accelerations after aircraft separation do not exceed both a DRR of 1 and MDRC of 1 at 600 KEAS, or 1.1 at 700 KEAS based on the maximum speed specified for the escape system envelope.

Values Used in MDRC Calculations

| For: | DRx > 0 | DRx < 0 | DRy > 0 | DRy < 0 | DRz > 0 | DRz < 0 |
|---|---|---|---|---|---|---|
| DR Limit = | 40 | 35 | 17 | 17 | 18 | 16.5 |
| Natural Frequency (rad/s) | 62.8 | 60.8 | 58.0 | 58.0 | 52.9 | 47.1 |
| Damping Coefficient | 0.2 | 0.04 | 0.09 | 0.09 | 0.22 | 0.24 |

Compliance: Inspection of engineering drawings verifies the escape system has all components necessary to allow aircrew escape. System level performance as integrated into the aircraft is verified by testing throughout the designated envelope with extreme permutations of crew anthropometry and mass properties. System level testing (such as sled tests & canopy jettison/fracture tests) using instrumented articulating dummies verifies that exposure to acceleration levels and other loads, forces, environments, and impacts do not exceed injury criteria and injury probability levels. Emergency egress demonstrations with human subjects

verifies the ability to safely operate required systems and egress the air vehicle. System level testing, analysis, and subsystem level test and demonstration verify integration and compatibility with the air vehicle and other subsystems. (e.g., structural testing/analysis, electromagnetic compatibility testing, power/electrical system tests, software verification testing, aerodynamic analysis, etc).

DoD/MIL Doc: JSSG-2010-3: para 3.3.4

JSSG-2010-7: para 3.7.3.5.3;

JSSG-2010-11: para 3.11.7, 3.11.7.2, 7.3.3.3.5.3;

NATO Working Party 61

**9.1.1.1** Verify that the systems and subsystems of the escape system have a designed and demonstrated reliability *sufficient for use.*

Standard: Ejection seats, capsules, modules, and escape path clearance systems have a minimum demonstrated reliability of 90% with a 90% confidence interval at the system level. Minimum design reliability at the system level is 98%. Subsystems including Cartridge Actuated and Pyrotechnic Actuated Devices (CAD/PAD) have demonstrated reliability that supports the system design level for the environments specified.

Compliance: Sufficient reliability and confidence level is verified by analysis and system level escape system testing. Ejection seat reliability is verified by qualification with 22 consecutively successful tests. Air vehicle escape system level tests (such as sled tests) verify integration of previously qualified ejection seats, with at least 8 system level ejections conducted unless otherwise specified. Reliability of CAD/PAD devices is verified by subsystem level testing, completed prior to system level tests.

DoD/MIL Doc: JSSG-2010.

MIL-C-83124

MIL-C-83125

MIL-C-83126

**9.1.2** Verify that escape exits and escape routes are provided in appropriate sizes and numbers for emergency evacuation, landing or ditching to permit timely and complete egress of occupants.

Standard: All crew members can evacuate the aircraft with 60 seconds. Transport aircraft exits and sizes have twice the capacity for the maximum number of aircraft occupants to egress the aircraft. Crew station and aircraft interior design permits all occupants to egress the aircraft within 90 seconds with half of the exits randomly blocked, and with all exits on one side of the aircraft blocked. The crew and passenger area has emergency means to allow complete abandonment in 90 seconds during ground egress or ditching of the air vehicle with half of the exits blocked, with the landing gear extended as well as retracted, considering the possibility of the air vehicle being on fire, and at maximum seating capacity. Note: The 90 second evacuation criteria is not applicable for patients on aeromedical evacuation missions. Number and size of exits permit all occupants of round operating stations to egress unit within specified time limits, or 60 sec if not otherwise specified. Maximum number of occupants permitted in ground station at any one time is posted.

Compliance: Testing, inspection, demonstration, and time study analyses documents verify that the aircrew and passengers can egress the aircraft from any combination of half the exits. An emergency egress demonstration from the vehicle, ground control station, or a high fidelity mockup is used to verify egress capability and time required under both day and night lighting conditions. For transport aircraft, participants have no prior practice or rehearsal for the demonstration.

DoD/MIL Doc: NATO Draft Working Party 61B;

JSSG-2010

FAA Doc: 14CFR reference 25.803

**9.1.3** Verify that emergency exits have operating instructions and markings, both internally and externally.

Standard: Emergency exits are clearly marked and have readily apparent, discernable operating instructions for use by crewmembers and/or passengers internally, and are marked with relevant markings for external rescue.

Compliance: Inspection of emergency exits or engineering drawings verifies instructions and markings. Demonstrated utility and discernability have been documented during emergency egress and rescue demonstrations with simulated or actual anticipated lighting conditions.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.3

JSSG-2010: para 3.8, 4.8, 3.9, 4.9, 3.11, 4.11, 3.12, 4.12, 3.13, 4.13, 3.14, 4.14

FAA Doc: 14CFR reference: 23.803-23.815, 25.801-25.819, 23.1411, 23.1415, 25.1411, 25.1415, 25.813, 23.813, 25 Appendix F; 25 Appendix J 25.1423

**9.1.4** Verify that devices for ground emergency egress assist (slides, descent reels, life rafts, etc.) and their deployment handles/actuators meet safety requirements.

Standard: Ground emergency egress devices can be safely used by the intended crew and passenger populations, without unacceptable risk of major injury. Deployment handles/actuators capable of creating a flight safety or injury hazard are designed to prevent inadvertent actuation during normal operations and incidental contact. The safety requirements of each individual emergency ground egress assist device bound and include the application requirements of the platform or system into which it is being incorporated. This includes the number and anthropometric range of occupants, the ground egress time requirements of the platform, the operational environmental requirements of the platform, and applicable physical and power integration requirements of the platform.

Compliance: Safety of emergency egress devices is verified by system testing and analysis. Qualification testing confirming compliance with specified requirements for each device verifies safe operation. Analysis, Inspection, and Demonstration of capability when integrated into the host platform verify system level safety. Emergency egress demonstrations verify the ability to operate and use emergency egress devices without unacceptable major injuries.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.3

JSSG-2010: para 3.8, 4.8, 3.9, 4.9, 3.11, 4.11, 3.12, 4.12, 3.13, 4.13, 3.14, 4.14

FAA Doc: 14CFR reference: 23.803-23.815, 25.801-25.819, 23.1411, 23.1415, 25.1411, 25.1415

**9.1.5** Verify that ground/ditching emergency egress and rescue processes and procedures exist, are incorporated in system documentation, and are implemented in training.

Standard: Flight and training manuals incorporate required procedures. System training and syllabus documentation includes instruction for emergency egress. Documentation of required passenger briefings include emergency egress instructions. Rescue procedures and processes are documented for ground rescue personnel. (Ground emergency egress includes aircraft with and without automatic emergency escape systems. The process includes the design of the aircraft to permit timely egress of the aircraft including disconnection of restraint systems and personal equipment as well as training systems for aircrew, and ground/water rescue personnel.) Procedures are documented that inform and enforce the ground/ditching egress procedures for both aircrew, passengers and rescue personnel. The procedures are distributed to training groups, aircrew and rescue personnel.

Compliance: Documentation of egress/rescue processes and procedures, including flight manuals, training manuals/syllabus, and rescue procedures are verified by inspection. Demonstration, test, and analysis documentation verifies that the design of the

ground/ditching egress process provides timely egress for aircrew and passengers with high fidelity mockups, actual personal equipment, and aircraft hardware. Demonstration and analysis verify effectiveness of processes for rescue personnel including canopy, hatch/door removal by external actuation or cutting. Inspections verify that procedures exist in document form for egress training for aircrew, passengers and rescue personnel and are distributed to all organizations that either operate the aircraft or could possibly support it.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.3, JSSG-2010: 3.8, 4.8, 3.9, 4.9, 3.11, 4.11, 3.12, 4.12, 3.13, 4.13, 3.14, 4.14

FAA Doc: 14CFR reference: 23.803-23.815, 25.801-25.819, 23.1411, 23.1415, 25.1411, 25.1415

**9.1.6** Verify that egress equipment exists to aid escape in the event exits are blocked, damaged, or when exit opening actuation fails.

Standard: Creation of necessary exits in aircraft transparencies and designated aircrew compartment surfaces can be performed by using either onboard devices (crash axe, canopy penetrator, etc.) and/or ground rescue tools ( fire rescue axe, powered saw). Depending on the operational concept of the aircraft, the egress equipment exists either on the aircraft and/or with organizations where the aircraft could operate. If applicable, onboard egress equipment exists in every compartment where an occupant could be under landing and takeoff conditions.

Compliance: Emergency egress/rescue demonstrations, test, and analysis documentation verify that exits can be generated in aircraft transparencies and designated aircrew compartments with either onboard devices or ground rescue tools.

DoD/MIL Doc: No information available in current JSSG. Information to be included in next revision of JSSG.

FAA Doc: 121.309, 121.310

## 9.2 Crew stations and aircraft interiors.

Aircrew station (accommodations, lighting, furnishings and equipment): This element provides the crewmember with crew station geometry covering workspace size and arrangement as specified by the anthropometric requirements, internal and external visibility necessary to perform the specified missions safely, cockpit illumination (primary, secondary, night vision imaging systems (NVIS), laser eye protection (LEP), utility and emergency lighting), thermal and acoustic protection, and storage facilities. Additionally, for manned air vehicles, other elements include sanitary facilities, cockpit finish and trim, instrument panel and consoles, and protection from cockpit generated reflections (glareshields). It may also cover boarding arrangements such as ropes or ladders. Crew and passenger accommodations may also be covered. This element also covers UAV/ROA control station requirements, where appropriate.

FAA Doc: 14CFR reference: 23.771-23.775, 25.771-25.773, 23.803-23.815, 25.801-25.81923.1411, 23.1415, 25.1411, 25.1415

**9.2.1** Verify that all controls and displays are arranged and located so that they are completely functional and visible and that cockpit or operator station geometry (including seats) accommodates the specified multivariate flight and mission crew population.

Standard: 1. Crew station controls, displays, geometry, and human interfaces accommodate the physical attributes, body dimensions, and capabilities of the intended user population. Critical flight information can be obtained, and control inputs can be made to sustain flight under all operational conditions.

2. The geometry, design, and layout of controls, displays, and seating are compatible with human perception capabilities, and do not induce sufficient fatigue, distraction, or discomfort to induce control errors.

Compliance: 1. Mockup evaluations and crew-in-the-loop flight simulations with human subjects

representative of the intended anthropometric range, demonstrate the ability to obtain required flight information, and to make necessary control inputs.

2. Crew-in-the-loop flight simulations demonstrate that accommodation features do not produce risk of error sufficient to cause loss of control, or the inability to sustain flight.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.14, 4.14

JSSG-2001: para 3.4.3.1.1, typical anthropometric dimensions and ranges considered acceptable to accommodate the US pilot population

JSSG-2001: para 3.4.3.1.5, guidance on controls and displays

MIL-STD-1472, section 5.6, design criteria and features recommended to provide human accommodation

FAA Doc: 14CFR references: 23.777, 25.777

**9.2.1.1** Verify that all displays are readable, from all crewmember (or operator/controller) eye positions, under the full range of ambient conditions.

Standard: Displays are readable from full darkness to direct sunlight. Displays are constructed, arranged and mounted so as not to adversely affect information transfer due to reflection, while minimizing reflection of instruments and consoles in windshields and other enclosures. Displays are located so that they are legible from the crew member position, under all expected illumination conditions from full darkness to direct sunlight (up to 10,000 fc), with adequate luminance, contrast and lighting balance. Luminance uniformity is maintained throughout the entire range of luminance control.

Compliance: Mockup evaluations and crew-in-the-loop flight simulations with human subjects representative of the intended anthropometric range, demonstrate the ability to obtain required flight information. Physical measurements and demonstration/simulations under various lighting conditions expected for the actual operational environment take into account both extremes for ambient illumination and any extreme viewing conditions that can be anticipated.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.14, 4.14;

MIL-STD-1472, section 5.2 addresses visual displays of various types

FAA Doc: 14CFR references: 23.777, 25.777

**9.2.1.2** Verify that the interior and exterior fields of view are sufficient to safely perform all flight and mission-critical functions.

Standard: 1. All internal visual information and crew response necessary to complete all mission activities/tasks are readily accessible throughout all aircraft operating regimes (including environmental) and mission activities.

2. Sufficient external vision is provided to permit the pilot to perform any maneuver within the operating limits of the aircraft safely and at the same time affords an unobstructed view of the flight instruments and other critical components and displays from the same eye position. The external field of view is optimized relative to the fully accommodated population such that all required mission activities/tasks (including take-off, landing, and aerial refueling) are readily achievable and can be safely conducted throughout all aircraft operating regimes (including environmental) and mission activities.

Compliance: 1. A cockpit/crew station mockup, using production representative components to the maximum extent possible, is used to verify the quality and extent of internal field of view/visual access.

2. Analysis of rectilinear plots verifies the total envelope (within plus and minus 180 deg□ in azimuth and plus and minus 90 deg□ in elevation) of each operator's unobstructed vision (clear vision area). Flight simulators and flight test assessments verify sufficient visibility to

safely conduct all flight tasks.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.14, 4.14;

JSSG-2010: para 4.3.2, rectilinear plots

JSSG-2010-3: para 3.3.2, rectilinear plots

JSSG-2001: para 3.4.3.1.7 and 3.4.3.1.8, 2. interior and exterior vision, respectively.

FAA Doc: 14CFR references: 23.771-23.781, 25.771-25.781

**9.2.2** Verify that all controls are properly designed and can be operated through their complete range of travel without interference with other controls, structures, or crewmembers' bodies; and that all emergency action controls are reachable by the aircrew member from a restrained shoulder position in all air vehicle attitudes and throughout the complete range of "g" force loads.

Standard: Controls are operable by the full range of aircrew population as defined by anthropometric requirements while wearing all applicable clothing and equipment ensembles. Controls can be fully actuated without travel restrictions under all combinations of operating conditions and flight equipment use/locations.

Compliance: Anthropometric extremes, while wearing applicable clothing and equipment, have been incrementally verified, by test using zone techniques and high fidelity integrated modeling or simulation. Human factors mockup evaluations verify ability to operate controls throughout the full range of travel.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.14, 4.14;

JSSG-2001: para 3.4.3.1.1, typical anthropometric dimensions and ranges considered acceptable to accommodate the US pilot population

JSSG-2010-3: para 4.3.3, Table VI, definition and application of zones

FAA Doc: 14CFR references: 23.771-23.781, 25.771-25.781

**9.2.3** Verify that the master caution and warning systems' displays are located in the prime visual signal area, and that all warning and caution situations are displayed and/or conveyed to the aircrew or operator in a fashion that permits recognition in sufficient time to take actions necessary for safe flight.

Standard: 1. Visual warnings are located within 30deg of the operator’s normal line of sight, and are of sufficient magnitude to ensure rapid detection.

2. The aircrew alerting system alerts the aircrew and gives feedback of all events, conditions, and situations which could present a hazard to the safety of the occupants, endanger human life, or cause substantial damage to the aircraft.

Compliance: 1. Location of visual warnings are verified by inspection and analysis of crew station layout drawings and “mockups” as well as inspection and physical measurements of display hardware. Flight simulations and mockup evaluations demonstrate the capacity of caution/warning systems to garner attention in sufficient time to take appropriate actions.

2. The completeness of the alerting system is verified by analysis of subsystem integration testing, Failure Modes and Effects Criticality Analyses (FMECA), and crew system simulation testing.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.14, 4.14

FAA Doc: 14CFR references: 23.1321-23.1322, 25.1321-25.1322

**9.2.4** Verify that emergency action controls are properly marked.

Standard: Functional groups are set apart by outlining them with contrasting lines which completely encompass the groups or, when gray panels are used, functional groups involving

emergency or extremely critical operations are outlined with a 5 mm (3/16 in) red border (21136 of FED-STD-595) or, as an alternate method, contrasting color pads or patches are used to designate critical functional areas, if approval by the procuring activity. If red compartment lighting is used, an orange-yellow (23538 of FED-STD-595) and black (27038 of FED-STD-595) striped border is used to outline functional groups involving emergency or extremely critical operations.

Compliance: Proper marking of emergency action controls is verified by inspection and analysis of program documentation including, crew station layout drawings and “mockups”, as well as inspection of hardware and manufacturing or engineering drawings.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.9.7, 3.14, 4.14

FAA Doc: 14CFR references: 23.1555, 23.1561, 25.1555, 25.1561

**9.2.5** Verify that, if appropriate, the design allows each crewmember, in an emergency, to operate all controls essential for crew survival.

Standard: 1) Ejection seat equipped aircraft: Ejection controls (automatic and/or manual) are readily accessible and activation is possible with either hand. Provisions are incorporated to guard against accidental activation of ejection system/controls.

2) All aircraft: Controls and switches necessary for emergency actions can be operated under all flight conditions, and crewmember restrained positions. Required safety equipment to be used by the crew in an emergency is readily accessible. The controls are located and arranged, with respect to the crewmember's seats, so that there is full and unrestricted movement of each control without interference from the cockpit structure or the clothing of the flight crew when seated with the seat belt and shoulder harness fastened.

3) Stowage provisions for required safety equipment must be furnished and must be arranged so that the equipment is directly accessible and its location is obvious.

Compliance: Operation of the controls is verified by inspection and analysis of crew station layout drawings and "mockups" as well as inspection and physical measurements of the control hardware. Operation by the anthropometric extremes, as defined in Section 9.2.2, is incrementally verified, while wearing applicable clothing and equipment, by test using zone techniques and high fidelity integrated modeling or simulation. Human factors demonstrations verify the ability to operate controls across the range of crewmember capabilities.

**9.2.6** Verify that all interior finishes, components, and equipment, including lavatories, galleys, and areas that are not continuously occupied, are made with flame-resistant materials.

Standard: Any combustible materials used are burn resistant and have low smoke generation properties.

The crash protection system prevents post-crash fire or protects aircraft occupants from fire which cannot be prevented. This applies to interior components including ceiling and wall panels, other than lighting lenses and windows; partitions, other than transparent panels needed to enhance cabin safety; galley structure, including exposed surfaces of stowed carts and standard containers and the cavity walls that are exposed when a full complement of such carts or containers is not carried; and large cabinets and cabin stowage compartments.

Compliance: Analysis verifies materials are burn resistant and have low smoke generation. Testing (including finishes or decorative surfaces applied to the materials) verifies materials meet the applicable test criteria prescribed in Part I of Appendix F of FAR Part 25 or other approved equivalent methods.

DoD/MIL Doc: JSSG-2010-7: para 3.7.3.4

FAA Doc: 14CFR references: 25.791, 23.853, 25.854, 25 Appendix F

**9.2.7** Verify that a system exists such that the flight deck can readily communicate with other aircrew.

Standard: A means is provided to alert the aircrew in a timely manner and to give time-critical feedback of all events, conditions, and situations which could present a hazard to the safety of the occupants, endanger human life, or cause substantialdamage to the aircraft.

An intercom system is accessible for immediate use at any crew station and provides two way communication between all crew compartments. The intercom systems is capable of operation independent of any public address system.

Compliance: Functionality of communication systems is verified by analysis of subsystem integration testing, and crew system simulation testing.

DoD/MIL Doc: JSSG-2010-4

FAA Doc: 14CFR references: 121.319

**9.2.8** Verify that all audio communication systems have speech intelligibility of sufficient quality to ensure safe and effective aircraft operation.

Standard: The following intelligibility criteria is used for voice communication. The efficiency of communications needed and the type material to be transmitted determines which of the three communication requirements (phonetically balanced (PB), Modified Rhyme Test (MRT), or Articulation Index (AI)) is to be selected.

Exceptionally high intelligibility; separate syllables understood PB 90%; MRT 97%; AI 0.7

Normal acceptable intelligibility: 98% of sentences correctly heard; single digits understood PB 75%; MRT 91%; AI 0.5

Minimally acceptable intelligibility: limited standardized phrases understood; 90% sentences correctly heard (not acceptable for operational equipment) PB 43%; MRT 75%; AI 0.3

Compliance: 1) The modified rhyme test (MRT) described in ANSI 3.2 is used to measure the communication performance of most military communication systems. It is easy to administer and requires only a short training time of 1-2 hours.

2) The phonetically balanced (PB) word test is used when the highest accuracy and sensitivity are required. It is difficult to administer accurately and requires a long training time (typically 20-40 hours) before the responses of the listeners have peaked and are stable.

3) The articulation index (AI) and/or the speech transmission index (STI) are predictive estimators of intelligibility. They are used to estimate system performance during the concept and design phase but not as a substitute for intelligibility test when system hardware is available. The Articulation Index (AI) is not used to measure intelligibility of synthetic speech because some key acoustic features are not present in non-human “speech.” Instead, intelligibility of synthetic speech is measured using representative panels of talkers and listeners.

## 9.3 Air vehicle lighting.

This element involves the following: Lighting environments and mechanisms (e.g., NVIS, LEP) allowing crewmembers to see information from displays and instruments, to operate controls, to move safely throughout and emergency egress the compartment, to see other vehicles in formation and during aerial refueling, and to perform all other mission-critical functions where sight is necessary.

FAA Doc: AC 20-30B, AC 20-30A, 23.1381-23.1401, 25.1381-25.1403

**9.3.1** Verify that lighting systems exist to illuminate everything in or on the air vehicle that needs to be seen by crew, wing men, passengers, maintainers, and ground support personnel, regardless of ambient lighting conditions.

Standard: The lighting system provides adequate illumination for the anticipated range of aircrew tasks throughout all environmental lighting conditions. These tasks include normal ingress and emergency egress for all occupants within the cockpit/crewstation. Illumination is sufficient for exterior visibility and tasks to be accomplished by external aircrews, including aerial refueling operations and formation flights. Adequate lighting for aircrew and passenger safety is provided for the cargo compartment, loading and ramp areas, passageways, passenger seating area, avionics bays, auxiliary power plant compartment, and all flight critical maintenance areas.

Compliance: Illumination is verified by direct measurement in Foot-Candles (FT-C). Lighting Mockup, System Integration Laboratory (SIL), and aircraft evaluations demonstrate the adequacy of the lighting system, both internal and external to the cockpit/crewstations.

DoD/MIL Doc: JSSG-2010-5;

MIL-STD-1472F: para 5.2.1.2 and 5.8.2.1 thru 5.8.2.3 and Table XVI, criteria for the operator station lighting system

MIL-STD-3009: para 4.2.2 table 1, criteria for the operator station lighting system

FAA Doc: 14CFR references: 23.1381-23.1401, 25.1381-25.1403

**9.3.2** Verify that the lighting is fully controllable and uniform and does not produce unacceptable glare, shadows, or reflections.

Standard: 1. All devices that emit or transmit light within the flight deck or other crew compartments are attached to the aircraft power via a common dimmer control.

2. At any given luminance level, lighting components within a lighting subsystem (primary instrument panel, secondary instrument panel, primary console, secondary console, warning, caution and advisory signals, utility, and compartment) provide luminance such that the average luminance ratio between lighted components is not greater than 2 to 1.

3. Reflections from the canopy, windshields, and windows are minimized and reflections that affect the outside vision of the aviator are not sufficient to result in a hazard. Specular reflections resulting from aircraft lighting sources do not occur within the area subtended by a solid angle of one steradian centered at the pilot's design eye position and along the pilot's horizontal vision line.

4. The lighting system is housed so as to prevent the leakage of stray light and shield all lamp filaments from direct view.

Compliance: 1. Dimability control is verified by lighting mockups and aircraft demonstrations

2. Average luminance ratio is verified by measurements in a lighting mockup or aircraft with each lighting subsystem independently energized to half brightness and maximum brightness measuring the required contrast ratio between the brightest and dimmest lighting component of the subsystem. Visual inspection determines the brightest and dimmest lighting component of that subsystem.

3. Acceptability of specular reflections is verified by unaided eye inspections at full bright lighting levels for each lighting subsystem. Any evidence of foreign matter, cracks, scratches, bubbles, delamination, warps or stray light is considered as cause for rejection.

4. Prevention of light leakage is verified by demonstration using lighting sources as installed.

DoD/MIL Doc: JSSG-2010-5

FAA Doc: 14CFR references: 23.1381-23.1401, 25.1381-25.1403

**9.3.3** Verify that the lighting allows the air vehicle to operate in commercial airways without restriction.

Standard: 1. Taxi and landing lights are installed and provide sufficient light for night operations.

2. The position light system is installed so that:

a. Left and right position lights consist of a red and a green light spaced laterally as far apart as practicable and installed on the airplane such that, with the airplane in the normal flying position, the red light is on the left side and the green light is on the right side.

b. The rear position light is a white light mounted as far aft as practicable on the tail or on each wing tip.

c. Each position light, as installed, shows unbroken light within the dihedral angles described in CFR Title 14 Sec. 23.1387 with sufficient light distribution and intensities as described in CFR Title 14 Sec. 23.1389-1395.

d. Each position light color has the applicable International Commission on Illumination chromaticity coordinates as described in CFR Title 14 Sec. 23.1397

3. The riding (anchor) light required for a seaplane or amphibian is installed so that it:

a. Shows a white light for at least two miles at night under clear atmospheric conditions; and

b. Shows the maximum unbroken light practicable when the airplane is moored or drifting on the water

Note: Externally hung lights may be used.

4. An anti-collision light system is installed so that:

a. One or more approved anti-collision lights are located so that their light will not impair the flight crewmembers' vision or detract from the conspicuity of the position lights; and

b. It meets the requirements for field of coverage, flashing characteristics, color, light intensity, and minimum effective intensity as described in CFR Title 14 Sec. 23.1401

Compliance: 1. Landing and taxi light performance is verified by geometrical and photometric analysis in addition to demonstration of coverage, aimability, and minimized glare to the crew.

2. Position light location and chromaticity lighting requirements are verified by inspection, test, and analysis as in paragraph 4.2.2.2.1 of MIL-L-87240. Position light distribution and intensity are verified by test per paragraph 4.2.2.2.3 of MIL-L-87240 requiring direct measurement of intensity in candelas.

3. Riding light conspicuity and visual interference is verified by analysis and inspection.

4. Anti-collision lights are verified by analysis of the aircraft configuration as it applies to the position of the lights, conspicuity and visual interference. Anti-collision light intensity is verified by direct measurement of intensity in candelas

DoD/MIL Doc: JSSG-2010-5: section 3.5.3 addresses exterior lighting subsystems

FAA Doc: 14CFR references: 23.1381-23.1401, 25.1381-25.1403

**9.3.4** Verify that lighting and illumination exists for crewmembers to perform all flight-critical tasks and that lighting systems are NVIS and laser eye protection (LEP) compatible, if applicable.

Standard: 1. The crew station and air vehicle lighting does not degrade aircrew visibility while using night vision devices or laser eye protection devices, sufficiently to maintain flight and conduct safety critical tasks. NVIS lighting is compliant with MIL-STD-3009.

2. A lighting system with sufficient luminance is provided so as not to degrade crew performance throughout the anticipated range of flight-critical aircrew tasks. Aircrew

members are assured the capability to rapidly and accurately obtain required crew station information without vision enhancing devices. During day operations, illuminated visual signals and cockpit/crew station displays that are related to flight-critical tasks are readable in the full range of anticipated ambient lighting requirements.

3. Instruments and their collocated controls (if applicable), that are used during flight-critical tasks, are readable and discernible. The visibility of any graduations, numerals, pointers, or other specific markings is not restricted. Except for self-luminous displays, all illuminated instrument indicia are daylight readable when not energized.

4. The lights do not cause direct or indirect glare that interferes either with the aircrew member's interior or exterior unenhanced vision.

5. The lights do not have a direct or indirect affect on the image intensification capabilities of the NVIS

Compliance: 1. LEP compatibility is verified by lighting wavelength analysis or mockup/aircraft demonstrations indicating visibility is acceptable to conduct flight critical tasks.

2. NVIS compatibility is verified by:

a. Placing the aircraft with full-up NVIS interior lighting in an environment which is as dark as possible (e.g., a hangar with the doors shut, lights out, at night time, an engine hush house, etc.).

b. Placing a visual acuity eye chart(s) within 6-10 m (20-30 feet) from the nose of the aircraft where the pilot/copilot can see it.

c. Using human subjects to look through the NVGs that will be used operationally, and read the charts as if taking an eye test and record their visual acuity scores. Do this with NVIS lights (only) ON as one condition and with all lights OFF as the other condition. The canopy should be closed.

d. This test is through the HUD and canopy (i.e., straight ahead) and off-axis (i.e., through canopy alone).

e. Compare the two visual acuity scores. If there is a significant difference/ degradation in visual acuity between NVIS lights ON and lights OFF, then this may be due to an unacceptable level of NVIS incompatible light.

3. Sufficient luminance is verified by direct measurement using calibrated photometric equipment that verifies specified levels.

4. Readability and discernability of instruments is verified by lighting mockup or laboratory (SIL) and aircraft demonstrations with human subjects, in addition to inspections of installed equipment and testing (i.e., making instrumented measurements).

5. Non-interference with interior and exterior unaided vision is verified by Lighting mockup or laboratory (SIL) and aircraft demonstrations with human subjects, in addition to inspections of installed equipment and testing.

DoD/MIL Doc: JSSG-2010-5

JSSG-2010: para 3.1, 4.1, 3.2, 4.2, 3.3, 4.3, 3.4, 4.4, 3.5, 4.5, 3.14, 4.14;

JSSG-2010-5: para 3.5.2.1.8, cockpit and crew station lighting

MIL-STD-3009: para 5.7.2.2, addresses NVIS compatible aircraft lighting and Visual acuity charts.

FAA Doc: 14CFR references: 23.1381-23.1401, 25.1381-25.1403

## 9.4 Human performance.

This element provides the means for the crewmember to monitor and control the system flight path management, navigation, caution, warning, advisory, communications, identification,

propulsion, and mission and utilities subsystems. It covers presentation of emergency checklists and procedures. It encompasses the location and arrangement of the primary flight display suite, crew workload, situation awareness, and spatial disorientation aspects.

DoD/MIL Doc: MIL-STD-1472F: Human Factors Engineering

FAA Doc: 14CFR references: 23.1311-23.1322, 25.1321-25.1322

**9.4.1** Verify that all functional operations can be safely performed including tasks performed by aircrew, operators, and maintainers.

Standard: Aircrew/operator and maintenance tasks are defined and can be accomplished within the capabilities of the personnel without undue risk of injury or loss of vehicle.

Compliance: All aircrew/operator and maintainer tasks are defined/documented and verified by workload and hazard analysis. Analysis and simulation, using fully trained and qualified operators and maintainers, verifies that trained personnel can perform the task in a safe manner.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2;

JSSG-2010-1 - Handbook para 3.2.1 and 4.2.1 for Method of Compliance. Table 2 of the document provides a list of Figures of Merit.

FAA Doc: 14CFR references: 23.1311-23.1322, 25.1321-25.1322

**9.4.1.1** Verify that the primary flight display suite provides the necessary information to the crewmembers to enable all basic and unique flight maneuvers to be performed safely, in both normal emergency conditions.

Standard: 1. Flight symbology presents the information needed for all flight maneuvers to include takeoff, navigation, and landing.

2. All crew stations from which an operator is to control an air vehicle have at least one complete set of PFR data. All PFR displays provide full-time presentation of critical flight data, to include climb/dive angle (or pitch and vertical velocity), bank, altitude, airspeed, a prominent horizon reference, and any other parameter that is essential to safe flight in a particular aircraft. All PFR displays are endorsed by the Flight Standards Agency.

3. HUDs are installed IAW MIL-STD-1787, para 4.1.6.3. If the HUD or HMD is designated as the PFR, then a head down, supplementary PFR is, as a minimum, selectable with a single control input from the operator. Head down displays are IAW MIL-STD-1787, para 4.1.6.2 .

Compliance: 1. New PFR designs (or significant deviations from baseline designs) are verified by simulation and flight testing to include the following: unusual attitude recovery (UAR); precision instrument control tasks (PICT); instrument landing system (ILS) approach; and mission demonstrations.

2. PFR displays are endorsed by the Air Force Flight Standards Agency.

3. Inspection of HUD, HMD, and HDD program documentation including crew station layout drawings and "mockups" as well as inspection of hardware and engineering drawings verify compliance with MIL-STD-1787 requirements. Selectability of supplemental PFR is verified by mockup demonstration and functional testing.

DoD/MIL Doc: Air Force Flight Standards Agency white paper (Single Medium Flight Instrument Display Endorsement Process, Jan 01) provides procedures for requesting and getting PFR endorsement

JSSG-2010-3: para 3.2, 4.2;

MIL-STD-1787: Appendix E, Figures 91, 92, and 93 list the parameters for basic flight performance, unusual attitude and recovery performance, and dynamic maneuvering performance.

FAA Doc: 14CFR references: 23.1311-23.1322, 25.1321-25.1322

**9.4.2** Verify that all operating instructions, flight handbooks/checklists, flight/performance management and planning systems, and other relevant documentation, are not in conflict with system descriptions and procedures (normal and emergency) and actual system performance; that emergency procedures are clear and corrective actions do not create other hazardous situations; and that all procedures or pilot/vehicle interfaces can be accomplished within acceptable crew workload limits.

Standard: (Criterion sufficient for stand alone)

Compliance: Flight Manuals/Checklists are verified by documentation reviews and demonstration of system performance. Emergency procedures are verified when they are identified and documented; compared to results from the Failure Modes Effects and Criticality Analyses (FMECA), with no inconsistencies found to exist; and analysis ensures that corrective actions do not create other hazardous situations. Acceptable crew workload is verified by task analysis and human-in-the-loop flight simulation.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2;

MIL-DTL-7700G, Flight manuals/checklists accordance

MIL-HDBK-46855, guidance on human workload assessment techniques

FAA Doc: 14CFR references: 23.1581-23.1589, 25.1581-25.1587

**9.4.3** Verify that external visibility, or transmitted visual indications, is sufficient for the aircrew to maintain flight, conduct all necessary flight tasks, and avoid ground or flight obstacles.

Standard: External visibility or transmitted visual information allows all flight tasks to be conducted. No unsafe blind spots exist from posts, canopy bow, windshield frames, heads up display (HUD) supports, etc. that can introduce hazardous conditions.

Compliance: The total vision envelope is verified by inspection of engineering drawings (including vision plots), a review of computer vision analyses, mock-ups, and first article demonstrations. Human factors evaluations with aircraft or representative mockups verify visibility for intended user population. Flight simulations and initial flight tests verify the ability to maintain flight and conduct necessary tasks.

DoD/MIL Doc: JSSG-2010: para 3.1, 4.1, 3.2, 4.2;

JSSG-2010-2: para 3.2.13.3 and 3.2.13.5

FAA Doc: 14CFR references: 23.1581-23.1589, 25.1581-25.1587

**9.4.4** Verify that the crew system interface is designed to reduce the potential for, and minimize the consequences of, a crew-induced error, and provides a simple means to correct an error.

