NOT MEASUREMENT SENSITIVE

JSSG-2009-9
15 November 2018

SUPERSEDING
JSSG-2009A, Appendix I
20 November 2015

DEPARTMENT OF DEFENSE
JOINT SERVICE SPECIFICATION GUIDE

AIR VEHICLE MECHANICAL SUBSYSTEMS REQUIREMENTS AND GUIDANCE

This specification guide is for guidance only.
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Comments, suggestions, or questions on this document should be addressed to AFLCMC/EZSS, BLDG 28, RM 133, 2145 MONAHAN WAY, WPAFB, OH 45433-7017 USA or emailed to ENGINEERING.STANDARDS@US.AF.MIL. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

AMSC N/A FSC 15GP

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FOREWORD

1. This specification guide is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This specification guide replaces Appendix I, "Air Vehicle Mechanical Subsystems Requirements and Guidance," in JSSG-2009A, "Air Vehicle Subsystems."

3. The purpose of this Joint Service Specification Guide (JSSG) is to provide guidance for use by Government and Industry program teams in developing program-unique specifications. This document shall not be placed on contract.

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1. SCOPE

1.1 Scope.

This specification guide provides the requirements, verifications, tailoring guidance, and background information for the mechanical subsystems. The specification guide has been developed and coordinated by technical personnel from the Air Force, Navy, and Army and has been approved as an official guide for use by Government personnel for assistance in tailoring the air vehicle subsystems specifications for acquisition and model specifications. This specification guide is a mandatory part of the air vehicle subsystem specification. The information contained herein is intended for compliance.

1.2 Structure.

The specification guide structure replicates the structure of the air vehicle subsystems specification except it places each corresponding section 3 requirement and section 4 verification together.

1.3 Overview.

This specification guide provides tailoring guidance and background information for individual paragraphs of the air vehicle subsystems specification. Guidance gives recommendations on how to tailor the specification paragraph. Where (TBS) appears, the guidance paragraph provides recommended values or text that the using service may use to insert in the (TBS). When contractors are expected to complete the (TBS), the guidance paragraph will so state. The using service makes the final decision on whom completes the (TBS) in the specification. Finally, lessons learned are provided to give insight to past events that could affect the tailoring of the specification.

1.4 Deviations.

Projected designs for given applications which will result in improvement of the system performance, reduced life cycle cost, or reduced developmental cost through deviations from this guidance, or where requirements of the specification results in compromise in operational capability, should be brought to the attention of the using service.

1.5 Environmental impact.

Air vehicle subsystems will be designed such that their operation, maintenance, and repair may be accomplished without violating the most stringent environmental regulations applicable to locations where subsystems are used or supported. Compliance with environmental regulations will not prevent subsystems from achieving and sustaining mission performance capability. Materials, processes, and environmental control equipment necessary to meet these environmental requirements must currently be available in the using service's maintenance and supply system. The design will not use environmentally unsuitable materials such as ozone depleting fluorocarbons, chlorofluorocarbons, and halons, or highly volatile organic compounds in solvents and coatings during development, production, operation, maintenance, or repair. The Environmental Protection Agency maintains an online list of toxic chemicals and hazardous substances on its Ozone Layer Depletion Website at https://www.epa.gov/ozone/snap/ that should be consulted. The Significant New Alternatives Policy (SNAP) Program available thereon identifies substitutes for ozone depleting chemicals.

The contractor will conduct an environmental analysis of air vehicle subsystems.

1.6 Responsible engineering office.

The responsible engineering office (REO) for this specification guide is AFLCMC/EZFA, BLDG 28 RM 118, WPAFB, OH 45433-7017; DSN 785-2023, COMMERCIAL (937) 255-2023; AFLCMC.EZF.MAILBOX@US.AF.MIL.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed in this section are specified in sections 3 and 4 of this specification guide. This section does not include documents cited in other sections of this specification guide or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 and 4 of this specification guide, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks.

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

JSSG-2001	Air Vehicle Joint Service Specification Guide
JSSG-2006	Aircraft Structures Joint Service Specification Guide

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-1599	Bearings, Control System Components, and Associated Hardware Used in the Design and Construction of Aerospace Mechanical Systems and Subsystems

(Copies of these documents are available online at https://quicksearch.dla.mil.)

2.2.2 Other Government documents, drawings, and publications.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL AVIATION ADMINISTRATION

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

(Information on this document's availability is provided at https://www.mmpds.org/.)

2.3 Non-Government publications.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

NAS0331	Bearing Installation and Retention by Swaging or Staking
NASM1312	Fastener Test Methods

(Copies of these documents are available at https://www.aia-aerospace.org/.)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME B1.15	Unified Inch Screw Threads (UNJ Thread Form)

(Copies of this document are available from https://www.asme.org)

SAE INTERNATIONAL

SAE ARP777	Gas Actuators (Linear and Vane Rotary Type)
SAE ARP4058	General Specification Guide for Mechanical Geared Rotary Actuators
SAE ARP4255	Electrical Actuation Systems for Aerospace and Other Applications
SAE ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
SAE AS6038	Bearings, Ball, Bellcrank, Antifriction, Airframe
SAE AS6039	Bearings, Ball, Rod End, Double Row, Self-Aligning

SAE AS7949	Bearings, Ball, Airframe, Antifriction
SAE AS8914	Bearings, Roller, Self-Aligning, Airframe, Antifriction
SAE AS81820	Bearings, Plain, Self-Aligning, Self-Lubricating, Low Speed Oscillation

(Copies of these documents are available from https://www.sae.org/.)

STANDARDS AUSTRALIA INTERNATIONAL LTD

SAI AS 3990	Mechanical Equipment – Steelwork

(Copies of this document are available from https://infostore.saiglobal.com/.)

2.4 Order of precedence.

Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.5 Streamlining.

The air vehicle subsystems specification has been streamlined. The documents listed in this specification guide that are required for acquisition have the same status as those referenced directly in section 2 (first tier). All other documents referenced through tiering may be used for guidance and information only.

3. REQUIREMENTS

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Mechanical subsystems shall consist of (a) doors, hatches, and ramps; (b) airframe bearings; (c) fasteners; and (d) utility actuators.

REQUIREMENT RATIONALE (3.4.9)

Mechanical subsystems are used where securing, fastening, and mechanizing are required.

REQUIREMENT GUIDANCE (3.4.9)

This specification guide has specific sections which address these mechanical subsystems: (1) doors, hatches, and ramps; (2) airframe bearings; (3) fasteners; and (4) utility actuators.

REQUIREMENT LESSONS LEARNED (3.4.9)

(TBD)

4.4.9 Mechanical subsystems.

The function and performance of mechanical subsystems shall be verified incrementally by (TBS).

VERIFICATION RATIONALE (4.4.9)

Verification is essential to ensure that mechanical requirements are met.

VERIFICATION GUIDANCE (4.4.9)

TBS: Verification should be accomplished incrementally and should include inspection, analysis, demonstration, or test or a combination of these methods.

VERIFICATION LESSONS LEARNED (4.4.9)

(TBD)

3.4.9.1 Air vehicle doors, hatches, hinged access panels, and ramps subsystem.

Air vehicle door, hatch, and ramp mechanical subsystems shall provide latching, locking, door status monitoring, door control, and sealing.

REQUIREMENT RATIONALE (3.4.9.1)

Air vehicles in general require numerous openings in the fuselage to permit access to and escape from the flight and passenger compartments, the cargo and baggage hold, and equipment bays. The purpose of the air vehicle door and hatch mechanical subsystems is to provide the mechanization of these functions.

REQUIREMENT GUIDANCE (3.4.9.1)

The air vehicle doors and hatches should be designed so jamming or blocking by cargo, baggage, or foreign objects in the open or closed position is not possible.

The air vehicle doors and hatches should withstand jam loads at any point without detrimental deformation.

Means should be provided to hold the air vehicle doors in the open or closed position for ground operation with power off. Subsequent power operation of the doors, with these means left in place, should not result in damage.

Main entrance doors should permit passage of personnel and necessary equipment. Main entrance doors for patrol, transport, antisubmarine warfare, and utility air vehicles should be provided with a lock and key for locking the door from the outside. However, the doors should be operable from the inside when locked.

Special consideration should be given to cargo doors for ease of loading and unloading. Main cargo-loading openings should admit packages of maximum practicable dimensions so that as varied a cargo as possible may be carried. The main side-cargo-loading-opening should be on the left side, unless such openings are symmetrical about the centerline of the air vehicle. Cargo doors should be flush with the floor except where it is required to make them watertight or pressure-tight. Cargo door locations and the manner of opening should render minimum interference to cargo loading and unloading and should not restrict the use of loading platforms, cranes, fork lift trucks, or such for transferring cargo. Servicing of the air vehicle should be possible without interference with loading or unloading when done simultaneously.

Doors for parachute jumping should be operable from the inside in flight and located for safe egress. There should be no projections on which personnel might stumble or foul their clothing or gear in preparing to jump or while jumping. Air vehicles capable of carrying more than 20 troops should be provided with 2 door spaces to permit simultaneous jumping. Doors for parachute jumping should be at least 36 inches wide by 70 inches high and should be flush with the floor.

Compartment hinged access panels and other openings with covers should be provided as required. The covers and hatches should permit ready securing or opening and should be watertight in flight. All equipment compartments should be accessible without the use of work stands or platforms and should be eye level or lower to permit maintenance personnel access to equipment contained therein. Equipment compartments should be free of structural obstruction and armament recesses.

All seaplane and amphibian air vehicles should have provisions for boarding to and from boats brought along side in choppy water. Doors most suitable for this purpose should be clearly designated. Recessed fittings should be provided forward and aft of entrance doors for steadying or securing a small boat raft. Amphibian air vehicles should have provisions for boarding from the ground when ashore.

REQUIREMENT LESSONS LEARNED (3.4.9.1)

Air vehicle door and hatch bearings should be selected in accordance with MIL-HDBK-1599.

Air vehicle door mechanical joints that do not have standard bushings or bearings should have a life equal to the air vehicle service life with at least one rework. Parts containing friction surfaces subject to wear should be designed for easy repair or replacement. Joints of air vehicle doors and hatches should be smooth with no gaps to cause a breakdown of airflow.

The performance requirements of JSSG-2006 apply to the air vehicle door and hatch mechanical components.

Door sills, coamings, and lower edges of doors should be so constructed as to provide edges that may not be readily damaged by normal personnel traffic. Additionally, all corners of doors, hatches, panels, or covers should be rounded to preclude injury to maintenance personnel with the doors, hatches, panels, or covers in the open position.

4.4.9.1 Air vehicle doors, hatches, hinged access panels, and ramps subsystem.

Testing shall be conducted to verify the door, hatch, hinged access panels, and ramp mechanical subsystems' ability to handle operating loads and jam loads. Demonstrations shall be conducted to verify functionality. The design and operating characteristics shall be substantiated by analysis.

VERIFICATION RATIONALE (4.4.9.1)

The design and operating characteristics of the mechanical subsystems to fulfill the functional needs of the air vehicle must be made known prior to operational deployment.

VERIFICATION GUIDANCE (4.4.9.1)

The integration of the mechanical subsystems should be demonstrated in a mock-up simulating the expected loads and structural attachments. Testing should be designed and conducted to establish integrity and durability of the mechanisms. The sizing and operating characteristics should be determined analytically.

VERIFICATION LESSONS LEARNED (4.4.9.1)

(TBD)

3.4.9.1.1 Air vehicle door maintenance.

Air vehicle door, hatch, hinged access panels, and ramp hinges requiring disassembly for maintenance shall be installed by a method that will prevent damage to all the corrosion-protected surfaces.

All door hardware (latches and hinges) and any items mounted to or within the door or hatch structure shall be readily accessible for lubrication, rigging, adjustment, removal, and replacement without disassembly of structure.

REQUIREMENT RATIONALE (3.4.9.1.1)

The purpose of this requirement is to ensure that the installation techniques will not damage the corrosion protected surfaces of bushings and joints during the assembly process and that the door hardware will be easily serviced.

REQUIREMENT GUIDANCE (3.4.9.1.1)

Hardware should not require lubrication at the organizational or intermediate level. All latches and locks should be accessible without the use of special tools, equipment, or work stands.

REQUIREMENT LESSONS LEARNED (3.4.9.1.1)

(TBD)

4.4.9.1.1 Air vehicle door maintenance.

Verify by analysis of the design drawings that air vehicle door bushings and joints requiring disassembly for maintenance will be installed by a method that will prevent damage to all corrosion protected surfaces. Also, verify that design can allow easy access for maintenance of door hardware.

VERIFICATION RATIONALE (4.4.9.1.1)

Verification is needed to confirm that the manufacturing process used in the installation of bushings will not induce corrosion in protected surfaces and that door hardware will be easily accessed for maintenance.

VERIFICATION GUIDANCE (4.4.9.1.1)

Analysis of the drawings should include inspection of the installation tolerances of the assembly methods with particular attention to the corrosion protected surfaces. Ease of maintenance for the door hardware should also be inspected.

VERIFICATION LESSONS LEARNED (4.4.9.1.1)

(TBD)

3.4.9.1.2 Powered door position.

Powered doors shall not change position due to loss of power in any associated system.

REQUIREMENT RATIONALE (3.4.9.1.2)

The purpose of this requirement is to ensure the loss of a powered door will not cause injury or damage.

REQUIREMENT GUIDANCE (3.4.9.1.2)

A positive mechanical device should be provided to prevent change in selected door positions due to fluid bleeding down after fluid power is shut off or electrical power is lost.

REQUIREMENT LESSONS LEARNED (3.4.9.1.2)

(TBD)

4.4.9.1.2 Powered door position.

Powered door position requirements shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.1.2)

This verification is necessary to assure continued controlled flight and landing in the event of a door loss or door component failure.

VERIFICATION GUIDANCE (4.4.9.1.2)

TBS should include an inspection of the air vehicle drawings. In addition, failure modes and effects analysis should be conducted to predict the consequence of hydraulic, electrical, or mechanical failures.

VERIFICATION LESSONS LEARNED (4.4.9.1.2)

(TBD)

3.4.9.1.3 Latching.

Latches shall keep the doors and hinged access panels secured under all design conditions. The latches shall withstand limit design loads without detrimental deformation or loss of fuselage pressurization and shall withstand ultimate loads without failure.

REQUIREMENT RATIONALE (3.4.9.1.3)

Door latching secures doors to prevent loss in flight.

REQUIREMENT GUIDANCE (3.4.9.1.3)

Maximum possible relative deflection between the air vehicle structure, doors, and the latches should not cause unlatching under any ultimate design loading condition.

The latches should be incapable of completing the latching cycle under all operating conditions unless the doors are in the fully closed position.

Latch installations on the doors that affect the safety of flight and are operational in flight should be visible and accessible by ground crew and by aircrew members to ensure a fully latched condition by direct visual observation.

The latches should be independent of the locks so that any inadvertent unlatching attempt will not cause unlocking.

Flight and pressurization loads should not exert an unlatching force.

Damage or permanent deformation to the latches or support structures should not result from the most critical jam load conditions.

Single, simple action door latches should be used. Latches on exterior doors should be of the irreversible type. Spring action should not be used to return the latch to the locked position; however, it may be used to hold the latch in the locked position and resist vibration forces tending to unlock the door. Latching mechanisms of hair trigger type should not be used. Latches on interior doors that do not open into watertight or pressurized compartments may utilize simple spring actuated mechanisms.

REQUIREMENT LESSONS LEARNED (3.4.9.1.3)

(TBD)

4.4.9.1.3 Latching.

The security, under all design to conditions, of air vehicle door and hinged access panel latches shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.1.3)

The tests are intended to ascertain whether or not door openings could occur subsequent to simulated single latch failure or combination of probable multiple failures.

VERIFICATION GUIDANCE (4.4.9.1.3)

TBS: Testing should be accomplished in conjunction with other tests whenever possible. To accomplish this goal, all suitable latch tests should be coordinated with the structural test program to avoid duplication. Tests should be conducted duplicating the most critical conditions. In conjunction with these tests, all failures should be analyzed for any detrimental after effects caused by the initial failure.

VERIFICATION LESSONS LEARNED (4.4.9.1.3)

(TBD)

3.4.9.1.4 Locking.

The door locks shall prevent the door latches from opening unless the door locks are opened.

REQUIREMENT RATIONALE (3.4.9.1.4)

The purpose of this requirement is to ensure that the locks hold the latches closed under all air and ground load conditions and single failure modes.

REQUIREMENT GUIDANCE (3.4.9.1.4)

Maximum possible deflection of the lock actuator, linkage, and support structure should not cause unlocking under any ultimate load conditions.

The locks should be incapable of locking or indicating they are locked unless all the latches are properly latched in the fully secured position. This requirement applies to the following door subsystems: (TBD).

The locks and their components should have an actuation service life of (TBD) cycles.

The lock installation on the door subsystems should be accessible to the flight and ground crew members to ensure a fully locked condition by direct visual observation. In addition, the lock installation should be visible to the aircrew members for doors that are in the pressurized volume or that affect safety of flight and are opened and closed in flight.

The locks should be independent of the latches and inadvertent unlocking should not cause unlatching. Inadvertent latch activation should not cause unlocking or unlatching with the locking subsystem engaged.

The locks should be incapable of unlocking at unsafe pressurization levels.
Damage or permanent deformation to the locks or support structure should not result from the most critical jam load conditions.

REQUIREMENT LESSONS LEARNED (3.4.9.1.4)

(TBD)

4.4.9.1.4 Locking.

Verify by analysis and test that the air vehicle door locks shall prevent unlatching under all operating and ultimate load conditions.

VERIFICATION RATIONALE (4.4.9.1.4)

It must be verified that the door locks prevent any movement of latches to the open position due to pressurization loads or single failure modes.

VERIFICATION GUIDANCE (4.4.9.1.4)

All testing should be accomplished in conjunction with the door latch test on the full-scale test model.

VERIFICATION LESSONS LEARNED (4.4.9.1.4)

(TBD)

3.4.9.1.5 Pressurization.

All air vehicle pressurized doors, whose inadvertent opening would present a probable hazard to personnel or to continued safe flight and landing, shall have provisions to prevent pressurization of the air vehicle if the doors are not fully closed, latched, andlocked.

REQUIREMENT RATIONALE (3.4.9.1.5)

The air vehicle could over pressurize or lose pressurization if a door is not secured properly. The provisions not only must give positive evidence of an improperly locked and latched door, but also guard against unsafe pressurization.

REQUIREMENT GUIDANCE (3.4.9.1.5)

The air vehicle doors should be designed so that the air vehicle cannot be pressurized unless the doors are completely closed, latched and locked. The design of the doors should prevent pressurization of the air vehicle at the maximum airflow rate from the pressurization system.

REQUIREMENT LESSONS LEARNED (3.4.9.1.5)

(TBD)

4.4.9.1.5 Pressurization.

Verify by analysis and inspection that doors and hatches are designed to prevent the cabin from being pressurized if they are not properly closed, latched, and locked. Demonstrations shall be conducted to verify system pressurization is prevented if doors are not properly closed.

VERIFICATION RATIONALE (4.4.9.1.5)

Analysis and inspection are necessary to verify that door and hatch designs will not permit the cabin to be pressurized if doors and hatches are not properly closed, latched, and locked.

VERIFICATION GUIDANCE (4.4.9.1.5)

Analysis and inspection should cover all the probable failure modes of the subsystem. Demonstrations should be performed on a full-scale article.

VERIFICATION LESSONS LEARNED (4.4.9.1.5)

(TBD)

3.4.9.1.6 Unlocking under pressurization.

When the air vehicle is pressurized, the doors and hatches shall not unlock with the locks energized to the open position.

REQUIREMENT RATIONALE (3.4.9.1.6)

The intent of this requirement is to ensure that the pressurization prevention design will hold the locks in the closed position when the fuselage is pressurized and the locks are energized to open.

REQUIREMENT GUIDANCE (3.4.9.1.6)

This requirement primarily applies to the larger doors, whose in-flight loss could cause a safety hazard.

REQUIREMENT LESSONS LEARNED (3.4.9.1.6)

(TBD)

4.4.9.1.6 Unlocking under pressurization.

Verify by demonstration that the design shall prevent unlocking when the air vehicle is pressurized with the locks energized to the open position.

VERIFICATION RATIONALE (4.4.9.1.6)

Demonstration is intended to ascertain whether or not unlocking can occur while the air vehicle is pressurized.

VERIFICATION GUIDANCE (4.4.9.1.6)

Demonstration should be accomplished at various fuselage pressure differentials until the pressure is low enough to permit unlocking. A determination should then be made regarding the safety aspects of the door opening at that pressure. All demonstrations should be performed on a full-scale test model.

VERIFICATION LESSONS LEARNED (4.4.9.1.6)

Demonstration should be performed at pressure levels significantly away from structural limits and to prevent rapid depressurization that could harm personnel.

3.4.9.1.7 Pressurization prevention device failures.

(TBS) failures of the pressurization prevention device shall not permit the fuselage to be pressurized without air vehicle doors being locked and latched.

REQUIREMENT RATIONALE (3.4.9.1.7)

The purpose of this requirement is to prevent the air vehicle from pressurizing with the locks in the open position. This requirement is included to ensure that in no case will a single or multiple failure permit the fuselage to be pressurized.