Standard: Crew Systems interfaces are in accordance with human factors engineering principles. The intended crew population can conduct flight critical tasks with low risk of error. Errors which jeopardize flight safety can be quickly corrected with a minimal number of steps.

Compliance: Crew Systems interfaces are designed with human factors principles to reduce error potential and provide a means of simple correction. This is verified by inspection of engineering drawings, mockup demonstrations, inspection of crew procedures documentation, and by mockup and simulation analyses.

DoD/MIL Doc: MIL-STD-1472F para 5.1 through 5.4 and 5.4.3, guidance for the human factors design of equipment that minimizes the occurrence of human error.

MIL-STD-1472F: para 5.1.14, design guidance for human computer interface and associated methods for the minimization of human error.

**9.4.5** Verify that technical manuals/technical orders and publications are accurate and complete for all tasks that may have flight safety impacts.

Standard: Technical manuals/technical orders and publications are evaluated with respect to usefulness and accuracy in the areas of Job Instructions (how to perform maintenance tasks), Training, and Job Performance Aids (fixed procedures and trouble shooting).

Compliance: Technical manuals/technical orders and publications are verified by demonstration and inspection.

## 9.5 Life support systems.

This element provides the human with breathing and anti-g provisions, and natural, induced, and combat hazard protection. This includes chemical biological protection, laser protection, cold water immersion protection, head protection, noise protection, altitude protection (pressure suits), protection from rapid decompression, personal services, etc.

**9.5.1** Verify that the air vehicle integrated life support systems (for example, high altitude, "g" protection, ocular protection, and breathing) are fully functional and accessible within the flight envelope.

Standard: The life support and personal protective equipment are designed, tested, and installed as part of an overall system. The life support and personal protective equipment supports the intended personnel in the operational envelope of the air vehicle. The life support and personal protection system could include: chemical/biological (CB) protection, G protection, ballistic protection, personal altitude protection, thermal stress protection, flame and heat protection, smoke and toxic fumes protection, head protection, eye protection and augmentation devices, hearing protection and communication devices, clothing and accessories.

Compliance: Life support system integration and functionality is verified by a combination of testing, inspections, demonstrations, and analyses, accomplished from the standpoint of the overall system performance and installation. System verification by inspection includes examination of hardware samples, components, and on-aircraft system checkout. Verification by demonstration include mockups and simulations in the areas of human factors and cockpit compatibility and pilot acceptability. Verification by test include centrifuge using live subjects, altitude chamber testing, sled and windblast testing to verify ejection compatibility, live parachute jumping, water immersion tests using live subjects, chemical/biological verification of the specified threat. Analysis is used to verify specific aspects of the system where testing is not appropriate or possible. System validation is demonstrated by the system functional review so that more detailed analysis and inspections can progress to meet design review milestones.

DoD/MIL Doc: JSSG-2010: para 3.6, 4.6, 3.9, 4.9, 3.10, 4.10, 3.13, 4.13;

JSSG-2010-9 Personal Protective Equipment Handbook para 3.9.1, 4.9.1

FAA Doc: 14CFR references: 23.1301, 23.1441, 25.1301, 25.1441

**9.5.2** Verify that the system satisfies the physiological requirements of the occupants during mission, escape, and survival.

Standard: The pilot/controller or air crew operators are provided sufficient provisions and protection to sustain life and maintain vehicle control under natural and induced environmental conditions for the intended mission of the aircraft. This includes environmental effects that degrade human physical and cognitive capabilities. Provisions are incorporated to ensure:

A. Core body temperature can be maintained at or below 100.4 degrees F

B. Breathing gas pressures and concentrations are in accordance with physiological requirements

C. Ocular protection against foreign matter, irritants, or laser threats that may be present

D. Protection from chemical or biological threats

E. Consciousness can be maintained during g loads

In addition, for an in-flight escape capability, physiological protective features incorporated ensure:

A. Impact protection from flying debris

B. Flame protection to ensure the maximum skin temperature does not exceed 107.6 degrees F

C. Flotation and drowning prevention for an unconscious crewmember

D. Physiological protection from cold weather/water survival to 32 degrees F for 2 hours, maintaining a core temperature in excess of 96.8 degrees F and skin/foot temperature in excess of 60 degrees F

Compliance: Physiological requirements are verified by human testing in mockups and simulators to ensure that physiological needs are met and vehicle control can be maintained.

DoD/MIL Doc: JSSG-2010: para 3.6, 4.6, 3.9, 4.9, 3.10, 4.10, 3.13, 4.13;

JSSG-2010-9 Personal Protective Equipment Handbook

FAA Doc: 14CFR references: 23.1301, 23.1441, 25.1301, 25.1441

**9.5.3** Where the life support system must interface with other air vehicle subsystems, verify that the operation of the life support system is not degraded by, and does not degrade, the normal or failure modes of operation of those subsystems (for example, controls and displays, escape systems, communication, environmental management system (EMS)).

Standard: The life support system is designed such that total aircraft performance and capability are not compromised and hazards are minimized. Interface with aircraft occupants allows crew members and passengers to properly use the life support equipment and successfully perform other essential flight duties and operations. Design limits are specified for the life support subsystem where there is interface with other aircraft subsystems so that proper equipment may be selected and accountability is provided should adjustments to these limits be required. No operational mode of the life support system degrades other aircraft systems sufficiently to cause an unsafe condition. No normal or emergency operational mode for aircraft subsystems causes a life support system failure or condition that can injure occupants, fail to meet physiological needs, or prevent sustained flight.

Compliance: The life support system's interface with other air vehicle subsystems is verified to ensure that the operation of any of the systems interfacing with the life support system does not result in the degradation of the system involved. Verification includes inspection of the hardware components, demonstrations using mock-ups and simulations, on-aircraft system check-outs, and/or flight tests. Analysis is used to verify specific aspects of the system where other methods of verification are not appropriate or possible. A Failure Modes Effects and Criticality Analysis (FMECA) also identifies potential failure mode causes, to include those that could be induced by life support system or subsystem operations.

DoD/MIL Doc: JSSG-2010: para 3.6, 4.6, 3.9, 4.9, 3.10, 4.10, 3.13, 4.13;

JSSG-2010-9 Personal Protective Equipment Handbook

FAA Doc: 14CFR references: 23.1301, 23.1441, 25.1301, 25.1441

**9.5.4** Verify that emergency oxygen is available for all occupants of the air vehicle.

Standard: The emergency oxygen system(s) provides a supply of breathing gas to all crewmember and passengers in the event of an emergency where the flow of oxygen from the primary system is interrupted or stopped. It is desirable for the system to activate automatically and alert the crewmember that it is activated. The duration of the supply is maximized to the greatest extent possible, and as a minimum, supplies enough oxygen to allow the crew and

to safely descend from the aircraft's maximum altitude to below 10,000 feet MSL.

Compliance: Emergency oxygen system capabilities is verified by inspection of drawings, demonstrations in mockups, and analysis of test data from system qualification tests. Emergency oxygen system operation to maximum aircraft altitude is verified by analysis of data from the oxygen system qualification program, including altitude chamber man rating tests.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2, JSSG-2010: 3.7, 4.7, 3.13, 4.13

FAA Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**9.5.4.1** Verify sufficient emergency oxygen is available during high altitude escape.

Standard: A sufficient emergency oxygen supply to each crewmember is available for use during high altitude escape. This system is an integral part of the ejection seat or part of the parachute system. Emergency oxygen flow is automatically initiated and supplied to crewmembers at ejection. The duration of the supply is maximized to the greatest extent possible, but as a minimum, supplies enough oxygen to allow the crew to safely descend from the maximum altitude within the escape system envelope.

Compliance: Oxygen requirements are verified by system man rating consisting of initial simulated human exposures to operational environments, followed by human testing in mockups and simulators (including altitude chamber testing) to ensure that physiological needs are met. Emergency ejection actuation and supply are verified by sled tests.

**9.5.5** Verify that each life raft has obviously marked operating instructions. Ensure that approved survival equipment is marked for identification and method of operation and that emergency flotation and signaling equipment is installed so that it is readily available to the crew and passengers.

Standard: For air vehicles with extended overwater operations, life rafts of a rated capacity and buoyancy to accommodate the occupants of the airplane are available. The buoyancy and seating capacity of the rafts accommodate all the occupants of the airplane in the event of a loss of one raft with the largest rated capacity (unless excess rafts of enough capacity are provided). At least one pyrotechnic signaling device is included with each life raft. Each life raft has obviously marked operating instructions. Approved survival equipment is marked for identification and method of operation. Stowage provisions for the required survival equipment is conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Compliance: Verification testing is accomplished from the standpoint of the overall system performance and installation. It consists of inspections, analyses, demonstrations, and tests of normal and emergency operations for all intended air vehicle occupants. The existence of markings and instructions are verified by air vehicle and article inspections. Floatation accessibility is verified by mockup demonstrations and functional tests of floatation deployment and inflation systems.

DoD/MIL Doc: JSSG-2010-9: para 3.11.7.3

FAA Doc: 14CFR references: 25.1561, 23.1561, 23.1415, 121.339

**9.5.6** Verify that each life raft to be released automatically or by a crewmember is attached to keep it in place alongside the air vehicle until the raft is afloat on water. Verify that this attachment is sufficiently weak to break away from the air vehicle before submerging the fully occupied life raft to which it is attached.

Standard: Each life raft capable of release is attached to the airplane by a line that will keep it alongside the airplane. The line holds the raft near the aircraft but releases if the airplane becomes totally submerged, and cannot submerge a fully occupied raft.

Compliance: Manual and automatic life raft deployment selection is verified by demonstration in a cockpit mockup, inspection of drawings, or by similarity with legacy systems. Verification of the

physical characteristics of the aircraft flotation system is verified by a combination of analyses, inspections, demonstrations, and tests, as necessary, to ensure all specified requirements have been met. Attachment line release is verified by floatation system and lanyard load tests.

FAA Doc: 14CFR references: 25.1561, 23.1561, 23.1415, TSO C70a

## 9.6 Transparency integration.

This element provides the crewmember with exterior vision capability in accordance with system requirements. It may consist of a remote camera system, a flat transparency window, a windscreen, and/or a canopy system. It also may include the transparency/canopy frame, canopy actuator, canopy latch/locking system, etc.

**9.6.1** Verify that canopies and associated support structure, as well as the actuation, latching, and locking mechanisms, are compatible with the air vehicle escape system to permit safe egress and escape in the event of an emergency.

Standard: The transparency system mates with the escape system in a fashion that does not degrade the capabilities of either system or impose a hazardous situation for the crew member or maintenance person.

At least, the following interface areas have been considered and addressed, as applicable:

A. Canopy thrusters, removers, or rockets.

B. Explosive assemblies (shielded mild detonating cord, flexible linear shaped charge assemblies, etc.).

C. Energy transmission (electrical connections, tubing, etc.).

D. Canopy lanyards.

E. Aerodynamic decelerators.

F. Ejection through the canopy.

G. Canopy breakers.

H. Canopy/seat clearance and canopy/helmet clearance.

I. Jettisoned canopy trajectory (external path clearance with aircraft and seat hardware/crew member).

J. Canopy/seat sequencing.

K. Seat adjustment range.

L. Ejection clearance envelope.

M. Ingress/egress (normal and emergency).

N. Pitot clearance with transparency.

O. Canopy seals (remain intact during jettison).

P. Canopy locking mechanism.

Q. Noise.

R. Power rescue saw.

S. Training hoods/vision restriction device.

Compliance: Transparency system compatibility is verified by a combination of flight tests, computer modeling, inspections of engineering drawings, demonstrations, and qualification tests (including sled tests) to allow the integration aspects of an escape system to be evaluated from an engineering standpoint, an operational standpoint, and a human factors standpoint.

Seat adjustment range and ejection clearance envelope are verified by inspection of engineering drawings and demonstrations using full scale functional mockups or simulators. Other escape system interface requirements are verified by analysis, inspection of documentation, and qualification test programs, as applicable.

Comm'l Doc: For a new transparency in an existing aircraft, it is recommended that reference be made to the existing aircraft specifications.

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14;

JSSG-2010-11

MIL-STD-1474.

FAA Doc: 14CFR references: 23.775, 25.775

**9.6.2** Verify that the transparency system meets survivability requirements for bird-strike impact.

Standard: 1. The transparency and all supporting structure withstands, without penetration, the impact of a four-pound bird over the maximum operational true airspeed which can be achieved at altitudes up to 8000 feet and at the most adverse temperatures.

2. Impact at the specified airspeed and bird weight does not result in deflections or material failures sufficient to cause incapacitating crewmember injury or loss of the air vehicle.

Compliance: 1. Structural analysis verifies that maximum stresses due to a bird strike are below material allowables.

2. Full scale bird strike tests at worst case impact locations verify no transparency or backup structural failure is sufficient to cause loss of the air vehicle or crew member incapacitation.

Comm'l Doc: ASTM F330, Bird Impact Testing of Aerospace Transparent Enclosures,

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14

FAA Doc: 14CFR references: 23.775, 25.775

**9.6.3** Verify that the structural/thermal capability of the transparency system is adequate for all loads and flight conditions.

Standard: Transparency system does not fail when exposed to maximum thermal and structural load stresses that may be experienced in operational conditions.

Compliance: Structural analysis verifies stresses within material allowables. Coupon or full scale transparency tests verify thermal and flight load capabilities.

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14

FAA Doc: 14CFR references: 23.775, 25.775

**9.6.4** Verify that the transparency system shape is compatible, and does not interfere, with crewmember and equipment positions and motions used during normal and emergency conditions.

Standard: The transparency system is shaped so as to minimize contact with crew member equipment and systems used in the cockpit during design missions and normal and emergency crew member positions and movements.

Crew member equipment considered includes helmets, visors, anti-drown devices, breathing system components, chemical defense equipment, flash blindness protection, night vision systems, helmet mounted displays, head or helmet position tracking systems, vision restriction devices, helmet mounted sights, etc., and combinations of this equipment as required by the system's design missions.

Crew member motions considered includes normal and emergency ingress and egress, check-six, landing, use of specialized cockpit equipment, transferring equipment from one crew member to another, inertial reactions to accelerations, etc.

Compliance: Verification is performed as a demonstration. However, testing is performed to evaluate the extent of any scratching or crazing, or the activities or positions that may cause contact. Analysis or inspection is used to provide preliminary estimates of the potential for problems with crew systems contact, but is not the sole basis for evaluating this integration. Verification addresses each item of crew member equipment and each anticipated crew member activity to ensure adequate integration with the transparency system.

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14

FAA Doc: 14CFR references: 23.775, 25.775

**9.6.5** Verify that the optical characteristics of the transparencies (windshield, canopy, windows, as applicable), including transmissivity, angular deviation, optical distortion, haze, multiple imaging, binocular disparity, birefringence, and minor optical defects are compatible with the safety-critical optical systems used by the aircrew and provide a safe optical environment to the pilot.

Standard: 1. Transparency system optical characteristics do not cause distortion, obscurity, reflections, or low level light transmittance sufficient to render flight critical sensors or systems ineffective. Critical optical zones for transparencies meet the following limits: haze less than 10%; angular deviation less than 3.0 mrads in azimuth and 2.0 mrads in elevation; distortion as measured by grid line slope ratios less than a range of 1:12 to 1:9; binocular disparity less than 2.0 mrad in azimuth and 3.0 mrad in elevation; binocular magnification disparity less than 2%.

2. Transparency system optical characteristics allow the pilot to maintain sufficient visibility under all operational lighting conditions (including ANVIS lighting) to maintain vehicle control and safe flight.

3. Transparency system optical characteristics do not contribute to pilot loss of situational awareness, susceptibility to pilot errors, or an inability to make flight critical decisions that could result in loss of the air vehicle.

Compliance: 1. Transparency system optical characteristics are verified by optical test of coupon samples and representative first articles.

2. System level optical train tests verify compatibility of all optical elements, with sufficient light transmittance and characteristics to meet flight critical sensors or systems requirements. Lighting mockup evaluations, flight simulations, and flight testing verify pilot visibility sufficient to maintain vehicle control and perform critical tasks for sustained flight, such as aerial refueling. ANVIS lighting demonstrations verify compatibility of lighting.

3. Human factors engineering tests using system mockups, flight simulators, and flight test vehicles/control stations demonstrate adequate situational awareness is maintained, and pilot/controller can make flight critical decisions.

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14;

JSSG-2010-14: para 3.1.4.1, for additional transparency optical characteristics and recommended values

FAA Doc: 14CFR references: 23.775, 25.775

**9.6.6** Verify that necessary deployment power is available under normal and emergency conditions and that there is no interference with manual actuation of the canopy when air vehicle or external power is not available.

Standard: An alternate or secondary power source is provided that will operate the canopy. A manual system is provided for ingress and egress with all aircraft power off and for canopy operation

when primary actuation system is not available. An external means is provided to enable a ground rescue crew to manually open the canopy.

Compliance: Deployment power availability and manual capabilities are verified through system demonstrations, subsystem testing, and vehicle functional tests.

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14

FAA Doc: 14CFR references: 23.775, 25.775

**9.6.7** Verify that provisions for rain removal, deicing and defogging, and snow and ice removal are adequate for pilot external vision and that these provisions do not cause temporary or permanent optical degradation of the transparencies.

Standard: 1. Provisions are incorporated to sufficiently remove rain, snow, ice, and fog from transparencies, within the operational limits of the air vehicle, such that adequate visibility and sensor operation is maintained to enable the pilot/controller or air crew to obtain necessary information and situational awareness to sustain flight; avoid obstacles; make flight critical decisions; and land the air vehicle.

2. The subsystems used to remove rain, snow, ice, or fog do not expose transparencies to temperatures, fluids or other conditions that obstruct operator vision or degrade sensor operation to the extent that the conditions listed above cannot be accomplished.

Compliance: 1. System tests in simulated flight conditions verify the capability of removing fog, ice, snow, or rain from the transparency. Testing is accomplished in an environmental chamber that simulates potential operational conditions. Air Vehicle flight tests verify the system capabilities under actual flight conditions.

2. Material and transparency coupon tests with exposure to rain, snow, ice, or fog removal systems verify the capability to maintain adequate light transmittance and optical qualities.

DoD/MIL Doc: JSSG-2010-14: para 3.14, 4.14

FAA Doc: 14CFR references: 23.775, 25.775

## 9.7 Crash survivability.

This element provides the pilot, crew, and passengers with protection/procedures in the event of a crash scenario. It covers crash rescue procedures, fire protection, equipment containment, smoke protection, emergency lighting and seating.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563

**9.7.1** Verify that seating system load capabilities are commensurate with the air vehicle type for aircrew and passengers and that the design of the floor and load paths to the seat attachments is capable of sustaining the loads of the seat system in applicable crash load conditions.

Standard: The seating and restraint system has been designed to a hold in place an occupant for design static and dynamic loading. The seating and restraint system including structural attachment to the aircraft withstands static loads defined in SAE AS8049 table 4, and dynamic load defined in section 5.3 with a maximum weight occupant (250 lbs unless otherwise specified). For military ejection seat equipped fighter type aircraft, the dynamic forward g load capability is 40 g's. The loading directions are specific to airframe type and orientation of the seat.

Compliance: Analysis and test documentation show that the seat and restraint system with associated aircraft structure meet the standard with the seated occupant. Static and dynamic load capabilities are verified by testing defined in SAE AS8049 sections 5.1 and 5.3.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563

**9.7.2** Verify that the stroke clearance envelope for energy absorbing seats is clear of structures and equipment that could impede seat stroke.

Standard: Stroke volume for both the functioning of the seat and the occupant is provided in the aircraft installation for the impact velocity environment specified for the aircraft.

Compliance: Stroke clearance envelope is verified by dynamic seat tests, analysis and documentation inspection, indicating the occupied stroke volume for the design impact velocity of the aircraft and that volume exists and is unobstructed in the aircraft design.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

FAA Doc: Refer to technical point of contact for this discipline (listed in section A.2).

**9.7.3** Verify that restraint systems are designed to restrain the occupant properly for the escape system environment and the crash loading of the seat.

Standard: The occupant is kept in position with respect to support of the seating system under both inertial and applied loads (such as aerodynamic pressure). The restraint system prevents "submarining" or translation of the pelvis under the lap belt. The shoulders are restrained to align the thoracic and lumbar spine with primary ejection seat catapult loads and vertical crash loads. Torso restraint holds occupant under aerodynamic and parachute opening shock loads. Leg restraints prevent the major injuries due to adduction of the femur. Restraint systems in forward facing seats limit dynamic overshoot of reaction loads into the seating structure during required crash loads.

Compliance: Analysis and test documentation show that the restraint system properly restrains the occupant. Dynamic crash load tests verify restraint integrity and body restraint. Ejection sled tests and parachute jump tests verify escape system restraint capability.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2;

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563

**9.7.4** Verify that the strike envelope of the occupant during crash loads are kept free of objects that are risks to survival or may cause serious injury that renders the crewmember unable to perform post-crash egress functions.

Standard: There are no objects in the crew station that would cause major injury within the throw distance of restrained occupants during design crash loads. Torso and head motion do not contact surfaces, edges, corners, or structures/equipment with sufficient velocity to cause injury.

Compliance: Analysis and test documentation shows that occupant body translation is determined for design crash loads and that no objects in the crew station that would cause major injury are within that translation volume. Analytical models of human body motion under crash load conditions verify that no strike hazards exist.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563

**9.7.5** Verify that the exits are post-crash operational up to the design crash loads.

Standard: Aircraft exits designated for ground egress by aircraft occupants will function after exposure

to the design crash loads of the aircraft platform. Function is defined by the exit opening.

Compliance: Mechanical and structural analysis, test, and demonstration shows that the exit functions up to design crash loads.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563

**9.7.6** Verify that, under emergency landings, ditching, and crash loads, items of mass do not cause serious injury to occupants or prevent escape.

Standard: Ultimate loads for structural installations are considered for normal and emergency operations/conditions. Installed equipment in passenger compartments is provided with a restraining means to protect passengers during an emergency landing. Items of mass located in a manner that could result in injury to personnel or prevent egress are analyzed and designed to withstand loading in all potential directions without failure. Installation/mounting provisions shock load mounts or restraints are sufficient to prevent injury to personnel under the following crash load conditions; Longitudinal 9.0 forward, 1.5 aft; Lateral 1.5 right and left; Vertical 4.5 down, 2.0 up

Compliance: Documentation exists of analyses and/or testing of aircraft component installations for static and dynamic reactions using the aircraft system level crash condition requirements. Analysis and test verify that items of high mass are properly restrained and do not cause a hazard to aircrew.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

JSSG-2010-7: para 3.7.3.7.3, 3.7.3.2.3

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563, 25.787, 25.789, 23.787, 25.801, 25.1411, 25.1421

**9.7.7** Verify that the air vehicle is equipped with breathing and eye protection equipment, fire fighting equipment, and fire extinguishers appropriate for the expected use.

Standard: If required, the air vehicle is equipped with breathing and eye protection equipment to protect the crew from the effects of smoke, carbon dioxide or other harmful gases, or an oxygen deficient environment. Crewmembers are protected from these effects while combating fires on board the aircraft. If required, fire extinguishers and other fire fighting equipment must be conveniently located and readily accessible by the crew.

Compliance: Inspection of crew equipment provisions and the air vehicle configuration verifies availability and accessibility of fire protection equipment. Verification is accomplished from the standpoint of the overall mission accomplishment and consists of inspections, analyses, and demonstrations of normal and emergency operations for all intended air vehicle occupants.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

JSSG 2010-9: para 3.9.3

FAA Doc: 14CFR references: 25.851

**9.7.8** Verify that ditching provisions, including flotation devices for all occupants, are installed on all air vehicles without assisted escape systems.

Standard: For aircraft with overwater missions, ditching provisions are installed on all air vehicles without assisted escape systems. This would include one life preserver for each occupant. For extended overwater operations, an aircraft has enough life rafts of a rated capacity and

buoyancy to accommodate the occupants of the airplane. Unless excess rafts of enough capacity are provided, the buoyancy and seating capacity of the rafts must accommodate all the occupants of the airplane in the event of a loss of one of the largest rated capacity. Approved survival equipment is attached to each life raft. There is an approved survival type emergency locator transmitter for use in at least one life raft.

Compliance: Verification is accomplished from the standpoint of the overall system performance and installation. It consists of inspections, analyses, demonstrations, and tests of normal and emergency operations for all intended air vehicle occupants. Inspection of the vehicle configuration verifies availability of flotation devices. Device floatation and buoyancy characteristics are verified by tests in ocean or fresh water environments.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

FAA Doc: 14CFR references: 23.561, 23.562, 25.561, 25.562, 25.563

**9.7.9** Verify that pre-crash warning between aircrew and all compartments is possible without aircrew or occupants leaving their seating position.

Standard: For troop and passenger carrying aircraft, the system provides a warning method or system that enables pilots, in the event of potential or impending mishap, to quickly and clearly convey a crash warning to aircraft occupants so that they can prepare for impact.

Pre-crash warning displays are unambiguous and redundant (visual and auditory, for example).

Pre-crash warnings do not cause confusion or induce panic.

When visual and auditory displays are used in conjunction with each other, the auditory warning devices supplement or support the visual displays (MIL-STD-1800).

Pre-crash warning shall be intelligible at all passenger seats, lavatories, and crew seats and work stations.

Means of activating the warning shall be accessible for immediate use from each crew station in the pilot compartment.

Compliance: Pre-Crash warning systems are verified by inspection of drawings and passenger emergency egress demonstration tests. System functional tests verify the ability to activate the warning system from seated positions, and the ability to convey a warning indication to all crew and passengers.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.2

JSSG-2010: para 3.7, 4.7, 3.13, 4.13

**9.7.10** Verify that, for rotary wing air vehicles, occupiable volume reduction resulting from design crash loads provides reasonable protection against occupant injury.

Standard: When subjected to the design crash loads parameters, the rotary wing airframe provides containment of the occupants with no more than 15% reduction in volume and the prevention of intrusion into the occupant strike zone of injurious structures or objects. The mounting of engines, transmissions, fuel cells, rotor masts, and other high mass objects are designed to prevent their displacement in a manner that would be hazardous to the occupant volume. The transmission and rotor hub does not displace in a manner hazardous to the occupant volume during the following impact conditions: rollover about the aircraft's pitch or roll axes, main rotor obstacle strike that occurs within the outer 10% of the blade span assuming the obstacle is an 8 inch cylinder, ultimate load factors for high mass items around the occupant volume commensurate with the crash parameters of the airframe.

Compliance: Structural test and analysis, and crash load tests verify that the design meets occupant volume requirements.

DoD/MIL Doc: JSSG-2001: para 3.3.10.2.1, 4.3.10.2.1

JSSG-2010-7: para 3.7.3.2.1

FAA Doc: 14CFR reference: 27.562

**9.7.11** Verify that mechanisms used for emergency crew extraction and for firefighting are properly marked and can be operated while wearing personal protective equipment.

Standard: When provided, crew extraction devices and fire fighting equipment are conspicuously marked and identifiable in normal and emergency lighting conditions. Aircrew training incorporates methods of operation and/or methods are marked on or near the device. Limits and restrictions for use as well as safety devices (such as those used for handheld fire extinguishers ) are clearly marked. Devices can be unstowed or deployed while wearing personal and emergency flight equipment appropriate to the aircraft. Devices can be used and effective while being used by aircrew in personal and emergency flight equipment appropriate to the aircraft. Emergency controls and actuation mechanisms for fire fighting or extraction can be accessed and utilized with protective gloves.

Compliance: Emergency egress and rescue demonstrations verify the ability to operate required mechanisms. Inspection, demonstration and human factors analysis documentation verify existence of markings and the ability of rescue personnel and aircrew to operate devices.

DoD/MIL Doc: MIL-STD-1472: para 5.5, 5.6;

JSSG-2001: para 3.4.3, 4.4.3

JSSG-2010-9: para 3.9.5, 4.9.5

JSSG-2010-13: para 3.13.6, 4.13.16

FAA Doc: 14CFR reference 25.811

## 9.8 Air transportability and airdrop.

This element addresses technical requirements in the area of aerial delivery of cargo and personnel with regard to safety of the air vehicle. It may cover cargo restraint, tiedowns, external load equipment, transport of hazardous materials, handling/loading of either problem or unique cargo, and airdrop of cargo and personnel.

Standard: Definition: Air transportability and airdrop are aircraft capabilities that enable an aircraft to perform cargo transport as a prime mission. These capabilities involve primary and secondary aircraft structure, size and shape of the cargo carrying compartment, and aircraft interactions with the cargo mass and weight, especially if cargo is airdropped during flight.

**9.8.1** Verify that the air vehicle structure can support all loads (internal or external, as applicable) imposed by the transported items during operational usage.

Standard: The Operational Concept identifies applicable transported items (cargo, baggage, stowed equipment, etc) and dictates range of structural requirements. Structural interfaces are calculated from worst case loading/flight conditions with the cargo floor and related systems. The aircraft's allowable structural limits for ground and flight operations exceed the identified cargo loads by a margin acceptable to the Program Office.

Compliance: Analysis and structural testing of subsystems (coupon tests) or complete structures is performed. Structural testing verifies analytical results such that an acceptable margin of safety is attained for the design condition.

DoD/MIL Doc: JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6

**9.8.2** Verify that clearance exists for aircrew and passengers during flight-critical and emergency functions.

Standard: Dimensional data is compared on largest cargo items and internal aircraft dimensions. Cargo is considered in worst possible position as allowed by aircraft structure and weight & balance limits. Compared clearances meet or exceed accepted anthropometric requirements for passageways.

Compliance: Acceptable clearance exists for aircrew access during flight of all required cargo items. Acceptable clearance exists for passenger egress on flights required to carry passengers. (Note that passenger egress clearances are different than aircrew access clearances.)

DoD/MIL Doc: JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6;

MIL-HDBK-1791 illustrates the minimum acceptable aircrew access clearances for C-130 aircraft.

AFI 11-2C-130 Vol 3, addenda A, defines C-130 passenger safety aisle requirements.

MIL-STD-1472 defines anthropometric data.

**9.8.3** Verify that cargo-loading manuals include shear, bending, crushing, or puncture load limits such that the cargo does not impart excessive loads into the air vehicle structure during any phase of the loading process.

Standard: Individual cargo items are accepted for flight based on measurable data such as wheel loads, overall weight, or load density. Cargo loading manuals define the overall parameters needed to approve cargo for structural interface with the aircraft. Cargo loading manuals consider and define all dimensional or load bearing limits that would damage the aircraft if exceeded by one or more individual cargo items. As backed by structural test reports and analyses, cargo loading limits are included in tabular or graphical form in the aircraft's cargo loading manual (AF TO 1C-XX-9, Army Operator Manual-10, Army Maintenance Manual -23 App G, etc.) Manuals list limits in generic terms of max compartment loads, axle loads, puncture loads, etc in lieu of specific cargo item identification.

Compliance: Existence of required information is verified by inspection of cargo loading manuals and supporting structural test or analysis data.

DoD/MIL Doc: TO 1C-XX-9, the aircraft loading manuals include cargo loading limits in the desired formats.

JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6

**9.8.3.1** Verify cargo hook and backup structural load limits and verify that limits are included in applicable operators and maintenance manuals.

Standard: Cargo floor tiedown rings and backup structure have strength levels equal to or in excess of the tiedown devices, and are capable of withstanding specified loads. Unless otherwise specified, tiedown devices have an ultimate strength capability 1.5 times the rated or working load capacity. Individual tiedown rings that can be used by more than one tiedown device and can be subject to forces in more than one direction within the hemisphere above the floor plane can withstand total applied loads. Limitations on the use of tiedown rings are spelled out in the operator manuals. Repair of tiedown rings is included in the maintenance manuals.

Compliance: Through analysis and coupon testing, the tiedown ring, pan assembly, and backup structure into the main parts of the floor are verified to withstand pulling forces greater than the rated capacities of the tiedown devices specified for use with that ring. Ring assemblies are tested in vertical up, lateral, and longitudinal directions plus other directions as dictated by the analysis.

**9.8.4** Verify that the positioned cargo meets required flight weight and balance requirements.

Standard: Overall weight and CG location of cargo item(s) is compatible with aircraft weight & balance limits. Repositioning is considered for cargo that can be moved within the confines of the compartment. Fuselage station loading locations are specified if required to satisfy CG and structural limits.

Compliance: Cargo weight data and analysis is inspected to verify that it is within allowable limits for the possible CG locations.

DoD/MIL Doc: TO 1C-XX-1, TO 1C-XX-9, TO 1C-xx-5 contain approximate permissible cargo center of gravity graphs (chimney curves) for mission equipped aircraft.

JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6

**9.8.5** With the exception of items designated for airdrop, verify that the loaded item will not change the air vehicle C.G. position during flight.

Standard: For flight, loaded cargo items are secured against movement in all six degrees of freedom. Restraint criteria exceeds cargo weight by a dynamic factor. Procedures and restrictions exist such that all restraints are applied before the aircraft begins ground movement and removal of the restraints are not accomplished until after the aircraft parks, except in the case of combat offload operations. Combat offload is permitted only with palletized loads, through release of the aft restraints while the aircraft is slowly rolling on the ground. Combat offload does not cause the aircraft to lose ground steering authority. A necessary quantity of straps/chains is applied to vehicular items or by having general cargo netted to pallets which are in turn locked into the aircraft restraint rail system to maintain C.G. positions.

Compliance: The ability to maintain C.G. of items in flight is verified by structural analysis and test of restraining devices, and by measurement and analysis of loaded item mass properties, including all subassemblies and components capable of position change that can affect C.G. location.

DoD/MIL Doc: JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6;

MIL-HDBK-1791, restraint criteria for transported cargo.

MIL-A-8865B, restraint criteria for transported cargo.

**9.8.6** Verify that restraints afford sufficient capacity and are provided in sufficient quantity to restrain the transported items safely .

Standard: The quantity and capacity of tiedown devices on board is sufficient to restrain the entire payload capacity of the aircraft to the specified level of force in the forward, aft, lateral and vertical up directions. Restraint devices are of an approved type and are stowed throughout the aircraft when not in use.

Compliance: Through analysis and demonstration, the quantity of tiedown devices is shown to be sufficient to restrain various mass quantities of cargo items. The strength level of the tiedowns is of a standard or otherwise approved value.

DoD/MIL Doc: JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6;

MIL-T-25959, standard restraint devices

MIL-PRF-27260, standard restraint devices

**9.8.7** Verify that all operator and maintenance manuals (T.O.'s) are accurate and provide cargo preparation, handling, carriage, and delivery procedures necessary for safe ground and flight operations.

Standard: Aircraft Technical Orders, Operator's Manuals, Maintenance Manuals, Field Manuals, etc., provide a level of instruction that permits ground crew and air crew members to prepare and load cargo without damage to the aircraft and without confusion on part of the reader. Procedures are accurate and consistent with handling, carriage, and delivery capabilities.

Compliance: Demonstration with draft copies of the operator, maintenance and loading manuals is successfully used by properly trained crewmembers to perform necessary functions.