REQUIREMENT GUIDANCE (3.4.9.1.7)

TBS should be completed by referring to JSSG-2001, "Reliability."

REQUIREMENT LESSONS LEARNED (3.4.9.1.7)

(TBD)

4.4.9.1.7 Pressurization prevention device failures.

Verify by analysis that a single failure or multiple failures of the pressurization prevention device shall not permit the fuselage to be pressurized without the proper positioning of the door locks and latches.

VERIFICATION RATIONALE (4.4.9.1.7)

The analysis is intended to ascertain whether or not hazardous pressurization can occur subsequent to a single pressurization system failure or a combination of probable multiple failures.

VERIFICATION GUIDANCE (4.4.9.1.7)

All failures in the pressurization system, which were identified in the analysis, should be tested to ascertain the severity of the failure. The most critical condition can be identified by structural analysis.

VERIFICATION LESSONS LEARNED (4.4.9.1.7)

(TBD)

3.4.9.1.8 Door status monitoring.

The indication subsystem shall continuously monitor and provide an unsafe indication when the doors, latches, or locks are unsecured, and provide a safe indication when they are secured. The following air vehicle doors shall require indicators: <u>(TBS)</u>.

REQUIREMENT RATIONALE (3.4.9.1.8)

The purpose of this requirement is to ensure that the safe or unsafe status of the doors is continuously presented to the aircrew members. The indicators also assist in trouble shooting in the event of a malfunction.

REQUIREMENT GUIDANCE (3.4.9.1.8)

TBS should be completed with a listing of all power-operated doors and other doors considered critical to air vehicle safety.

a. Multiple indicators (mechanical or electrical) should communicate the flight status of the pressurized air vehicle doors. A separate sensor and an independent circuit should energize each indicator. At least a single indicator should be considered for unpressurized doors that are operated in flight.

b. Indicator sensors should sense the position of the doors, latches, and locks directly, without the use of auxiliary devices such as sensor targets.

c. Mechanical indicators should use positive mechanical linkage for extension and retraction.

d. The indication subsystem should be such that the deflection of the air vehicle structure under all ground and flight load conditions should not cause false indications.

e. Indication that latching is complete should result only from full engagement of the mating latch members.

f. Indication that locking is complete should result only from full engagement of the mating locking members.

g. Remote electrical indication subsystems should incorporate a built-in test capability to test the integrity of the indicator lights and circuits and should not fail passively for any probable failure modes.

REQUIREMENT LESSONS LEARNED (3.4.9.1.8)

(TBD)

4.4.9.1.8 Door status monitoring.

Verify by analysis and demonstration that each indication subsystem will continuously monitor and provide an unsafe indication when either the door, latch, or lock is unsecured; and provide a safe indication when they are secured.

VERIFICATION RATIONALE (4.4.9.1.8)

Analysis and demonstration is intended to confirm that the indication subsystem continuously monitors the door status.

VERIFICATION GUIDANCE (4.4.9.1.8)

Demonstration should be accomplished on the full-scale article in conjunction with other tests, such as the life cycle tests, and should include all the malfunctions that could give a false indication determined by the analyses. Particular emphasis should be placed on those malfunctions that could give a safe indication for an unsafe condition.

VERIFICATION LESSONS LEARNED (4.4.9.1.8)

(TBD)

3.4.9.1.9 Door control.

Controls shall be provided for all doors and hatches by (TBS).

REQUIREMENT RATIONALE (3.4.9.1.9)

The purpose of this requirement is to ensure that controls are provided for doors in a manner that will enable the crew to open or close the doors quickly and safely.

REQUIREMENT GUIDANCE (3.4.9.1.9)

TBS: The following should be considered:

a. Door control interruption. Control power interruption or a reversal of the door controls during an actuation cycle should not cause subsystem damage. Reversal of the controls during a cycle should cause reversal of the door movement. The controls should be capable of stopping door movement at any time in the cycle by the operator selecting the control stop position. In the event of a power interruption, the door controls should go to the stop position, and it should not require reprogramming upon resumption of power.

b. Manual actuation of door control subsystem. The controls should be designed for emergency operation by means of manual actuation of the door sequence.

c. Inadvertent door actuation. Means should be provided to prevent inadvertent actuation of the doors.

d. Malfunction or failure during cycle. The controls should automatically stop the sequence in the event a malfunction or failure occurs part way through a cycle.

e. Alternate power. An alternate power source should be provided that will operate any door that would require an alternate power source if the main power source is lost. The time to operate the door with alternate power should reasonably approximate the time using main power.

REQUIREMENT LESSONS LEARNED (3.4.9.1.9)

(TBD)

4.4.9.1.9 Door control.

Verify by analysis and demonstration that the door controls are provided in a manner such that the aircrew can operate the controls quickly and safely without the danger of damaging the air vehicle.

VERIFICATION RATIONALE (4.4.9.1.9)

Analysis and demonstration is intended to confirm that the door controls can be operated safely and efficiently.

VERIFICATION GUIDANCE (4.4.9.1.9)

Demonstration should be accomplished on the full-scale article in conjunction with other tests, such as the life cycle tests. The door controls should be tested both opening and closing from several points in the actuation cycle. Manual operation of the door and a reversal of door movement should also be tested.

VERIFICATION LESSONS LEARNED (4.4.9.1.9)

(TBD)

3.4.9.1.10 Sealing.

All door and hatch seals and their supporting structures shall retain air pressurization during all flight and ground operations when the engines are running.

REQUIREMENT RATIONALE (3.4.9.1.10)

The purpose of this requirement is to ensure that cabin pressurization is not lost as a result of fuselage or canopy deflections.

REQUIREMENT GUIDANCE (3.4.9.1.10)

The seals should retain air pressurization caused by maximum fuselage deflections. Seals should be positively retained by methods other than or in addition to adhesive bonding and should be designed for easy removal and replacement.

REQUIREMENT LESSONS LEARNED (3.4.9.1.10)

(TBD)

4.4.9.1.10 Sealing.

Verify by analysis and demonstration that the seals will retain cabin pressurization as a result of expected fuselage or canopy deflections.

VERIFICATION RATIONALE (4.4.9.1.10)

Pressurization tests are intended to demonstrate the canopy and door seals' ability to maintain cabin pressurization.

VERIFICATION GUIDANCE (4.4.9.1.10)

Tests should be performed on a full-scale air vehicle under full load and maximum pressurization.

VERIFICATION LESSONS LEARNED (4.4.9.1.10)

(TBD)

3.4.9.1.11 Ramp load cycle time.

The ramp shall be capable of lifting ramp maximum load from the normal open to the fully closed position in (TBS).

REQUIREMENT RATIONALE (3.4.9.1.11)

The purpose of this requirement is to ensure that ramp actuation can be accomplished within the allowable time specified.

REQUIREMENT GUIDANCE (3.4.9.1.11)

TBS: Time should be determined by referring to JSSG-2001.

REQUIREMENT LESSONS LEARNED (3.4.9.1.11)

(TBD)

4.4.9.1.11 Ramp load cycle time.

Ramp load cycle time shall be verified by analysis and test.

VERIFICATION RATIONALE (4.4.9.1.11)

The purpose of the analysis and test is to verify that the ramp is designed properly to lift the specified loads in the specified time.

VERIFICATION GUIDANCE (4.4.9.1.11)

All testing should be performed at rated system pressure and voltage and at normal actuation rates. Ground test on the full-scale article should precede flight tests.

VERIFICATION LESSONS LEARNED (4.4.9.1.11)

(TBD)

3.4.9.1.12 Extending and holding the cargo ramp.

The ramp shall have the capability of extending and holding full operational load in a position level with the floor during ground and flight operations.

REQUIREMENT RATIONALE (3.4.9.1.12)

The purpose of this requirement is to ensure that the ramp will not drop with its load as a result of a power system failure or interruption. All probable failure modes that may cause a ramp to drop should be considered.

REQUIREMENT GUIDANCE (3.4.9.1.12)

Specify the failure modes that the ramp is expected to withstand in order that it be restrained in the loaded, fixed position. If trapped, hydraulic pressure is used to hold the ramp, the trapping valve should be located at the actuator port.

REQUIREMENT LESSONS LEARNED (3.4.9.1.12)

(TBD)

4.4.9.1.12 Extending and holding the cargo ramp.

Verify by analysis and test that the ramp will stop and hold its position while loaded to its operational capability in the event of power system failure or interruption.

VERIFICATION RATIONALE (4.4.9.1.12)

Analysis and test are intended to reveal any deficiency that would permit the ramp to drop in the event of a failure.

VERIFICATION GUIDANCE (4.4.9.1.12)

Various hydraulic and electrical power interruptions singularly and in combination should be simulated for the tests. Consult the structure engineers for the maximum ramp loads. All tests should be performed on the full-scale article before testing on test air vehicle. If a hydraulic trapping value is used, verify that it is located at the actuator port.

VERIFICATION LESSONS LEARNED (4.4.9.1.12)

(TBD)

3.4.9.1.13 Weapons bay door.

Weapons bay door latches shall be provided with a positive lock to prevent external air loads from moving the weapons bay doors toward their open positions while the air vehicle is in flight with the door controls set in the closed position. Manually operated hold-open latches shall be provided to secure doors in the open position, shall incorporate a lock, and shall be located in an area where personnel can access safely.

REQUIREMENT RATIONALE (3.4.9.1.13)

The purpose of this requirement is to ensure that the weapons bay doors do not open or close unexpectedly due to external air loads.

REQUIREMENT GUIDANCE (3.4.9.1.13)

Hold-open latches should be located away from turbine engine bleed-air exhausts, engine intakes and exhausts, propellers, and such.

REQUIREMENT LESSONS LEARNED (3.4.9.1.13)

(TBD)

4.4.9.1.13 Weapons bay door.

Verify by analysis and inspection that weapons bay doors will not open due to external air loads. Verify by analysis and test that latches are in place to secure weapons bay doors in the open position.

VERIFICATION RATIONALE (4.4.9.1.13)

Analysis and test are intended to reveal any design deficiencies that may permit the weapons bay doors to open or close unexpectedly.

VERIFICATION GUIDANCE (4.4.9.1.13)

In-flight testing should be performed under various flying conditions to ensure weapons bay doors do not open or close unexpectedly. Ground testing on the full-scale test model should precede any ground or flight tests on test air vehicle. Tests on the full-scale test model should simulate the wind loads.

VERIFICATION LESSONS LEARNED (4.4.9.1.13)

(TBD)

3.4.9.1.14 Weapons bay door performance.

Weapons bay doors shall be designed to travel from fully closed to fully open in (TBS 1) under a (TBS 2) knot wind.