DoD/MIL Doc: JSSG-2000: para 3.1.7.2

JSSG-2001: para 3.4.5, 3.4.6

**9.8.8** Verify that cargo compartment dimensions allow enough room to load, transport, and/or airdrop required items safely.

Standard: The cargo compartment loading envelope provides a minimum of six inches clearance around the outside of the largest defined cargo item. Cargo entrance geometry permits loading cargo with an underbelly clearance of at least one inch. Aircrew access and passenger escape envelopes are outside the cargo compartment loading envelope.

Compliance: Selected cargo loading demonstrations and analysis of loaded cargo via drawings indicates the clearance envelope is maintained throughout the loading and flight activities.

DoD/MIL Doc: MIL-HDBK-1791: para 4.2, 5.2

JSSG-2009: Appendix J

**9.8.9** Verify that air vehicle flight performance/control is not hazardously affected by movements in C.G. of airdrop loads or by load and C.G. movement experienced during external load operations.

Standard: Flight control and flight safety performance are maintained during airdrop of the designated payload weight at the required airspeeds. Air vehicle can ground load the specified payload weight without adverse movement of the airframe. Stability struts for ground loading are permitted to satisfy this requirement.

Compliance: Flight control and performance analysis is conducted to verify safety of dynamic airdrop conditions. As predicted by dynamic analysis, airdrop testing with mass weights verifies aircraft has sufficient stability margins to maintain stable level flight during exit of heaviest payloads. Loading demonstrations verify that aircraft has sufficient stability in ground mode to present a stable platform for loading operations.

DoD/MIL Doc: MIL-HDBK-1791: para 4.2, 5.2

JSSG-2009: Appendix J

**9.8.10** Verify that air vehicle personnel airdrop systems can withstand the loads imposed by personnel during airdrop and possible malfunctions of personnel airdrop equipment.

Standard: Air vehicle subsystem components and supporting structure such as anchor cables, jump platforms, air deflectors, seating, floor structure, retrieval winches, retrieval cables, etc are designed to withstand load stresses imposed by airdrop and retrieval of the specified numbers and weights of paratroopers. Airdrop retrieval components are designed to retrieve a hung jumper (weighing a minimum of 400 lbs if not otherwise specified) when operated by the minimum crew size required by the operational concept.

Compliance: Analysis of structural loads verified with instrumented results from flight testing demonstrate the aircraft structure and subsystems are not adversely affected by personnel airdrop operations and retrieval under a worst case scenario.

DoD/MIL Doc: MIL-HDBK-1791: para 4.2, 5.2

JSSG-2009: Appendix J

**9.8.11** Verify that the air vehicle provides the capability to safely recover a towed jumper.

Standard: The air vehicle has a capability to retrieve a hung paratrooper without injury using onboard equipment operated by the available aircrew. Onboard equipment is readily available to permit this operation without extensive delay.

Compliance: Flight testing results demonstrate the capability exists for a single aircrew member (unless otherwise specified) to readily retrieve a maximum weight towed dummy using the onboard equipment. Flight testing results encompass a range of dummy weights to verify no adverse airflow effects during retrieval into the aircraft doorway.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2)

**9.8.12** Verify that, for personnel airdrop, acceptable risk levels exist to avoid paratrooper collision, adverse vortex interaction, and adverse multi-ship formation effects induced by the air vehicles.

Standard: The air vehicle provides an airdrop capability for specified numbers of paratroops to deliver them within defined drop zone regions both in single ship and mass formations. The risks of personnel injuries attributed to aircraft effects is at a level acceptable by the user.

Compliance: Extensive testing, modeling, and analyses demonstrate that aircraft induced effects on streams of jumpers presents no increase in risk beyond that acceptable to the user. Multi-ship drop formations are determined to minimize interactions to an acceptable level of risks.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2)

**9.8.13** Verify for airdrop or jettisonable cargo, that the loaded items can be safely jettisoned during flight.

Standard: Airdrop or jettisonable cargo within specified parameters, does not impact or damage the air vehicle, or cause injury risk to the crew.

Compliance: The capability to airdrop the specified types and sizes of cargo is defined and substantiated through flight testing. The ability to jettison certain items of palletized cargo is demonstrated and documented. Extensive flight testing defines the range of hardware items and the required parameters necessary to perform preplanned airdrop and unplanned jettisoning of cargo loads. Range of testing includes maximum and minimum weights, locations, airspeeds, and other limitations as needed for technical input into the operational manuals.

DoD/MIL Doc: MIL-HDBK-1791: para 4.2, 5.2

JSSG-2009: Appendix J

**9.8.14** Verify that necessary in-flight movement or operation of transported items and mission equipment does not adversely affect aircraft flight systems or cause injury to aircrew and passengers.

Standard: Movement or operation of non-fixed equipment or transported items during flight will not cause the aircraft to exceed limits for stability and control nor impose a risk to personnel within the aircraft. Items that may be moved in flight do not create a hazardous environment, or fail in a fashion that causes flight or injury risks when dropped.

Compliance: Analysis and testing verifies that operation or movement of equipment does not put the aircraft out of established balance limits if relocated or used anywhere within operational possibilities. Transported equipment that could impose risks to personnel in a dynamic situation is only moved in a system that affords control of the object at all times. Items with components or materials that could pose a hazard are drop tested to verify safety of possible post drop configurations and any release of hazardous materials.

DoD/MIL Doc: MIL-HDBK-1791: para 4.2, 5.2,
JSSG-2009: Appendix J

## 9.9 Lavatories, galleys, and areas not continuously occupied.

This element addresses air vehicle compartments, and areas that may be accessible to crew, passengers or maintainers, but that may not be occupied at all times during flight.

Standard: Definition: The aircraft may require facilities for storage, preparation, and consumption of sustenance for the crew members and passengers consistent with the described missions. According to aircraft type and missions, the aircraft may provide for the collection, storage, and handling of human waste, medical waste, and general refuse in accordance with accepted sanitary practices and as required by the mission.

**9.9.1** Verify that food service carts, refuse carts, and waste containers used to receive any combustible materials contain a fire ignited within.

Standard: The sustenance and waste management components and plumbing is installed to minimize fire hazards. The sustenance and waste management system is installed on the aircraft such that the operational envelope of the components does not violate the operational envelopes of any other aircraft subsystem, and the cabling, wiring, and plumbing routing between aircraft subsystems. Refuse containers include self-closing covers and prevent the spread of wastepaper fires beyond the container interior. All systems are designed to limit the spread of any fire.

Designated fire containment areas (such as identified in SAE AS 1426) are constructed of fire resistant material; openings for ventilation, entry, or other use is minimized; either self-closing openings or placards are employed to advise that the opening must be kept closed when not in use; and use of wiring, hoses, or other equipment within that space is minimized.

Compliance: The adequacy of the refuse containers' placement and operation is verified by inspections. The ability of the dry waste containers to prevent the spread of wastepaper fires beyond the container interior is analyzed and tested. The ability of the disposal receptacle to contain those fires under all probable conditions of wear, misalignment, and ventilation expected in service is demonstrated by test.

**9.9.2** Verify that all compartments have separate and approved smoke and/or fire detectors to alert the crew at the pilot or flight engineer station for both in-flight and ground operations; that each compartment has dedicated hand fire extinguishers; and that if unoccupied cargo holds are present, fire protection and fire detection/suppression requirements are met.

Standard: a. Hand fire extinguishers

(1) The following minimum number of hand fire extinguishers are conveniently located and evenly distributed in passenger compartments:

| Passenger capacity | No. of extinguishers |
|---|---|
| 7 through 30 | 1 |
| 31 through 60 | 2 |
| 61 through 200 | 3 |
| 201 through 300 | 4 |
| 301 through 400 | 5 |
| 401 through 500 | 6 |
| 501 through 600 | 7 |

| | |
|---|---|
| 601 through 700 | 8 |

(2) At least one hand fire extinguisher is conveniently located in the pilot compartment.

(3) At least one readily accessible hand fire extinguisher is available for use in each baggage compartment that is accessible to crewmembers in flight.

(4) At least one hand fire extinguisher is located in, or readily accessible for use in, each galley.

(5) Each hand fire extinguisher is approved.

b. Built-in fire extinguishers. If a built-in fire extinguisher is provided—

(1) Each built-in fire extinguishing system must be installed so that;

(i) No extinguishing agent likely to enter personnel compartments will be hazardous to the occupants; and

(ii) No discharge of the extinguisher can cause structural damage.

(2) The capacity of each required built-in fire extinguishing system is adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilation rate.

c. Lavatory fire protection.

(1) Each lavatory is equipped with a smoke detector system or equivalent that provides a warning light in the cockpit, or provides a warning light or audible warning to the crew.

(2) Each lavatory is equipped with a built-in fire extinguisher for each disposal receptacle for towels, paper, or waste, located within the lavatory. The extinguisher is designed to discharge automatically into each disposal receptacle upon occurrence of a fire in that receptacle.

d. Cargo or baggage compartment smoke or fire detection systems.

(1) The detection system provides a visual indication to the flight crew within one minute after the start of a fire.

(2) The system is capable of detecting a fire at a temperature significantly below that at which the structural integrity of the airplane is substantially decreased.

(3) There are means to allow the crew to check in flight, the functioning of each fire detector circuit.

Compliance: Aircraft and engineering drawing inspections verify that smoke detectors, fire extinguishers, and fire protection/detection/suppression systems are installed. System and subsystem functional tests and analysis verify the ability to detect or suppress fires under all specified operating configurations and conditions.

DoD/MIL Doc: JSSG-2010-7: para 3.7.3.4

JSSG-2009 Appendix G: para 3.4.7.9

FAA Doc: 14CFR references: 25.855, 25.857, 25.858, 25.859, 25.854,

**9.9.3** Verify that the fire alarm and intercom/public address system can be heard in all lavatories, galleys, and other compartments.

Standard: The fire alarm, intercom and/or public address system is intelligible at all passenger seats, lavatories, and flight attendant seats and work stations. System volume is sufficient to be detected in all compartments, during all normal flight noise levels. Alarm and intercom or PA systems are capable of functioning independently of any required crewmember interphone system and are accessible for immediate use from each of two flight crewmember stations in the pilot compartment.

Compliance: Test and analysis of fire alarm, intercom, and public address systems verifies functionality under all approved operating configurations and conditions. Human factors engineering analysis verifies ability of crew and passengers to hear alarm and understand intercom/PA communications.

**9.9.4** Verify that the human factors design for operation of installed equipment minimizes the probability of human error that could create a safety hazard in the aircraft.

**9.9.5** Verify that all equipment installed in lavatories, galleys, and other areas can be safely operated in the aircraft environment, and is designed to withstand all potential aircraft environmental exposures, including rapid decompression, without creating a safety hazard.

Standard: All structural elements have sufficient strength, rigidity, and durability to resist accelerations and inertia loads for a safe installation on the aircraft without permanent deformations, loss of rigidity, or loss of proper structural functioning for the specified usage. Structural integrity is consistent with strength requirements for the aircraft.

Sustenance and waste management equipment is made of quality parts, does not include sharp corners, uses adequate retention and latches, and does not create hazardous noise levels.

The sustenance and waste management equipment is designed to withstand, without degradation, exposure to the natural and induced environments of an equipment life cycle. Equipment, including enclosed chambers, assemblies, and pressure vessels can withstand rapid decompression at maximum aircraft altitudes without structural failures, deformations, or material releases that can cause injury or create a flight safety hazard.

Compliance: Analyses, demonstrations, inspections, and tests are used to verify the sustenance and waste management system is properly designed. Safe operation is verified by system tests in actual or simulated flight environments. Structural analysis is accomplished to ensure that adequate installation strength is provided. Decompression tests verify ability of equipment to safely withstand rapid pressure changes.

**9.9.6** Verify that occupants cannot become trapped in lavatories, galleys, and other compartments during emergency evacuation situations, and that emergency lighting is available to aid egress.

Standard: All lavatory doors are designed to preclude anyone from becoming trapped inside the lavatory. If a locking mechanism is installed, it must be capable of being unlocked from the outside without the aid of special tools. Each enclosed cabin with passenger accommodations has at least one adequate and easily accessible external door.

Enclosed spaces, such as lavatories and compartments, have emergency lighting to permit the occupants to perform flight safety critical functions and escape during a loss of electrical power to the normal space lighting. The lavatory and all enclosed spaces has ceiling-mounted emergency lighting that produces illumination on the floor and the door handle. The lighting automatically operates upon loss of power.

Compliance: Verification is by inspection of drawings and emergency egress demonstrations. Lighting system tests and analysis verify functionality for all approved operating configurations and conditions.

## 10. DIAGNOSTICS SYSTEMS

TYPICAL CERTIFICATION SOURCE DATA

1. Failure modes, effects, and criticality analysis (FMECA)
2. Acceptance test procedures
3. Preflight test results
4. Built-in-test software
5. Flight test plan
6. Testability analysis reports
7. BIT demos reports
8. Test & evaluation master plan (TEMP)
9. Failure report and corrective action system (FRACAS) data
10. Test reports
11. System safety analysis report

CERTIFICATION CRITERIA

### 10.1 Failure modes.

**10.1.1** Verify that critical functional failure modes are identified and detection methods incorporated.

Standard: Critical failures are detected and displayed by the system to enable actions (by system and/or operator) that prevents loss of the aircraft or personnel injury.

Compliance: Critical failures are identified in a Failure Mode Effects Criticality Analysis (FMECA), and the detection and the timely display of those failures is verified by a combination of analysis and test.

Comm'l Doc: SAE AIR 4845 details the FMECA process.

DoD/MIL Doc: JSSG-2000: para 3.3.2

JSSG-2001: para 3.3.7, 3.3.7.1

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

**10.1.2** Verify that all critical functional failures, including built-In-test (BIT) features, are linked to the caution and warning function and message indicators.

Standard: All critical functional failures activate a visual and/or aural indication in sufficient time to enable the operator or pilot to take necessary action. Redundant and back-up systems are cross-compared with the primary systems and any out-of-tolerance comparisons are alerted to the operator or flight crew.

Compliance: The timely linkage of critical failures to the caution and warning indication is verified by conducting component, subsystem, system analysis, simulation and tests. FMECA and FMEA data along with time lines for timing and latency demonstrate compliance.

DoD/MIL Doc: JSSG-2000: para 3.3.2

JSSG-2001: para 3.3.7, 3.3.7.1

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

## 10.2 Operation.

**10.2.1** Verify that the operation of air vehicle and ground diagnostic systems is proper for all SOF parameters.

Standard: On-board and ground diagnostic systems measure the appropriate safety-of-flight parameters.

Compliance: The appropriate safety-of-flight parameters are verified by conducting on-board and ground diagnostic analysis, component, subsystem, and system tests.

DoD/MIL Doc: JSSG-2000: para 3.3.2

JSSG-2001: para 3.3.7, 3.3.7.1, 3.4.4.1.6;

AFGS 87256, Integrated Diagnostics, para 3.1.4.1, 3.2.2.3, address the diagnostic capability needed to support safety decisions.

MIL-HDBK-2165 addresses testability and the extent to which a system supports fault detection and fault isolation.

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

**10.2.2** Verify that critical parameter values can be measured within the established tolerances and that operation and calibration procedures are defined.

Standard: Critical parameters that need to be detected and measured by diagnostics have tolerances, accuracy and test accuracy ratio (TAR) defined. The calibration of the diagnostic sensors is specified with traceability to the National Institute of Standards and Test (NIST).

Compliance: The tolerances, accuracy and TAR of the critical parameters are verified by analysis and test. The calibration of the diagnostic sensors is verified by a Calibration Measurement Requirements Summary (CMRS) which shows traceability to NIST standards.

DoD/MIL Doc: JSSG-2000: para 3.3.2

JSSG-2001: para 3.3.7, 3.3.7.1

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

**10.2.3** Verify that measures are taken to ensure the diagnostic system itself does not induce undetected failures or otherwise damage the air vehicle.

Standard: Diagnostic hardware and software are designed to be minimally invasive and failures of the diagnostic sensors or software do not affect the operation of the air vehicle.

Compliance: Fail safe operation of the air vehicle in response to a diagnostic system failure is verified by a combination of analysis, component, subsystem, and system tests.

DoD/MIL Doc: JSSG-2000: para 3.3.2

JSSG-2001: para 3.3.7, 3.3.7.1;

JSSG-2001 Air vehicle: para 3.3.7 Diagnostics.

AFGS 87256 Integrated Diagnostics provides general guidance regarding diagnostics.

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

**10.2.4** Verify functionality of safety systems that provide protection against catastrophic failures prior to potential need of the safety system.

Standard: Air vehicle safety systems need to be checked by built-in-test and/or their health monitored to verify functionality prior to the safety systems being activated.

Compliance: A combination of engineering analysis, component, subsystem, and system testing verifies that critical safety systems are checked and reported to the operator.

DoD/MIL Doc: JSSG-2000: para 3.3.6

JSSG-2001: para 3.3.7, 3.4.4.1.6

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

**10.2.5** Verify that all operator and maintenance manuals containing diagnostic systems are complete and accurate.

Standard: Operation and maintenance manuals reflect the appropriate engineering data to ensure diagnostic systems address SOF parameters.

Compliance: All manuals have undergone quality assurance review by the contractor and final versions of the manuals have been verified by the Government.

DoD/MIL Doc: JSSG-2000: para 3.6.2

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

## 11. AVIONICS

Avionics certification criteria apply to manned air vehicle avionics, as well as airborne and ground segment avionics for UAVs/ROAs.

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Design studies and analyses
3. Design, installation, and operational characteristics
4. Design approval and system compatibility tests
5. Simulation tests and modeling results
6. Component and system level qualification and certification tests
7. Electromagnetic environmental effects
8. Hazard analysis and certification
9. Failure modes and effects analysis
10. Avionics flight-critical hardware and software
11. Avionics preliminary design review (PDR) and critical design review (CDR) open items
12. Avionics integration tests and results
13. Avionics/electronics integrity program documentation
14. Flight test simulation plan
15. System/subsystem self-test design and capabilities
16. Acceptance test plans, procedures, and results
17. Qualification test plans, procedures, and results
18. Functional configuration audit (FCA) and physical configuration audit (PCA) data
19. Test reports
20. Environmental analysis and test results
21. Diminishing manufacturing sources plan
22. Obsolete parts plan

CERTIFICATION CRITERIA

(Note: For subsystems that use computer resources, see section 15 for additional, specific criteria.)

DoD/MIL Doc: JSSG-2005 Avionics

### 11.1 Avionics architecture.

**11.1.1** Avionics subsystems. Verify that the number and type of sensors, data processors, data buses, controls and displays, and communications devices are adequate for SOF considerations. As a minimum, the following are provided: (for criteria 11.1.1.1 through 11.1.1.6)

**11.1.1.1** (was 11.1.1.a) Air data system, including provisions for displaying primary flight parameters

Standard: The air data system shall provide vehicle and/or operator(s) all needed air data information with sufficient accuracy and reliability to satisfy SOF requirements. The specific requirements shall be defined in program detailed design information and shall be included

in the System Safety Hazard Analysis. No single air data system component failure shall result in Flying Qualities less than Level 1. Air data system external sensors shall be installed with sufficient separation and redundancy to ensure a single event (such as a bird strike or a lightning attachment) shall not degrade air data system performance below that necessary to support Level 1 Flying Qualities. No two air data system component failures shall result in Flying Qualities less than Level 2. Air Data System performance shall meet air vehicle Vertical Separation Minimums (VSM), Reduced Vertical Separation Minimums (RVSM), and Vertical Navigation (VNAV) requirements (as applicable). RVSM and VNAV performance matrices shall be tailored to the specific needs of the program.

Compliance: Performance of Air Data SOF components shall be verified through analysis and laboratory test. Air Data System SOF performance shall be validated through system level analysis, simulation and test. Safety Hazard Analysis shall verify that all air data system related failures have acceptable risk levels. Safe operation of the air vehicle following air data system failures shall be verified using FMECA. Laboratory based failure mode tests shall verify acceptable performance for single and dual failure operation. On-aircraft ground testing shall verify performance and redundancy of the air data system safety critical functions. Flight testing shall verify air data system level performance.

Comm'l Doc: RTCA DO-236A, guidance on CNS/ATM related air data system requirements

DoD/MIL Doc: MIL-HDBK-87213 sect. 3.1

GATOMC2 Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) RVSM, Barometric Vertical Navigation (BARO VNAV), Area Navigation Vertical Navigation (RNAV VNAV), Performance Matrices provide CNS/ATM related air data system safety guidance. Contact GATOMC2 for current applicable performance matrices and current supporting civil documents.

MIL-STD-1787: para 4.1.1

FAA Doc: AC-23.1301, 23.1309, 25.1301, 25.1309, RTCA DO-200A

AC 27-1B, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

AC 20-145 Guidance for Integrated Modular Avionics (IMA)

AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

FAA IG 91-RVSM, para 7.c(4), 7.C(5), 7.c(8), 7.d, 8.b(5), 8.b(6), 8.b(7), 8.c, and 8.d. (RVSM)

AC-23.1323, 23.1325, 23.1326, 25.1323, 25.1325, 25.1326;

AC 90-97 Para 7 (Baro VNAV);

AC 20-129 Para 6 (RNAV VNAV)

### 11.1.1.2 (was 11.1.1.b) Propulsion system instrumentation, with the ability to monitor performance, fuel status, and integrity of the system

Standard: System displays engine power indication (RPM, temperature, percent thrust, or other parameter(s) as appropriate for the engine type) at all times. System displays fuel quantity remaining, along with any necessary fuel location or balance information, at all times, Power and fuel indications may be replaced / obscured by other display data if: sufficient automatic monitoring of these parameters is provided to ensure that the pilot will always be notified of impending abnormal or dangerous situations; and presentation of detailed status and trend information is always available with only one control action. Power and fuel status information are available after any single point failure.

Compliance: Required system displays are verified through inspection of the design. Testing verifies the accuracy of the information displayed. FMECA verifies that power and fuel status

information are available after any single point failure.

Comm'l Doc: RTCA DO-186A is the civil standard for VHF radio;

RTCA DO-219,

RTCA SC-189

DoD/MIL Doc: MIL-HDBK-87213 sect. 3.1

MIL-STD-1787: para 4.1.1 provides guidance on displayed information

FAA Doc: AC-23.1301, 23.1309, 25.1301, 25.1309, RTCA DO-200A

AC 27-1B, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

AC 20-145 Guidance for Integrated Modular Avionics (IMA)

AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

14CFR reference: 23.1301, 13.1305, 23.1309, 25.1301, 25.1305, 25.1309 and FAA AC-1307-1C section 8.5 provide more extensive guidance.

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

### 11.1.1.3 (was 11.1.1.c) Display of other air vehicle or vehicle management system parameters as required for safe flight

Standard: The system continuously displays any other aircraft parameter(s) defined to be important to flight safety. This may include landing gear status, cabin pressure, hydraulic system pressure, oxygen status, etc, as well as items specific to aircraft type, e.g., swing wing position, tilt rotor position, etc. These indications may be replaced / obscured by other display data if: sufficient automatic monitoring of these parameters is provided to ensure that the pilot will always be notified of impending abnormal or dangerous situations; and presentation of detailed status information is always available with only one control action. Air vehicle or vehicle management system parameters required for safe flight continue to be available after any single point failure.

Compliance: Required system displays are verified through inspection of the design. Testing verifies the accuracy of the information displayed. FMECA verifies that air vehicle or vehicle management system status information required for safe flight is available after any single point failure.

DoD/MIL Doc: MIL-HDBK-87213 sect. 3.1

MIL-HDBK-87213 sect. 3.1 provides display system guidance.

FAA Doc: AC-23.1301, 23.1309, 25.1301, 25.1309, RTCA DO-200A

AC 27-1B, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

AC 20-145 Guidance for Integrated Modular Avionics (IMA)

AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

AC 23.1301, 23.1309, 23.1351d, 25.1301, 25.1309, 25.1351d;

14CFR reference: 23.1301, 23.1307, 25.1301 and 25.1307 provide additional guidance.

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

**11.1.1.4** (was 11.1.1.d) An installed interoperable communications subsystem capable of supporting SOF operations with the required integrity and continuity of service throughout the intended missions.

Standard: Requirements for voice and data communications systems (including communications requirements for air traffic coordination) shall be defined and documented for military and civilian air traffic coordination and communication. Minimum SOF communication range shall be specified. The communication subsystem installed performance shall meet these requirements. As a minimum, the following apply:

(a) Voice communications shall be intelligible. 98% of sentences shall be correctly heard and single digits understood. A Modified Rhyme Test (MRT) score of at least 80% shall be achieved.

(b) Data communications bit error rate shall be sufficient to preclude loss of data that would impact SOF. Bit-Error-Rate (BER) of SOF data shall not exceed 10^-4 for manned systems.

(c) System shall provide sufficient link margin and antenna coverage to preclude loss of signal that would impact SOF. Antenna coverage for SOF systems shall have 360 degrees spherical coverage. Any antenna nulls shall not impact SOF.

(d) When SOF instrumentation telemetry is used, appropriate SOF data shall be made available to ground coordinators and BER of SOF data shall not exceed 10^-4 for manned systems.

(e) The SOF information transmitted via a communications system shall be received and displayed without degradation and shall not cause a misinterpretation of the intended information. Safety critical Information Exchange Requirements (IER) shall be identified and substantiated. Interfaces with safety critical nodes (as identified in the IER matrix) shall be interoperable.

(f) No single point failure shall result in a SOF condition.

Compliance: Analysis, laboratory, open-air, and aircraft testing shall verify installed system performance. Safety Hazard Analysis shall verify that all communication system related failures have acceptable risk levels.

(a) Voice intelligibility shall be verified through statistical analysis and testing via a Modified Rhyme Test, per MIL-STD-1472F, paragraph 5.3.14 on installed systems.

(b) Data bit error rates shall be verified through analysis, laboratory, open-air, and aircraft testing.

(c) Link margins shall be verified through analysis, laboratory, open-air, and aircraft testing. Antenna coverage shall be verified with analysis, laboratory, open-air, and aircraft testing.

(d) Instrumentation telemetry shall be verified with analysis, laboratory, open-air, and aircraft testing.

(e) Interoperability certification via Joint Interoperability Test Center (JITC) procedures shall be obtained.

(f) A failure modes and effects analysis (FMEA) and a quantitative probability analysis of the installed communications system shall be performed to verify no single point failure.

Comm'l Doc: RTCA DO-186A is the civil standard for VHF radio;

RTCA DO-219,

RTCA SC-189

DoD/MIL Doc: MIL-HDBK-87213 sect. 3.1

JSSG-2005: para 3.2.1.6 and 4.2.1.6;

MIL-STD-188-141B Interoperability and Performance Standards for Medium and High frequency Radio System

MIL-STD-188-242 Interoperability and Performance Standards for Tactical Single Channel Very High Frequency (VHF) Radio Equipment

MIL-STD-188-243 Interface Standard for Tactical Single Channel Ultra High Frequency (UHF) Radio Communications

MIL-STD-188-181B Interoperability Standard for Single-Access 5-kHz and 25-kHz UHF Satellite Communications Channels

MIL-STD-188-182A Interoperability Standard for 5-kHz UHF DAMA Terminal Waveform

MIL-STD-3005 Analog-To-Digital Conversion of Voice By 2,400 Bit/Second Mixed Excitation Linear Prediction (MELP)

CNS/ATM performance requirements are found in the GATOMC2 CNS/ATM Performance Matrices (8.33 kHz VHF, SATCOM Voice, HFDL, VDL, CPDLC, ADS, AFN, Data Comm, etc.) for military performance requirements necessary for safe access to civil airspace. Contact GATOMC2 for current applicable performance matrices and current supporting civil documents.

IL-STD1472F para 5.3.14, guidance in conducting Modified Rhyme Testing

AFI 11-202 Vol 3: para 2.6.2;

Interoperability and IERs are discussed in CJCSI 6212.01

FAA Doc: AC-23.1301, 23.1309, 25.1301, 25.1309, RTCA DO-200A

AC 27-1B, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

AC 20-145 Guidance for Integrated Modular Avionics (IMA)

AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

AC 20-140, Guidelines for Design Approval of Aircraft Data Communications Systems

**11.1.1.5** (was 11.1.1.e) A navigation subsystem capable of meeting SOF performance, integrity, availability and continuity of service requirements for long range reference, local area reference, and landing/terminal reference

Standard: The navigation system shall provide the vehicle and/or operator(s) all needed navigation information with sufficient accuracy and reliability to satisfy SOF requirements. The amount, quality and refresh rate of information needed for SOF shall be defined in the design information and shall be included in the System Safety Hazard Analysis. No single navigation subsystem component failure shall result in loss of the air vehicle. Navigation subsystem performance, integrity, availability and continuity of service shall meet air vehicle Required Navigation Performance (RNP), VNAV, Basic Area Navigation (BRNAV), Precision Area Navigation (PRNAV) requirements (as applicable). RNP, VNAV, BRNAV, and PRNAV performance matrices shall be tailored to the specific needs of the program.

Compliance: Performance of the navigation system SOF components shall be verified through analysis and laboratory test. Navigation System SOF performance shall be validated through system level analysis, simulation and test. Safety Hazard Analysis shall verify all navigation system related failures have acceptable risk levels. Safe operation of the air vehicle following any single navigation system component failure shall be verified using FMECA. Laboratory based failure mode tests shall verify acceptable performance for single failure operation. On aircraft ground testing shall verify performance and redundancy of the navigation system safety critical functions. Flight testing shall verify previous analysis and testing. For example, when a Kalman filter is used in an integrated navigation system, a representative subset of operational flight profiles must be chosen via analysis to demonstrate direct compliance to performance requirements as well as validate navigation system analysis simulations. Once validated these navigation system simulations shall be used to verify

performance for all other operational flight profiles not directly tested.

Comm'l Doc: RTCA DO-236A, for CNS/ATM related navigation system requirements

RTCA DO-200A: para 2.3.2, 2.3.3, 2.3.5, and 2.4.1 (RNP Data Processing);

RTCA DO-236

DoD/MIL Doc: MIL-HDBK-87213 sect. 3.1

GATOMC2 CNS/ATM RNP Top Level, RNP Data Processing, RNP Path Following, RNP Pilot/Vehicle Interface (PVI), RNP-10, RNAV VNAV, BRNAV, and PRNAV Performance Matrices provide CNS/ATM related navigation system safety guidance. Contact GATOMC2 for current applicable performance matrices and current supporting civil documents.

JSSG-2005: para 3.2.1.5 and 4.2.1.5,

AFI 11-202 Vol 3: 2.6.2

FAA Doc: AC-23.1301, 23.1309, 25.1301, 25.1309, RTCA DO-200A

AC 27-1B, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

AC 20-145 Guidance for Integrated Modular Avionics (IMA)

AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

AC-25.1303, AC 90-96;

AC_90-96 (BRNAV only)

AC_90-96A (Draft containing both BRNAV and PRNAV requirements);

FAAO 8400.12A para 10.a-b, & para 15a (RNP-10)

AC 20-129 Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. National Airspace System (NAS) and Alaska, 9-12-88, Para 6 (RNAV VNAV)

**11.1.1.6** (was 11.1.1.f) An installed surveillance and identification subsystem capable of meeting the SOF performance, integrity, and continuity of service requirements for identification, relative positioning, trajectory, timing, and intent.

Standard: Requirements for surveillance systems (including requirements for air traffic coordination) shall be defined and documented for military and civilian air traffic coordination and surveillance. The surveillance subsystem installed performance shall meet these requirements. As a minimum, the following apply:

(a) IFF MK XII/XIIA capabilities shall be implemented IAW AIMS 97-1000/AIMS 03-1000.

(b). Mode S capabilities shall be implemented IAW Mode S performance requirements specified in the Mode S GATOMC2 CNS/ATM Performance Matrix.

(c) TCAS (as appropriate) capabilities shall be installed and performing IAW specified performance requirements specified in TCAS GATOMC2 CNS/ATM Performance Matrix. Use of TCAS capabilities for formation/station keeping shall not create a SOF condition.

(d) No single point failure shall result in a SOF condition.

Compliance: Analysis, laboratory, open-air, and aircraft testing shall verify installed system performance. Safety Hazard Analysis shall verify that all surveillance system related failures have acceptable risk levels.

(a). AIMS certification shall be obtained.

(b) A FMEA and a quantitative probability analysis of the TCAS II equipment, Mode S transponder, and altitude information source shall be performed resulting with no single

point critical SOF failures.

Note: If commercial or commercial derivative aircraft, FAA experimental type certification achieved prior to first flight, and complete type certification achieved prior to production.

Comm'l Doc: RTCA DC-181C is the civil standard for Mode S.

RTCA DO-185A Is the civil standard for TCAS II.

RTCA DO-212

DoD/MIL Doc: MIL-HDBK-87213 sect. 3.1

DOD AIMS 97-1000/DOD AIMS 03-1000 provide the requirements for AIMS certification.

GATOMC2 CNS/ATM Performance Matrices (Mode S, TCAS II) for military performance requirements necessary for access to civil airspace. Contact GATOMC2 for current applicable performance matrices and current supporting civil documents.

JSSG-2005: para 3.2.1.6 and 4.2.1.6;

AFI 11-202 Vol 3: para 5.4.2;

FAA Doc: AC-23.1301, 23.1309, 25.1301, 25.1309, RTCA DO-200A

AC 27-1B, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

AC 20-145 Guidance for Integrated Modular Avionics (IMA)

AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors

TSO C112, AC 20-131A, TSO C151a,

**11.1.2** Verify that redundancy is incorporated such that failure of any single sensor, connection, processor, or display unit does not result in loss of safety-critical data or display of unsafe or misleading data.

Standard: Potential failure modes, required diagnostic capability, and the impacts on system safety are defined and documented. Failure modes identified, including degradation/loss due to single point failures; generation of corrupt data; memory upset conditions; blank cockpits; and processor, system, and subsystem resets, are prevented using a combination of diagnostics capability (> 95 % fault detection), fault isolation, real time principles such as Rate Monotonic Scheduling (RMS) and data stream cross check. Probability of presenting Hazardously Misleading Information (HMI) to the pilot is found to be consistent with the type and mission of the aircraft.

Compliance: Potential failure modes are verified by inspection of the FMEA (ARP 4761 sections 4.2 FMEA, 4.4 CCA, 4.4.2 PRA, 4.4.3 CMA apply). Laboratory and flight testing under fully loaded conditions verify that no failure modes exist that result in SOF condition. Analysis shows probability of HMI is consistent with the type and mission of the aircraft.