REQUIREMENT RATIONALE (3.4.9.1.14)

The purpose of this requirement is to ensure the weapons bay door can be opened within the allowable time specified at the speed specified.

REQUIREMENT GUIDANCE (3.4.9.1.14)

TBS 1 and TBS 2: Refer to JSSG-2001.

REQUIREMENT LESSONS LEARNED (3.4.9.1.14)

(TBD)

4.4.9.1.14 Weapons bay door performance.

Weapons bay door performance shall be verified by analysis and test.

VERIFICATION RATIONALE (4.4.9.1.14)

The verification is intended to demonstrate that the operation of the weapons bay doors is completed within the established period under the specified load.

VERIFICATION GUIDANCE (4.4.9.1.14)

The demonstration should be performed on a fully assembled subsystem, preferably on a full-scale article. Ground tests should precede flight tests. In-flight tests should be performed at maximum speed.

VERIFICATION LESSONS LEARNED (4.4.9.1.14)

(TBD)

3.4.9.2 Airframe bearings.

Airframe bearings shall be capable of joining mechanical elements; transmitting design loads through the full range of the system operating parameters; permitting rotation, misalignment, or both while maintaining a specified dimensional relationship between the joined elements; reducing friction and wear; and making friction and wear more predictable. Airframe bearings shall be standardized to the maximum extent possible without compromising performance.

REQUIREMENT RATIONALE (3.4.9.2)

Proper selection of airframe bearings will provide structurally efficient joints that are trouble free in service at the lowest possible total cost. Standard bearings are given priority in new design in order to minimize the cost of procurement and testing, reduce schedule and technical risk, and obtain multiple sources of supply.

REQUIREMENT GUIDANCE (3.4.9.2)

MIL-HDBK-1599 should be used for selection, application, and installation of airframe bearings. The information contained within MIL-HDBK-1599 is considered guidance that may be deviated from when adequate technical justification exists. Parts listed in MIL-HDBK-1599 are standard parts and should be given selection priority in mechanical and functional system design.

REQUIREMENT LESSONS LEARNED (3.4.9.2)

The system operating parameters are the basis of selecting what type of bearing should be used for a particular application. Table 201-VII in MIL-HDBK-1599 provides bearing selection parameters. The first step in the selection of an airframe bearing is to determine whether an antifriction or a plain bearing would best fit the needs of the application. Under normal circumstances, the type of bearing that is superior in the greatest number of desirable properties would be the logical choice. However, in some instances one property may be so important that a selection can be made based on this quality alone.

Standard bearings should be used in all possible application because:

a. Nonstandard bearings may be priced from 3 to 20 times the cost of equivalent standard bearings.

b. Due to lack of reliable data on load-life relationships and static limit loads, calculations alone are used on nonstandard bearings by the vendor to determine capacity. No qualifications or service testing has been done, making the performance of the bearing the responsibility of the purchaser.

c. Standard bearings can, in many cases, be obtained from stock or from frequent production runs that should shorten the lead time needed to obtain bearings. Special bearings can require up to one year from the time the order is placed to delivery.

d. It is wise to have a multiple source of supply because strikes, disasters, or material shortages can cause long delays when special bearings are obtained from one vendor. Standards with Qualified Products Lists are required to identify at least two suppliers.

Bushings have been provided for all bolts and pins subject to angular or other motions, which tend to distort or enlarge the hole. Bushings have been economical replaceable elements that protect expensive structural members from wear and galling. Bushings that have been securely installed and assume all of the wear and deformation at the joint have assured that (1) relative motion, and thus wear, occurred at the intended surface; (2) the bushings have not migrated out of the housing; and (3) proper stresses have been maintained in the bushing and housing.

Bushing installed with a sliding fit have been used as a spacer to eliminate clevis deflection in a clevis-and-lug bearing joint. Bushings have not been necessary in standard items such as fork-end cable terminals and turn buckles.

In previous applications, it has been found that only a portion of the shaft will be in contact with the bearing surface due to shaft bending in large length-to-diameter bushings. Therefore, when the effective projected area was computed to determine static capacity, the length used in the computation did not exceed the bushing diameter even though the length of the bushing may have exceeded the diameter.

In the past, design activities prepared a Program Parts Selection List (PPSL). Design selection of parts from a PPSL promoted standardization. All parts introduced in the design of equipment, system or subsystem, were listed on the PPSL.

4.4.9.2 Airframe bearings.

The airframe bearing shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.2)

Analysis and test of the airframe bearing reduces the risk of costly design changes, which would result from the need to increase bearing capability. A design change could also affect surrounding structure design. The risk of bearing replacement becoming a high maintenance item is also reduced.

VERIFICATION GUIDANCE (4.4.9.2)

TBS: MIL-HDBK-1599 should provide guidelines for analysis of airframe bearings. Verify by demonstration that airframe bearings are standardized to the maximum extent possible without comprising performance. Analysis and testing of nonstandard bearings should take into account the nonstandard features of the bearing as well as the design application for which the nonstandard bearing is intended.

VERIFICATION LESSONS LEARNED (4.4.9.2)

(TBD)

3.4.9.2.1 Capacity.

Airframe bearings shall have the highest load capacity rating consistent with space and weight as specified in (TBS).

REQUIREMENT RATIONALE (3.4.9.2.1)

Growth of air vehicle capabilities generally result in bearing design load increases as the air vehicle program matures. Providing the highest capacity bearing that will fit in the available space during the initial design will preclude overloading bearings in future model air vehicles or expensive structural redesign to incorporate larger bearings.

REQUIREMENT GUIDANCE (3.4.9.2.1)

TBS: MIL-HDBK-1599 should be used to provide capacity equations for the most common airframe bearing types. The capacity equations or other analytical tools should be used to compare candidate bearings.

REQUIREMENT LESSONS LEARNED (3.4.9.2.1)

The proper size of the bearing have been determined after choosing what type of bearing best meets the operating parameters. The two primary load conditions that have been considered to properly select a bearing for aerospace vehicle applications were (1) "static" loading, which is concerned with the strength of the bearing and its ability to resist significant deformation and fracture, and (2) "dynamic" loading, which is concerned with the oscillation or rotation of the bearing while under fixed or changing load and is limited by fatigue and wear. After a tentative selection was made on the basis of static capacity, the size selected was reviewed to determine if it had adequate life for the rotation or oscillation desired.

4.4.9.2.1 Capacity.

Airframe bearing capacity shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.2.1)

Analysis and test of the airframe bearing capacity reduces the risk of costly design changes, which would result from the need to increase bearing capacity. The risk of bearing replacement becoming a high maintenance item is also reduced.

VERIFICATION GUIDANCE (4.4.9.2.1)

TBS: Verify by test or analysis that the bearing meets the capacity requirements of the application. Analysis of bearing capacity using the capacity equations of MIL-HDBK-1599 should be sufficient to verify the requirement of most airframe bearing applications. When unique applications or nonstandard bearings are used, use of other analytical techniques may be appropriate.

VERIFICATION LESSONS LEARNED (4.4.9.2.1)

An airframe bearing may be subjected to radial, axial, and moment loading at the same time. It will be necessary to calculate the equivalent thrust load and to determine the proper size bearing by a comparison of the calculated equivalent load and the limit thrust load using appropriate analytical techniques.

3.4.9.2.2 Installation and retention.

Bearings shall be sized to fit within a housing as specified in (TBS). If lubrication of the bearing is required, the bearing shall be lubricated when installed and provisions shall be made for re-lubrication, inspection, and replacement.

REQUIREMENT RATIONALE (3.4.9.2.2)

The proper fit of bearings within the housing will preclude adverse effects such as fretting corrosion, unacceptable stress levels in either the bearing or housing, migration of the bearing out of the housing, and reduced bearing fatigue and wear life.

Some bearings require periodic re-lubrication to achieve rated life. Provisions are needed for the maintainer to re-lubricate the bearings with standard tools.

REQUIREMENT GUIDANCE (3.4.9.2.2)

TBS should be filled in with AIA/NAS 0331, MIL-HDBK-1599, or other specifications that provide guidelines for airframe bearing installation, retention, and replacement. Requirement 202 of MIL-HDBK-1599 provides guidelines for establishing engineering criteria and design information relative to the installation and retention of bearings, including recommended shaft and housing fits to mount standard bearings. Requirement 203 of MIL-HDBK-1599 provides guidance for establishing standard practices for the lubrication of the bearings and bearings surfaces. Nonstandard bearings may require special consideration to select the proper fit for the bearing to operate as designed.

REQUIREMENT LESSONS LEARNED (3.4.9.2.2)

Landing gear trunnion bearings require a special fit to ensure the landing gear meets the requirement to drop and lock under its own weight.

4.4.9.2.2 Installation and retention.

Compliance with the installation and retention requirement shall be verified by (TBS). Verify by inspection that bearings that require lubrication are lubricated when installed and provisions have been made for re-lubrication, inspection, and replacement.

VERIFICATION RATIONALE (4.4.9.2.2)

Verification of installation requirements during the initial design assures that the bearing operates as intended when exposed to the loads, temperatures, and contaminants of the design environmental conditions. Verification of lubrication requirements assures that bearings operate as intended when installed and that proper maintenance can be performed.

VERIFICATION GUIDANCE (4.4.9.2.2)

TBS should be filled in with inspection: inspection of assembly, installation, and fabrication drawings. Process specifications confirms that proper provisions have been specified for installing, maintaining, and replacing airframe bearings. AIA/NAS 0331 and MIL-HDBK-1599 provide a basis for evaluating installation and lubrication provisions on engineering drawings. Unique application or nonstandard bearings may require provisions that differ from AIA/NAS 0331 and MIL-HDBK-1599, which is acceptable with adequate justification.

VERIFICATION LESSONS LEARNED (4.4.9.2.2)

(TBD)

3.4.9.2.3 Antifriction bearings.

If required, antifriction bearings shall be in accordance with (TBS 1). Design and usage limitations shall be as follows (TBS 2).

REQUIREMENT RATIONALE (3.4.9.2.3)

Standard bearings should be given priority in new design in order to minimize the cost of procurement and testing, reduce schedule and technical risk, and obtain multiple sources of supply. Design and usage limitations reflect accepted design practices within the aerospace industry to provide structurally efficient joints that are trouble free in service.

REQUIREMENT GUIDANCE (3.4.9.2.3)

TBS 1 should be filled in with MIL-HDBK-1599 selection recommendations, SAI AS 3990, and SAE AS6038, AS6039, AS7949, and AS8914.

TBS 2 should be filled in with information from table 201-VII of MIL-HDBK-1599, which provides guidance for design and usage limitations.

REQUIREMENT LESSONS LEARNED (3.4.9.2.3)

Antifriction (or rolling element) bearings have several advantages over plain bearings. A life with essentially no wear, a comparatively small lubricant requirement, and a low starting and dynamic friction coefficient are the principal advantages. Their use results in reduced control system friction and pilot effort. The extremely close internal clearances permit backlash or looseness to be reduced to a minimum.

Caution: antifriction bearings are manufactured to very close tolerances and are adversely affected by contaminants or moisture. Rough and careless handling and installation can seriously reduce the life.

When nonstandard bearings were used, they were approved via the program process for inclusion in the PPSL.

4.4.9.2.3 Antifriction bearings.

Antifriction bearings shall be verified by inspection.

VERIFICATION RATIONALE (4.4.9.2.3)

Conformance with the specified standards is necessary to achieve required performance.

VERIFICATION GUIDANCE (4.4.9.2.3)

The inspection should verify that the antifriction bearing is in accordance with MIL-HDBK- 1599, SAI AS 3990, and SAE AS6038, AS6039, AS7949, and AS8914.

VERIFICATION LESSONS LEARNED (4.4.9.2.3)

Additional laboratory testing is not necessary for parts listed on a DOD approved qualified products list as long as the proposed application is well within the loads and conditions established in the associated specification and standards.

3.4.9.2.4 Plain bearings.

If required, plain bearings shall be in accordance with (TBS 1). Design and usage limitations shall be as follows: (TBS 2).

REQUIREMENT RATIONALE (3.4.9.2.4)

Standard bearings should be given priority in new design in order to minimize the cost of procurement and testing, reduce schedule and technical risk, and obtain multiple sources of supply. Design and usage limitations reflect accepted design practices within the aerospace industry to provide structurally efficient joints that are trouble free in service.

REQUIREMENT GUIDANCE (3.4.9.2.4)

TBS 1 should be filled in with MIL-HDBK-1599 selection recommendations and SAE AS81820, AS81934, AS81935, AS81936, and AS8952.

TBS 2: Select one or more of the listed limitation parameters that apply to the air vehicle subsystem and equipment:

a. Table 201-VII of MIL-HDBK-1599 provides guidance for design and usage limitations.

b. Self-aligning bearings should be employed where linkage geometry or structural deflections would induce unacceptable stress levels in rigid bearings.

c. Sintered bearings generally are not suitable for airframe applications. If used the following limitations should be observed:

   1. Design loads should be less than 1000 psi.

   2. The bore should not be reamed since metal can be smeared over the voids in the bearing surface, thus preventing oil from being released from the porous structure.

   3. They should be used in continuous rotation applications only. Oscillation under unidirectional load does not allow liberated oil to be spread freely on the bearing surface, resulting in accelerated wear.

   4. Do not use where subjected to shock loads.

d. Plain annular and plain self-aligning bearings are generally not suitable in air vehicle primary control systems and other critical applications.

They are intended for use under the following conditions:

1. Moderate friction and bearing play at low rotational speeds are not objectionable.
2. Wear is not excessive.

Bearings are not subject to vibratory shocks and alternating loads.

REQUIREMENT LESSONS LEARNED (3.4.9.2.4)

Generally, plain (or sliding surface) bearings have higher friction than antifriction types of the same size but have greatly increased static load capabilities. Dynamic life is a function of the type of lubricant and the imposed load and is the limiting condition for this class of bearing. Dynamic load allowables are much lower than static load allowables, which is a major difference when compared to antifriction bearing values. In general, plain bearings are more rugged than antifriction types and can better tolerate contamination and careless handling.

For SAE AS81820 plain spherical bearings, the radial static limit load is calculated for the capacity of the bearing, housing, and pin. Because the wide series has a greater pin bending, the radial capacity is rated lower than the bearings listed in the narrow series.

Nonstandard plain bearings have been approved via the program process for inclusion in the PPSL and may be used.

4.4.9.2.4 Plain bearings.

Verify by inspection and test that plain bearings are in accordance with (TBS). Verify by inspection that plain bearing design and usage limitations are followed.

VERIFICATION RATIONALE (4.4.9.2.4)

Inspection of assembly, installation, and fabrication drawings confirms that specified plain bearings conform to the specified standards or have been approved via the PPSL process and that design and usage limitations have been followed.

VERIFICATION GUIDANCE (4.4.9.2.4)

TBS should be filled in with SAE ARP5448, which provides recommended practices for testing plain bearings.

VERIFICATION LESSONS LEARNED (4.4.9.2.4)

Additional laboratory testing is not necessary for parts listed on a DoD-approved Qualified Products List (QPL) if the proposed application is within the loads and conditions established in the associated specification and standards. Non-standard bearings may require additional testing as recommended in SAE ARP5448 to verify the bearing will meet the performance requirements of the application.

3.4.9.3 Fastener subsystem.

The fastener subsystem shall be capable of joining and securing airframe structural members, air vehicle components, access panels and doors while preserving the structural integrity of the elements being joined. The fastener subsystem shall use common fasteners and attributes to the maximum extent possible without compromising performance.

REQUIREMENT RATIONALE (3.4.9.3)

It has been estimated that 20 to 30 percent (20-30%) of the cost of air vehicle procurement and maintenance can be attributed to fasteners and fastening subsystems. The selection of appropriate fasteners is of extreme importance. Standard fasteners should be given priority in new aerospace systems design.

REQUIREMENT GUIDANCE (3.4.9.3)

The design activity should prepare a PPSL. A PPSL inhibits the proliferation of fastener designs used in aerospace applications; and assists in reducing part numbers, lowering procurement cost, utilizing common maintenance practices, and reducing support tool variations. All parts introduced in the design of equipment, system or subsystem should be listed on the PPSL.

Where possible and practical, mating parts (except where flush head bolts or plate nuts are used) should have similar external wrenching configurations.

REQUIREMENT LESSONS LEARNED (3.4.9.3)

(TBD)

4.4.9.3 Fastener subsystem.

The fastener subsystems ability to join and secure airframe structural members, air vehicle components, access panels and doors while preserving the structural integrity of the elements being joined shall be incrementally verified by (TBS). Verify by demonstration that the fastener subsystem uses common fasteners and attributes to the maximum extent possible without compromising performance.

VERIFICATION RATIONALE (4.4.9.3)

Standard fasteners and fastener subsystems are expected to be used in most applications. This requirement can be verified through analysis and test of new fasteners and fastener subsystems to determine their mechanical and physical properties. This verification also establishes the methods to demonstrate that the fastener subsystem uses common fasteners and attributes.

VERIFICATION GUIDANCE (4.4.9.3)

TBS should be filled in with analysis, inspection, demonstration, test, or a combination of these methods.

AIA/NAS NASM1312 describes the unified standard methods of testing, analysis of data, and presentation of results.

VERIFICATION LESSONS LEARNED (4.4.9.3)

(TBD)

3.4.9.3.1 Fastened joint allowables.

The fastener and joint design allowables shall not exceed those design allowable values specified in (TBS 1). Where the design allowables are nonexistent, they shall be as established in (TBS 2).

REQUIREMENT RATIONALE (3.4.9.3.1)

To determine the strength of mechanical joints, it is necessary to know the strength of the individual fastener, both by itself and when installed in various thicknesses of various materials.

REQUIREMENT GUIDANCE (3.4.9.3.1)

TBS 1 should be filled in with DOT/FAA/AR-MMPDS, Chapter 8, which presents joint design allowable loads for a variety of mechanically fastened joints.

TBS 2 should be filled in with DOT/FAA/AR-MMPDS, Chapter 9, which establishes procedures necessary to develop joint design allowable loads.

REQUIREMENT LESSONS LEARNED (3.4.9.3.1)

(TBD)

4.4.9.3.1 Fastened joint allowables.

The fastener and joint design allowable loads shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.1)

The design allowable loads in DOT/FAA/AR-MMPDS are used in the design of aerospace structures and elements. DOT/FAA/AR-MMPDS is the most authoritative document reflecting the actual properties of the products covered.

VERIFICATION GUIDANCE (4.4.9.3.1)

TBS should be filled in with test or analysis. The joint design allowable loads can be confirmed with the use of DOT/FAA/AR-MMPDS, Chapter 8. Where the design allowable loads have not been predetermined, DOT/FAA/AR-MMPDS, Chapter 9 provides the detailed information on the generation and analysis of joint data that results in the determination of joint allowable loads. The minimum data requirements and analytical procedures are defined in this chapter for the establishment of DOT/FAA/AR-MMPDS design allowable loads. AIA/NAS NASM1312 is the recommended source for the test procedures in developing joint allowable load information.

VERIFICATION LESSONS LEARNED (4.4.9.3.1)

(TBD)

3.4.9.3.2 Fastener threads.

Fastener threads shall be as defined (TBS 1). Fastener threads used in safety critical applications shall be as defined (TBS 2). The military engineering cognizant activity for air vehicle subsystem and equipment shall approve designation of a fastener thread as safety critical.

REQUIREMENT RATIONALE (3.4.9.3.2)

Selection of thread geometry should be limited to a single specification to standardize thread dimensions (preferred diameter-pitch).

REQUIREMENT GUIDANCE (3.4.9.3.2)

TBS 1 should be completed using the following guidance. The UNJ thread form has been adopted by the aerospace industry as the all-purpose thread standard, with the exception of thread sizes 0.138 inches and smaller, which may use the UN thread form. Within standard UNJ threads, the use of fine threads should be given preference to facilitate the maximum usage of a limited number of threads. For aerospace applications, Classes 3A and 3B should be used. ASME B1.15 contains basic thread data for all standard pitches of threads.

TBS 2 should be filled in with consideration given to the following safety critical applications: (1) thread failure that results in structural failure, loss of canopy, landing gear failure, subsystem failure, or engine ingestion of foreign objects; (2) thread failure that is not the result of multiple failures; and (3) the primary joint failure mode is tension.

It is the responsibility of the design activity of new equipment to identify safety critical applications. The designation of a fastener thread as safety critical indicates that the fastener is used in a safety critical application.

REQUIREMENT LESSONS LEARNED (3.4.9.3.2)

The C-17 incorporated a buttress thread design on the main landing gear collars. The extremely sharp thread bottom caused an abnormally high stress concentration, which ultimately failed in the field. Multiple Class A incidents also occurred. The correction was to use a UNJ-3A thread design and to proof load each joint prior to delivery.

4.4.9.3.2 Fastener threads.

Configuration compliance shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.2)

(TBD)

VERIFICATION GUIDANCE (4.4.9.3.2)

TBS should be filled in with inspection.

VERIFICATION LESSONS LEARNED (4.4.9.3.2)

(TBD)

3.4.9.3.3 Fastener usage limitations.

Fastened joint usage limitations shall be as follows (TBS).