Comm'l Doc: ARP 4761 sections 4.2 FMEA, 4.4 CCA, 4.4.2 PRA, and 4.4.3 CMA

DoD/MIL Doc: JSSG-2005: para 3.2.1.4.1, 4.2.1.4.1

FAA Doc: AC-23.1309, 23.1311, 23.1331, 25.1309, 25.1331;

14CFR references: 23.1309, 23.1311, 23.1331, 25.1309, 25.1331

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

**11.1.3** Verify that data buses have sufficient redundancy, reliability, and integrity to meet system safety and flight-critical requirements to preclude: (for criteria 11.1.3.1 through 11.1.3.3)

**11.1.3.1** (was 11.1.3.a) Loss of flight-critical functioning

Standard: Loss of flight critical functioning and the impacts on system safety are defined and documented. Air vehicle/System/Subsystem end to end timing and latency is documented for normal and fully loaded conditions of all bus components (e.g., networks, switches, hubs, etc) and interfaces for each function. Bus retries, network data error rates, message size, non blocking operation, numbers of priorities, level of compliance with Rate Monotonic Scheduling (RMS) are documented.

Compliance: Loss of flight critical functioning documented in FMEA, analysis, and simulation. Underlying real time principles are identified (e.g., RMS based, deterministic, stochastic, etc) and documented. Bus retries, network data error rates (e.g., 10^-12), message size, numbers of priorities, level of RMS compliance are appropriate by design. Laboratory and flight testing under fully loaded conditions verify that no loss of flight critical functioning occurs.

DoD/MIL Doc: JSSG-2005: 3.2.2, 4.2.2

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC-23.1301, 23.1309, 25.1301, 25.1309

**11.1.3.2** (was 11.1.3.b) Display of undafe or misleading information to the operator or maintainer

Standard: Data bus performance supports system latency requirements, including the Primary Flight Display (PFD) latency criteria under paragraph 11.1.4. Integrity of data transmitted on the bus supports system integrity requirements, including the Hazardously Misleading Information (HMI) criteria under paragraph 11.1.2.

Compliance: Analysis documents the timing and latency of buses, including latency in the presence of single point failures. Analysis and testing documents the bit error rate and other parameters that define bus integrity. FMEA and testing verify results.

DoD/MIL Doc: JSSG-2005: 3.2.2, 4.2.2

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC-23.1301, 23.1309, 23.1311, 25.1301, 25.1309;

14CFR references: 23.1301, 23.1309, 23.1311, 25.1301, 25.1309

**11.1.3.3** (was 11.1.3.c) Undetected failure modes

Standard: Undetected failure modes in all architecture elements (processors, buses, memory, etc) are defined, assessed, and compensated for as required to ensure safe operation. Undetected failures include undetected hardware and interface failures (i.e., hard and intermittent) as well as failures due to priority inversions, lack of real time support (e.g., lack of Rate Monotonic Scheduling (RMS)), unpredictable software execution (e.g., unknown execution timeline), and timing anomalies.

Compliance: Undetected failure modes are verified by inspection of the FMEA, timeline, and latency data. Laboratory and flight testing verify that no undetected failure modes exist that result in SOF condition.

DoD/MIL Doc: JSSG-2005: 3.2.2, 4.2.2

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC-23.1301, 23.1309, 25.1301, 25.1309

**11.1.4** Verify the overall avionics system operates in a deterministic or bounded manner and limits latency of any time-critical data, including primary flight data, as needed to support all safety-critical functions.

Standard: Avionic system/subsystem real time operation and latency (aircraft and avionic level end to end timing and latency) are defined, assessed, and documented. The avionic system and subsystems must be compliant with real time principles based on Rate Monotonic Scheduling (RMS) and other mathematically based principles. Latency of a PFD presentation used for real-time control of an aircraft does not exceed 100 ms unless characteristics or design of the system mitigate the effects of latency.

Compliance: Avionic system/subsystem real time operation and latency are defined and documented. Laboratory and flight testing verify that no deficiencies result in a SOF condition.

DoD/MIL Doc: JSSG-2005: para 3.2.1.3, 4.2.1.3

FAA Doc: AC-23.1301, 23.1309, 23.1331, 25.1301, 25.1309, 25.1331

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

**11.1.5** Verify that all normal, backup, and emergency modes of operation are safe for the integrated system. Verify the following events do not result in unsafe system operation: (for 11.1.5.1 through 11.1.5.3)

**11.1.5.1** (was 11.1.5.a) Undetected failure modes (failures not automatically detected by diagnostics).

Standard: Undetected failure modes are defined (e.g., failure condition, timing, performance, graceful degradation, etc) and documented for normal, backup, and emergency modes.

Compliance: Undetected failure modes are shown to be safe and verified by inspection of FMEA, analysis, and test data. Laboratory and testing should establish that each mode is safe and predictable.

DoD/MIL Doc: JSSG-2005: para 3.3.5, 4.3.5

JSSG-2005: para 3.2.1.3.2, 4.2.1.3.2

FAA Doc: AC-23.1301, 23.1309, 23.1329, 23.1335, 25.1301, 25.1309, 25.1329, 25.1335

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC 20-145, Guidance for Integrated Modular Avionics (IMA) That Implement TSO-C153 Authorized Hardware Elements.

**11.1.5.2** (was 11.1.5.b) Timing or latency anomalies.

Standard: Timing (e.g., priorities, margins, bounded timelines) and latency anomalies for normal, backup, and emergency modes will be assessed and documented and shown to be compliant with SOF.

Compliance: Timing (e.g., priorities, bounded timelines) and latency anomalies for normal, backup, and emergency modes are verified by FMEA, analysis, and testing. Laboratory and flight testing under fully loaded conditions verify that no timing or latency anomalies degrade SOF.

DoD/MIL Doc: JSSG-2005: para 3.3.5, 4.3.5

JSSG-2005: para 3.2.1.3.2, 4.2.1.3.2

FAA Doc: AC-23.1301, 23.1309, 23.1329, 23.1335, 25.1301, 25.1309, 25.1329, 25.1335

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC 20-145, Guidance for Integrated Modular Avionics (IMA) That Implement TSO-C153 Authorized Hardware Elements.

**11.1.5.3** (was 11.1.5.c) Interface/interconnect failures.

Standard: All failures (e.g., hard failures, unpredictable operation) of either an interface or an interconnect for normal, backup, and emergency modes are defined and documented.

Compliance: All failures are shown to be compatible with the SOF requirements and verified with FMEA, analysis, and testing. Laboratory and system level testing should establish that each failure is safe and predictable.

DoD/MIL Doc: JSSG-2005: para 3.3.5, 4.3.5

JSSG-2005: para 3.2.2.2, 4.2.2.2, 3.2.2.3, 4.2.2.3

FAA Doc: AC-23.1301, 23.1309, 23.1329, 23.1335, 25.1301, 25.1309, 25.1329, 25.1335

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC 20-145, Guidance for Integrated Modular Avionics (IMA) That Implement TSO-C153 Authorized Hardware Elements.

**11.1.6** Verify that the avionics system integrated diagnostics provides the fault coverage, low false alarm rates, fault isolation, and fault detection needed to detect bad data and failed components that would degrade safe operation.

Standard: The diagnostic system parameters are derived from the Capability Development Document and the System Specification. Fault coverage, False alarm rates, Fault isolation (FI) and Fault Detection (FD) are normally specified as a %. There are no set percentages but are based on current technology, criticality of the system being diagnosed and sound engineering and economic principles.

Compliance: A combination of simulation, design analysis and testing is required to mature the diagnostic system. A discreet event to verify the diagnostic parameters is not practical. Maturation of the diagnostics is accomplished by carefully documenting all system testing, failures and corrective action to determine if the diagnostic system meets the specified requirements.

DoD/MIL Doc: JSSG-2005: para 3.2.1.3.2, 4.2.1.3.2

FAA Doc: AC-23.1309, 25.1309;

14CFR reference 23.1309, 25.1309

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

AC 29-2C, Certification of Transport Category Rotorcraft

## 11.2 Avionics subsystems.

**11.2.1** Verify that critical information is provided to the crew as follows: (for criteria 11.2.1.1 through 11.2.1.5)

**11.2.1.1** (was 11.2.1.a) Legibility of primary flight displays. Verify that primary flight information is provided to the crew at all times and is fully legible in all mission environments, including full sunshine on displays, sun in the eyes, and total darkness

Standard: Primary Flight Reference (PFR) information is provided IAW sections 4 and 5 of MIL-STD-1787. PFR data is considered legible when it is presented on a display meeting all the following criteria. Variations on these criteria may be acceptable where data is provided showing equivalent or better legibility in all environments.

1. Display produces symbols with maximum luminance of at least 700 cd/m^2 for clear canopy type aircraft, 500 cd/ m^2 for aircraft with an opaque overhead area, and 200 cd/m^2 for crewstations with a controlled lighting environment.

2. Displays which will be used with NVIS produce symbols with maximum luminance of at least 10 cd/m^2 in NVIS mode.

3. Displays which will be used with NVIS have controlled radiance in compliance with MIL-STD-3009 table III.

4. Display is dimmable to a max luminance of 0.1 cd/m^2 for crewstations where out-the-window vision is required, dimmable to 20 cd/m^2 for crewstations where out-the window vision is not required.

5. Contrast of all critical data is at least 3.0 in an illumination environment of: 108,000 lux with a 6800 cd/m^2 glare source for clear canopy type aircraft, 86,000 lux with a 6800 cd/m^2 glare source for aircraft with an opaque overhead, or 640 lux with a 3400 cd/m^2 glare source for a crewstation with a controlled lighting environment (e.g., indoor UAV/ROA control station).

6. Attitude indicator is at least 75 mm wide.

7. Critical alpha-numeric characters (e.g., airspeed, altitude and heading) subtend at least 24 minutes of arc vertically.

8. Viewing angle is sufficient to allow viewing from the full range of pilot seating positions.

9. Display has sufficient resolution, uniformity, refresh rate and update rate to present the PFR in highly dynamic situations with no objectionable smear, jerking or other artifacts.

Compliance: Display capabilities sufficient to continuously display primary flight information are verified by analysis. Legibility and balance of the entire installed system are verified by a lighting demo of the complete cockpit. Legibility of individual display units is verified by review of specifications and test. Pilot evaluation of the real aircraft system in flight demonstrates that all parts of the system perform correctly in the installed environment under real dynamics.

DoD/MIL Doc: AFI 11-202 Vol 3: para 2.6, 2.6.1, 2.6.1.1, 2.6.1.2, and 2.6.1.2.1 provides Air Force instructions on PFRs.

MIL-HDBK-87213 section 3.1.1 provides guidance on legibility of displays; section 3.2.1.6 provides guidance on verification of displays in high ambient lighting environments.

JSSG-2005: para 3.2.1.8, 4.2.1.8, 3.2.1.8.1, and 4.2.1.8.1, provides additional avionics systems requirements guidance.

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

AC 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351 23.1311, 23.1321, 25.1321;

14CFR references: 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351, 23.1311, 23.1321, 25.1321 provide related FAA criteria.

### 11.2.1.2 (was 11.2.1.b) Accuracy. Verify that accuracy of flight-critical information meets SOF requirements

Standard: Altitude, air speed, vertical velocity (or angle-of-attack), pitch, roll and heading shall be sufficiently accurate to satisfy SOF requirements under all operational flight conditions / environments, profiles, specified geographic locations and with any single failure of a component. The specific requirements shall be defined in program detailed design information and included in the System Safety Hazard Analysis.

Compliance: Accuracy shall be validated through system level analysis, simulation and test. Safety Hazard Analysis shall verify critical information related failures do not degrade accuracy below acceptable risk levels. Laboratory based failure mode tests shall verify acceptable performance for single failure operation. On aircraft ground testing shall verify accuracy of critical information. Flight testing shall verify previous analysis and testing.

DoD/MIL Doc: MIL-HDBK-87213: para 3.2.1.25.4.1 and App A

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

14CFR reference 23.1311, 23.1323, 23.1325, 23.1326, 23.1327, 25.1323, 25.1325, 25.1326, 25.1327

**11.2.1.3** (was 11.2.1.c) Warnings, cautions, and advisories. Verify that cautions and warnings are legible in all mission environments and are provided in an organized, prioritized system, and that the presentation of high-priority information is not masked by older or lower priority warnings and cautions.

Standard: Cockpit Warnings, Cautions and Advisories (WCAs) meet the luminance and contrast requirements of MIL-STD-411. Where the operator is in a controlled ambient indoor lighting environment, WCAs are presented on a display capable of 200 cd/m^2 peak luminance. WCAs are presented and prioritized IAW MIL-STD-411 section 5.2.4. No probable failure of the WCA system results in a "safe" indication while an unsafe condition requiring pilot action exists.

Compliance: Luminance and contrast throughout the mission lighting environment is verified by test of each WCA display device. Legibility and balance of the entire installed system is verified by a lighting demo of the complete cockpit. Performance of each warning and caution function and performance of prioritization schemes in the presence of worst-case multiple system failures is verified by FMEC analysis and in testing.

DoD/MIL Doc: JSSG-2005: para 3.2.1.8.5, 4.2.1.8.5;

MIL-HDBK-87213

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

14CFR reference 23.1311, 23.1322, 25.1322.

**11.2.1.4** (was 11.2.1.d) Symbology. Verify that instruments and symbols used to display flight-critical information employ accepted formats, directions, etc.

Standard: Instruments and symbols used to display airspeed, altitude, attitude, heading, and any other parameter considered essential to flight are IAW MIL-STD-1787 in the areas of shape and scaling, direction of motion and color.

Compliance: Primary Flight Reference (PFR) presentations are analyzed against the requirements and guidance in MIL-STD-1787 and tested in manned simulations, mockups, and/or the actual aircraft, to verify that flight instrument standards and conventions are followed. Any deviation from flight instrument standards and conventions that is necessary (to implement new technology or mission capabilities, for example) is documented in T.O.s and training. Assessment by an independent team of pilots (e.g., the Air Force PFR endorsement process) is used to assess any new or unique approaches.

DoD/MIL Doc: MIL-STD-1787 section 4.2

MIL-STD-1787 Appendix A

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

AC-1311-1A section 9.

14CFR reference 23.1321, 23.1541, 25.1321 and 25.1541.

**11.2.1.5** (was 11.2.1.e) BIT features. Verify that BIT features of equipment alert the flight crew of flight-critical equipment status.

Standard: All flight-critical failures identified through a FMECA should be linked to a caution and warning function and message indicator (appropriate visual and/or aural indicators) to warn the flight crew or operators of impending or failed functions. The crew and/or operators should be able to determine the failed function in a timely manner to take appropriate action.

Compliance: A combination of analysis and test should be utilized to ensure that the critical functional failures tied to the caution and warning indication do indeed activate the indication and necessary information is displayed to the crew or operator. FMECA and FMEA data along with time lines for timing and latency demonstrate compliance.

DoD/MIL Doc: JSSG-2005: para 3.2.1.3.2, 4.2.1.3.2

FAA Doc: AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

14CFR reference 23.1309, 25.1309.

**11.2.2** Verify that controls have adequate redundancy and/or reliability to maintain control of all safety-critical functions.

Standard: Avionic subsystem controls such as that for controlling avionic modes and system function are defined, (e.g., redundancy, robust reliability, timelines, latency, etc) and documented. Controls should be redundant in terms of presentation of data, power, and function.

Compliance: Avionic system control functionality verified by inspection of FMEA, ICD, analyses, and test. Laboratory and system level testing should establish that control functionality is safe and predictable.

DoD/MIL Doc: JSSG-2005: para 3.2.1.8.6, 4.2.1.8.6

FAA Doc: AC-25.777

AC-27-1 and AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

**11.2.3** Verify that data links, such as unmanned air vehicle (UAV)/remotely operated aircraft (ROA) command and control data links, manned systems with automatic/semi-automatic (man-in-the-loop) landing, formation, or other control functions with off-board aiding, used for safety- and flight-critical requirements to: (for 11.2.3.1 though 11.2.3.2)

**11.2.3.1** (was 11.2.3.a) Preclude loss of flight-critical functioning and ensure SOF integrity and continuity of service throughout the intended missions.

Standard: Requirements for data link communication systems shall be defined and documented. The data link subsystems' installed performance shall meet these requirements. As a minimum, the following apply:

(a) Data communications bit error rate shall be sufficient to preclude loss of data that would impact SOF. BER of SOF data shall not exceed 10^-6 for UAV/ROA systems.

(b) Systems shall provide sufficient link margin and antenna coverage to preclude loss of signal that would impact SOF. Antenna coverage for SOF data link systems shall have 360 degrees spherical coverage. Any antenna nulls shall not impact SOF.

(c) When SOF instrumentation telemetry is used, appropriate SOF data shall be provided to ground controllers. BER of SOF data shall not exceed 10^-6 for UAV/ROA systems.

(d) Contingency systems and procedures shall be defined, documented and verified. SOF critical data links shall be either redundant, include backup data link systems, and/or have contingent flight path/route management (e.g., automatic return-to-base) capabilities.

Compliance: Analysis, laboratory, open-air, and aircraft testing shall verify installed system performance.

(a) Data bit error rate shall be verified with analysis, laboratory, open-air, and aircraft testing.

(b) Link margin analysis shall be performed and verified with analysis, laboratory, open-air, and aircraft testing. Antenna coverage shall be verified with analysis, laboratory, open-air, and aircraft testing.

(c) Instrumentation telemetry shall be verified with analysis, laboratory, open-air, and aircraft testing.

(d) Contingency systems and procedures shall be verified with analysis, laboratory, open-air, and aircraft testing.

DoD/MIL Doc: JSSG-2005: para 3.2.2, 4.2.2

FAA Doc: 14CFR reference 23.1301, 23.1309, 25.1301, 25.1309

AC 29-140, Guidelines for Design Approval of Aircraft Data Communications Systems

**11.2.3.2** (was 11.2.3.b) Preclude display of unsafe or misleading information to the operator or maintainer, and to satisfy fault-tolerant SOF requirements

Standard: Requirements for display of data linked information shall be defined and documented. The display's installed performance shall meet these requirements. The SOF information that is transmitted via a data link shall be received and displayed, as appropriate, without degradation or misinterpretation of the intended information.

Compliance: All data links that handle SOF information shall be verified by analysis, laboratory, and aircraft testing for installed system performance. Criteria of 11.2.3.a, and 11.1.3 shall be satisfied. A failure modes and effects analysis (FMEA) and a quantitative probability analysis of the installed data link system shall be performed resulting with no single point critical SOF failures.

DoD/MIL Doc: JSSG-2005: para 3.2.2, 4.2.2

FAA Doc: 14CFR reference 23.1301, 23.1309, 25.1301, 25.1309

AC 29-140, Guidelines for Design Approval of Aircraft Data Communications Systems

**11.2.4** Verify that each subsystem (including any off-the-shelf equipment) and the overall system operates throughout the required operational environment without imposing a SOF risk. This verification typically includes environmental qualification and/or analysis.

Standard: Applicable climatic, shock and vibration environments are specified in the system specification.

Compliance: Verify proper operation of the avionic subsystem by analysis, and test to demonstrate that it can actually provide required performance within the envelope of possible operational environments as required in the system specification without imposing a SOF risk. (Note that for airworthiness certification, verification need only be accomplished to the extent of verifying SOF risk. Operational/Mission requirements may impose further environmental qualification upon subsystems and the overall system).

DoD/MIL Doc: JSSG-2005: para 3.2.3, 4.2.3;

MIL-STD-810 can be used as guidance in selection and tailoring of appropriate requirements for specified environments. MIL-STD-810 provides guidance and test methods for verification.

FAA Doc: AC-23.1309, 25.1309

**11.2.5** Verify safe avionics subsystem operation with required power characteristics.

Standard: Avionics subsystem equipment utilizes electric power in accordance with MIL-STD-704. The avionics subsystem equipment specification also specifies the type of electric power to be utilized and the detailed performance required during normal, abnormal, emergency, starting and transfer operation of the aircraft electric system.

Compliance: Verify proper operation of the avionics subsystem by test to demonstrate that the equipment provides required performance within the envelope of possible conditions present within the electrical power system. Equipment testing is used to demonstrate avionics subsystem compatibility with the electric power characteristics of MIL-STD-704.

DoD/MIL Doc: JSSG-2005: para 3.2.2.5, 4.2.2.5;

MIL-STD-704

FAA Doc: AC-23.1351, 25.1351

## 11.3 Avionics air vehicle installation.

**11.3.1** Verify that the avionics equipment installation, including arrangement and crashworthiness, is adequate for SOF.

Standard: Applicable climatic, shock and vibration environments are specified in the system specification to address the equipment installation. The hardware meets crashworthiness and is retained in the aircraft in a manner that does not result in additional injury to the crew. The SOF equipment is mounted in such a manner that it is easily accessible and visible by the crew to prevent a SOF risk in normal and emergency conditions.

Compliance: Verify proper operation/installation via analysis, demonstrations, and tests of the avionic subsystems to demonstrate that it can provide required performance and safety within the envelope of possible operational environments as required in the system specification without imposing a SOF risk.

DoD/MIL Doc: JSSG-2005: para 3.2.3, 4.2.3,

MIL-HDBK-87213 para 3.2.3 provides guidance on environmental requirements for cockpit display equipment.

MIL-STD-810 provides guidance on environmental qualification.

FAA Doc: 14CFR reference 23.1309, 23.1321, 25.1309, 25.1321.

**11.3.2** Verify that flight manual and maintenance manual limits are adequate to conduct safe flight, including emergency operations.

Standard: Flight and maintenance manuals contain all necessary limits to ensure safe flight including all limitations established as a result of all other Airworthiness Criteria assessments. All emergency operations are documented.

Compliance: All manuals have undergone a quality assurance review by the contractor and verified by the government. An independent group of pilots and maintenance experts conduct reviews of all flight and maintenance manuals to ensure all limitations and emergency operations are clearly identified and easily understood.

DoD/MIL Doc: JSSG -2005: para 3.2.2, 4.2.2

FAA Doc: 14CFR reference 23.1501, 25.1501.

AC 27-1B, Subpart G, Certification of Normal Category Rotorcraft

AC 29-2C, Certification of Transport Category Rotorcraft

**11.3.3** Verify that antenna performance and patterns for safety/flight-critical transmitting and receiving systems provide adequate coverage to ensure: (for criteria 11.3.3.1 through 11.3.3.3)

**11.3.3.1** (was 11.3.3.a) Flight-critical functioning is retained.

Standard: Requirements for systems' link margins and antenna coverage necessary for SOF shall be defined and documented. The subsystems' installed performance shall provide sufficient link margin and antenna coverage to preclude loss of signal that would impact SOF. Any antenna nulls shall not impact SOF.

Compliance: Analysis, laboratory, open-air, and aircraft testing shall verify installed system performance. Antenna coverage shall be verified with analysis, laboratory, open-air, and aircraft testing.

DoD/MIL Doc: JSSG-2005: para 3.3.5, 4.3.5

FAA Doc: 14CFR reference 23.1309.

**11.3.3.2** (was 11.3.3.b) Unsafe information is not displayed to the operator or maintainer.

Standard: Requirements for information integrity and assurance shall be defined and documented. Displayed SOF information obtained using antenna based systems shall not be degraded or altered to cause an unsafe condition.

Compliance: Analysis, laboratory, open-air, and aircraft testing shall verify installed system performance. Criteria of 11.2.3.a, and 11.1.4 shall be satisfied. A failure modes and effects analysis (FMEA) and a quantitative probability analysis of the installed system shall be performed resulting with no single point critical SOF failures.

DoD/MIL Doc: JSSG-2005: para 3.3.5, 4.3.5

FAA Doc: 14CFR reference 23.1309.

**11.3.3.3** (was 11.3.3.c) Adequate availability and continuity of service for SOF operations.

Standard: Requirements for antenna based systems shall be defined and documented. The subsystems installed performance shall meet these requirements. Systems shall provide sufficient link margin and antenna coverage to preclude loss of signal that would impact SOF. Any antenna nulls shall not impact SOF.

Compliance: Analysis, laboratory, open-air, and aircraft testing shall verify installed system performance. Link margins shall be verified through analysis, laboratory, open-air, and aircraft testing. Antenna coverage shall be verified with analysis, laboratory, open-air, and aircraft testing.

DoD/MIL Doc: JSSG-2005: para 3.3.5, 4.3.5

FAA Doc: 14CFR reference 23.1309.

## 12. ELECTRICAL SYSTEM

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Design studies and analyses, including electrical loads analysis
3. Failure modes, effects, and criticality analysis (FMECA)
4. Hazard analyses
5. Functional operations test results
6. Performance test results
7. Installation and operational characteristics
8. Component and system qualifications
9. Flight manual, flight test procedures, and limitations
10. Wiring diagrams, which may include information regarding
    - Wire types, wire sizes and current/voltage carried, wire identification, circuit breaker sizes and part numbers
    - Harness diameters including modified harnesses
    - Connector and accessories part numbers and identification
    - Clamping and part numbers
    - Miscellaneous parts identification and part numbers-nuts, bolts, washers, terminal lugs, environmental splices/shield terminations
11. 3D routing diagrams with several views and pictures
12. Visual assessment of the design implementation and installation
13. Component and system qualifications
14. Installed equipment list
15. Diminishing manufacturing sources plan
16. Obsolete parts plan

CERTIFICATION CRITERIA

(Note: For subsystems that use computer resources, see section 15 for additional specific criteria.)

### 12.1 Electric power generation system.

*Definition: For airborne, shipborne or ground applications, the electric power generating system includes electrical power sources, main power buses, transmission cables, and associated control, regulation and protective devices.*

Standard: Summary Description:

Good design practice and electrical compatibility principles applicable to aircraft electrical power systems are particularly emphasized by/in the associated commercial and DoD/MIL referenced documents listed below. This list should not be considered to be an exclusive list.

Compliance: Summary Description:

Engineering evaluation of systems design. Data may include, but are not necessarily limited to, wiring diagrams (including routing diagrams) and data, installed equipment list/s, E3 test report/s, qualification data (including system, subsystem & parts level), flight manuals, flight test procedures, operational limitations, operational test results, installation & operational characteristics, performance test results, visual assessments, hazard analyses, Failure Modes and Effects Criticality Analysis (FMECA), design criteria, and design data/studies/analyses (including Electrical Loads Analyses).

Comm'l Doc: For guidance/principles regarding aspects of assuring effective and proper electric power generation system design, integration and compatibility:

SAE AS50881

ARINC Report 609

NFPA 70

For electric power quality:

SAE AS1831

DoD/MIL Doc: For guidance/principles regarding aspects of assuring effective and proper electric power generation system design, integration and compatibility:

MIL-E-7016

AFGS-87219

MIL-STD-1683

MIL-STD-7080

MIL-HDBK-299

MIL-HDBK-454

ADS-51-HDBK chapter/section 4-8.6;

MIL-STD-464

For electric power quality:

MIL-STD-704

MIL-HDBK-704

MIL-STD-1399-300

**12.1.1** Verify that sufficient power is available to meet the power requirements during all modes of operation and failure conditions.

Standard: Electrical load demand for each mission requirement is defined both without and with failures. Power supply capacity exceeds load demand for all operating conditions, including transient and probable failure conditions.

Compliance: The Electrical Loads Analysis properly documents the power requirements and conditions anticipated on the aircraft. Qualification, simulator, ground and flight tests verify that adequate power is available for all operating conditions. Failure conditions are analyzed in the Failure Modes and Effects Criticality Analysis (FMECA). Analysis of the architecture verifies sufficient electrical flow paths for normal and abnormal conditions.

DoD/MIL Doc: For guidance/principles relating to assurance of electrical system capacity:

MIL-E-7016

AFGS-87219

JSSG-2009: Appendix C para C.3.4.3.5.2, C.4.4.3.5.2; Appendix H para H.3.4.8.2, H.4.4.8.2;

FAA Doc: 14CFR references: 23.1351; 25.1351.

**12.1.2** Verify that the operation of the electric power generation system and its component parts is safe, including adequate implementation of cooling provisions, status/failure indications, and mechanical/thermal disconnect (as applicable) of generators, converters, inverters, batteries, etc.

Standard: 1. Each installed system is free of hazards in its own operation, in its effects on other parts or components of the aircraft, and in its use and interaction with operating, passenger and servicing personnel.

2. Provisions are included to allow flight crew members to selectively disconnect electrical power sources from the system.

3. Status and failure indications are provided in a clear manner for operating and maintenance personnel.

4. Generator(s) withstand(s) operational parameters, including overload applications for five seconds and five minutes in accordance with MIL-G-21480 (Generator System, 400 Hz Alternating Current, Aircraft, General Specification for) Paragraph 3.4.8.2, or equivalent applicable specification/s for the type/s of equipment/s being utilized.

5. Means are provided for electro-mechanical/thermal disconnect of generators under all stressing conditions.

Compliance: 1. FMECA verifies that the system is free of hazards in its own operation.

2. Analysis of design documentation verifies proper disconnects are provided.

3. Performance of the status/failure indications are verified by analysis, test and demonstration.

4. The generator(s) capability is(are) verified by tests with no degradation in performance.

5. Provisions for electro-mechanical/thermal disconnect are verified by test.

DoD/MIL Doc: For guidance/principles regarding design and operation of safe electrical generation systems:

AFGS-87219

MIL-G-21480

MIL-HDBK-454

MIL-STD-464

ADS-51-HDBK Chapter/Section 8-7;

JSSG-2009: Appendix H para H.3.4.8, H.4.4.8, H.3.4.8.4, H.4.4.8.4;

FAA Doc: 14CFR references: 23.1351-23.1367, 25.1351-25.1363.

**12.1.3** Verify that operation of the integrated electrical power system for normal and emergency modes is safe. This includes use of actual or simulated drives and loads, all flight and control configurations, transition between modes, bus switching, load shedding, fault condition operation (detection, clearing, and reconfiguration), and assurance that no single fault affects more than one power source.

Standard: Proper function of electric power sources is maintained whether connected in combination or independently. No malfunction or failure of any electric power source or bus impairs the ability of any remaining source or bus to supply circuits essential for safe operation. Load

management, fault detection/protection and bus switching arrangements maintain safe delivery of electric power.

Compliance: Operation of the integrated system during normal and emergency modes is verified with analysis of the engineering design, Electrical Loads Analysis, and FMECA. Proper functioning of the integrated system is verified by system level tests including on-aircraft testing using documented test procedures for checkout.

DoD/MIL Doc: For guidance/principles regarding/affecting design and operation of safe integrated electrical systems:

AFGS-87219

MIL-STD-464

MIL-E-7016

ADS-51-HDBK Chapter/Section 8-7);

JSSG-2009: Appendix H para H.3.4.8, H.4.4.8, H.3.4.8.4, H.4.4.8.4, H.3.4.8.5, H.4.4.8.5;

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363.

**12.1.4** Verify that required power quality is maintained for all operating conditions and load combinations.

Standard: The electrical power system provides the required electric power quality (in accordance with MIL-STD-704, Aircraft Electric Power Characteristics) to each load circuit and load combination under all operating conditions. Operation of other aircraft systems does not degrade power quality below minimum acceptable levels.

Compliance: Component qualification and aircraft system level tests verify that power quality levels are maintained for all electrically powered aircraft systems operating under all operating conditions and load combinations.

Comm'l Doc: SAE AS1831 for guidance/principles regarding/affecting design and operation of electrical systems to provide compatible and predictable electric power quality.

DoD/MIL Doc: For guidance/principles regarding/affecting design and operation of electrical systems to provide compatible and predictable electric power quality:

AFGS-87219

MIL-STD-464

MIL-STD-704

MIL-HDBK-704

MIL-STD-1399-300

ADS-51-HDBK chapter/section 7

JSSG-2009: Appendix H para H.3.4.8.1, H.4.4.8.1

MIL-HDBK-704 for test methods and procedures for verification of power quality.

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363

**12.1.5** Verify that the independent, uninterruptable power sources, including power control panels, are available to satisfy requirements of essential redundancy for flight-critical functions after failure of the primary power system and there is no single-point failure (including circuit boards) anywhere in the power system.

Standard: Provision of uninterruptible power is assured for flight-critical functions and all other essential loads.

Compliance: Engineering evaluation of systems design, evaluation of Electrical Loads Analysis, and systems level tests verify that electric power is reliably delivered to essential systems and equipment under both normal and adverse operating conditions. Evaluation of FMECA shows that single point failures are precluded by the system design.

DoD/MIL Doc: For guidance/principles regarding/affecting design and operation of electrical systems for uninterruptible electric power:

AFGS-87219

MIL-E-7016

NAVSEA TM-S9310-AQ-SAF-010

JSSG-2009: Appendix H para H.3.4.8, H.4.4.8.

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363

**12.1.6** Verify that, if batteries are employed for SOF backup power, adequate charging methods and checks are provided and installation provisions for all batteries are safe.

Standard: 1. Safe battery cell temperatures and pressures are maintained during any probable charging and discharging conditions, and under the most adverse cooling conditions likely to occur in service.

2. No explosive or toxic gases emitted by any battery in normal operation, or as the result of any probable malfunction in the battery subsystem, accumulate in hazardous quantities within the aircraft.

3. Any corrosive fluids or gases which escape from the battery do not damage surrounding structures or adjacent essential equipment.

4. Each battery installation has provisions to prevent any hazardous effect on structure or essential systems caused by the maximum amount of heat the battery can generate during a short circuit of the battery or of its individual cells.

5. Battery charging systems are designed to automatically control the charging rate of the battery in order to prevent overheating.

6. Nickel cadmium battery installations, including charging systems, are designed for safe operation.

7. Lithium Battery (Both rechargeable and non-rechargeable) installations are defined in NAVSEA TM-S9310-AQ-SAF-010.

Compliance: 1. Bench and aircraft level testing verifies battery cell temperatures and pressures.

2. Analysis and test verify that means exist to remove or safely contain any gases.

3. Analysis, test and inspection verify that means exist to contain any fluids.

4. Analysis and test verify that the design precludes damage from possible battery overheating.

5. Analysis and subsystem tests verify proper operation of battery equipment/charger(s).

6. Analysis, test and inspection verify proper operation of battery equipment/charger(s).

7. Analysis and test verify safe application of the lithium batteries in every application.

DoD/MIL Doc: For guidance/principles regarding/affecting the integrated design and operation of battery subsystems within aircraft electrical systems:

AFGS-87219

NAVSEA TM-S9310-AQ-SAF-010

JSSG-2009: Appendix H para H.6.4.2

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363.

**12.1.7** Verify that emergency backup electrical power systems provide required power for flight conditions associated with the mission profiles of the platform and for malfunction recovery procedures.

Standard: In the event of a complete loss of the primary electrical power generating system, battery capability exists for providing thirty minutes (or more, if so specified) of electric power to those loads which are essential to continued safe flight and landing. This time period includes the time required for pilot recognition and corrective load shedding action.

Compliance: Analysis of Electrical Loads Analysis substantiates the ability of the backup system components to power required equipment and systems. System tests are successfully performed, including battery tests under actual load conditions using a non-new, nominally aged battery.

DoD/MIL Doc: For guidance/principles regarding/affecting the integrated design and operation of backup power within aircraft electrical systems:

AFGS-87219

MIL-E-7016

JSSG-2009: Appendix H para H.3.4.8, H.4.4.8, H.3.4.8.5, H.4.4.8.5

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363.

**12.1.8** Verify that any subsystem limitations are defined and included in the appropriate manuals.

Standard: Self explanatory

Compliance: Component/subsystem/system level test, FMECA and Electrical Loads Analysis define limitations. Technical Orders and Flight Manuals describe limitations.

DoD/MIL Doc: For guidance/principles affecting/providing awareness of limitations of aircraft electrical systems:

MIL-E-7016

JSSG-2009: Appendix H para H.3.4.8, H.4.4.8

FAA Doc: 14CFR references: 23.1301, 23.1309; 25.1301, 25.1309.

**12.1.9** Verify that suitable normal and emergency operating procedures are included in the flight manual.

Standard: Self explanatory

Compliance: Inspection verifies that the FMECA defines abnormal modes and that the appropriate procedures are included in the flight manuals. Engineering and operational personnel demonstrations verify suitability of procedures. Tests using operating procedures are completed successfully. Technical Orders comply with operating criteria.

DoD/MIL Doc: JSSG-2009: Appendix H para H.3.4.8, H.4.4.8 for guidance/principles regarding/providing awareness of operating characteristics and procedures for aircraft electrical systems.

FAA Doc: 14CFR references: 23.1301, 23.1309; 25.1301, 25.1309.

**12.1.10** Verify that the system powers up in a safe state and, upon loss of power or power transient/fluctuation, the system remains in a known safe state or reverts to a known safe state.

Standard: Self-explanatory.

Compliance: Analysis of design and inspection of FMECA verify the system will operate properly. System level tests performed under normal and adverse conditions verify proper system response.

DoD/MIL Doc: For guidance/principles regarding design with knowledge of the states of aircraft electrical systems:

AFGS-87219

MIL-STD-464

JSSG-2009: Appendix H para 3.4.8.4, 3.4.8.5.

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363, 25.1309, 25.1529.

## 12.2 Electrical wiring system, including power distribution.

This element involves all wiring and wiring components (connectors, circuit breakers, etc.) throughout the air vehicle; and for UAVs/ROAs, the control station safety of flight-related wiring system.

Standard: Good design practice; fundamental requirements & guidance of basic practice for electrical wiring systems are outlined in SAE AS50881 (Wiring, Aerospace Vehicle) or its predecessor, MIL-W-5088 (same title). MIL-STD-464 (Electromagnetic Environmental Effects Requirements for Systems) (sections 5.10 & 5.11) contains requirements for electrical bonding and grounding. NFPA 70 (National Electrical Code) may be applicable for ground applications & systems/subsystems. Other specification/s may apply for shipboard applications. The preceding should not be considered to be an exclusive list.

Compliance: Summary Description:

Engineering evaluation of systems design. Data may include, but are not necessarily limited to, wiring diagrams (including routing diagrams) and data, installed equipment list/s, E3 test report/s, qualification data (including system, subsystem & parts level), flight manuals, flight test procedures, operational limitations, operational test results, installation & operational characteristics, performance test results, visual assessments, hazard analyses, FMECA, design criteria, and design data/studies/analyses (including Electrical Loads Analyses).

Comm'l Doc: For guidance/principles regarding design of aircraft electrical wiring systems:

ARINC Report 609

SAE AS50881

SAE ARP1870

NFPA 70

DoD/MIL Doc: For guidance/principles regarding design of aircraft electrical wiring systems:

AFGS-87219

MIL-HDBK-419

MIL-STD-1310

MIL-STD-1683

MIL-STD-7080

MIL-HDBK-299

MIL-HDBK-454

MIL-STD-464

**12.2.1** Verify that appropriate electrical wiring (conductor material and coating and insulation system), electrical system components, and support devices in the design are suitable for the physical environment in each area on the air vehicle. Verify that electrical wiring system installation is safe regarding shock hazard protection for personnel.

Standard: Electrical wiring, electrical system components, and support devices comply with physical environment and bonding/grounding requirements of SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection of engineering drawings and aircraft installation verifies compliance with bonding and grounding requirements. Component and wiring qualification testing verifies compliance with physical environments and bonding requirements.

Comm'l Doc: For guidance/principles regarding design and selection of aircraft electrical system components:

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles regarding design and selection of aircraft electrical system components:

MIL-HDBK-299

MIL-HDBK-454

MIL-STD-1683

MIL-STD-7080

JSSG-2009: Appendix H para H.6.4.1;

FAA Doc: 14CFR references: 23.1365; 25.1353.

**12.2.2** Verify that wiring is sized properly for the required current handling capability and voltage drop.

Standard: Wire sizes comply with requirements of SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Analysis of the design verifies that wire sizing is sufficient for its associated voltage and current.

Comm'l Doc: For guidance/principles regarding proper selection/sizing of aircraft electrical system wiring components:

SAE AS50881

NFPA 70

DoD/MIL Doc: JSSG-2009: Appendix H para H.6.4.1 for guidance/principles regarding proper selection/sizing of aircraft electrical system wiring components:

FAA Doc: 14CFR references: 23.1365; 25.1353.

**12.2.3** Verify that proper circuit protection is provided for wiring associated with power distribution throughout its entire run, including circuits contained in or exiting from any electronic enclosures performing intermediate power switching or distribution functions.

Standard: Circuit protection complies with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents and assembled product verifies proper circuit protection.

Comm'l Doc: For guidance/principles regarding design and selection of aircraft wiring protection:

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles regarding design and selection of aircraft wiring protection:

MIL-HDBK-454

MIL-STD-7080

JSSG-2009: Appendix H para H.3.4.8.5, H.4.4.8.5;

FAA Doc: 14CFR references: 23.1357; 25.1357.

**12.2.4** Verify that redundant circuits provided for safety are sufficiently isolated.

Standard: Redundant circuits are isolated in compliance with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies sufficient isolation of redundant circuits.

Comm'l Doc: For guidance/principles regarding provision of isolation for aircraft electrical circuits:

SAE AS50881

NFPA 70

DoD/MIL Doc: JSSG-2009: Appendix H para H.6.4.1 for guidance/principles regarding provision of isolation for aircraft electrical circuits:

FAA Doc: 14CFR references: 23.1301, 23.1309; 25.1301, 25.1309.

**12.2.5** Verify that design precludes single-point failures related to wiring when redundant functions are integrated within an electronics enclosure.

Standard: Design complies with good engineering practice to avoid single point failures, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies the absence of single point failures.

Comm'l Doc: For guidance/principles relating to design of equipment to minimize single point failures in redundant circuits:

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles relating to design of equipment to minimize single point failures in redundant circuits:

MIL-HDBK-454, Guideline 69;

JSSG-2009: Appendix H para H.6.4.1, 6.1;

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351-23.1367; 25.1301, 25.1309, 25.1351-25.1363, 25.1529;

SFAR No. 88--Fuel Tank System Fault Tolerance Evaluation Requirements.

**12.2.6** Verify that the design of the wiring system installation, including connectors, is adequate for all planned operating conditions.

Standard: Wiring system installation complies with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies wiring system is appropriate for all operating conditions.

Comm'l Doc: For guidance/principles regarding good engineering design of wiring system installations:

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles regarding good engineering design of wiring system installations:

JSSG-2009: para 3.3, 3.3.4; Appendix E para E.4.4.5.1.3, E.3.4.5.1.11, E.4.4.5.1.11, E.3.4.5.8.7, E.4.4.5.8.7, E.3.4.5.8.12, E.4.4.5.8.12; Appendix G para G.3.4.7.2, G.3.4.7.6, G.4.4.7.6; Appendix H para H.6.4.1, 6.1;

FAA Doc: 14CFR references: 23.1301, 23.1309, 23.1351-23.1367; 25.1301, 25.1309, 25.1351-25.1363, 25.1529;

SFAR No. 88--Fuel Tank System Fault Tolerance Evaluation Requirements;

AC 43.13-1B CHG 1 - Acceptable Methods, Techniques and Procedures - Aircraft Inspection and Repair.

**12.2.6.1** Verify that wiring in areas containing explosive vapors is protected to prevent potential ignition sources, including issues with aging and deterioration of the wiring.

Standard: Wiring in explosive vapor areas is protected in compliance with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies protection and suitability of the wiring system. Inerting may assist in providing additional protection.

Comm'l Doc: For guidance/principles regarding wiring design principles/practice for prevention of ignition sources:

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles regarding wiring design principles/practice for prevention of ignition sources:

JSSG-2009: para 3.3, 3.3.4; Appendix E para E.4.4.5.1.3, E.3.4.5.1.11, E.4.4.5.1.11, E.3.4.5.8.7, E.4.4.5.8.7, E.3.4.5.8.12, E4.4.5.8.12; Appendix G para G.3.4.7.2, G.3.4.7.6, G.4.4.7.6; Appendix H para H.6.1;

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363, 25.1309, 25.1529;

SFAR No. 88--Fuel Tank System Fault Tolerance Evaluation Requirements.

**12.2.6.2** Verify that failure (either open circuit fault or shorted/crossed-circuits fault) within a wiring harness that includes safety-critical wiring does not cause loss of, or unacceptable degradation to, any safety-critical functions.

Standard: Wiring harnesses comply with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies a failure within the wiring harness does not cause loss or degradation of safety critical functions.

Comm'l Doc: For guidance/principles leading toward good design practice and minimization of loss of safety-critical functions:

SAE AS50881

NFPA 70

DoD/MIL Doc: JSSG-2009: Appendix H para H.6.1 for guidance/principles leading toward good design practice and minimization of loss of safety-critical functions:

FAA Doc: 14CFR references: 23.1351-23.1367; 25.1351-25.1363, 25.1309, 25.1529;

SFAR No. 88--Fuel Tank System Fault Tolerance Evaluation Requirements.

**12.2.6.3** Verify that the wiring design and installation procedures maintain positive separation of wiring from all fluid or gas carrying lines and flight controls (taking into account movement caused by dynamic G loading, thermal effects and vibration).

Standard: Wire installation complies with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies that positive wiring separation is maintained.

Comm'l Doc: For guidance/principles regarding the fundamentals of sound design for effective separation of wiring from other subsystem components:

SAE AS50881

NFPA 70

DoD/MIL Doc: JSSG-2009: para 3.3.8; Appendix B para B.3.4.2.1.17; Appendix H para H.6.4.1; Appendix M para M.6.4.1 for guidance/principles regarding the fundamentals of sound design for effective separation of wiring from other subsystem components

**12.2.6.4** Verify that the routing design and installation procedures are such that the installation of wiring is free from chafing conditions.

Standard: Wire installation complies with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled product verifies that no chafing conditions exist.

Comm'l Doc: For guidance/principles regarding the prevention of wire/cable/harness chafing:

SAE AS50881

NFPA 70

DoD/MIL Doc: JSSG-2009: para 3.3.8; Appendix A para A.3.4.1.5.8.1; Appendix B para B.3.4.2.1.17; Appendix H para H.6.4.1; Appendix L para L.3.4.12; Appendix M para M.6.4.1 for guidance/principles regarding the prevention of wire/cable/harness chafing:

**12.2.6.5** Verify that wiring design provides primary and secondary support for the wiring throughout the installation.

Standard: Wiring support complies with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including drawings, documents, FMECA and assembled

product verifies proper support of wiring.

Comm'l Doc: For guidance/principles regarding the provision of proper support for wiring:

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles regarding the provision of proper support for wiring:

JSSG-2001: para 4.3.10.1.1;

JSSG-2009: para 3.2.6, 3.2.9.2; Appendix H para H.6.4.1, H.6.4.2.

**12.2.6.6** Verify that maintainability is a factor in the design and installation procedures for wiring and components.

Standard: Maintainability characteristics of wiring installation comply with good design practice, as defined in SAE AS50881 (Wiring, Aerospace Vehicle) for aircraft and NFPA 70 (National Electrical Code) for ground stations.

Compliance: Inspection and analysis of design, including processes, drawings, documents, FMECA and assembled product verifies that wiring installation is maintainable.

Comm'l Doc: For guidance/principles leading toward maintainable design(s):

SAE AS50881

NFPA 70

DoD/MIL Doc: For guidance/principles leading toward maintainable design(s):

JSSG-2001: para 3.1.5, 4.1.5, 3.3.10.2.2, 4.1.8.2.5.1, 4.1.8.2.5.2, 4.4.8;

JSSG-2009: Appendix H para 6.4.1.

**12.2.6.7** Verify that all equipment and equipment racks are designed for proper electrical bonding.

Standard: Bonding complies with standards as defined in MIL-STD-464 (Electromagnetic Environmental Effects Requirements for Systems), Sections 5.10 and 5.11 inclusive.

Compliance: Tests, analyses & inspections verify proper bonding. Documentation establishes appropriate bonding values to be maintained throughout system life, via drawings, specifications, maintenance manuals, etc.

Comm'l Doc: SAE ARP1870 for guidance/principles regarding the provision of proper electrical bonding

DoD/MIL Doc: For guidance/principles regarding the provision of proper electrical bonding:

MIL-HDBK-419

MIL-HDBK-454

MIL-STD-464 sections A5.10 and A5.11;

MIL-STD-1310

JSSG-2001: para 3.2.1, 4.2.1, 3.3.10.1.1, 4.3.10.1.1;

JSSG-2009: para 3.3, 3.3.4; Appendix E para E.4.4.5.1.3, E.3.4.5.1.11, E.4.4.5.1.11, E.3.4.5.8.7, E.4.4.5.8.7, E.3.4.5.8.12, E.4.4.5.8.12; Appendix G para G.3.4.7.2, G.3.4.7.6, G.4.4.7.6.

## 13. ELECTROMAGNETIC ENVIRONMENTAL EFFECTS ($E^3$)

TYPICAL CERTIFICATION SOURCE DATA

1. $E^3$ design criteria, analysis, and tradeoff studies
2. Results of $E^3$ modeling and simulation
3. $E^3$ failure modes, and effects, and criticality analyses
4. Electromagnetic hazard analyses
5. Equipment/subsystem $E^3$ qualification reports
6. Details of installation and operation
7. System $E^3$ qualification tests
8. Flight and operational manuals, and flight test procedures, and limitations
9. Safety-of-flight (SOF) certifications
10. Authorized radio frequency allocations

CERTIFICATION CRITERIA

DoD/MIL Doc: MIL-STD-464

### 13.1 Component/subsystem $E^3$ qualification.

**13.1.1** Verify that all flight-critical equipment complies with all electromagnetic environmental effects requirements, including lightning susceptibility, that are appropriate for the system application; or verify that appropriate flight restrictions are imposed.

Standard: All equipment and subsystems comply with the conducted and radiated emissions and conducted and radiated susceptibility requirements of MIL-STD-461, section 5, MIL-STD-464 section 5.4 or equivalent requirements from industry/commercial standards such as RTCA DO-160, sections 18 through 22 and SAE ARP5412, section 4.

Compliance: Verification methods of MIL-STD-461, section 5 or equivalent verification methods from industry/commercial standards such as RTCA DO-160, sections 18 through 22 demonstrate that the equipment complies with the emissions and susceptibility requirements.

Comm'l Doc: RTCA DO-160 sections 18 through 22;

SAE ARP5412, section 4.

DoD/MIL Doc: MIL-STD-461, section 5;

MIL-STD-464, section 5.4.

**13.1.2** Verify that all non-flight-critical equipment complies with the conducted and radiated emissions and susceptibility requirements (including external electromagnetic environments), and does not impact the safe operation of flight-critical equipment.

Standard: All equipment and subsystems comply with the conducted and radiated emissions and conducted and radiated susceptibility requirements of MIL-STD-461, section 5 or equivalent requirements from industry/commercial standards such as RTCA DO-160, sections 18 through 22.

Compliance: Verification methods of MIL-STD-461, section 5 or equivalent verification methods from industry/commercial standards such as RTCA DO-160, sections 20 and 21demonstrate that the equipment complies with the emissions and susceptibility requirements.

Comm'l Doc: RTCA DO-160 sections 18 through 22.

DoD/MIL Doc: MIL-STD-461, section 5.

**13.1.3** Verify that all non-flight critical equipment complies with transient susceptibility requirements that include consideration of indirect effects levels derived from the external lightning environment, and does not impact the safe operation of flight-critical equipment.

Standard: The indirect effect requirements are defined based on the lightning environment in MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP 5412, section 4. While in flight, the equipment withstands the indirect effects of lightning (current and voltage transients).

Compliance: Analysis defines the indirect effects on the equipment. The test levels are derived from the aircraft level analysis and the test waveforms are defined in MIL-STD-464, section 5.4 or an equivalent industry/commercial standard such as RTC DO-160, section 22.

Comm'l Doc: RTCA DO-160, section 22;

SAE ARP 5412, section 4.

DoD/MIL Doc: MIL-STD-464, section 5.4.

## 13.2 System-level $E^3$ qualification.

**13.2.1** Verify that all equipment and subsystems exhibit mutual electromagnetic compatibility.

Standard: Intra-system electromagnetic compatibility (EMC) is required at the aircraft level to demonstrate that equipment and subsystems are capable of providing safety of flight in conjunction with other equipment and subsystems which are required to operate concurrently.

Compliance: Aircraft system level EMC test and analysis of the test results.

DoD/MIL Doc: MIL-STD-464, section 5.2.

**13.2.2** Verify that antenna-connected equipment is compatible with one another and it is not degraded beyond its operational requirements, by any other on-board and off-board equipment to a level that would impact safety.

Standard: Intra-system electromagnetic compatibility (EMC) is required at the aircraft level to demonstrate that equipment and subsystems are capable of providing safety of flight in conjunction with other equipment and subsystems which are required to operate concurrently.

Compliance: Aircraft system level EMC test and analysis of the test results.

DoD/MIL Doc: MIL-STD-464, section 5.2.

**13.2.3** Verify that the system is electromagnetically compatible with its intended external radio frequency (RF) electromagnetic environment.

Standard: Aircraft equipment can safely operate in the external RF electromagnetic environment defined in MIL-STD-464, section 5.3 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7.

Compliance: 1. Aircraft high level pulse testing and analysis of the test results, or

2. Aircraft shielding effectiveness testing and analysis of the test results, or

3. A combination of aircraft high level pulse and shielding effectiveness testing and analysis of the test results.

Comm'l Doc: SAE ARP5583, sections 5 and 7.

DoD/MIL Doc: MIL-STD-464, section 5.3.

**13.2.4** Verify that the system has met all requirements for lightning, either direct (physical) or indirect (electromagnetic) effects and that any potential for ignition of fuel vapors are eliminated.

Standard: While in flight, the aircraft can withstand the direct effects of lightning when exposed to the external lightning environment of MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4. Also while in flight, the aircraft can withstand the indirect effects of lightning which are current and voltage transients coupled to the wiring and aircraft equipment. The indirect effect requirements are determined by an aircraft level analysis when the aircraft is exposed to the external lightning environment defined in MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4. The requirement for eliminating the potential for ignition of fuel vapors is achieved by eliminating possible ignition sources and reducing flammability when the aircraft is exposed to the external lightning environment of MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4. The elimination of ignition sources can be accomplished by:

1. Inerting fuel tanks or,

2. If tanks are not inerted:

a. Provide electrical insulation for the tank's fasteners.

b. Electrically bonding of the lines and wires penetrating the fuel tanks to the dry part of the fuel tank structure or by interrupting the low electrical conductivity of these lines inside the fuel tanks using line isolators.

Compliance: Lightning Direct Effects:

1. Coupon testing to demonstrate no puncture of aircraft skin/structure. This includes full scale testing of radomes and canopies.

2. Fuel tanks:

a. If fuel tanks are not inerted, electrical bonding measurements of lines and wiring penetrating fuel tanks, or via validated electrical bonding process specifications.

b. If fuel tanks are inerted, verify by measuring the oxygen content of the tanks.

Lightning Indirect Effects:

1. Aircraft system level analysis.

2. Aircraft test using high level pulse or low level continuous wave (CW) techniques and analysis of the test results.

Comm'l Doc: SAE ARP5412, section 4.

DoD/MIL Doc: MIL-STD-464, section 5.4

**13.2.5** Verify that the system meets the requirements for electromagnetic pulse (EMP) protection, if applicable.

Standard: While in flight, the aircraft can withstand the effects of the electromagnetic pulse (EMP) when exposed to the classified environment of MIL-STD-2169.

Compliance: Aircraft level EMP coupling analysis or aircraft level testing and analysis of the test results.

DoD/MIL Doc: MIL-STD-464,section 5.5;

MIL-STD-2169.

**13.2.6** Verify that the system is able to control and dissipate the build-up of electrostatic charges caused by particle impingement, fluid flow, air flow, and other tribolectric charge-generating mechanisms to avoid ordnance hazards, personnel shock hazards and to control p-static interference or damage to electronics.

Standard: Control of electrostatic charging ensures that all structural surfaces are at least mildly conductive, that all components are electrically bonded, and that an electric path to earth ground is provided. An 1 ohm static bond is the accepted industry standard.

Compliance: Verification is accomplished by bonding measurements or by validated bonding assembling/process specifications. A 1 ohm is typically specified, but for must applications resistive paths of up to 10E6 ohms are sufficient to dissipate the charge buildup.

DoD/MIL Doc: MIL-STD-464, section 5.7.

**13.2.7** Verify that sources of electromagnetic radiation pose no hazard to personnel (HERP), fuel (HERF), and ordnance (HERO), and that the appropriate manuals include safe criteria regarding distance from on-board and off-board transmitters to personnel and fuel sources.

Standard: 1. HERP: The criteria to protect personnel from the electromagnetic radiation from aircraft emitters is defined in DoDI 6055.11

2. HERF: Fuel can not be inadvertently ignited by radiated electromagnetic fields from aircraft emitters or by the external RF electromagnetic environment defined in MIL-STD-464, section 5.3 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7.

3. HERO: Electrically initiated devices (EID's) used in ordnance and other parts and equipment of the aircraft can not be inadvertently actuated during or experience performance degraded characteristics after exposure to the radiated electromagnetic fields from aircraft emitters or by the external RF electromagnetic environment defined in MIL-STD-464, section 5.3 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7, and the effects of the lightning environment defined in MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4. EID's are required to demonstrate a 16.5 dB of safety margin no fire stimulus to the above external environments for safety assurances and a 6 dB margin for EID's where are consequences other than safety.

Compliance: 1. HERP: Verification is accomplished by measurements of the RF generated by the on-board emitters and analysis based on the methodology of Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers, DoDI 6055.11. The following publications also provide guidance and methodology for assessing RF Hazards: (Air Force) Electromagnetic Radiation Hazard TO 31Z-10-4; (Navy) Electromagnetic Radiation Hazard NAVSEA OP 3565; and (Army) Control of Hazards to Health from Microwave and Radio Frequency Radiation and Ultrasound TB MED 523.

2. HERF: Verification is accomplished by inspection and analysis based on the methodology of TO 31Z-104 and NAVSEA OP 3565 for calculating hazard distance from RF emitters.

3. HERO: Verification is accomplished by testing of the EID's and associated circuitry to the external RF electromagnetic environment defined in MIL-STD-464, section 5.3 or an equivalent RF electromagnetic environment such as the one defined in SAE ARP5583 sections 5 and 7. Also, verification is accomplished by testing of the EID's and associated circuitry to the effects of the lightning environment defined in MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4.

Comm'l Doc: SAE ARP5583, sections 5 and 7;

SAE ARP5412, section 4.

DoD/MIL Doc: MIL-STD-464, sections 5.3 and 5.4;

DoDI 6055.11, Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers;

TO 31Z-10-4, Electromagnetic Radiation Hazard;

NAVSEA OP 3565, Electromagnetic Radiation Hazard;

TB MED 523, Control of Hazards to Health from Microwave and Radio Frequency Radiation and Ultrasound .

**13.2.8** Verify that the system electrical bonding is adequate to ensure safe system operation.

Standard: Electrical bonding is required for the control of the electromagnetic effects environments, and it is specified in accordance with the characteristics of the materials used. The aircraft bonding requirements are defined in MIL-STD-464, section 5.10

Compliance: Verification is accomplished by bonding measurements or by validated bonding assembling/process specifications.

DoD/MIL Doc: MIL-STD-464, section 5.10

**13.2.9** Verify that the required safety margins for electroexplosive devices are met.

Standard: Electrically initiated devices (EID's) used in ordnance and other parts and equipment of the aircraft can not be inadvertently actuated during or experience performance degraded characteristics after exposure to the radiated electromagnetic fields from aircraft emitters or by the external RF electromagnetic environment defined in MIL-STD-464, section 5.3 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7, and the effects of the lightning environment defined in MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4. EID's are required to demonstrate a 16.5 dB of safety margin no fire stimulus to the above external environments for safety assurances and a 6 dB margin for EID's where are consequences other than safety.

Compliance: Verification is accomplished by testing of the EID's and associated circuitry to the external RF electromagnetic environment defined in MIL-STD-464, section 5.3 or an equivalent RF electromagnetic environment such as the one defined in SAE ARP5583 sections 5 and 7. Also, verification is accomplished by testing of the EID's and associated circuitry to the effects of the lightning environment defined in MIL-STD-464, section 5.4 or an equivalent environment such as in SAE ARP5412, section 4.

Comm'l Doc: SAE ARP5583, sections 5 and 7;

SAE ARP5412, section 4.

DoD/MIL Doc: MIL-STD-464, sections 5.3 and 5.4

**13.2.10** Verify that the system meets the electromagnetic spectrum licensing requirements in accordance with DoD, national, and international regulations and has received electromagnetic spectrum certification.

Standard: Spectrum certification denotes the supportability of an electronic system or equipment for operation in a designated frequency band to avoid interference with other system or equipment and for compliance with the national and international spectrum certification regulations cited in DoDD 4650.1, Management and Use of the Radio Frequency Spectrum.

Compliance: Submittal and approval of DD Form 1494, Application for Frequency Allocation, which contains the information on the operating characteristics of the equipment.

DoD/MIL Doc: DoDD 4650.1, Management and Use of the Radio Frequency Spectrum.

DD Form 1494, Application for Frequency Allocation.

## 14. SYSTEM SAFETY

TYPICAL CERTIFICATION SOURCE DATA

1. System safety program plan
2. Preliminary hazard analyses
3. Subsystem hazard analyses (fault hazard analyses or fault tree analyses)
4. System hazard analyses (including hardware, software and human system integration causal factors)
5. Operating and support hazard analyses
6. Test hazard analyses
7. Occupational health hazard assessment
8. Specialized analyses such as a sneak circuit analyses and software hazard analyses
9. Type T-2 modification documentation (for correction of safety deficiencies)
10. Component/system test results (waivers/deviations and equipment conditional usage documents)
11. Minutes of system safety group meetings (open items)
12. Minutes of system safety program reviews (open items)
13. Engineering change proposals (safety related)
14. Hazard identification, evaluation and correction-tracking system files
15. Safety assessment reports
16. SOF test plans and test results
17. Test temporary engineering orders (not previously included in any safety analyses)
18. Failure modes, effects, and criticality analysis (FMECA)
19. Hazard risk index
20. MIL-STD-882, System Safety Program Requirements
21. Test review board reports
22. Safety review board reports
23. Flight readiness review reports
24. Safety requirements traceability matrix (both hardware and software)

CERTIFICATION CRITERIA

### 14.1 System safety program.

**14.1.1** Verify that an effective system safety program is implemented that mitigates risks/hazards attributed to hardware, software, and human system integration and that the safety program documents and tracks the risks/hazards of the design/modification.

Standard: The system safety program meets the eight minimum mandatory requirements of MIL-STD-882D, para 4, and the system safety requirements are incorporated into the program functional baselines. The Programmatic Environmental Safety and Health Evaluation (PESHE) includes all hazards identified for the program.

Compliance: Effectiveness of the system safety program is verified by inspection of program documentation for inclusion of system safety requirements in program functional baselines.

Inclusion of system safety hazards in PESHE is verified by inspection.

DoD/MIL Doc: MIL-STD-882D: para 1.1, 4.1, 4.2, 4.3, 4.4, 4.5;

DoDI 5000.2 Enclosure 3 Table E3.T1, for details of PESHE content and relation to system safety.

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.1.1.1** Verify that the system safety program incorporates system safety into all aspects of systems engineering.

Standard: System safety program requirements are incorporated into the functional baseline and operating procedures. System safety requirements, analyses, time lines and other milestones are in synchronization with the rest of the program schedules.

Compliance: Incorporation of system safety program requirements into the systems engineering process is verified by inspection of functional baseline documents and operating procedures.

DoD/MIL Doc: MIL-STD-882D: para 4.1

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.1.1.2** Verify that appropriate analysis tasks of MIL-STD-882 are accomplished for all programs, including temporary and permanent modifications.

Standard: Process is in place to analyze all changes or modifications to ensure that they do not have a negative impact on system safety or the mishap risk baseline.

Compliance: Evidence of a change process is verified by inspection of safety risk analyses for each proposed modification, and that impact on the mishap risk baseline has been assessed.

DoD/MIL Doc: MIL-STD-882D: para 4.1, 4.2, 4.3, 4.4, 4.5;

JSSG-2001: section. 3.3.10 discusses mishap risk baselines

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.1.1.3** Verify that hazards/risks are tracked and residual risks documented.

Standard: Processes are in place to establish a closed loop hazard tracking system and to document risk acceptance for safety hazards as defined by Appendix A of MIL-STD-882D.

Compliance: Evidence of the closed loop hazard tracking system and the risk acceptance processes is verified by inspection of safety program documentation.

DoD/MIL Doc: MIL-STD-882D: para 4.1, 4.2, 4.3, 4.4, 4.5

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.1.1.4** Verify that the system safety program addresses the following: (for criteria 14.1.1.4.1 through 14.1.1.4.12)

DoD/MIL Doc: MIL-STD-882D: para 1.1, 4.1, 4.2, 4.3, 4.4, 4.5

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.1.1.4.1** (was 14.1.1.4.a) Flight safety

Standard: No single point failure results in loss of aircraft or system. Safety design deficiencies uncovered during flight mishap investigations or in materiel deficiency reports (MDRs) are assessed, and residual risks identified. Flight mishap rates for system do not exceed threshold limits that are established for program.

Compliance: Evidence of a flight safety process is verified by: review of all hazards associated with single point failures to document their elimination or reduction of risks to an acceptable level; by

inspection of design deficiencies identified in flight safety reports and MDRs to assure they are assessed, and resolution actions are tracked to closure; by analysis that actual flight mishap rates comply with pre-set program threshold limits.

**14.1.1.4.2** (was 14.1.1.4.b) Ground/industrial safety

Standard: Ground/Industrial safety requirements are established for activities at the plant to minimize the risk of Foreign Object Damage (FOD) or undetected damage to the assembled air vehicle and all required support equipment.

Compliance: Evidence of an established FOD prevention program is verified by review of FOD program documents and inspection of reports, or on-site certification by DCMA that an acceptable FOD program exists.

**14.1.1.4.3** (was 14.1.1.4.c) Explosives and ordnance safety; non-nuclear munitions

Standard: Requirements for system safety analyses are established IAW MIL-STD-882D to support weapons testing, certification, and obtainment of explosive hazard classifications.

Compliance: Safety program requirements for explosives and ordnance safety are verified by inspection of system safety program analysis data.

DoD/MIL Doc: DOD Standard 6055.9-STD and DoD TO-11A-1-47

**14.1.1.4.4** (was 14.1.1.4.d) Range safety

Standard: The system safety program is responsive to test range safety requirements and official requests for safety analysis information.

Compliance: System safety program support for range safety is verified by inspection of system safety process documentation.

**14.1.1.4.5** (was 14.1.1.4.e) Nuclear safety

Standard: The nuclear safety program adheres to the four key DoD Nuclear Weapon System Safety design Standards for hardware and software.

Compliance: Evidence that a process is in place to incorporate the four key nuclear safety design requirements into the safety analyses, program functional baselines and other design requirements is verified by inspection of program safety documents and functional baselines.

DoD/MIL Doc: DoD Directive 3150.2, 23 Dec 1996, para 4.1 lists the four key design standards.

**14.1.1.4.6** (was 14.1.1.4.f) Radiation/laser safety

Standard: Key design requirements for radiation/LASER Safety are established including: Protective Housing; Safety Interlocks; Remote Interlock Connector; Key Control/ Arming Device; Emission Indicator; Beam Stop/Attenuator; Location of Controls; Viewing Optics; Scanning Safeguard; Manual Reset; Labeling Requirements; Laser Classification; Hazard Evaluation; Protective Eyewear; Laser Area Control; Informational Requirements

Compliance: Evidence of a process to establish the key safety design requirements for radiation/LASER safety is verified by inspection of safety analyses, design specifications and program functional baselines.

Comm'l Doc: ANSI Z 136.1 for definitions of key laser safety design requirements

DoD/MIL Doc: MIL-STD-1425A

MIL-HDBK-828

**14.1.1.4.7** (was 14.1.1.4.g) Test safety and support

Standard: System safety organization actively participates in test planning and post-test reviews to analyze all test-related hazards and recommended corrective actions to ensure hazard closeout or mitigation. Appropriate system safety requirements criteria are incorporated into test program for validation and verification.

Compliance: System safety support of the test and evaluation process and incorporation of safety requirements criteria are verified by inspection of the system safety program plan, test-related hazard analyses and the Test and Evaluation Master Plan.

**14.1.1.4.8** (was 14.1.1.4.h) Software safety

Standard: N/A, covered under section 14.3 and subparagraphs.

DoD/MIL Doc: Section 14.3 of this document

**14.1.1.4.9** (was 14.1.1.4.i) Materials

Standard: Risks associated with use of new/alternate/substituted materials or material deficiencies do not exceed the hazard baseline set for the program.

Compliance: Evidence of a material safety process is verified by inspection of program safety documentation and safety analyses to assure cumulative risks of identified hazards do not exceed the program's hazard baseline.

**14.1.1.4.10** (was 14.1.1.4.j) Failure modes and effects testing and built-in-test

Standard: System safety participates in all tests/test planning on parts and assemblies that establish failure modes and rates, and conducts safety analyses on all built-in test equipment to assure that integration into a system doesn't induce new or severe hazards.

Compliance: Evidence of the safety process to support FMET and BIT evaluations is verified by inspection of the system safety program documents and the hazard tracking data base.

**14.1.1.4.11** (was 14.1.1.4.k) Fail safe design

Standard: Design ensures system remains inherently safe, or that a single failure will cause system to revert to a state which will not cause a mishap.

Compliance: Evidence that a process is in place to assure that no single point failure results in loss of aircraft or system is verified by inspection of safety analyses and the hazard tracking data base.

**14.1.1.4.12** (was 14.1.1.4.l) Support equipment

Standard: Design related hazards and interfaces of support equipment with the weapon system are included in system safety analyses. Identified safety hazards are resolved or risks reduced to an acceptable level before first test use, or first operational use of the support equipment

Compliance: The process to incorporate design safety requirements for support equipment into functional baselines/safety documents and eliminate or control their associated safety risks is verified by inspection of safety process documentation, safety analyses and review of the closed loop hazard tracking system.

## 14.2 Safety design requirements.

**14.2.1** Verify that a systematic process is employed that provides for hazard identification, hazard control requirement generation and implementation, and residual risk assessment.

Standard: A process is in place to identify and characterize hazards, devise corrective actions, and assess residual risks. A System Safety Group is established to implement the process.