REQUIREMENT RATIONALE (3.4.9.3.3)

This requirement provides fastener usage limitations associated with their use. These usage limitations have been developed by the military and aerospace industry and indicate accepted design practices necessary for air vehicles and subsystems.

REQUIREMENT GUIDANCE (3.4.9.3.3)

TBS should be filled in by selecting one or more of the listed limitation parameters that apply to the air vehicle subsystem and equipment.

a. In the design selection of inserts, consideration should be given to the axial load-carrying capabilities of the installed insert in a specific parent material.

b. Inserts should be installed in accordance with manufacturer's instructions or approved user procedures to ensure prevention of their movement during installation or removal of the externally threaded part.

c. Screw thread or screw-locking inserts should not be used in the following applications, unless the externally threaded part is held by a positive-locking device that requires shearing or rupture of material before torsion loads would be applied to the externally threaded part in such a manner as to relieve the initial stress of the assembly:

   1. At joints in control systems, at single attachments, or where loss of the threaded member affect safety of flight.

   2. With an externally threaded part that serves as an axis of rotation.

d. Externally threaded fasteners used in conjunction with self-locking inserts should be selected to ensure full engagement of locking device and sufficient thread engagement to guarantee full development of the required design tension load.

e. Silver-plated or cadmium plated inserts should not be used in titanium housings.

f. Self-locking inserts require suitable lubricant at thread interface when being mated with titanium or corrosion resistant screws or bolts.

g. When using studs in tapped holes, consideration should be given to eliminating the possibility of stud rotation when installing or removing the mating unit.

h. Stepped studs may be used to provide higher strength capabilities in relatively low strength structural (parent) materials with a shorter length of engagement than required for straight studs (both ends same diameter). In the design selection of studs for structural applications, it is necessary that the proper degree of consideration be given to the axial load carrying capabilities of the installed stud in the specific parent materials at the maximum operating temperature of the assembly. The axial load capability of an installed stud is determined either by the lesser value of the minimum tensile strength of the nut end or by the resistance to pull out from the parent material.

i. Resistance to pull out of the installed stud is the product of the shear engagement area of the stud end thread and the allowable shear stress of the parent material at the maximum operating temperature. It does not represent a dimension of either of the members in an unassembled condition.

j. The allowable shear stress for most metallic materials is listed in DOT/FAA/AR-MMPDS. The shear engagement areas of the stud end thread may be obtained from the stud standard. Most studs are intended to be loaded primarily in tension. Joints carrying shear loads should be designed to preclude subjecting the studs to shear loads or use only those studs whose features allow their use under shear loading.

k. Quick release pins may be of the following types: positive-locking, single-acting, and positive-locking, double-acting. Quick release pins are primarily designed to be used in applications that require double shear strength capabilities combined with quick-disconnect features.

l. The specific shear and tension load capabilities are a function of the material being attached, hole size, and hardness of application material. Typical applications are quick attachment and removal of ground support equipment and attaching warning streamers to critical joints.

m. Plain washers may be used to accommodate variations in grip length. In addition, plain washers can be used under a nut to protect surface from damage and to reduce the stress of the joint by increasing the bearing area. Plain washers should be used to avoid electrolytic corrosion by preventing contact of dissimilar metals.

n. Lock washers should not be used in airframe applications.

REQUIREMENT LESSONS LEARNED (3.4.9.3.3)

(TBD)

4.4.9.3.3 Fastener usage limitations.

Fastener usage limitations shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.3)

Inspection and demonstration are considered the most appropriate verification methods to confirm that the fasteners meet the requirements.

VERIFICATION GUIDANCE (4.4.9.3.3)

TBS: Verification of this requirement should be accomplished by an inspection of assembly, installation, fabrication drawings, and processing specifications to confirm the fastener adherence to the design and usage limitation requirements.

VERIFICATION LESSONS LEARNED (4.4.9.3.3)

(TBD)

3.4.9.3.4 Externally threaded fastener usage limitations.

Externally threaded fastener usage limitations shall be as follows: (TBS).

REQUIREMENT RATIONALE (3.4.9.3.4)

This requirement provides screw and bolt usage limitations associated with their use. These usage limitations have been developed by the military and aerospace industry and indicate accepted design practices necessary for air vehicles and subsystems.

REQUIREMENT GUIDANCE (3.4.9.3.4)

TBS should be filled in by selecting one or more of the listed limitation parameters that apply to the air vehicle subsystem and equipment.

a. Structural screws and bolts loaded in shear should have sufficient grip length so that no threads are in bearing.

b. Interference between the hole and the head to shank radius should be avoided. It is standard design practice to use countersunk washers or countersunk bolt holes under high-strength (160 ksi and above) protruding head screws and bolts for clearance of the head-to-shank fillet radius.

c. Screws and bolts smaller than 0.250 inches in diameter should not be used in any single bolted structural connection, including primary control systems, or any application where failure would adversely affect safety of flight.

d. The smallest recommended diameter for 100 degree reduced flush head screws and bolts is normally 0.250 inches. However, 0.190-inch diameter 100 degree reduced head screws and bolts may be used in panels whose removal is not required for scheduled maintenance.

e. Aluminum alloy threaded screws and bolts should not be used in structural applications.

f. Silver or cadmium plated screws and bolts should not be used in contact with titanium structure. Cadmium plated screws and bolts should not be used in temperature probes, electrical or life support space vehicle components or subsystems, portable water supplies, or food processing equipment.

g. Titanium alloy screws and bolts should not be used with silver plated self-locking nuts at temperatures above 600 degrees F or cadmium plated nuts at temperatures above 200 degrees F.

h. Self-locking screws and bolts or screws and bolts utilizing self-locking elements should not be used as follows:

   1. At joints in control systems, single attachments, or where the loss of the bolt would affect safety of flight.

   2. As an axis of rotation for another part unless the fastener is held in a positive locking

device that requires shearing or rupture of material before torsion loads would be applied to the bolt in such a manner as to relieve the internal stress of the assembly or turn the bolt loose.

3. At any single bolted structural joint that serves as a primary load path, the failure of which would endanger the safety of personnel or would render the equipment inoperative or cause its destruction.

i. Self-locking screws and bolts or screws and bolts utilizing self-locking elements should not be used to attach access panels, doors, or to assemble any parts that are routinely disassembled at intervals less than 400 flight hours.

j. Self-locking screws and bolts or screws and bolts utilizing self-locking elements should not be used on jet engine air vehicle locations where a loose fastener could fall or be drawn into the engine intake.

k. For screws and bolts utilizing a self-locking element, the entering end of the threaded holes used in conjunction with the self-locking externally threaded fastener should be countersunk 90 to 120 degrees. This countersink should have a minimum diameter of 0.015 inches larger than the major thread diameter of the fastener. This is to prevent the first thread from cutting the self-locking element.

l. Unthreaded holes or portions of holes through which a bolt utilizing a self-locking element must pass should have a minimum diameter sufficient to clear the locking element.

Self-locking screws and bolts or screws and bolts utilizing self-locking elements should not be used with castellated nuts or self-locking nuts.

Fasteners of the same diameter having the same grip length but different shank length or those having the same shank length but different grip length should not be used in the same bolt circle or in proximity where they could be inadvertently interchanged.

REQUIREMENT LESSONS LEARNED (3.4.9.3.4)

(TBD)

4.4.9.3.4 Externally threaded fastener usage limitations.

Externally threaded fastener usage limitations shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.4)

Inspection and demonstration are considered the most appropriate verification methods to confirm that the screws and bolts meet the limitation requirements.

VERIFICATION GUIDANCE (4.4.9.3.4)

TBS should be filled in with consideration given to the following: Verification of this requirement should be accomplished by an inspection of assembly, installation, fabrication drawings, and processing specifications to confirm screw and bolt adherence to the design and usage limitation requirements.

VERIFICATION LESSONS LEARNED (4.4.9.3.4)

(TBD)

3.4.9.3.5 Nut usage limitations.

Nut usage limitations shall be as follows (TBS).

REQUIREMENT RATIONALE (3.4.9.3.5)

This requirement provides nut usage limitations associated with their use. These usage limitations have been developed by the military and aerospace industry and indicate accepted design practices necessary for air vehicles and subsystems.

REQUIREMENT GUIDANCE (3.4.9.3.5)

TBS should be filled in by selecting one or more of the listed limitation parameters that apply to the air vehicle subsystem and equipment.

a. Self-locking nuts are preferred over non-self-locking nuts in air vehicle applications. Self- locking nuts for use with bolts or studs with a minimum ultimate tensile strength of 160 ksi and designed for high tension fatigue loading should be external wrenching nuts, barrel nuts, or plate nuts, which will develop the full tensile strength of the bolt.

b. Plain or self-locking nuts used in:

   1. any joint that serves as an axis of rotation,

   2. any joint that is designed to transmit motion which may result in relative rotation between components in the joint, or

   3. any bolted structural joint with less than three bolts and serves as a primary load path, the failure of which would endanger the safety of personnel or would render the air vehicle inoperative or could cause its destruction, should be secured by positive type mechanical locking devices.

c. Bolts, studs, or screws should extend through the self-locking nut for a length equivalent of two threaded pitches. This length includes the chamfer.

d. Self-locking nuts that are attached to the structure should be attached in a positive manner to eliminate the possibility of their rotation or misalignment when tightening is to be accomplished by rotating the bolts or screws. The manner of attachment should permit removal without injury to the structure and permit replacement of the nuts. When projection spot welding is used for attaching plate nuts, control should be maintained in order that removal by drilling out welds permits replacement with drilled plate nuts.

e. Self-locking nuts should not be used:

   1. at joints in control systems at single attachments or

   2. where loss of the bolt would affect safety of flight, unless the treaded parts are held by a positive locking device that requires shearing or rupture of materials before torsion loads relieve the initial stresses of the assembly.

f. Self-locking nuts should not be used with bolts or screws in locations where the loose nut, bolt, or screw could fall or be drawn into an engine air intake duct.

g. Self-locking nuts should not be used with bolts, screws, or studs to attach access panels, doors, or to assemble any parts that are routinely disassembled prior to or after each flight.

h. All nuts, except self-locking nuts and nuts for machine screws, should be locked by cotter pins or safety wire.

REQUIREMENT LESSONS LEARNED (3.4.9.3.5)

(TBD)

4.4.9.3.5 Nut usage limitations.

Nut usage limitations shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.5)

Inspection and demonstration are considered the most appropriate verification methods to confirm that the nuts meet the requirements.

VERIFICATION GUIDANCE (4.4.9.3.5)

TBS should be filled in with consideration given to the following: Verification of this requirement can best be accomplished by an inspection of assembly, installation, fabrication drawings and processing specifications to confirm the nuts' adherence to the design and usage limitation requirements.