Compliance: Evidence of a hazard identification/control/resolution process is verified by inspection of safety process documentation and review of safety analyses and system safety group procedures.

DoD/MIL Doc: MIL-STD-882D: para 4.1, 4.2, 4.3, 4.4, 4.5, Appendix A

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.2** Verify that the design is free from unacceptable mishap risk.

Standard: Unacceptable risks to personnel or equipment are eliminated or controlled IAW MIL-STD-882.

Compliance: Evidence of a process to eliminate/control hazards with "unacceptable" mishap risk IAW procedures identified in MIL-STD-882D, Section 4, is verified by inspection of the safety hazard tracking database and the residual risk acceptance process.

DoD/MIL Doc: MIL-STD-882D: para 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, Appendix C; Appendix A, A.4.3.3.1.1 shows unacceptable conditions; Table A-IV shows mishap risk categories & acceptance levels

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.3** Verify that no single-point failure unacceptably affects the safety of the system.

Standard: The severity of all hazards associated with single point failures are reduced to an acceptable level or have residual risk accepted IAW MIL-STD-882D. A mishap of catastrophic or critical severity cannot be caused by a single design feature.

Compliance: Evidence that there will be no loss of aircraft or system due to a single point failure is verified by inspection of the safety analyses for single point failures and the relevant data in the closed loop hazard tracking system.

DoD/MIL Doc: MIL-STD-882D: para 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, Appendix C; Appendix A identifies severity levels

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.4** Verify that the design adequately protects the power sources, controls, and critical components of redundant subsystems.

Standard: A safety process is in place to assure power sources, controls, and critical components of redundant subsystems are separated/shielded per the general safety requirements of MIL-STD-882D.

Compliance: Evidence that this process is in place is verified by inspection of safety documentation and program functional baselines.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A.

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.5** Verify that all aspects of human factors are addressed and unacceptable human factors safety issues/risks are resolved in the design process.

Standard: Human factors design requirements are established and the interface with system safety is accomplished IAW MIL-STD-882D.

Compliance: The standard to establish human factors requirements and identify safety issues/risks related to human factors and reduce them to an acceptable level, is verified by inspection of safety documentation, safety analyses and program functional baselines.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A;

MIL-STD-1472 gives the human-factor design requirements

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.6** Verify that the system is produced/manufactured ensuring risk reduction of failures or hazards potentially created by human error during the operation and support of the system.

Standard: System design minimizes risk created by human error in the operation and support of the system.

Compliance: Evidence that a process is in place to reduce the mishap risks associated with human error to acceptable levels per MIL-STD-882 is verified by inspection of safety documents and analyses and review of the closed loop hazard tracking system.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A.

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.7** Verify that the system design is within acceptable risk bounds over worst-case environmental conditions.

Standard: A design safety process is in place to minimize risks due to excessive environmental conditions throughout the complete range of all expected environmental conditions.

Compliance: Evidence that the safety risk minimization process addresses impacts of excessive environmental conditions on the design is verified by review of safety analyses, test reports and environmental/climatic test results.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A;

MIL-STD-810 gives environmental and climatic testing requirements

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.8** Verify that personnel exposure to hazards during the installation process, including hazards due to locations of systems in the air vehicle, are at an acceptable risk level.

Standard: A safety process is in place to prevent errors in assembly, installation, or connections which could result in a safety hazard or mishap for the system.

Compliance: Evidence of a design and procedural safety requirements process is verified by inspection of equipment installation, operation and maintenance processes documentation.

DoD/MIL Doc:MIL-STD-882D: para 4, Appendix A.

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.9** Verify that the system design isolates hazardous substances, components, and operations from other activities, areas, personnel, and incompatible material.

Standard: A safety design process is in place to isolate hazardous substances, components, and operations from other activities, areas, personnel, and incompatible materials.

Compliance: The standard to assure that hazardous substances, components and operations have been identified and corrective measures taken, and/or risks reduced to an acceptable level for the program, is verified by review of safety analyses and program functional baselines.

DoD/MIL Doc:MIL-STD-882D: para 4, Appendix A.

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

**14.2.10** Verify that a system safety change analysis is accomplished on changed or modified equipment or software.

Standard: A process is in place to analyze all changes/modifications to existing systems to ascertain

their impacts on the mishap risk baseline prescribed for the program. Process to assure that changes or other modifications do not: a). create new hazards; b). impact a hazard that had previously been resolved; c) make any existing hazard more severe; d). adversely affect any safety-critical component.

Compliance: Evidence of the process to analyze changes and modifications is verified by review of safety program documentation and hazard tracking databases.

DoD/MIL Doc: Reference sections 14.3.3, 15.3.3.2, 15.3.3.3 of this document

## 14.3 Software safety program.

Note: Software safety is additionally verified through Section 15.3

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A.

DoD/MIL Doc: Joint Software System Safety Committee, "Software System Safety Handbook: A Technical & Managerial Team Approach," Dec 1999

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

### 14.3.1 Verify that a comprehensive software safety program is integrated into the overall system safety program.

Standard: Key software safety issues such as: a.) Software integrity levels are established for the program IAW prescribed industry standards; b.) Safety Critical Functions and their associated Safety Critical Software are identified and analyzed; c.) no single point failure caused by software results in loss of aircraft or system; are addressed as part of the system safety program in the software safety plan.

Compliance: Verify via review of program safety and software documentation that: safety requirements for critical software items have been identified and appropriate testing requirements have been established; and that they are included in the software specification, software development plan, or similar documentation.

Comm'l Doc: DO-178B to establish software integrity levels for commercial aircraft.

DoD/MIL Doc: MIL-STD-882 provides mishap severity categories which can lead to establishment of software integrity levels.

DoD/MIL Doc: Joint Software System Safety Committee, "Software System Safety Handbook: A Technical & Managerial Team Approach," Dec 1999

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

### 14.3.2 Verify the software safety program requires that appropriate software safety-related analyses be performed as part of the software development process. (for criteria 14.3.2.1 through14.3.2.2)

Standard: Accomplish software safety analyses as identified in the system safety program plan or equivalent commercial safety documentation.

Compliance: Review safety analysis process to verify inclusion of the requirement to accomplish software hazard analyses throughout the entire software development and testing process.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A.

DoD/MIL Doc: Joint Software System Safety Committee, "Software System Safety Handbook: A Technical & Managerial Team Approach," Dec 1999

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

#### 14.3.2.1 (was 14.3.2.a) Software safety analyses preparation

Standard: Establish the types and quantities of required software safety analyses and their delivery

schedules in the contract and in the appropriate safety plan

Compliance: Verify by inspection that the delivered safety analyses for the program have a complete systems view, including identification of software hazards, and associated software risks.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A.

DoD/MIL Doc: Joint Software System Safety Committee, "Software System Safety Handbook: A Technical & Managerial Team Approach," Dec 1999

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

### 14.3.2.2 (was 14.3.2.b) Software safety requirements analysis

Standard: The software requirements specification documents are analyzed to assure system safety requirements for software are correctly and properly translated into baseline software requirements.

Compliance: Verify by review of baseline software requirements that system safety requirements for software development, software testing and tracking of software modifications, are correctly and properly identified.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A.

DoD/MIL Doc: Joint Software System Safety Committee, "Software System Safety Handbook: A Technical & Managerial Team Approach," Dec 1999

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

### 14.3.3 Verify that the design/modification software is evaluated to ensure controlled or monitored functions do not initiate hazardous events or mishaps in either the on or off (powered) state.

Standard: The software as designed or modified does not initiate hazardous events in either the on or off (powered) state.

Compliance: Verify by inspection that a system safety assessment process in place which includes evaluation of software and identification of anomalous software control/monitoring behavior.

Comm'l Doc: DO-178B defines software integrity levels for safety critical functions.

DoD/MIL Doc: MIL-STD-882D: para 4, Appendix A;

DoD/MIL Doc: Joint Software System Safety Committee, "Software System Safety Handbook: A Technical & Managerial Team Approach," Dec 1999

FAA Doc: 14CFR references: system safety sections of Parts 23, 25, 27, 29

# 15. COMPUTER RESOURCES

TYPICAL CERTIFICATION SOURCE DATA

1. Computer resources utilization
2. Design review/audits/meeting minutes and action items
3. Software requirements specifications (SRS)
4. Software top-level design documents (STLDD)
5. Software development plans (SDP) and/or software development integrity master plans (SDIMP)
6. Software test plans, procedures, and reports
7. Quality assurance and configuration management plans
8. Master test planning documents and scheduling
9. Software regression testing criteria/procedures (all levels)
10. Software development folders
11. Failure modes, effects, and criticality analysis and testing (FMECA/FMET) or equivalent
12. Hazard analyses (software)
13. Test reports
14, Diminishing manufacturing sources plan
15. Obsolete parts plan

CERTIFICATION CRITERIA

DoD/MIL Doc: In addition to VCMS systems, JSSG-2008 provides useful guidance for all airborne computer resources involved in safety critical processing. Consequently in reading the reference information contained in JSSG-2008 it may be useful to interpret VCMS to mean any aircraft system involved in safety critical processing.

## 15.1 Air vehicle processing architecture.

**15.1.1** Verify that the flight-essential configurations are identified and proper levels of redundancy (hardware and software) exist at the system level to preclude loss of critical processing capabilities.

Standard: Safety critical functions have been identified and their flow through the system determined. All safety critical items in the architecture have been identified based on program safety definitions. Proper levels of redundancy and sufficient cross checks are incorporated in the system architecture to ensure safety critical (flight essential) components accommodate failures while achieving safety/PLOC (Probability of Loss Of Control) and fail-op/fail-safe requirements.

Compliance: Hazard Analyses IAW MIL-STD-882, Safety Critical Function Thread Analysis, system level Failure Modes and Effects Testing and Analysis (FMET&A), and PLOC Analysis verify compliance with fail op/fail safe program requirements. These analyses verify that proper levels of redundancy and sufficient cross checks exist throughout the architecture to mitigate safety risks. The robustness of the architecture design mechanization is verified through extensive FMET (typically several hundred test cases) at all levels.

Comm'l Doc: RTCA DO-178B, RTCA DO-254

DoD/MIL Doc: JSSG-2008: para 3.1.12, 3.3.1;

JSSG-2008 Appendix A: 3.1.7, 3.1.12, 3.3.1 for further guidance concerning redundancy,

system and processing architectures.

MIL-STD 882D, sections 4.2, 4.7, 4.8 for further guidance concerning identification, review and tracking of safety hazards to establish program safety definitions.

JSSG-2008 Appendix A: 3.1.2.1 for establishing safety criticality along with CNS/ATM safety performance references in the ESC developed Generic Performance Matrices (10E-5 to 10E-7 hazard rates depending on flight phase).

FAA Doc: AC 20-115B,

**15.1.2** Verify that all processing elements of the architecture that interface (physically and functionally) with SOF functions are designed to meet SOF requirements.

Standard: Safety critical system architectures employ processing elements designed as safety critical or employ mitigating strategies (e.g., redundancy management, voting schemes, integrity monitors) to address weaknesses resulting from non-safety critical processing elements.

Compliance: Verification is through system integration testing of the entire system mechanization using flight hardware and interfaces. This testing includes a comprehensive set of failure modes effects tests which verify the robustness of the safety critical physical and functional interfaces. All safety critical processing elements of the architecture have been determined from the safety critical function thread analysis, or equivalent, and associated designs meet allocated SOF requirements.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3;

JSSG-2008 Appendix A: para 3.3 Requirement Guidance and Lessons Learned for additional information concerning processing element selection; para 3.1.7.3, 3.1.8, 3.1.11, 3.14.4 and 3.2.2.6 provide guidance for integrating safety critical VCMS systems with non-safety critical processing elements.

FAA Doc: AC 20-115B

**15.1.3** Verify that all hardware and software safety/flight-critical items are identified and their safety critical functions are allocated to components within the architecture.

Standard: All safety critical functions have been allocated to the component level and all safety critical components have been identified.

Compliance: Verification is by inspection of configuration documentation, architecture trade studies and safety analyses which clearly and accurately identifies the flight/safety criticality of all hardware and software elements of the architecture and addresses hardware, software and interface design adequacy.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.1.16;

MIL-STD-882D Appendix A: para A.4.4.2 establishes hardware and software analysis in the hazard identification process.

FAA Doc: AC 20-115B,

**15.1.4** Verify that SOF hardware and software interfaces are clearly defined and documented and that control flow and information flow are established.

Standard: All interfaces which handle data associated with safety critical functions have been identified (baselined and documented) as safety critical. Safety critical interfaces are designed to ensure data/calculation/system-timing dependencies do not impede system performance in any operational mode or degrade architectural safety coverage.

Compliance: Verification methods include inspection of documentation and interface testing. The documentation is checked for completeness in identifying all safety critical interfaces. Testing of these interfaces addresses interface loading and handshaking/protocols for all operational modes to ensure timing/data/calculation/system dependencies do not impede safe system operation.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.7;

JSSG-2008 Appendix A: para 3.1.7.1 provides guidance for identifying subsystem interfaces and ensuring sufficient data communication timing margins; para 3.5.7 discusses the application of integrity processes in the design of system interfaces from both the hardware and software standpoint.

FAA Doc: AC 20-115B,

**15.1.5** Verify that redundancy (hardware and software) is incorporated to satisfy fault tolerant SOF requirements, including probability of loss of control (PLOC) and reliability numbers.

Standard: The system redundancy management/fault tolerance hardware and software design mechanization is compliant with the safety requirements including Probability of Loss of Control. This requires review of redundant elements, voting schemes utilized, Cross Channel Data Links (CCDL) mechanization, high speed data buses, I/O data rates required/utilized, Input/Output Signal Management approach and the overall fault tolerance robustness of the redundancy management system mechanization.

Compliance: Verification methods include analysis and several kinds of testing. The analysis covers all hardware and software elements of the redundancy management/fault-tolerance design mechanization from the system-level downward, to identify design weaknesses and establish SOF verification test requirements. Extensive FMET, system integration and lower-level software testing verifies the fault tolerance of the design.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.1;

JSSG-2008 Appendix A: Para 3.3.1 provides guidance for fault tolerant processing including fault detection and redundancy. Para 3.1.2, 3.1.7 and 3.1.5.7 provide guidance for allocating quantitative safety requirements to subsystem level in the context of VCMS and mission avionics allowing for variability factors. Para 3.1.9 gives guidance on establishing redundancy levels based on control criticality. Para 3.1.11+ and 3.1.12+ provide detailed guidance on the establishment of proper levels of redundancy.

FAA Doc:AC 20-115B,

**15.1.6** Verify that separate and independent power sources are provided for redundant operations.

Standard: Power mechanization maintains dedicated/uninterruptible power for safety critical applications in the presence of failures. Safety critical architectures require dedicated/uninterruptible power sources. Redundancy (alternate power sources or battery) is required to achieve safety requirements.

Compliance: Verification methods include analysis and several kinds of testing. The analysis covers the power mechanization scheme which supports Flight Critical/Safety Critical (FC/SC) processing to verify design adequacy and establish SOF verification test requirements. Extensive FMET, system integration and lower-level software testing verifies the fault tolerance of the design.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.2.2.2.2, 3.2.2.2.5, 3.3;

JSSG-2008 Appendix A: para 3.2.2.2.2 and 3.2.2.2.5 give extensive guidance on aircraft power system support to safety critical equipment.

FAA Doc: AC 20-115B,

**15.1.7** Verify that single component failure does not impede redundant operations.

Standard: The system architecture design is fault tolerant and does not contain any components (e.g., digital hardware, interfaces, software components/modules, operating system/executive, input signal management, BIT) whose failure defeats the redundancy mechanization.

Compliance: Verification methods include analysis and follow-up testing. The design is analyzed to identify single-point failures which could defeat fault tolerance/redundancy mechanisms. Any identified single point failures are mitigated and demonstrated in extensive FMET, system integration and lower-level software testing.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: 3.3.1;

JSSG-2008 Appendix A: para 3.3.1 provides processing architecture design strategies to mitigate component failures. Para 3.1.9 contains single point failure guidance regarding in-flight hazards and redundancy. Para 3.1.11.1 addresses safe operation in the case of multiple failures.

FAA Doc: AC 20-115B,

**15.1.8** Verify that physical and functional separation between safety/flight critical and mission critical is accounted for in the computer system architecture.

Standard: The computer systems architecture physically and functionally separates/isolates safety critical items/elements from non-safety critical items/elements to maintain safe system operation. Elements of the safety critical function threads within the architecture are identified/treated as safety critical. Review of all elements is required, including hardware (groups of LRUs, single LRUs, connections between LRUs, etc.), software (CSCI's, CSCs, operating systems/executives, application software, etc.), and computer system internal interfaces. Non-safety critical components residing on the same processing element as a safety critical component are developed to safety critical design, development, integration and test standards.

Compliance: Verification includes FMET (at all levels) and integration testing. Lab facilities and test requirements are driven by the complexity of the architecture. Integration tests are conducted of the entire integrated architecture at the highest criticality level of the functions residing within. These tests verify the non-safety critical hardware/software/systems do not impact the safe operation of the system.

Comm'l Doc: RTCA DO-178B

RTCA DO-254

DoD/MIL Doc: JSSG-2008: para 3.1.7.1;

JSSG-2008 Appendix A: para 3.1.7.1 provides for basic partitioning of the architecture (hardware and software). Para 3.1.7.2 gives guidance regarding "system arrangement" (architecture design). Para 3.1.7.3 directly addresses isolation of less critical elements to prevent their failure from impacting critical functions.

FAA Doc: AC 20-115B,

**15.1.9** Verify that no patches (object code changes not resulting from compilation of source code changes) exist for flight-critical software.

Standard: No further explanation required.

Compliance: Verification is by inspection of delivered product and review of the software release and change control records.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.7contains guidance on Software Change Control.

FAA Doc: AC 20-115B,

## 15.2 Functional design integration of processing elements.

**15.2.1** Verify that all parameters passed among SOF processing elements are defined and that unnecessary coupling is avoided.

Standard: The system architecture design mechanization accounts for the critical dependencies of data/parameters utilized by the safety critical processing elements within the safety critical functional threads. The processing element interdependencies (e.g., modules/units/objects, CSCs, CSCIs, microprocessors, memory, circuit cards, internal and external buses, signals/discretes, subsystems, feedback loops, cockpit I/O) satisfy the safety critical function requirements for the entire thread. Parameters coupled to these threads are defined in terms of criticality and requirements to minimize unnecessary coupling.

Compliance: Verification includes testing including FMET to determine the dependence of the processing elements to meet the processing requirements and parameter dependencies for each safety critical element of the entire thread. Processing rates, associated allowable latencies and transient limitations, required for safety critical data, must be analyzed, tested and demonstrated. Lowest level element testing may be informal or automated to minimize costs/time to establish this critical foundation of verification.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.6;

JSSG-2008 Appendix A: para 3.3.6+ and 3.1.14.6 address software structure, partitioning and CSCI integration. Para 3.1.5.1 gives guidance on data latency issues. Para 3.1.7 gives overall architecture design guidance along with specific data latency discussions in Lessons Learned subparagraph l.

FAA Doc: AC 20-115B

**15.2.2** Verify that level of autonomy achieved by the flight-essential elements is sufficient to preclude loss of flight-critical functions due to failure in mission- or maintenance-related elements.

Standard: The system is designed to preclude reliance on single source safety critical data or from non-safety critical sources for safety critical application.

Compliance: Verification is through a combination of FME analysis and testing. Analysis and tests verify that non-safety critical (mission related) portions of the system along with maintenance equipment (built-in or otherwise) will not cause loss of flight, loss of control or degradation below Level I handling qualities.

Comm'l Doc: RTCA DO-178B

RTCA DO-254

DoD/MIL Doc: JSSG-2008: para 3.3.1;

JSSG-2008 Appendix A: para 3.3.1 contains guidance addressing redundant data path

management, data validity and reasonableness. Para 3.1.7.3 and 3.1.8 provide guidance for interfacing between safety and non-safety critical subsystems.

FAA Doc: AC 20-115B

**15.2.3** Verify that a controlled methodology is established and applied to integrate all safety-critical elements of the processing architecture, including verification coverage.

Standard: The system is integrated and verified using an established, proven process which includes complete test coverage at all levels. Each hardware and software element is developed and tested individually, then the software is integrated with the hardware for each element followed by collections of elements until the entire flight critical system is integrated and tested. Next, each flight critical system is integrated with the rest of the systems, possibly through a series of builds repeating the same integration process for each. Each build to fly must have all the safety critical functionality necessary to ensure safe flight.

Compliance: Verification is by inspection of planning and test documentation. The safety critical elements of the system architecture are clearly identified in the planning such that any dependencies that safety critical systems (e.g., VMS) have on other systems are addressed. Build plans show a reasonable build-up approach. Test documents reflect all levels of testing throughout all levels of the architecture.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.1;

JSSG-2008 Appendix A: para 4.3 addresses processing element verification and 3.3.1 addresses integration. Para 4.1.14.4, 4.2.2.2 and 4.5.7 specify a build up approach in verification and testing.

FAA Doc: AC 20-115B,

## 15.3 Subsystem/processing element.

**15.3.1** Electronics.

**15.3.1.1** Verify that all computer resources hardware components are safe and SOF elements have redundant buses that are physically separated.

Standard: Electronic components identified through safety critical function thread decomposition are of mature/proven technology with safety critical application heritage. These components (safety of flight elements) may include but are not limited to the following: circuit cards, internal and external buses, signals/discretes, interfacing subsystems, feedback loops, cockpit I/O, and Cross Channel Data Links. Components which carry safety critical data such as buses are redundant, implemented with proper redundancy management mechanization, and are physically separated (not run through same connector, wiring bundle, etc.)

Compliance: Verification methods include both analysis (FMECA) and various tests including SOF tests which have been successfully completed or are planned for completion with appropriate justification and suitable flight restrictions. Subsystems should complete a minimum of 50 hours burn-in time with no failures, manufacturer acceptance test of all electronic components, FMECA of all electronic components along with associated review, substantial test of any immature electronic components to substantiate safety critical application, and extensive FMET testing of the component/element fail effects and overall safety critical function threads.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.1;

JSSG-2008 Appendix A: para 3.4.1 and 3.4.5 cover components and parts pedigree , Para 3.1.11.11.2 addresses integrity of signal transmission.

FAA Doc: AC 20-115B,

**15.3.1.2** Verify that all safety/flight-critical electronic components are physically and functionally separated from non-safety-critical items. (This includes items such as processors, memory, internal/external buses, input/output (I/O) management, internal/external power supplies, circuit cards, motherboards, etc.) If not separated, verify that non-safety-critical elements are treated as safety-critical items.

Standard: All electronics for safety critical functions threads are designed, developed, integrated and tested to safety critical assurance levels. Safety critical functions operating on electronic hardware is physically separate from non-safety critical electronic components. All electronic components of computer system which mix implementation of safety critical functions with non-safety critical functions are designed, developed, integrated and tested to safety critical levels.

Compliance: Verification is through review of hardware architecture and design documentation and extensive FMET testing. Non-safety critical components residing in safety critical computer resources are developed according to safety critical design standards. FMET testing verifies single component failure does not compromise fault tolerant design.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.1;

JSSG-2008 Appendix A: para 3.3.1 lessons learned addresses systems partitioning. Para 3.1.7.3 addresses isolation of less critical elements to prevent their failure from impacting critical functions.

FAA Doc: AC 20-115B,

**15.3.2** Architecture mechanization.

**15.3.2.1** Verify that the executive/control structure execution rates are sufficient and consistently obtainable for SOF requirements given the control structure, priority assignments, and interrupts.

Standard: Software flow and execution is deterministic. Frame rates are compatible with real time system performance requirements and support execution rate requirements. Processing architecture mechanization including priority task assignments, interrupt structure and overall processing control structure is sufficient for SOF processing. The executive structure or operating system is designed, developed, integrated and tested as safety/flight critical.

Compliance: Verification is through combination of analysis, document inspection and test. Analysis verifies execution rates directly correlate to required frame rates and allowable data latencies. Documentation verifies that the executive structure or operating system was developed as safety/flight critical. Software development lab tests verify that executive control structure meets required execution rates under fully loaded, worst case timing conditions.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2001: para 3.3.3.1

JSSG-2008: para 3.3.4;

JSSG-2001: para 3.3.3.1 provides guidance for establishing adequate computer hardware reserve capacity.

JSSG-2008 Appendix A: para 3.3.1 establishes timing and control allocations based on

operational requirements. Para 3.3.4 addresses synchronization, deterministic execution and frame rate issues.

FAA Doc: AC 20-115B,

**15.3.2.2** Verify that the software design, timing, control flow, interrupt structure, and data structures meet the required processing capabilities of the SOF subsystem/system real-time architecture.

Standard: The software design architecture, software functional control flow mechanization and data structures are compatible with the system/subsystem real-time dependencies for safety/flight critical processing without latencies.

Compliance: Verification is accomplished through extensive system/subsystem integration tests and FMET. These tests ensure the OFP meets required execution rates under worst case operational timing and failure conditions.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2001: para 3.3.3.1, JSSG-2008: 3.3;

JSSG-2001: Para 3.3.3.1 provides guidance for establishing adequate computer hardware reserve capacity.

JSSG-2008 Appendix A: para 3.3.4 addresses synchronization, deterministic execution and frame rate issues. Para 3.1.7 gives overall architecture design guidance along with specific data latency discussions in Lessons Learned subparagraph l. Para 3.1.5.1 gives guidance on data latency issues.

FAA Doc: AC 20-115B,

**15.3.2.3** Verify that all mode inputs, failure detection techniques, failure management, redundancy management, self-checks, and interfaces operate safely under all dynamic conditions.

Standard: Review of safety risk mitigation techniques employed in the software, hardware and computer system architecture mechanization of the system is required. Typical areas to address are: the techniques for detecting/monitoring/isolating/accommodating failures, the entire redundancy management/fault tolerance mechanization scheme (from the lowest level through the system level), the techniques for assessing self health, the techniques employed for determining other channels and external dependent subsystem/system health status, the voting scheme mechanization, the mechanization of all mode unique inputs through the system, and the implementation of internal/functional/subsystem/system interfaces are safe throughout all dynamic conditions/modes/envelopes expected. This includes the verification that flight test features and software hooks for lab testing can not be activated in any unintended flight mode

Compliance: Verification is accomplished through extensive system/subsystem integration tests and FMET. These tests ensure the detection/monitoring/isolation of failures, the adequacy of the entire redundancy mechanization scheme (from the lowest level to the system level), the means of assessing own /other health, voting schemes utilized, all mode unique inputs, flight test features, software test hooks, and internal/subsystem/system/functional interfaces are safe under all expected dynamic conditions/modes/envelopes.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.1;

JSSG-2008 Appendix A: para 3.3.1 lessons learned provides guidance regarding fault management and systems partitioning. Para 3.3.2 provides guidance regarding failure propagation and redundancy. Para 3.1.4 addresses survivability. Para 3.1.5.2 addresses mode transitions. Para 3.1.5.7 addresses sensitivity analysis. Para 3.1.7.2 discusses

overall system arrangement issues impacting invulnerability and failure immunity.

FAA Doc: AC 20-115B,

**15.3.2.4** Verify that embedded SOF software provides acceptable performance and safety.

Standard: All embedded SOF software development adheres to a rigorous development process. No deviations are allowed. The process and associated life cycle are based on a development standard that represents industry best practices for safety critical software. The schedule allows adequate time to complete all activities, since safety critical software typically drives the overall schedule. The process is documented in a software development plan that addresses the following as minimum:

a. Design and software requirements analysis

b. Identifying and documenting safety-critical software requirements

c. Requirements Traceability

d. Programming Language

e. Using standardized programming procedures

f. Formal reviews and audits

g. Development testing

h. Training and support

i. Software engineering tools

j. Software Change Control

k. Software Quality Assurance

l. Configuration Management

m. Risk management

Compliance: Review the SDP to verify the process. Spot check program data to verify that no deviations occurred. Check for the following specific items:

1. Mature tools
2. Use of high order language (<5% assembly)
3. Process is flowed down to all vendors
4. Full qualification test after every flight release, regression test as driven by each change
5. Documentation is concurrent
6. 100% requirements traceability
7. Independence of SQA
8. Software developers are effectively involved with systems engineering

Comm'l Doc: IEEE STD 12207 provides industry best practice software development guidance.

RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.6;

JSSG-2008: para 3.1.14.6, 3.2.4.6, 3.3.6+ and 3.3.7+ provide guidance regarding software design and development for safety critical systems.

ASC Engineering Technical Guide version 1.1 dated 11 October 2002 established an integrity program for software development.

FAA Doc: AC 20-115B,

**15.3.2.5** Verify that the SOF software design has the necessary interrupt, reinitialization, resynchronization, recheck, and reconfiguration provisions to restart or reset safely and quickly in flight.

Standard: The system software is designed in conjunction with the digital hardware to reset/restart the computer system safely without catastrophic transient effects. Aspects of the design include channel/data synchronization/resynchronization, the systems interrupt structure, the system reinitialization and reconfiguration to safe states. The design accommodates transient time limits dependent on the air vehicle platform's inherent stability/safety margins, altitude and flight maneuvers before unrecoverable departure.

Compliance: Verification includes both analysis and test at all levels from software to integrated system, including FMET. These analyses coupled with FMET ensure the channel/data synchronization/resynchronization, the systems interrupt structure, the system reinitialization and the reconfiguration meets the system reset/restart safety requirements. System integration test demonstrates all safety related state transitions meet required timelines, are stable, and do not result in loss of safety critical data.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3;

JSSG-2008 Appendix A: Para 3.1.12.1 discusses redundancy management support for restart. Para 3.2.4.6 addresses software support for failure recovery. Para 3.1.17 provides guidance regarding failure propagation of computational failures. Para 3.3.2.2 discusses microprocessor timing and synchronization. Para 3.3.4 details issues surrounding synchronization rates. Para 4.1.13.2 provides lessons learned in verification of in-flight monitoring capability.

FAA Doc: AC 20-115B,

**15.3.2.6** Verify that the method of SOF software loading and verification is safe and carefully managed. (This includes the software operational flight program (OFP) loaded on individual black boxes or the air vehicle-loadable OFP.)

Standard: A sound process is used to build and load the OFP onto the air vehicle including equipment, security, time, safety and configuration. Any single OFP or image is configured insuring all software elements have been properly loaded into the corresponding hardware.

Compliance: Verification is through a combination of document inspections and test. The OFP build and loading process is rigorously tested prior to first flight and FMET encompasses the OFP load function in the aircraft and ground support equipment. Configuration and process documents are reviewed for completeness to assure all CSCI developers are included, along with all software elements/associated hardware, configuration data including CSCI constraints, interface requirements, sizing requirements and version descriptions, and OFP build and load process addresses issues of equipment, security, time, safety and configuration.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.1.16;

JSSG-2008 Appendix A: para 3.3.2 gives guidance for single point OFP load and verification. Para 3.3.7 addresses software change control. Para 3.3.8 addresses software certification of hardware compatibility. Para 3.1.14.6 discusses system invulnerability to software errors.

FAA Doc: AC 20-115B,

**15.3.2.7** Verify that the SOF software design has adequate self-check, failure monitoring, redundancy management, reconfiguration, voting, transient suppression, overflow protection, anti-aliasing, saturation interlock, memory protection, and techniques for preventing failure propagation to preclude SOF issues.

Standard: The overall computer system architecture design mechanization, through techniques employed in the software and associated hardware, is robust and fault tolerant. Typical areas to address are identified in the criteria.

Compliance: Verification is by process compliance inspection, FME analysis and test. Complete software testing is accomplished at all levels including unit level (always) to on aircraft (in some cases). Process documentation, QA reports, and peer review minutes are reviewed for evidence of software development process compliance. FMEA results are used to derive software design, integration and test requirements.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.6;

JSSG-2008 Appendix A: para 3.1.11.9, 3.1.13, 3.1.17 and 3.3.2.1 provide guidance for integrity and BIT checks often implemented in software. Para 3.1.12.1 gives detailed guidance for redundancy management. Para 3.3.6.2 provides guidance for robust integrated CSCI design.

FAA Doc: AC 20-115B,

**15.3.2.8** Verify that there is sufficient throughput margin for both input/output and processor capabilities (including memory) under worst-case mode performance scenarios for both average and peak worst-case loading conditions.

Standard: The computing systems are designed with enough processing capacity (throughput, memory, bus & I/O capacity) to complete all critical software tasks precluding unsafe system behavior. Each processing element is designed with enough capacity such that any limits (in major and minor frames) are not reached even under peak loading. Processing rates and margins are not allowed to degrade to unacceptable levels as a result of additional capability or deficiency corrections implemented in subsequent software releases.

Compliance: Verification includes systems analysis and testing. Systems analysis develops throughput, memory, bus and I/O utilization allocations in terms of actual units of time. These allocations have adequate margin to accommodate system inefficiencies related to memory caching, bus scheduling, pipeline dumping, etc. These allocations are verified in test under worst-case, fully loaded conditions.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.5;

JSSG-2008 Appendix A: para 3.3.5 contains guidance regarding reserve capacity. Para 3.1.14.6 contains guidance for worst case throughput and I/O spare. Para 3.5.7 establishes performance parameters for spare capacity and margin.

FAA Doc: AC 20-115B,

**15.3.2.9** Verify that a controlled methodology is established and applied to integrate all functional elements of a highly coupled, integrated OFP.

Standard: For a highly coupled/integrated OFP, the software is designed, developed, integrated and verified using an established, proven process. Individual CSCIs are combined into multiple elements and tested until the entire set of CSCIs is integrated and tested with each other resulting in a single integrated OFP.

Compliance: Verification is through systems integration and FMET testing on the integrated highly-

coupled OFP. Safety critical functional thread identification and integration process has been documented and enforced. FMET has addressed the safety critical function thread testing within the integrated computer system architecture.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.6;

JSSG-2008 Appendix A: para 3.3.6 addresses breaking down complex software into manageable CSCIs. Para 3.2.2.2 discusses subsystem integration. Para 4.3 discusses verification of integrated processing capabilities. Para 3.3.1 provides guidance for integrated architecture design.

FAA Doc: AC 20-115B,

### **15.3.3** Processing architecture verification for SOF items.

#### **15.3.3.1** Verify the operation of BIT and redundancy/failure management algorithms.

Standard: The system Built-in-test (BIT) is designed to detect 100% of critical failures to support fault isolation/accommodation coupled to the redundancy/failure management mechanization. Coverage typically is defined as the conditional probability that, given a failure, the system continues to perform its function. Coverage of as high as 1.0 for first failure and .94 or better for the second failure is typical. The system design addresses acceptable transient levels, prevention of propagation of failures, maximum use of voting, re-admittance of failed elements, maximum transparency of I/O and in-flight restart of safety critical systems due to "generic software fault".

Compliance: Verification methods include analysis, simulation, FMET, testing in a system integration facility with actual flight hardware and possibly flight test. The combination of analysis, simulation and flight test verifies meeting conditional probabilities that, given a failure, the system will continue to perform its function. System integration testing and FMET ensures that the design accommodates transient levels, prevention of propagation of failures, maximum use of voting, re-admittance of failed elements, maximum transparency of I/O and in-flight restart of safety critical systems due to "generic software fault".