VERIFICATION LESSONS LEARNED (4.4.9.3.5)

(TBD)

3.4.9.3.6 Blind fastener usage limitations.

Blind fastener usage limitations shall be: (TBS).

REQUIREMENT RATIONALE (3.4.9.3.6)

This requirement provides blind fastener usage limitations associated with their use. These usage limitations have been developed by the military and aerospace industry and indicate accepted design practices necessary for air vehicles and subsystems.

REQUIREMENT GUIDANCE (3.4.9.3.6)

TBS should be filled in by selecting one or more of the listed limitation parameters that apply to the air vehicle subsystem and equipment:

a. Solid rivets or blind fasteners should be used in structural joints only where shear loads are the primary design load consideration.

b. The edge distance (center of hole to edge of sheet) for the location of rivets in sheets should be a minimum of two rivet diameters. The minimum spacing for riveted joints in fuel tight areas should be three rivet diameters. Other minimum spacing should be four rivet diameters in the same adjacent rows or in staggered patterns.

c. To minimize galvanic corrosion of the joint, rivets should not be anodic to the most anodic material in the joint.

d. Solid rivets should be driven utilizing tools that conform to acceptable aerospace practices for the rivet size and material being upset. When using rivet material harder than the material to be joined, particular care should be taken to avoid distortion during riveting. Special care is recommended when selecting rivet types and materials for installation through nonmetallic structures. Soft materials may be riveted by using washers under the rivet-upset trail.

e. Spot-facing should be used to provide a flat surface under upset heads when:

   1. The surface slope is greater than 8 degrees under the upset head of the rivets,

   2. A curved surface has a radius less than three times the rivet shank diameter, and

   3. The roughness of the facing surface under the heads is greater than 500 RHR.

f. Solid rivets should not be used where forces required to upset the rivet could be detrimental to the structure.

g. Blind rivets and fasteners are intended for applications where inaccessibility from both sides precludes the use of conventional fasteners, and they are used to repair fastener for solid rivets.

h. Blind rivets and fasteners should not be used in liquid tight areas. Blind rivets and fasteners should not be used in applications where they are subject to removal during routine servicing and overhaul. Blind rivets and fasteners should not be used on control surface hinges, hinge brackets, flight control actuating systems attachment, wing attach fittings, landing gear fittings, or similar applications.

i. Mechanically locked spindle blind rivets may be used in engine inlet areas. Friction locked spindle blind rivets should not be used in engine inlet areas. Blind rivet holes for dimpled assembly should be drilled to size after dimpling.

REQUIREMENT LESSONS LEARNED (3.4.9.3.6)

(TBD)

4.4.9.3.6 Blind fastener usage limitations.

Blind fastener usage limitations shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.6)

Inspection and demonstration are considered the most appropriate verification methods to confirm that the blind fasteners meet the requirements.

VERIFICATION GUIDANCE (4.4.9.3.6)

TBS should be filled in with consideration given to the following: Verification of this requirement can best be accomplished by an inspection of assembly, installation, fabrication drawings and processing specifications to confirm blind fastener adherence to the design and usage limitation requirements.

VERIFICATION LESSONS LEARNED (4.4.9.3.6)

(TBD)

3.4.9.3.7 Fastener sizing.

The shank diameter of threaded structural fasteners shall not be less than 0.190 inches.

REQUIREMENT RATIONALE (3.4.9.3.7)

The rationale for having a fixed minimum fastener diameter for threaded structural applications is to provide structural integrity in the bearing and shear load paths. When a 0.190-inch minimum diameter for structural fasteners is established, maintainability is greatly aided. Fasteners with diameters less than 0.190 inches are easily over-torqued by hand-held drivers.

REQUIREMENT GUIDANCE (3.4.9.3.7)

This requirement should apply only to threaded structural fasteners that are torqued or installed by a driving recess in the head of the fastener. This requirement should not apply to rivets, either solid or blind, or pin and collar type fasteners where the driving recess is in the thread end when utilized with the intended or designed mating torque-off collar. When a regular nut or non-torque limiting device is used in conjunction with the point drive threaded fasteners, the above requirement should apply.

REQUIREMENT LESSONS LEARNED (3.4.9.3.7)

When small diameter fasteners are utilized in long grip length, bolt bending also becomes a problem and joint stiffness is lost.

4.4.9.3.7 Fastener sizing.

Fastener sizing shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.7)

Sizing must be verified to assure adequate strength and fastener life is achieved.

VERIFICATION GUIDANCE (4.4.9.3.7)

TBS should be filled in with inspection and demonstration.

Since some military, industry, prime contractor. and vendor drawings on threaded fasteners allow or call out diameters smaller than 0.190 inches diameter, it is easy for a weight conscious designer to inadvertently select a smaller than 0.190 inch diameter. Merely checking a PPSL list, which usually does not go into detail as to diameter or limitations, will not find this problem. In addition, PPSL's usually do not indicate the mating parts, such as nut or collar with the pin or bolt. Inspection is the only way to determine what parts are mated together. Various shop practices, rework and repair procedures, and deviations from design drawings also may change what diameters are actually used from what is called out. Furthermore, there are "gray" areas where a designer may believe that his application is not structural or critical and select a smaller than 0.190 inch diameter.

VERIFICATION LESSONS LEARNED (4.4.9.3.7)

(TBD)

3.4.9.3.8 Head angle.

The head angle of countersunk fasteners and the nominal fastener recess angle shall be (TBS 1), except for (TBS 2), whose head angle shall be (TBS 3).

REQUIREMENT RATIONALE (3.4.9.3.8)

To determine the proper fastener head angle or countersink for flush type fasteners, it is necessary to know the joint thickness or top sheet skin thickness as well as the materials physical strength, such as sheet bearing, shear, and compression. The head countersink included angle of 100 degrees has been accepted as an aerospace industry standard to prevent any countersink mismatch and subsequent fastener hole deformation. In addition, it provides for cross-servicing of air vehicles between NATO countries. For thin sheet joints, 120 degrees and 130 degrees head angles have been used.

REQUIREMENT GUIDANCE (3.4.9.3.8)

TBS 1 should be completed using a specific value for the head angle of the countersunk fasteners.

TBS 2 should be completed by indicating any exceptions to the value in TBS 1.

TBS 3 should be completed by giving the value(s) for the exceptions indicated by TBS 2. For metallic structure, the 100 degrees countersink head angle has been accepted as an aerospace industry standard to prevent any countersink angle mismatch in assembled joints. This head angle has also been determined by test and field service life to be the optimum balance between sheet thickness and fastener strength for air vehicle structural materials. For non-metallic structure, tests have shown that head angles of 130 degrees work satisfactorily. Some solid rivets, which can be used in structural applications, provide head angles of 120 degrees. Fasteners with head angles of 130 degrees and 120 degrees provide the capability of utilizing thinner joint materials.

REQUIREMENT LESSONS LEARNED (3.4.9.3.8)

(TBD)

4.4.9.3.8 Head angle.

Head angle shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.8)

Verification of the proper countersink angle is accomplished by inspection since that is the only positive method of ensuring the compliance with this requirement. There are no quick, economical tests that will discern countersink angles with the fastener installed.

VERIFICATION GUIDANCE (4.4.9.3.8)

TBS should be filled in with inspection.

Since various countersink-included angles exist, not only on the fasteners but also in the sheet or plate in which the countersink fastener is installed, many inadvertent combinations exist. The wrong countersink fastener may be placed in the correct countersink hole. The correct countersunk fastener may be installed in the wrong countersunk hole, or the wrong countersunk fastener may be installed in a different but still wrong (per drawing call out) countersunk hole. These misapplications can only be detected by inspection. Inspection of drawings and PPSL will usually indicate the proper head countersink angle and the statistical probability that the physical hardware is per the drawing should be very high.

VERIFICATION LESSONS LEARNED (4.4.9.3.8)

(TBD)

3.4.9.3.9 Fasteners used in single point linkages.

In critical single point linkages, such as flight control linkages, the fastener subsystem shall use self-retaining bolts.

REQUIREMENT RATIONALE (3.4.9.3.9)

Single-bolt linkage-joints are used throughout an air vehicle. In many cases, loss of this single bolt could cause catastrophic failure and loss of the air vehicle and life. Examples of such usage are fuel controls, throttle controls, and flight controls. Two types of self-retaining bolts (SRB) have been developed to solve this critical flight safety requirement. These are described below as well as guidance for their selection. Both are equal in overall performance.

REQUIREMENT GUIDANCE (3.4.9.3.9)

Two types of SRB have been developed for critical flight safety applications and are considered of comparable performance. Type I, positive locking bolts, are designed to be installed and removed after the retaining element release button is actuated to allow the locking elements to retract into the bolt body. Type II, impedance type bolts, are designed to be installed and removed by overcoming the frictional force of the retaining elements.

The joint should be designed so that with a self-retaining bolt installed, the joint integrity is not dependent on washers or any other normally removable parts, other than the bolts. A maximum of two washers may be used to adjust for tolerance variation and, when required, they should be used under the head of the bolt but not under the nut. Bridging spacers may be used on positive-locking bolts only.

Self-retaining bolts should be used in control systems where the bolt serves as an axis of rotation and where separation of the linkage will affect safety of flight. These include controls for flight, fuel, engine air reduction, and propeller systems. The bolts should be additionally locked in position by counterbored-castellated nuts with captive washers. Type II, impedance, self-retaining bolts are less expensive to manufacture, easier to install and remove, and have a higher shear and tensile capability. However, the positive loading type I will ensure a positive joint, if installed properly. Corrosion-resistant steel parts are preferred over alloy steel parts.

REQUIREMENT LESSONS LEARNED (3.4.9.3.9)

(TBD)

4.4.9.3.9 Fasteners used in single point linkages.

Verify by inspection and demonstration that the fasteners used in critical single point linkages (such as flight control linkages) are self-retaining bolts.

VERIFICATION RATIONALE (4.4.9.3.9)

The type I and II self-retaining bolts specified in the requirements section have been developed specifically to solve the critical flight safety problem and have done so successfully whenever applied. Only by physical inspection and demonstration that all single bolt linkage joints actually contain a SRB can this requirement be met.

VERIFICATION GUIDANCE (4.4.9.3.9)

Many means of ensuring linkage integrity or connections exist. There are double and triple redundant systems, permanent fasteners whereby a piece or part has to be destroyed to be removed, cotter pining or safety wiring, and directives mandating that safety inspections should be rigorously complied with. However, none of these methods is practical or reasonable from the life cycle maintenance standpoint. Joints need to be periodically removed. Ground functional checks and inspections will only determine that a bolt is in the linkage joint and nut or cotter pin (or both) is installed. Therefore, because of the criticality of this item, inspection and demonstration methods of verification compliance areessential.