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.6.2;

JSSG-2008 Appendix A: para 3.3.6.2 establishes guidance for CSCI failure detection and execution of BIT. Para 3.1.13 (Requirement Guidance a. 2.) defines types of BIT and a list of typical items tested. Para 3.1.12 addresses redundancy management.

FAA Doc: AC 20-115B,

#### **15.3.3.2** Verify that critical hardware/software discrepancies are identified and corrected or mitigated.

Standard: As part of the system development process, ensure the software/hardware/system/lab/air vehicle discrepancy reporting process is applied to discover/document/correct/mitigate all critical faults at all levels. Typical areas to include are: software (i.e., design coding and mechanization errors), hardware anomalies, test case inconsistencies, simulation anomalies, and lab/tool problems. Ensure process/review board evaluates critical faults for safety impact, prioritization and urgency of correction required, and document appropriate operational safety restrictions (e.g., flight envelope, operating modes, grounding the fleet).

Compliance: Verification is through review of discrepancy reporting processes, and inspection of problem reports and Technical Orders (Flight Manuals). Inspection of problem reports and TOs reveals that critical faults are documented, appropriate restrictions imposed when necessary, and details of the corrective/mitigation action are reviewed.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.7;

JSSG-2008 Appendix A: para 3.3.8 provides guidance under lessons learned for tracking and mitigating software discrepancies.

FAA Doc: AC 20-115B,

**15.3.3.3** Verify that adequate configuration management controls are in place to ensure proper/ functionally compatible software loading for the intended use on the air vehicle.

Standard: Multiple versions and configurations of hardware and software in support of varying missions (e.g., service related) are carefully controlled. Providing an incorrect software version for loading into an aircraft is absolutely precluded.

Compliance: Verification is through inspection of process documents for configuration management controls along with any necessary testing to prevent incorrect version identification and loading.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.1.16;

JSSG-2008 Appendix A: para 3.1.16 provides guidance regarding OFP version control and integrity.

FAA Doc: AC 20-115B,

**15.3.3.4** Verify that all data or communications are secure against unwanted intrusions and that security techniques used are implemented safely.

Standard: Security requirements have been applied to the processing architecture to protect safety critical functions and included in any safety related analysis/testing. Note that current DOD anti-tamper programs do not specifically address safety critical functions.

Compliance: Verification is by inspection of specifications and traceability of security requirements along with test results.

Comm'l Doc: RTCA DO-178B

DoD/MIL Doc: JSSG-2008: para 3.3.7;

JSSG-2008 Appendix A: para 3.1.14.6.i and 4.1.14.6.d guidance addresses analysis, allocation and verification of security requirements. Para 3.3.4 directly addresses unauthorized modification and tampering with components. Para 3.3.7 establishes a place for traceable security requirements.

AFPam 63-1701 provides guidance for implementation of Systems Security Engineering

FAA Doc: AC 20-115B

# 16. MAINTENANCE

TYPICAL CERTIFICATION SOURCE DATA

1. Maintenance manuals/checklists (equivalent or supplement to –2 T.O.'s)
2. Inspection requirements (equivalent or supplement to –6 T.O.'s)
3. Life-limited/time replacement plan/list
4. Subsystem hazard analysis (SSHA)
5. Failure modes, effects, and criticality analysis (FMECA)
6. Maintenance records (including failure report and corrective action system (FRACAS))
7. Air Force Regulation (AFR) 8-2, T.O. 00-5-1
8. Test reports
9. Test plans

CERTIFICATION CRITIERIA

## 16.1 Maintenance manuals/checklists.

**16.1.1** Verify that servicing instructions are provided for all systems that require servicing; for example, fuel, engine oil, hydraulic systems, landing gear struts, tires, oxygen, escape system, etc.

Standard: All servicing information is provided for those subsystems that require servicing, including, as a minimum, fluid levels that require constant checking and servicing.

Compliance: The servicing information in the Technical Orders is verified by showing traceability from support analysis and the T.O.s have been undergone a quality assurance check by the contractor and verified by the government.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 14CFR references: 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

14CFR reference Part 23, Appendix G and Part 25, Appendix H, Instructions for Continued Airworthiness,

**16.1.2** Verify that cautions and warnings are included in maintenance manuals, aircrew checklists, and ground crew checklists.

Standard: Warning and Caution notes are used when alternative design approaches cannot eliminate a hazard per MIL-STD-882, Appendix A, Para. A4.3.3.i. All required Cautions and Warnings are prominently displayed in the pilot or operators checklist and the maintenance personnel's manuals and technical orders.

Compliance: Operator and maintenance actions requiring Cautions and Warnings are verified by review of the Failure Modes Effects Criticality Analysis (FMECA) and from the System Safety Hazard Analysis. The proper wording and placement of Cautions and Warnings per MIL-STD-38784, para. 3.2 and Appendix A, paras. A3.2, A3.3, A3.4, and A3.5 is verified by a review of the checklists and maintenance manuals.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563,

**16.1.3** Verify that maintenance checklists are available for critical maintenance tasks, such as fuel and oxygen serving procedures, towing procedures and restrictions, jacking procedures, engine operation during maintenance, lifting procedures, integrated combat turn procedures, etc.

Standard: Maintenance checklists are developed in accordance with T.O. 00-5-1, Air Force Technical Order System, Paras. 2.4.3, 2.4.3.1, 2.4.3.1.1., 2.4.3.2

Compliance: The maintenance checklists developed are verified by showing traceability from the support analysis and the T.O.s are verified.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563,

**16.1.4** Verify that support equipment does not adversely affect the safety of the air vehicle.

Standard: The support equipment used to perform maintenance functions on the air vehicle is safe to operate and cannot adversely impact the safety of the air vehicle.

Compliance: The safety of the support equipment is verified by review of the System Safety Hazard Analysis and through individual testing of the support equipment and compatibility testing with the aircraft.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563,

**16.1.5** Verify that maintenance manuals incorporate procedures for system/component removal.

Standard: Procedures for subsystem removal and installation are adequately covered in the appropriate maintenance manuals.

Compliance: The removal and installation instructions have undergone a quality assurance check by the contractor and verified by the government.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 14CFR reference Part 23, Appendix G and 14CFR reference Part 25, Appendix H

**16.1.6** Verify that maintenance manuals require system operational testing for normal/emergency system operation when systems are affected by removal/replacement of components.

Standard: Operational tests are performed to ensure system performance when components are removed/replaced that are critical to the operation of the air vehicle.

Compliance: The maintenance manuals detail the operational tests required to ensure system performance as the result of removal/replacement of key air vehicle components.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 14CFR reference Part 23 Appendix G and 14CFR reference Part 25, Appendix H

**16.1.7** Verify that maintenance manuals provide adequate troubleshooting procedures to correct expected system/component failures.

Standard: Maintenance manuals provide troubleshooting instructions, and lists support equipment and tools required to correct expected system/component failures.

Compliance: The maintenance manuals are verified to contain troubleshooting procedures for those systems/components that are expected to fail as part of the normal operation of the air vehicle.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 14CFR reference Part 23, Appendix G and 14CFR reference Part 25, Appendix H

## 16.2 Inspection requirements.

**16.2.1** Verify that ground crew work cards for preflight inspection are coordinated with the aircrew checklists.

Standard: Preflight checklists that are used by the ground crew and the aircrew or operator are consistent and well-coordinated.

Compliance: The quality of the preflight checklists is verified by joint validation of the checklists.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 23.1501, 23.1529

**16.2.2** Verify that special inspection procedures are available for unusual or specified conditions, such as

a. Exceeding operating limits
b. Severe vibration
c. Engine stall
d. Foreign object damage to engine or structure
e. Excessive loss of oil
f. Conditions requiring oil sampling and analysis
g. Severe braking action, hard landing, and running off runway
h. Air vehicle subject to excessive "g" loads or maneuvers outside the specified flight envelope
i. Lost tools
j. Emergency procedures implemented
k. Dropped objects or parts

Standard: Special inspection procedures are available for all conditions that have been identified as special situations requiring a special inspection.

Compliance: All special inspections are verified by an analysis or demonstration to ensure the adequacy of the work package.

DoD/MIL Doc: MIL-PRF-5096: para 3.2.2.3.1 gives guidance regarding special inspections after a specific occurrence.

JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5

FAA Doc: 23.1501, 23.1529

**16.2.3** Verify that life-limited items and replacement intervals are identified using relevant operational data.

Standard: All known life-limited parts are identified in the T.O.s.

Compliance: The identification of life-limited parts is verified by the review of appropriate source data such as the FMECA, and R&M predictions, and the life-limited parts are identified in the appropriate technical data.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5;

MIL-PRF-5096: para 3.2.2.4 gives guidance regarding flying time related or time change items.

FAA Doc: 23.1501, 23.1529

**16.2.4** Verify that all required inspection intervals are identified using relevant operational data.

Standard: All features of the air vehicle requiring periodic inspection are identified, inspection interval defined and procedures documented in the appropriate technical data.

Compliance: All required inspections and corresponding intervals are verified by reviewing Life Management Plans, Integrity Process Documents, etc.

DoD/MIL Doc: JSSG-2000: para 3.6.1, 3.6.2

JSSG-2001: para 3.1.5;

MIL-PRF-5096: para 3.2.1.1.1 gives guidance regarding frequency of maintenance items.

FAA Doc: 23.1501, 23.1529

## 17. ARMAMENT/STORES INTEGRATION

A store is any device intended for internal or external carriage, mounted on air vehicle suspension and release equipment, which may or may not be intended to be for in-flight separation from the air vehicle. Stores include missiles, rockets, bombs, nuclear weapons, mines, fuel and spray tanks (permanently attached and/or detachable), torpedoes, sonobuoys, dispensers, pods (refueling, thrust augmentation, gun, electronic countermeasures, etc.), targets, decoys, chaff and flares, and suspension equipment.

TYPICAL CERTIFICATION SOURCE DATA

1. User requirements and design requirements and validation results
2. Design studies and analyses
3. Design, installation, and operational characteristics
4. Component and functional level SOF, qualification and certification tests
5. Electromagnetic environmental effects
6. Plume ingestion/propulsion compatibility tests and plume/gun gas impingement test.
7. Failure modes, effects, and criticality analysis/testing (FMECA/FMET)
8. Hazard analysis and classification including explosive atmosphere analysis/test
9. Safety certification program
10. Computational, theoretical and/or semi-empirical prediction methods
11. Configuration: aerodynamic design and component location
12. Wind tunnel test results and correction methods
13. Mathematical representation of system dynamics
14. Loads analysis, wind tunnel and flight test results
15. Flutter, mechanical stability, aeroelastic, aeroservoelastic and modal analyses, wind tunnel and flight test results
16. Performance analysis
17. Environmental compatibility analysis and tests including gun fire vibration analysis/test
18. Interface control documents
19. Store separation models, wind tunnel and flight test results
20. Flight manual
21. Flight test plan and test results
22. MIL-HDBK-1763, Aircraft/Stores Compatibility: Systems Engineering Data Requirements and Test Procedures
23. MIL-HDBK-244, Guide to Aircraft/Stores Compatibility
24. MIL-STD-1760, Aircraft/Store Electrical Interconnection System
25. MIL-A-8591, Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase); General Design Criteria for
26. SEEK EAGLE engineering data
27. American National Standard for Safe Use of Lasers (ANSI Z136.1)
28. Nuclear Certification Impact Statement (NCIS)
29. Aircraft monitor and control (AMAC) and surveillance tests

30. Nuclear safety analysis report (NSAR)
31. Mechanical compatibility data
32. Electrical compatibility data
33. Certification requirements plan (CRP)
34. Operational flight program (OFP) source code
35. Systems integration lab data/results
36. Cooling analysis and ground/flight test results
37. MIL-STD-1530 Aircraft Structural Integrity Program
38. ASC/EN Stores Integration practice
39. Human factors to consider
40. Crew egress paths to consider
41. Aircraft weight and balance
42. Environmental analysis and test results
43. Store drawings including store mass properties (STAMP sheet)
44. Safety assessment report
45. Airworthiness qualification plan (AQP) (Army unique)
46. Airworthiness qualification specification (AQS) (Army unique)

CERTIFICATION CRITERIA

### 17.1 Gun/rocket integration and interface.

DoD/MIL Doc: MIL-HDKB-244A: para 5.1.10

MIL-HDBK-1763: para 4.1.4.7, 4.1.4.10

MIL-HDBK-1763:Appendix A, Test 161 Gun Firing Test

MIL-HDBK-1763 Appendix A, Test 162 Rocket/Missile Firing Test

MIL-HDBK-1763 Appendix B, Test 272 Launch Test or Weapons Survey and demonstrations

MIL-HDBK-1763 Appendix B, Test 273 Gun Firing Test

MIL-STD-331

FAA Doc: No applicable reference available for any of the criteria in this section.

**17.1.1** Verify that environment induced by gun/rocket operation is compatible with the air vehicle's limitations for muzzle blast and overpressure, recoil, vibroacoustics, cooling, egress, human factors, and loads of the air vehicle.

Standard: Gun/rocket operation is compatible with the aircraft's prescribed limits for overpressure, Vibration/Acoustics, and ammunition feed/ejection. Misfire handling and gun jams cause no catastrophic or negative effect on SOF and/or aircrew.

Compliance: Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, SIL, OGT, safety analysis, SEEK EAGLE certification, NNMSB certification, and live fire testing during DT&E/OT&E. Validation/Verification (Val/Ver) testing to verify loading of aircraft.

DoD/MIL Doc: MIL-HDBK-244A: para 5.1.9.1, 5.1.9.2, 5.1.9.2.4, 5.1.10 inclusive

**17.1.2** Verify that gun/rocket gases and plume do not create SOF hazards for the air vehicle, air and ground crew.

Standard: Gases or particulates from gun/rocket plume during operation do not cause engine flameout, stalling, and/or damage. Rounds do not fuze/detonate until they are a safe distance from the air vehicle.

Compliance: Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, SIL, OGT, safety analysis, power-on, SEEK EAGLE certification, NNMSB certification, and live fire testing during DT&E/OT&E. Validation/Verification (Val/Ver) testing to verify loading of aircraft.

**17.1.3** Verify that gun/rocket gas impingement does not cause unacceptable erosion of air vehicle structure/skin.

Standard: Gases from gun/rocket operation must not ablate transparencies, erode fuselage surfaces, and ablate faces of sensors.

Compliance: Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, SIL, OGT, safety analysis, power-on, SEEK EAGLE certification, NNMSB certification, and live fire testing during DT&E/OT&E.

**17.1.4** Verify that the gun/rocket gas ventilation/purge system prevents accumulation of explosive gas mixture.

Standard: Gases from gun/rocket operation do not accumulated beyond prescribed allowable toxic and/or explosive concentrations.

Compliance: Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, SIL, OGT, safety analysis, power-on, SEEK EAGLE certification, NNMSB certification, and live fire testing during DT&E/OT&E. Validation/Verification (Val/Ver) testing to verify loading of aircraft.

## 17.2 Stores integration.

DoD/MIL Doc: MIL-HDBK-1763

MIL-HDBK-244A

MIL-STD-1289D

JSSG-2001: para 3.3, 10.1.1, 3.4.2.1.5, and 3.4.2.2 for the testing methodology.

MIL-STD-464

MIL-HDBK-1760A

MIL-STD-1760D

MIL-STD-331

**17.2.1** Verify that the stores/air vehicle interface does not create unsafe conditions during ground and flight operations and that no unsafe environment is created for maintenance personnel.

Standard: Clearance between store and surroundings (such as Alternative Mission Equipment (AME), racks, and launchers) is sufficient to allow for stores loading, aircraft/munitions servicing, in flight vibration and deployment without contacting air vehicle, AME and other stores. Stores loading/unloading procedures are defined and documented.

Compliance: Stores/air vehicle interface is verified by test IAW AIR STD 20/21. SEEK EAGLE Certification and Non-Nuclear Munitions Safety Board Certification are achieved. Stores loading/unloading procedures are verified by demonstration using the stores loading manual.

**17.2.2** Verify that the stores separate safely from the air vehicle throughout the air vehicle/store launch or jettison flight envelope.

Standard: Stores can be jettisoned throughout vehicle/store employment flight envelope without inducing dangerous aerodynamic loads and moments, engine damage, propeller damage, store-aircraft collision, damage to any aircraft surface, or damage or interference to critical control functions.

Compliance: Stores safe separation is verified by SEEK EAGLE Certification.

**17.2.3** Verify that the store or suspension and release equipment and air vehicle are structurally capable of operating safely in the air vehicle/store carriage flight envelope.

Standard: No additional clarification required.

Compliance: Store and suspension and release equipment structural integrity is verified by SEEK EAGLE Certification.

DoD/MIL Doc: MIL-HDBK-1763 Test 131 Aircraft Stores Suspension Equipment Structural Integrity Ground Test

**17.2.4** Verify that electrical interfaces do not cause unsafe stores operation or interactions with the air vehicle for all required store configurations.

Standard: Aircraft electrical/logical interfaces are defined and prevent unintended release/launch/jettison and detonation of the stores.

Compliance: Aircraft electrical/logical interfaces are verified by System Integration Laboratory test, EMI/EMC test, Hazards of Electromagnetic Radiation to Ordnance (HERO) test, and flight test

**17.2.5** Verify that the environment induced by the stores on the air vehicle, and by the air vehicle on the store during carriage and launch/separation/jettison for the cleared usage, does not adversely affect SOF of the air vehicle.

Standard: Store carriage, jettison or launch do not cause SOF problem by inducing dangerous aerodynamic loads and moments, engine damage, store-aircraft collision, damage to any aircraft surface, excessive load on aircraft ECS, damage or interference with critical control functions.

Compliance: Compatibility of air vehicle and stores environments is verified by SEEK EAGLE Certification.

**17.2.6** Verify that the stores operations do not adversely affect any safety aspect of the flight control of the air vehicle.

Standard: Store carriage, jettison or launch do not cause SOF problem by inducing dangerous aerodynamic loads and moments, engine damage, store-aircraft collision, damage to any aircraft surface, excessive load on aircraft ECS, damage or interference to critical control functions.

Compliance: Verification is accomplished by Certification Recommendation/SEEK EAGLE Certification/flight clearance to include physical fit and function, loading/installation procedure, aeroelastic ground vibration test, wind tunnel tests, effects of aircraft on captive stores/suspension equipment, effects of stores/suspension equipment on aircraft, environmental vibration, aeroacoustic test, HERO test, EMC/EMI, ballistic tables, temperature extremes and thermal test, SIL, FTRR, and DT&E/OT&E.

**17.2.7** Verify that all stores configurations for the air vehicle are documented in the flight manuals.

Standard: Flight manual must include safe available ripple selections, safe release envelopes and flight

limits, proper loading procedures, appropriate store checklists, correct employment data for operational employment planning.

Compliance: Verification is accomplished by SEEK EAGLE Certification, NNMSB certification, SIL/Avionics testing, Validation/Verification of T.O. (Val/Ver) performed by maintainers to ensure proper loading/unloading procedures, and ground test during DT&E/OT&E to verify all store configurations.

**17.2.8** Verify that malfunctioning stores can be turned off or released if required to protect the air vehicle.

Standard: Air Vehicle has the capability to command/control/power down malfunction stores.

Compliance: Verification is accomplished to include SIL/HIL/Avionics Tests and DT&E/OT&E to ensure the stores management system control and condition the stores properly and jettison malfunction stores if necessary.

DoD/MIL Doc: MIL-STD-1760 for the electrical/logical interface.

MIL-STD-27733, Modification to Aerospace Vehicles

MIL-HDBK-244, Modification and Marking Requirements for Test Equipment in Aerospace Vehicles and Related Support Equipment

## 17.3 Laser integration and interface.

**17.3.1** Verify that the crew and maintenance personnel are not exposed to laser radiation (direct and reflected) in excess of maximum permissible exposure limits in order to ensure safe conditions.

Standard: The laser system and support equipment are designed to the lowest hazard classification and minimize the accessibility of the crew and maintenance personnel to hazardous emissions. Laser training procedures are defined for aircrew and maintenance personnel.

Compliance: Minimum crew and maintenance personnel exposed to laser radiation is verified by accessibility checks, wire verification, power-on, Armament Control system, Ground test equipment checks, Loading procedures checks, and inspection of training procedures.

Comm'l Doc: ANSI Z 136.1, Safe Use of Lasers, for the safety design requirements of laser systems.

DoD/MIL Doc: MIL-STD-1425 for the safety design requirements of laser systems.

AR-11-9, "The Army Radiation Safety Program";

AFOSH STD 48-139, Laser Radiation Protection Program;

RCC 316-98, Laser Range Safety

FAA Doc: 21CFR Part 1040, Performance Standards for Light-emitting products

**17.3.2** Verify that the induced environment resulting from laser operation is compatible with the air vehicle's limitations for vibroacoustics, thermal loads, and structural loads of the air vehicle.

Standard: Compatibility of laser operation is defined to meet vibration, acoustics, thermal and structure loads of the air vehicle.

Compliance: Laser operation compatibility is verified by accessibility checks, wire verification, power-on, Armament Control system, Ground test equipment checks, Loading procedures checks, SEEK EAGLE certification, and boresight alignment/retention

Comm'l Doc: ANSI Z 136.1, Safe Use of Lasers, for the safety design requirements of laser systems.

DoD/MIL Doc: MIL-STD-1425 for the safety design requirements of laser systems.

AFOSH STD 48-139, Laser Radiation Protection Program;

RCC 316-98, Laser Range Safety

FAA Doc: 21CFR Part 1040, Performance Standards for Light-emitting products

**17.3.3** Verify that laser chemical and exhaust gases do not create SOF hazards for the air vehicle.

Standard: Exhaust gases or chemicals produced by laser operation do not exceed the concentration defined as safe minimum values in any part of the aircraft or attached structures/pods.

Compliance: Exhaust gas and chemical concentrations acceptability are verified by installation tests, boresight alignment/retention, hazards of electromagnetic radiation to ordinance and captive carry flight testing

Comm'l Doc: ANSI Z 136.1 - Safe Use of Lasers, for the safety design requirements of laser systems.

DoD/MIL Doc: MIL-STD-1425, for the safety design requirements of laser systems.

ANZI 136.1 for the safety design requirements of laser systems.

AFOSH STD 48-139, Laser Radiation Protection Program

RCC 316-98, Laser Range Safety

FAA Doc: 21CFR Part 1040, Performance Standards for Light-emitting products

**17.3.4** Verify that a means is provided for the crew to determine when the laser is operating and discern the direction of the beam.

Standard: Laser is boresighted to prescribed alignment limit, the aircraft sighting display accurately points the laser to within prescribed limits (milliradians or microradians) and the aircraft display clearly indicates when the laser is firing.

Compliance: Laser boresighted alignment is verified by installation tests, SIL testing, hazards of electromagnetic radiation to ordinance, and captive Carry flight testing.

Comm'l Doc: ANSI Z 136.1, Safe Use of Lasers, for the safety design requirements of laser systems.

DoD/MIL Doc: Refer to MIL-STD-1425 for the safety design requirements of laser systems.

AFOSH STD 48-139, Laser Radiation Protection Program

RCC 316-98, Laser Range Safety

FAA Doc: 21CFR Part 1040, Performance Standards for Light-emitting products

**17.3.5** Verify that laser operation and direction is controllable only by the crew and does not latch on (radiating).

Standard: The aircraft maintains full control of the firing and pointing of the laser at all times. Tracking is initiated only by crew or operator consent and action. The laser does not fire unless activated by crew or operator and will immediately cease firing at command from crew or operator.

Compliance: Verification is accomplished by initial installation tests, SIL testing, captive carry during DT&E/OT&E, SEEK EAGLE Certification and laser operator certification.

Comm'l Doc: ANSI Z 136.1, Safe Use of Lasers, for the safety design requirements of laser systems.

DoD/MIL Doc: MIL-STD-1425 for the safety design requirements of laser systems.

AFOSH STD 48-139, Laser Radiation Protection Program

RCC 316-98, Laser Range Safety

FAA Doc: 21CFR Part 1040, Performance Standards for Light-emitting products

**17.3.6** Verify that the laser beam cannot contact any part of the airframe and/or rotor system.

**17.3.7** Verify the laser cannot inadvertently lase when the aircraft is on the ground.

### 17.4 Safety interlocks.

**17.4.1** Verify that appropriate safety lockout and interlocks are in place to assure that unsafe store operation does not take place.

Standard: Safety interlocks shall prevent unplanned/inadvertaent firing/initiation of armament subsystem causing unacceptable hazards.

Compliance: Test Reports or Design Analysis

DoD/MIL Doc: MIL-HDBK-244A: para 5.1.5.1 , 5.1.5.1.2

## 18. PASSENGER SAFETY

The passenger safety section addresses technical requirements in the area of passenger carrying air vehicles as they pertain to safety. This area covers seat belts, stowage compartments, ditching, emergency exits, emergency evacuation, seating arrangements, emergency lighting, signs, fire extinguishers, smoke detection, lavatories, fire protection, and physiological requirements. Safety requirements for crew stations normally used for aircrew and mission essential personnel are located in section 9, Crew Systems.

TYPICAL CERTIFICATION SOURCE DATA

1. Federal Aviation Regulations
2. FAA Airworthiness Directives and Advisory Circulars
3. Joint Service Specification Guide
4. Cabin/crew station layout/geometry
5. Crash survivability requirements and validation
6. Escape system requirements and validation
7. Life support system requirements and validation
8. Tech data package

CERTIFICATION CRITERIA

### 18.1 Survivability of passengers.

**18.1.1** Verify that seats with restraints are provided for each passenger that do not cause serious injury in an emergency landing. Verify each seat/restraint system is designed to protect each occupant during an emergency landing provided the restraints are used properly.

Standard: The seating and restraint system including structural attachment to the aircraft has been designed to a hold in place an occupant for design static and or dynamic loading. The loading directions and magnitudes are specific to airframe type and orientation of the seat, and meets requirements of SAE AS8049 with a 250 lb occupant.

There are enough seat and restraint systems for all passengers. Restraints apply body loads in a distributed fashion and location that do not cause major injury, (such as internal organ damage or skeletal fractures), and allow occupants to emergency egress after landing.

Compliance: Analysis, test, inspection documentation shows that the seating restraint system meets crash load requirements and that there are seat and restraint systems for all passengers. Static and dynamic loads are verified by tests defined in SAE AS8049, with maximum weight occupants (250 lbs if not otherwise specified).

DoD/MIL Doc: JSSG-2010-7: para 3.7.3.2.2

FAA Doc: 14CFR references: 25.785, 23.2, 23.562, 23.785, 25.562

**18.1.2** Verify that each restraint system has a single-point release for passenger evacuation.

Standard: All passenger restraint systems have a single point release for the restraint system of each occupant.

Compliance: Inspection and demonstration documentation exists to show that each passenger seat and restraint system has a single point release system for the restraint system.

DoD/MIL Doc: JSSG-2010-7: para 3.7.3.2.2

FAA Doc: 14CFR references: 25.785, 23.2, 23.562, 23.785

**18.1.3** Verify that, if stowage compartments are present, they are designed to contain the maximum weight of its contents and the critical load conditions in an emergency landing. The contents should not become a hazard to passengers due to shifting, such as under emergency landing conditions.

Standard: Stowage compartments are designed to restrain the specified cargo weight to a minimum of 9 G fwd, 1.5 G aft, 1.5 G laterally, 2 G up , and 4.5 G down or to other levels of restraint as may be determined from results of trade studies and analyses.

Compliance: Fixed or removable equipment located in a manner wherein failure could result in injury to personnel or prevent egress is secured to levels of restraint commensurate with aircraft crash load factors. Structural test and analysis verify the capability to withstand maximum content weights. Testing and analysis with simulated landing and in-flight load conditions verify that contents do not cause injury or other passenger hazards.

DoD/MIL Doc: MIL-A-8865B;

No information available in current JSSG. Information to be included in next revision of JSSG.

FAA Doc: 14CFR references: 25.561, 25.787, 25.789, 23.787

**18.1.4** Verify that each passenger carrying area has at least one external door that is operable from the inside and outside, is located to avoid hazardous external areas, and is inspected to ensure it is locked in flight.

Standard: Each compartment that will have a passenger restraint and seating system installed has an egress exit with a hatch or door that can be operated by an occupant from the inside, or by ground rescue personnel from the outside of the fuselage. The door or hatch is located away from hazardous areas of the aircraft (such as in close proximity to propellers, or jet engine inlets/outlets), and are not located in areas likely to be blocked after an emergency gear up landing. Inspection procedures and/or detection systems exist to ensure doors are fully locked in flight.

Compliance: Inspection of engineering drawings and the air vehicle configuration verify that each passenger compartment with a seat and restraint system has an external exit with a door that can be opened internally and externally, and that there is clear indication of a locked or unlocked condition. Analysis and demonstration verify the ability to operate doors internally and externally. Inspection of vehicle configuration and documentation verifies that exit locations are away from hazardous areas around the aircraft. Documentation exists to show training and information for passengers to safely egress the aircraft.

DoD/MIL Doc: JSSG-2010-7: para 3.7.5.3.1

FAA Doc: 14CFR references: 25.783

**18.1.5** Verify that exits are lockable, simple to open, and do not open in flight unless mission requirements necessitate this function.

Standard: All exits are lockable by aircrew trained to do so. All exits are uncomplicated to open such that no training is required for operation. All exits will stay locked and closed in passenger compartments when the aircraft is inflight unless mission needs allow the opening and use of exits inflight.

Compliance: Analysis, demonstration and inspection documentation verifies that all exits in passenger areas are lockable by aircrew, simple to open without training, and will stay locked in flight when not opened for mission need. Human factors analysis and demonstration verify the

expected passenger population's abilities to operate exits.

DoD/MIL Doc: JSSG-2010-7: para 3.7.5.3.1

FAA Doc: 14CFR references: 25.813, 25.809, 23.807, 25.813

**18.1.6** Verify that each non-over-wing exit higher than 6 feet off the ground has a means to assist passengers to the ground. Provisions should exist for evacuees to be assisted to the ground from the wing when the exit opens to the wing.

Standard: For each exit that is not over the wing and is more than 6 feet above the ground when the aircraft is on level ground with landing gear down, a means for rapid and safe decent to the ground is provided for passengers that requires no training to use with assistance from aircrew. For exits opening to wing areas, provisions are incorporated to safely assist passengers from the wing surface to ground level.

Compliance: Analysis, inspection and demonstration documentation verify which exits are more that 6 ft above the ground, that non-overwing exits of that set have a means for passenger descent, and that these descent devices can be used without passenger training but with the assistance of aircrew members. Emergency egress demonstrations using non-trained personnel, representative of the expected passenger population verify the ability to safely exit and descend to the ground.

DoD/MIL Doc: JSSG-2010-7: para 3.7.5.3.2

JSSG-2010-13: para 3.13.5 pg 67, 68

FAA Doc: 14CFR references: 25.810, 121.31a

**18.1.7** Verify that the weight of each passenger exit, if removable, and its means of opening, is conspicuously marked.

Standard: The means of opening and weight of each removable passenger exit hatch or door is clearly marked on the hatch or door.

Compliance: Inspection and engineering drawing documentation verify that each hatch door is clearly marked with it's means of opening and weight.

DoD/MIL Doc: JSSG-2010-13: para 3.13.5 pg 66

FAA Doc: 14CFR references: 25.811

**18.1.8** Verify that an emergency lighting system, independent of the main lighting system, provides sufficient illumination and guidance for passenger and crew emergency evacuation, including illumination of each exit and its exterior surrounding. Verify that energy to supply lighting allows complete egress of all passengers and crew before diminishing.

Standard: The lighting system provides adequate illumination for normal ingress and emergency egress for all occupants within the cockpit/crewstation. Illumination is sufficient for exterior visibility and tasks to be accomplished by external aircrews. Adequate lighting for aircrew and passenger safety is provided for the passageways and exits. The energy required for emergency lighting is sufficient to allow for the egress of all passengers and aircrew.

Compliance: Illumination is verified by direct measurement. Lighting Mockup, laboratory (SIL), emergency egress demonstrations and aircraft evaluations in night time lighting conditions demonstrate the adequacy of the lighting system, both internal and external to the cockpit/crewstations as well as the duration of the emergency lighting.

DoD/MIL Doc: JSSG-2010-13: para 3.13.5 pg 62, 65

FAA Doc: 14CFR references: 25.812, 23.812, 25.1351, 25.1353, 25.1355, 25.1357, 25.1363

**18.1.9** Verify that emergency exit signs are installed and that each seated passenger is able to recognize at least one emergency exit sign.

Standard: Emergency exit lighting signs are provided that are powered integrally and operate independently of the main lighting system so that the lighting will be available when aircraft power is not. Exit location indications are also apparent when not lighted under normal flight conditions. There are sufficient number of signs and they are located so that all passengers can locate an emergency exit based upon the viewing of one of the signs during adverse conditions that may occur during a crash such as the presence of smoke and water.

Compliance: Verification is by inspection of engineering drawings and emergency egress demonstrations. Test and analysis of lighting systems verify functionality for all approved operating configurations and conditions. CFR 14.25.812 applies to aircraft requiring FAA certification.

DoD/MIL Doc: JSSG-2010-13: para 3.13.5 pg 68

FAA Doc: 14CFR references: 25.812, 23.812, 25.811

**18.1.10** Verify that a public address system is installed that is powerable when the air vehicle is in flight or stopped on the ground, including after the shutdown or failure of all engines and auxiliary power units.

Standard: A public address system is:

Powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all power sources dependent on their continued operation, for:

(1) A time duration of at least 10 minutes, including an aggregate time duration of at least 5 minutes of announcements made by flight and cabin crewmembers, considering all other loads which may remain powered by the same source when all other power sources are inoperative; and

(2) An additional time duration in its standby state appropriate or required for any other loads that are powered by the same source and that are essential to safety of flight or required during emergency conditions.

Compliance: Test and analysis of public address systems verify that they work as required for all approved operating configurations and conditions.

DoD/MIL Doc: No information available in current JSSG. Information to be included in next revision of JSSG.

FAA Doc: 14CFR references: 25.1423

**18.1.11** Verify that the public address system is accessible for immediate use by all aircrew, is capable of functioning independently of any required crewmember interphone system, and is intelligible at all passenger seats, aircrew seats, and workstations.

Standard: The public address system is accessible for immediate use from each of two flight crewmember stations in the pilot compartment. The system is capable of operation within 3 seconds from the time a microphone is removed from its stowage, and is intelligible at all passenger seats, lavatories, and flight attendant seats and work stations. The system is designed so that no unused, unstowed microphone will render the system inoperative. The system is capable of functioning independently of any required crewmember interphone system and is readily accessible to the crewmember designated to make announcements.

Compliance: Test and analysis of the public address system verifies operation and functional requirements for all approved operating configurations and conditions.

DoD/MIL Doc: JSSG-2010-13: para 3.13.5 pg 55

FAA Doc: 14CFR references: 25.1423

**18.1.12** Verify that each safety equipment control to be operated in an emergency, such as controls for automatic life raft releases, is plainly marked to show its method of operation.

Standard: Each safety equipment control to be operated by the crew in emergency, such as controls for automatic life raft releases, is plainly marked as to its method of operation. Each life raft has obviously marked operating instructions. Approved survival equipment is marked for identification and method of operation. Illustrations, and pictoral representations are used to convey operation of critical safety controls where passenger language abilities vary or are unknown. Emergency controls have alternate stripes of 0.75-in. wide orange-yellow, color 13538, and 0.25-in. wide black, color 37038.

Compliance: Safety equipment control markings are verified by inspection and functional demonstration. Human factors analysis verifies the ability of control makings to be clearly discerned

DoD/MIL Doc: JSSG-2010-11: para 3.11.7.3

FAA Doc: 14CFR references: 25.1561, 23.1561, 23.1415

**18.1.13** Verify that each location, such as a locker or compartment, that carries fire extinguishing, signaling, or other life saving equipment is marked accordingly. Verify that stowage provisions for required emergency equipment are conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Standard: Each location, such as a locker or compartment, that carries any fire extinguishing, signaling, or other life saving equipment is marked accordingly. Stowage provisions for required emergency equipment are conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Compliance: Markings indicating stowage locations of life saving equipment are verified by vehicle and engineering drawing inspection. The ability to discern markings for passenger identification and removal is verified by human factors analysis and demonstration.

DoD/MIL Doc: JSSG-2010-11: para 3.11.7.3

FAA Doc: 14CFR references: 25.1561, 23.1561, 23.1415

**18.1.14** Verify that readily accessible individual flotation devices are provided for each occupant if the air vehicle flies missions over water.

Standard: For aircraft with over water missions, there is at least one approved floatation device for each occupant. Each passenger has ready access to a floatation device such as a removable seat floatation cushion, or under seat life preserver stowage location. Stowage provisions are conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Compliance: Availability and stowage provisions of approved floatation devices is verified by inspection of the vehicle interior configuration, and engineering drawings. Demonstrations verify the ability of passengers to access floatation devices. Emergency egress demonstrations verify the ability of each passenger to access a floatation device during emergency evacuation. Functionality of floatation devices, and the ability to deploy, inflate or provide buoyancy is verified by floatation testing with human subjects.

FAA Doc: 14CFR references: 25.1411, 25.1415

**18.1.15** Verify that the air vehicle is outfitted with equipment to deal with in-flight, ground, and ditching emergencies.

Standard: The aircraft is equipped with emergency equipment to deal with in-flight, ground, and ditching emergencies, tailored for the intended mission of the aircraft. This equipment may include emergency and floatation equipment, hand-held fire extinguishers, crash ax,

megaphones, medical kits and supplies, automatic external defibrillators, portable oxygen supply systems, means for emergency evacuation, specialized tools or fracturing equipment, survival aids and equipment, weapons, communication equipment, signaling and locator devices, and portable lights.

Compliance: Emergency equipment provisions are verified by vehicle configuration, engineering drawing, and mission equipment list inspections. Functional capabilities of equipment are verified by test for they're intended purpose. Testing and verification should be accomplished from the standpoint of the overall system performance and installation. In may consist of inspections, analyses, demonstrations, and tests of normal and emergency operations for all intended air vehicle occupants.

DoD/MIL Doc: JSSG-2010-11

FAA Doc: 14CFR references: 121.309, 121.310

## 18.2 Fire resistance.

**18.2.1** Verify, sources of ignition are located and/or designed to prevent contact with cargo.

Standard: The cargo compartment design and location is suitable for transport of flammable cargo under all operational conditions. Ignition sources are protected or cargo is prevented from contact with any compartment structure containing potential ignition sources. Cargo transport manuals incorporate any size restrictions necessary to preclude possible contact with an ignition source. The cargo compartment is free of any heat, flame, or electrical discharge sources in the vicinity of the transported cargo. All components within the cargo compartment are certified for operation in an explosive atmosphere.

Compliance: Sources, locations, and configurations of possible ignition sources are verified by vehicle and engineering drawing inspections. The inability of components and systems to ignite flammable materials, and to preclude ignition of an explosive atmosphere is verified by system testing. Cargo clearances and preventive means of contacting ignition sources is verified by engineering drawing and cargo loading manual inspections, and by cargo loading demonstration.

DoD/MIL Doc: No information available in current JSSG. Information to be included in next revision of JSSG.

AFMAN 24-204(I) identifies flammability limits for transported cargo.

FAA Doc: 14CFR references: 25.787, 25.789, 23.787

**18.2.2** Verify that oxygen equipment and lines are not located in any designated fire zone; are protected from heat that may be generated in, or escape from, any designated fire zone; are not routed with electrical wiring; and are installed so that escaping oxygen cannot cause ignition of grease, fluid, or vapor accumulations present in normal operation or as a result of failure or malfunction of any system.

Standard: Oxygen equipment and lines are not located in any designated fire zone, are protected from heat that may be generated in, or escape from, any designated fire zone, and are installed so that escaping oxygen cannot cause ignition of grease, fluid, or vapor accumulations that are present in normal operation or as a result of failure or malfunction of any system. The functional and operational installation requirements for aircraft oxygen systems effectively limit fire and explosion hazards associated with survivable crashes. Oxygen system lines do not run in close proximity parallel with hydraulic fluid (or other flammable fluid/gas) lines, or in common conduits or bundled with electrical wiring. Insulation and routing paths for oxygen lines minimizes ignition hazards.

Compliance: The location and routing of oxygen lines for criteria compliance is verified by inspection of engineering drawings and models. Heat protection is verified by temperature measurement in testing and by thermodynamic analysis. Identification and acceptability of

ignition/explosive hazards is verified by a Failure Mode and Effects Criticality Analysis and a System Safety Hazard Analysis. The functional requirements are verified by review of design analysis, modeling and simulation.

DoD/MIL Doc: JSSG-2010-7: para 3.7.3.4, 3.10, 4.10

FAA Doc: 14CFR references: 25.869

## 18.3 Physiology requirements of occupants.

**18.3.1** Verify that air vehicles flying above 10,000 feet mean sea level (MSL) are capable of providing supplemental oxygen from the air vehicle, or from a stand-alone system, and are capable of delivering it to each passenger.

Standard: For each passenger, the minimum mass flow of supplemental oxygen required at various cabin pressure altitudes is not less than the flow required to maintain, during inspiration and while using oxygen equipment (including masks) provided, the following mean tracheal oxygen partial pressures:

a) At cabin pressure altitudes above 10,000 feet up to and including 18,500 feet, a mean tracheal oxygen partial pressure of 100 mmHg when breathing 15 liters per minute, Body Temperature, Pressure, Saturated (BTPS) and with a tidal volume of 700cc with a constant time interval between respirations.

b) At cabin altitudes above 18,500 feet up to and including 40,000 feet, a mean tracheal oxygen partial pressure of 83.8 mmHg when breathing 30 liters per minute, BTPS, and with a tidal volume of 1100cc with a constant time interval between respirations.

There must be an individual dispensing unit for each passenger for whom supplemental oxygen is to be supplied. Units must be designed to cover the nose and mouth and must be equipped with a suitable means to retain the unit in position on the face.

For a pressurized airplane designed to operate at flight altitudes above 25,000 feet (MSL), the dispensing units for passengers must be connected to an oxygen supply terminal and be immediately available to each occupant wherever seated, and at least two oxygen dispensing units connected to oxygen terminals in each lavatory. The total number of dispensing units and outlets in the passenger section must exceed the number of seats by at least ten percent. For operations above 30,000 feet, the dispensing units for passengers must be automatically presented to each occupant before the cabin pressure altitude exceeds 15,000 feet.

Oxygen quantities are sufficient for the duration of time that passengers may be exposed to the cabin altitudes indicated.

Compliance: The existence of a supplemental oxygen system and availability to each passenger is verified by vehicle configuration and engineering drawing inspections, and by mock up demonstration. The ability of oxygen systems to provide necessary oxygen quantities, duration, and flow rates is verified by analysis and system test in simulated altitude environments, (such as altitude chamber testing).

DoD/MIL Doc: JSSG-2010-10: para 3.10.1, 4.10.1

FAA Doc: 14CFR references: 25.1439, 23.1441, 23.1443, 23.1445, 25.1447, 23.1449, 23.1450, 25.1441, 25.1443, 25.1445, 25.1449, 25.1450, 25.1453

**18.3.2** Verify that emergency medical kit(s) capable of providing medical support for the designed mission are installed in the air vehicle.

Standard: For treatment of injuries, medical events, or minor accidents that might occur during the designated mission of the aircraft, each passenger-carrying aircraft has an approved first-aid kit(s) and an approved emergency medical kit.

Compliance: Installation and availability of emergency medical kits is verified by air vehicle and engineering drawing inspections. Adequacy of medical kit contents is verified by inspection of kit configurations, and specified content requirements for mission needs.

DoD/MIL Doc: No information available in current JSSG. Information to be included in next revision of JSSG.

FAA Doc: 14CFR references: 121.309, 121.339, 121.310

## 19. MATERIALS

(This section is applicable for Navy and Marine Corps aircraft only. This section is not required for Air Force or Army aircraft. Materials criteria are addressed throughout the MIL-HDBK-516B. If section 19 is used, the using aircraft or rotorcraft system office should tailor out the materials related criteria throughout the rest of the document as nonapplicable since these criteria may be in conflict with section 19.)

Materials comprise the entire flight vehicle including air vehicle structure, air vehicle subsystems, propulsion systems, electrical power systems, mission systems, crew systems, and armament/stores systems.

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Materials properties data and analysis
3. Environmental effects data and analysis
4. Galvanic compatibility data and analysis
5. Effects of defects data and analysis
6. Hazardous materials data
7. Material trade study results
8. Design of experiments results
9. Statistical process control data
10. Nondestructive inspection (NDI) criteria
11. NDI plan and records
12. NDI probability of detection data
13. Preproduction verification test data
14. First article destructive test data
15. Wear and erosion data
16. Material specifications
17. Process specifications
18. Finish specifications
19. Metallic materials properties development and standardization (MMPDS)
20. MIL-HDBK-17, Polymer Matrix Composites
21. Material safety data sheets
22. Contractor policies and procedures
23. Quality records
24. Defect/failure data
25. Fracture control plan
26. Fracture critical parts list

CERTIFICATION CRITERIA

## 19.1 Properties and processes.

**19.1.1** Verify that the material property evaluations are performed using a combination of recognized and standardized analyses, tests, inspections, and examinations.

DoD/MIL Doc: JSSG-2006, Appendix A.3.2.19, A.4.2.19

MIL-HDBK-1587

**19.1.2** Verify that the material properties are certified as specification compliant and that specification properties are represented as minimum values achievable using standardized processes.

FAA Doc: MMPDS

14CFR reference: 23.603, 23.613, 25.603, 25.613

**19.1.3** Verify that the material design allowable properties are represented as statistical values that account for product form and size, production representative processing, manufacturing variability, effects of defects, final assembly interfaces, environmental exposure, and repair.

DoD/MIL Doc: JSSG-2006: Appendix A.3.2.19.1, A.4.2.19.1

FAA Doc: MMPDS

14CFR reference: 23.603, 23.613, 25.603, 25.613

**19.1.4** Verify that the likelihood and consequence of failure are accounted for when a material specification property is less than its corresponding material design allowable property.

FAA Doc: 14CFR reference: 23.613, 25.613

**19.1.5** Verify that the material property degradation due to the environment (e.g., moisture absorption; chemical, solvent, fuel, and lubricant exposure; hydrolytic instability; thermal exposure; electromagnetic radiation; wear; and erosion) is accounted for.

DoD/MIL Doc: JSSG-2001: para 3.2.2, 4.2.2, 3.2.3, 4.2.3

JSSG-2006: Appendix A.3.2.16, A.4.2.16, A.3.11.1, A.4.11.1.2.1, A.3.11.2, A.4.11.2, A.3.11.3, A.4.11.3, A.3.11.4, A.4.11.4

MIL-HDBK-1568

MIL-HDBK-1587

MIL-STD-889

FAA Doc: 14CFR reference: 23.609, 23.613, 25.609, 25.613

**19.1.6** Verify that critical process capability is demonstrated and that procedures for identifying, monitoring, and controlling critical process variation are in place.

DoD/MIL Doc: JSSG-2006: Appendix A.3.2.19.2, A.4.2.19.2, A.3.11.1, A.4.11.1.2.1

FAA Doc: 14CFR reference: 23.605, 25.605

**19.1.7** Verify that critical material and process integrity are established.

DoD/MIL Doc: Jssg-2006: Appendix A.3.2.19.2, A.4.2.19.2

FAA Doc: 14CFR reference: 23.605, 25.605

**19.1.8** Verify that the maximum size and severity limits for damage requiring repair do not exceed repair capability.

DoD/MIL Doc: JSSG-2006: Appendix A.3.2.28, A.4.2.28

FAA Doc: 14CFR reference 23.611

**19.1.9** Verify that insidious failure modes (e.g., hydrogen embrittlement, crack bifurcation) are understood and accounted for.

FAA Doc: 14CFR reference: 23.609

### 19.2 Corrosion.

**19.2.1** Verify that adequate corrosion prevention and control practices are in place for uniform surface corrosion, pitting, galvanic, crevice, filiform, exfoliation, inter-granular, fretting, high temperature oxidation (hot corrosion), corrosion fatigue, and stress corrosion cracking.

**19.2.2** Verify that corrosion prevention systems remain effective during the service life, including the mitigation of environmentally assisted cracking. Specific corrosion prevention and control measures, procedures, and processes are to be identified and established commensurate with the operational and maintenance capability.

**19.2.3** Verify that adequate prevention and control practices are in place for non-metallic materials degradation as a result of the degradation processes described in 19.2.1.

**19.2.4** Verify that the finish systems provide adequate corrosion protection for specific parts, surfaces of similar and dissimilar materials, and attaching parts and fasteners. Identify/specify all surface treatments, inorganic and organic coatings, and other protective finishes to be used and their application.

DoD/MIL Doc: JSSG-2001: para 3.2.3, 4.2.3

JSSG-2006: Appendix A.3.2.20, A.4.2.20, A.3.11.2, A.4.11.2

MIL-HDBK-1568

MIL-STD-7179

MIL-STD-889

FAA Doc: 14CFR references: 23.603, 23.609, 25.603, 25.609

### 19.3 Nondestructive inspection.

**19.3.1** Verify that specific defect types, sizes, and locations critical to material integrity are characterized and assessed for probability of detection.

**19.3.2** Verify that nondestructive inspection (NDI) accept/reject criteria are validated and correlated with 'effects of defects' testing.

**19.3.3** Verify that the nondestructive inspection manuals are developed and that each of the methods is valid.

**19.3.4** Verify that initial and recurring inspection intervals are defined where applicable.

DoD/MIL Doc: JSSG-2006: Appendix A.3.11.6, A.4.11.6

MIL-HDBK-6870

FAA Doc: 14CFR reference: 23.611

## 19.4 Wear and erosion.

**19.4.1** Verify that adequate wear and erosion practices are in place for wear mechanisms (abrasive, fretting, corrosive, and thermal wear) and erosion mechanisms (impinging fluid, solid particles). Specific wear and erosion prevention practices, measures, procedures, and processes are to be identified and established commensurate with the operational and maintenance capability.

DoD/MIL Doc: JSSG-2006: Appendix A.3.2.28, A.4.2.28, A.3.11.4, A.4.11.4

FAA Doc: 14CFR reference: 23.609

.

# 20. OTHER CONSIDERATIONS

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Design studies and analyses
3. Design, installation, and operational characteristics
4. Design approval and system compatibility tests
5. Component and system level qualification and certification tests
6. Electromagnetic environmental effects
7. Hazard analysis and certification
8. Failure modes and effects analysis
9. Avionics integration tests and results
10. System/subsystem self-test design and capabilities
11. Qualification test plans, procedures, and results
12. Ground test results
13. FCA and PCA data
14. Flight manual
15. Software development plan
16. Software development and product specifications
17. Software test plans, test procedures, and test reports
18. Software configuration control/management plan and procedure
19. Flight test reports
20. Environmental analysis and test results

CERTIFICATION CRITERIA

## 20.1 Mission/test equipment and cargo/payload safety.

**20.1.1** Verify that the following items do not adversely affect the primary SOF functionality (such as structural capability, flying and handling qualities, electronic compatibility) of the air vehicle:

a. Special non-SOF mission or test equipment and software including instrumentation and wiring
b. Non-SOF mission-specific equipment and software
c. Nonessential mission equipment (hardware and software)
d. Carry-on/carry-off equipment that will be operated in flight

Standard: Non-SOF equipment, installation design, and functional interfaces to the air vehicle are assessed for potential adverse impact to air vehicle structure, weight and balance, flying qualities, electromagnetic compatibility, power quality/delivery to flight critical equipment, and potential for fire and explosion. The presence/function of these items is shown not to increase the probability of loss of the air vehicle.

Compliance: Hazard analysis and/or test data is provided which verifies that no additional safety hazards to the air vehicle are induced by the installation & function of non-SOF equipment.

**20.1.2** Verify that carriage of cargo or payload does not adversely affect safety of the air vehicle system.

Standard: Cargo and/or payload, installation design, and functional interfaces to the air vehicle are assessed for potential adverse impact to air vehicle structure, weight and balance, flying qualities, electromagnetic compatibility, power quality/delivery to flight critical equipment, and potential for fire and explosion. The presence/function of these items is shown not to increase the probability of loss of the air vehicle.

Compliance: Hazard analysis and/or test data is provided which verifies that no additional safety hazards to the air vehicle are induced by the installation & function of cargo and/or payload.

DoD/MIL Doc: JSSGs corresponding to the appropriate item and/or installations under consideration.

FAA Doc: 14CFR reference sections corresponding to Structural and Installation requirements; and systems as applicable, i.e., Electrical.

**20.1.3** Verify that in-flight operation of mission-specific personnel and cargo equipment (e.g., cargo hooks, rescue slings and hoists, H-bar and FRIES bar) does not adversely affect safety of the air vehicle system.

Standard: Mission specific equipment, installation design, and functional interfaces to the air vehicle are assessed for potential adverse impact to air vehicle structure, weight and balance, flying qualities, electromagnetic compatibility, power quality/delivery to flight critical equipment, and potential for fire and explosion. The presence/function of these items is shown not to increase the probability of loss of the air vehicle.

Compliance: Hazard analysis and/or test data is provided which verifies that no additional safety hazards to the air vehicle are induced by the installation & function of mission specific equipment.

DoD/MIL Doc: Refer to technical point of contact for this discipline (listed in section A.2).

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## 21. NOTES

### 21.1 Changes from previous issue.

This version of this handbook contains numerous changes from the previously published issue. A traceability matrix from this version to the previous version is available upon request from ASC/ENSI, 2530 Loop Road West, Wright-Patterson AFB OH 45433-7101) or emailed to (MIL-HDBK-516B@wpafb.af.mil)

### 21.2 Subject term (key word) list.

aerial refueling system
air vehicle subsystems
avionics
computer resources
crew systems
diagnostics systems
electrical power
electromagnetic environmental effects
environmental management system
fire and hazard protection
flight technology
fuel system
hydraulics and pneumatic systems
integration, armament
integration, stores
landing gear and deceleration systems
maintenance
passenger safety
power systems, auxiliary
power systems, emergency
propulsion installations
propulsion
structures
system safety

# APPENDIX

# AIRWORTHINESS CERTIFICATION CRITERIA

## A.1. SCOPE

This appendix provides technical points of contact references for the Airworthiness Certification Criteria. Contact the appropriate member in the list of technical points of contact for additional information or clarification.

## A.2. TECHNICAL POINTS OF CONTACT

| POINT OF CONTACT INFORMATION | | | | |
|---|---|---|---|---|
| **Technical Discipline** | **Office** | **POC** | **DSN** | **Commercial** |
| **4.0 Systems Engineering** | ASC/ENS | Tech Director | 785-1799 | (937) 255-1799 |
| | NAVAIR 4.0P | Deputy Airworthiness Officer | 342-0301 | (301) 342-0301 |
| **5.0 Structures** | ASC/ENFS | Tech Advisor | 785-5485 | (937) 255-5485 |
| | NAVAIR 4.3.3 | Division Head | 342-9381 | (301) 342-9381 |
| | AMSAM-RD-AE-F | Division Chief | 897-2350 X9688 | (256) 705-9688 |
| **6.0 Flight Technology** | ASC/ENFT | Tech Advisor | 785-9595 | (937) 255-9595 |
| | NAVAIR 4.3.2 | Division Head | 342-8550 | (301) 342-8550 |
| **7.0 Propulsion** | ASC/ENFP | Tech Expert | 785-8604 | (937) 255-8604 |
| | NAVAIR 4.4.1 | Division Head | 757-0499 | (301) 757-0499 |
| **8.0 Air Vehicle Subsystems** | ASC/ENFA | Tech Advisor | 785-8596 | (937) 255-8596 |
| | NAVAIR 4.3.5 | Division Head | 342-9363 | (301) 342-9363 |
| **8.1 Hydraulics and Pneumatic Systems** | ASC/ENFA | Tech Specialist | 785-8509 | (937) 255-8509 |
| | NAVAIR 4.3.5.2 | Branch Head | 757-2001 | (301) 757-2001 |
| **8.2 Environmental Management System** | ASC/ENFA | Tech Specialist | 785-8514 | (937) 255-8514 |
| | NAVAIR 4.3.5.1 | Branch Head | 757-2345 | (301) 757-2345 |
| **8.3** | ASC/ENFA | Tech Expert | 785-5908 | (937) 255-5908 |

| POINT OF CONTACT INFORMATION | | | | |
|---|---|---|---|---|
| **Technical Discipline** | **Office** | **POC** | **DSN** | **Commercial** |
| **Fuel System** | NAVAIR 4.3.5.3 | Branch Head | 323-7127 | (732) 323-7127 |
| **8.4 Fire and Hazard Protection** | ASC/ENFA | Tech Expert | 785-5908 | (937) 255-5908 |
| | NAVAIR 4.3.5.1 | Branch Head | 757-2345 | (301) 757-2345 |
| **8.5 Landing Gear & Deceleration Systems** | ASC/ENFA | Tech Specialist | 785-8511 | (937) 255-8511 |
| | NAVAIR 4.3.5.2 | Branch Head | 757-2001 | (301) 757-2001 |
| **8.6 Auxiliary/Emergency Power Systems** | ASC/ENFA | Tech Specialist | 785-8506 | (937) 255-8506 |
| | NAVAIR 4.4.6 | Branch Head | 342-0806 | (301) 342-0806 |
| **8.7 Aerial Refueling System** | ASC/ENFA | Tech Specialist | 785-7267 | (937) 255-7267 |
| | NAVAIR 4.3.5 | Branch Head | 342-9371 | (301) 342-9371 |
| **8.8 Propulsion Installations** | ASC/ENFA | Tech Specialist | 785-8506 | (937) 255-8506 |
| | NAVAIR 4.4.1 | Branch Head | 757-0499 | (301) 757-0499 |
| **9.0 Crew Systems** | ASC/ENFC | Tech Advisor | 785-5797 | (937) 255-5797 |
| | NAVAIR 4.6 | Division Head | 342-8429 | (301) 342-8429 |
| **10.0 Diagnostics Systems** | ASC/ENS | Tech Director | 785-1799 | (937) 255-1799 |
| **11.0 Avionics** | ASC/ENA | Tech Director | 785-5153 | (937) 255-5153 |
| | NAVAIR 4.5.1.1 | Division Head | 342-9130 | (301) 342-9130 |
| **12.0 Electrical Power** | ASC/ENFA | Tech Specialist | 785-5078 | (937) 255-5078 |
| | NAVAIR 4.4.4 | Division Head | 342-0803 | (301) 342-0803 |
| **13.0 Electromagnetic Environmental Effects** | ASC/ENAD | Tech Expert | 785-8928 | (937) 255-8928 |
| | NAVAIR 4.1.7 | Division Head | 342-7967 | (301) 342-7967 |
| **14.0** | ASC/ENSA | Tech Advisor | 785-9711 | (937) 255-9711 |

| POINT OF CONTACT INFORMATION | | | | |
|---|---|---|---|---|
| **Technical Discipline** | **Office** | **POC** | **DSN** | **Commercial** |
| **System Safety** | NAVAIR | Division Head | 342-2137 | (301) 342-2137 |
| **15.0 Computer Resources** | ASC/ENFT | Branch Chief | 785-4166 | (937) 255-4166 |
| | ASC/ENAS | Tech Advisor | 785-3999 | (937) 255-3999 |
| | NAVAIR 4.1.11 | Division Head | 342-2102 | (301) 342-2102 |
| **16.0 Maintenance** | ASC/ENSS | Tech Expert | 785-9541 | (937) 255-9541 |
| **17.0 Armament/Stores Integration** | ASC/ENSI | Tech Specialist | 785-5882 | (937) 255-5882 |
| | NAVAIR 4.7.6 | Division Head | 437-7206 | (760) 939-7206 |
| | NAVAIR 4.11.2 | Division Head | 342-4390 | (301) 342-4390 |
| | AMSRD-AMR-AE-S-W | Branch Chief | 897-2350 x9765 | (256) 705-9765 |
| **18.0 Passenger Safety** | ASC/ENFC | Tech Advisor | 785-8608 | (937) 255-8608 |
| | NAVAIR 4.6 | Division Head | 342-8429 | (301) 342-8429 |
| **19.0 Materials** | NAVAIR 4.9.7 | Division Head | 342-8001 | (301)342-8001 |
| **20.0 Other Considerations** | ASC/EN | Technical Advisor, Systems Engineering | 785-1826 | (937) 255-1826 |

For commercial derivative aircraft (CDA), contact the FAA Military Certification Office:

FAA Military Certification Office
ACE-100M
8200 East 34th Street North
Building 1000, Suite 1005
Wichita, KS 67226

Phone: 316-350-1580
FAX: 316-350-1592

## A.3. CROSS-REFERENCE TABLE OF MAJOR SECTION CHANGES FROM MIL-HDBK-516A TO MIL-HDBK-516B

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| 1.0 | Scope | 1.0 | Scope | |
| 2.0 | Applicable documents | 2.0 | Applicable documents | |
| 3.0 | Definitions and abbreviations | 3.0 | Definitions and abbreviations | |
| 4.0 | Systems engineering | 4.0 | Systems engineering | |
| 4.1 | Design criteria | 4.1 | Design criteria | |
| 4.2 | Tools and databases | 4.2 | Tools and databases | |
| 4.3 | Materials selection | 4.3 | Materials selection | 4.3.2 – 4.3.6 incorporated into 4.3.1 |
| 4.4 | Manufacturing and quality | 4.4 | Manufacturing and quality | |
| 4.5 | Operator's and maintenance manuals (technical orders). | 4.5 | Operator's and maintenance manuals/technical orders | |
| 4.6 | Configuration identification | 4.6 | Configuration identification | |
| 4.7 | Configuration status accounting | 4.7 | Configuration status accounting | |
| 5.0 | Structures | 5.0 | Structures | |
| 5.1 | Loads | 5.1 | Loads | |
| | | 5.2 | Structural dynamics | Previously 5.7 |
| 5.2 | Strength | 5.3 | Strength | Previously 5.2 |
| 5.3 | Materials, processes, corrosion prevention, nondestructive evaluation, and repair | | | Incorporated into 5.3 and 5.4 |
| 5.4 | Damage tolerance and durability (Fatigue) | 5.4 | Damage tolerance and durability | |
| | | 5.5 | Mass properties | Previously 5.8 |
| 5.5 | Flight operating limits | 5.6 | Flight operating limits | |

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| 5.6 | Functionality | | | Incorporated into 5.1, 5.3, and 5.4 |
| 5.7 | Structural dynamics | | | Moved to 5.2 |
| 5.8 | Mass properties interface | | | Moved to 5.5. |
| 5.9 | Stores/armament interface | | | Incorporated into 5.1, 5.2, 5.3, and 17.0 |
| 5.10 | Structural Maintenance manuals (T.O.s) | | | Deleted |
| 5.11 | Rotary wing air vehicles | | | Deleted |
| 6.0 | Flight technology | 6.0 | Flight technology | |
| 7.0 | Propulsion | 7.0 | Propulsion and propulsion installations | |
| | | 7.1 | Propulsion safety management | |
| | | 7.2 | Gas turbine engine applications | |
| 7.1 | Performance | 7.2.1 | Performance | Previously 7.1 |
| 7.2 | Operability | 7.2.2 | Operability | Previously 7.2 |
| 7.3 | Engine structures | 7.2.3 | Structures | Previously 7.3 |
| 7.4 | Engine control and accessory systems | 7.2.4 | Engine subsystems, components, computer resources and software | Previously 7.4 |
| 7.5 | Engine monitoring system | | | Incorporated into 7.2.4 |
| 7.6 | Engine bearing and lubrication system | | | Incorporated into 7.2.4 |
| 7.7 | Engine installations compatibility | 7.2.5 | Installations | Previously 7.7 |
| 7.8 | Failure modes | | | Incorporated into 7.1 |
| 7.9 | Flight manual/procedures and | | | Incorporated |

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| | limitations | | | into 7.1 |
| 7.10 | Engine externals | | | Incorporated into 7.2.4 |
| 7.11 | Engine computer resources | | | Incorporated into 7.2.4 |
| | | 7.3 | Alternate propulsion systems | New |
| 7.12 | Propellers and associated subsystem components | 7.3.1 | Propeller driven systems | Previously 7.12 |
| 7.13 | Rotors and associated subsystem components. | 7.3.2 | Rotary wing systems | Previously 7.13 |
| | | 7.3.3 | Reciprocating engines | New |
| 8.0 | Air vehicle subsystems | 8.0 | Air vehicle subsystems | |
| 8.1 | Hydraulic and pneumatic systems | 8.1 | Hydraulic and pneumatic systems | |
| 8.2 | Environmental management system (EMS) | 8.2 | Environmental control system (ECS) | |
| 8.3 | Fuel System | 8.3 | Fuel system | |
| 8.4 | Fire and hazard protection | 8.4 | Fire and hazard protection | |
| 8.5 | Landing gear and deceleration systems | 8.5 | Landing gear and deceleration systems | |
| 8.6 | Auxiliary/emergency power system(s) (APS/EPS) | 8.6 | Auxiliary/emergency power system(s) (APS/EPS) | |
| 8.7 | Aerial refueling system | 8.7 | Aerial refueling system | |
| 8.8 | Propulsion Installations | 8.8 | (Deleted, number reserved) | Incorporated into 7.2.5 |
| 8.9 | Mechanisms | 8.9 | Mechanisms | |
| 8.10 | External cargo hook systems (rotary wing) | 8.10 | External cargo hook systems (rotary wing) | |

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| 8.11 | External rescue hoist (rotary wing) | 8.11 | External rescue hoist (rotary wing) | |
| 8.12 | Fast rope insertion/extraction system (FRIES) (rotary wing) | 8.12 | Fast rope insertion/extraction system (FRIES) (rotary wing) | |
| 9.0 | Crew systems | 9.0 | Crew systems | |
| 9.1 | Escape and egress system | 9.1 | Escape and egress system | |
| 9.2 | Crew stations and aircraft interiors | 9.2 | Crew stations and aircraft interiors | |
| 9.3 | Air vehicle lighting | 9.3 | Air vehicle lighting | |
| 9.4 | Human performance | 9.4 | Human performance | |
| 9.5 | Life support systems | 9.5 | Life support systems | |
| 9.6 | Transparency integration | 9.6 | Transparency integration | |
| 9.7 | Crash survivability | 9.7 | Crash survivability | |
| 9.8 | Air transportability and airdrop. | 9.8 | Air transportability and airdrop. | |
| | | 9.9 | Lavatories, galleys, and areas not continuously occupied | New |
| 10.0 | Diagnostic systems | 10.0 | Diagnostic systems | |
| 11.0 | Avionics | 11.0 | Avionics | |
| 12.0 | Electrical system | 12.0 | Electrical system | |
| 13.0 | Electromagnetic environmental effects ($E^3$) | 13.0 | Electromagnetic environmental effects ($E^3$) | |
| 14.0 | System safety | 14.0 | System safety | |
| 15.0 | Computer resources | 15.0 | Computer resources | |
| 16.0 | Maintenance | 16.0 | Maintenance | |
| 17.0 | Armament/stores integration | 17.0 | Armament/stores integration | |

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| 18.0 | Passenger safety | 18.0 | Passenger safety | |
| 18.1 | Survivability of passengers | 18.1 | Survivability of passengers | |
| 18.2 | Fire detection, suppression, and resistance | 18.2 | Fire resistance | |
| 18.3 | Physiology requirements of passengers | 18.3 | Physiology requirements of passengers | |
| | | 19.0 | Materials | New section added for Navy and Marine Corps aircraft use only |
| 19.0 | Other considerations | 20.0 | Other considerations | |
| 20.0 | Notes | 21.0 | Notes | |
| A.1 | Scope | A.1 | Scope | |
| A.2 | Applicable documents | | | Incorporated into 2.0 |
| A.3 | Definitions | | | Incorporated into 3.0 |
| A.4 | Systems engineering | | | References listed with respective criterion |
| A.5 | Structures | | | References listed with respective criterion |
| A.6 | Flight technologies | | | References listed with respective criterion |
| A.7 | Propulsion | | | References listed with respective criterion |

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| A.8 | Air vehicle subsystems | | | References listed with respective criterion |
| A.9 | Crew systems | | | References listed with respective criterion |
| A.10 | Diagnostics | | | References listed with respective criterion |
| A.11 | Avionics | | | References listed with respective criterion |
| A.12 | Electrical power | | | References listed with respective criterion |
| A.13 | Electromagnetic environmental effects ($E^3$) | | | References listed with respective criterion |
| A.14 | System safety | | | References listed with respective criterion |
| A.15 | Computer resources | | | References listed with respective criterion |
| A.16 | Maintenance | | | References listed with respective criterion |
| A.17 | Armament/stores integration | | | References listed with respective |

## APPENDIX

| MIL-HDBK-516A | | MIL-HDBK-516B | | |
|---|---|---|---|---|
| **Section or Criteria #** | **MIL-HDBK-516A Section Title/Subtitle** | **Section or Criteria #** | **MIL-HDBK-516B Section Title/Subtitle** | **Comments** |
| | | | | criterion |
| A.18 | Passenger safety | | | References listed with respective criterion |
| A.19 | Other considerations | | | References listed with respective criterion |
| A.20 | Technical points of contact | A.2 | Technical points of contact | Previously A.20 |
| | | A.3 | Cross-reference: MIL-HDBK-516A to MIL-HDBK-516B | New |

Custodians:
Navy – AS
Air Force – 11
Army – AV

Preparing Activity:
Air Force – 11

(Project: SESS-0057)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at www.dodssp.daps.mil.