VERIFICATION LESSONS LEARNED (4.4.9.3.9)

(TBD)

3.4.9.3.10 Fastener drive and wrenching element configuration.

Fastener drive and wrenching elements, installation and removal tooling, and torque control shall be as defined (TBS).

REQUIREMENT RATIONALE (3.4.9.3.10)

This requirement provides for the selection of drive and wrenching elements for use with aerospace structure fastener subsystems. The fastener recess design selected should influence maintenance manpower, maintenance cost, and driver inventory requirements.

In all applications of internal drive configuration fasteners, loads are applied in both torsional directions for removal and installation. If the recess cannot withstand or transmit sufficient torsional force in the installation direction, the desired pre-load is not reached and clamp up is not sufficient, which could result in failure. If the torsional strength of the recess is insufficient in the removal direction, then either the recess cams out or the driver bit breaks (or both). This results in the fastener having to be drilled out, which increases both maintenance cost and the mission down time of the weapon system.

REQUIREMENT GUIDANCE (3.4.9.3.10)

TBS should be filled in with consideration given to the following:

Hexagon drive external wrenching elements should be limited to use for fasteners up to 180,000-psi maximum ultimate tensile stress. All externally and internally threaded fasteners heat treated to 180,000-psi minimum ultimate tensile stress and higher should have spline drive or 12-point external wrenching element. Preference should be given to spline drive external wrenching element on high-strength fasteners. Fasteners less than 180,000 psi may use spline drive external wrenching element.

The cruciform recess may be used in fastener heat treated up to 160,000-psi maximum ultimate tensile stress. Fastener heat treated above 160,000-psi maximum ultimate tensile stress with cruciform recess may be used in secondary structure. Six lobe drive, offset cruciform, and offset cruciform-ribbed recesses should be used in fastener heat treated to 160,000-psi minimum ultimate tensile stress and higher. These recesses may be used in fasteners below 160,000 psi in order to reduce the recess types used in each system. The use of dovetail slot recesses should be avoided.

Internal hexagon recesses should be limited to the threaded end of pins without a head driving recess.

Care should be exercised to ensure that the correct size bit or wrench is identified, particularly for internal drives, so that specified installation torque requirements are not exceeded.

REQUIREMENT LESSONS LEARNED (3.4.9.3.10)

(TBD)

4.4.9.3.10 Fastener drive and wrenching element configuration.

Fastener drive and wrenching elements shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.10)

Inspection is the most suitable verification method to confirm the selection drive elements and compatibility with the wrenching elements.

VERIFICATION GUIDANCE (4.4.9.3.10)

TBS should be filled in with inspection of installation, assembly, and fabrication drawings.

VERIFICATION LESSONS LEARNED (4.4.9.3.10)

(TBD)

3.4.9.3.11 Fasteners used in doors and access panels.

Except for captive fasteners, fasteners used to retain access panels and doors shall be of equal diameter and length. Formed-in-place gasket material shall not be used as a spacer or in place of a counterbore for the retaining rings.

REQUIREMENT RATIONALE (3.4.9.3.11)

This requirement defines the basic design and engineering requirements for panel fastener assemblies for attaching structural load-carrying and non-structural panels, inspection doors, quickly detachable plates, control and instrument panels, and equipment rack systems.

REQUIREMENT GUIDANCE (3.4.9.3.11)

Fasteners used in doors and access panels should be classified as fully captive screws and semi-captive screws. Fully captive screws should be inseparable assemblies incapable of removal either from their retainer or from their associated panels without the use of special tools. Semi-captive screws should be capable of removal from their retainers or the retainers should be capable of removal from their associated panels without special tools. Semi-captive screws are single lead threads only.

Captive and semi-captive screws should be used to secure any panel, door, or other fastener retained device that must be routinely opened or released for maintenance, service, or equipment adjustment. These fasteners should be used where loss of attaching hardware could cause loss of system integrity, whether structural or electronic, or could endanger system operating personnel. These fasteners should be used where extensive equipment teardown for the retrieval of ordinary attaching hardware would be required.

The performance criteria for these fasteners should be indicated by requirements of individual applications. Consideration should be given to each application for fastener tensile and shear load carrying capabilities, clamp-up capabilities, and resistance to axial push-out forces.

REQUIREMENT LESSONS LEARNED (3.4.9.3.11)

(TBD)

4.4.9.3.11 Fasteners used in doors and access panels.

Fasteners used in doors and access panels shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.3.11)

(TBD)

VERIFICATION GUIDANCE (4.4.9.3.11)

TBS should be filled in with inspection and demonstration.

VERIFICATION LESSONS LEARNED (4.4.9.3.11)

(TBD)

3.4.9.4 Utility actuation subsystem.

Mechanical actuation subsystems shall 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. The mechanical actuator subsystem shall be capable of providing these functions via air vehicle or ground power and shall provide for manual operation as well as in applications necessary for maintenance, accessibility enhancement, or stowage or folding.

REQUIREMENT RATIONALE (3.4.9.4)

Mechanical actuation systems are necessary to provide motion to various stowable and deployable surfaces such as folding wing panels, folding rotor blade systems, folding tail rotors and pylons, air scoops, air vents, and weapons bay doors in ground and air applications for both operational and maintenance purposes.

REQUIREMENT GUIDANCE (3.4.9.4)

Guidance is provided in the following areas:

a. Motive/locking functionalities. Motion is typically of a limited (2-position) nature and may require positive locking in either one or all positions. Locking and motive functions should not be susceptible to extraneous interference causing inadvertent commands or motion [such as electromagnetic interference (EMI)].

b. Aerodynamic induced load effects. Actuation subsystems should be capable of operating normally through all points of the flight envelope where the subsystem in question may be used, including manual and automatic operation.

c. Oscillating loads effects. Irreversible-gearing should not be used as the sole means of position retention due to oscillating load effects.

d. High actuator case temperature/combustible environment separation. Actuator subsystems should not exhibit external case temperatures sufficient to provide a source of ignition for fuels or hydraulic fluid in the event of an actuator stall.

e. Motive source thermal protection. Means of ensuring subsystem shutdown, rather than a hiatus in subsystem operation, should be incorporated into the integration of safety/mechanism protection devices, such as thermal overheat switches, to prevent continued subsystem operation where such operation could result in an inadvertent deployment.

f. Externally-applied-load backdrive protection. All actuation subsystems should incorporate positive means of preventing backdriving of the motive source (motor, hand crank, or such) caused by loads being carried by the surface or device being actuated. These means should be in addition to the positive locking mechanism.

g. Maintainer-induced overload protection. Provisions should be made to prevent damage to actuation subsystems in case of over-torque or over speed conditions during improper manual operations (for example, using a high-power rotary tool instead of speed wrench).

h. Integration of cycle requirements between related systems. The cycle requirements of systems that operate in conjunction with each other, such as blade and wing stow subsystems on the same air vehicle, should be integrated with a common overall cycle requirement in mind.

i. Possibly applicable industry standards and recommended practices: Some industry documents which may prove beneficial for background information include SAE ARP4058, “General Specification Guide for Mechanical Geared Rotary Actuators”; SAE ARP4255, “Electrical Actuation Systems for Aerospace and Other Applications”; SAE ARP777, “Gas Actuators”; and SAE ARP4386, “Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies.”

j. Design life cycles: The actuation system should be designed, in fracture or flight critical cases, to a minimum of 4 lives as measured in actuation cycles and flight hours to ensure a statistically robust system.

REQUIREMENT LESSONS LEARNED (3.4.9.4)

The following lessons learned were created due to field experiences:

a. Oscillating loads effects. A no-back mechanism was used on an example air vehicle subsystem when irreversible gearing mechanism failed to operate as designed. The cause of the failure was a “ratchet-type” effect, induced by oscillating loads.

b. Aerodynamic induced load effects. An air vehicle environmental control system (ECS) auxiliary scoop mechanism experienced several problems related to aero-induced loads that were poorly understood at the time. Conservative approaches should have been used in estimating the loads.

c. Motive source thermal protection: Means of ensuring subsystem shutdown rather than a hiatus in subsystem operation should be incorporated into the integration of safety/mechanism protection devices, such as thermal overheat switches, to prevent continued subsystem operation where such operation could result in an inadvertent deployment. For example, an air vehicle experienced an inadvertent deployment of the boarding ladder due to thermal switch activation. After a command was issued, the actuator thermal protection engaged which caused the actuator to stop mid-operation. The actuator later resumed and continued actuation during ground engine runs when the thermal switch cooled since the command remained active. If this had happened prior to flight, the weight-on-wheels switch would have disconnected power on takeoff, creating the condition of a “live” boarding ladder ready to deploy as soon as the air vehicle hit the runway. The actuator command logic path did not adequately address this situation; it was also misidentified in the failure mode effects analysis as a “Failure” (which creates the impression of a fully- nonfunctional/subsystem-off situation). It really was a "hesitant operation" scenario instead. The command path was changed to utilize a regular switch as opposed to the momentary "depress-and-walk-away" switch used earlier.

d. Special accessibility: All actuation subsystems that can conceivably be performed on the deck should have their design closely coordinated with the fleet supportability and carrier suitability areas. An air vehicle blade-fold system was designed to accommodate the requirement that one side of the rotor system, due to deck spacing, would not be accessible on a carrier. This same system also required careful accessibility planning due to the possible dangers to maintainers and equipment from the nearby Auxiliary Power Unit (APU) exhaust during manual fold operations.

e. Integration of cycle requirements between related systems: The cycle requirements of blade and wing stow subsystems on the same example air vehicle were not readily integrated into a common overall cycle requirement. The existence of two, stand-alone requirements had the potential to cause confusion.

4.4.9.4 Utility actuation subsystem.

The function of the utility actuation subsystem shall be verified by analysis and test.

VERIFICATION RATIONALE (4.4.9.4)

Verification of utility actuation subsystems is necessary to validate performance and envelope derived requirements. Verification, dependent on the specific system, may be required by analysis, testing, or by similarity to existing, prequalified systems.

VERIFICATION GUIDANCE (4.4.9.4)

The following effects and factors should be considered and validated:

a. Oscillating loads effects.

b. Aerodynamic induced load effects.

c. High actuator case temperature/combustible environment separation.

d. Oscillating loads effects including vibration, cyclic loading and backlashing.

e. Motive source thermal protection.

f. Externally-applied-load backdrive protection.

g. Maintainer-induced overload protection.

h. Special accessibility for maintainers.

i. Integration of cycle requirements between related systems.

j. Test life cycles. The actuation system should be tested, in fracture or flight critical cases, to a minimum of 2 lives as measured in actuation cycles and flight hours to ensure a statistically robust system.

VERIFICATION LESSONS LEARNED (4.4.9.4)

Field verification experiences include:

a. Aerodynamic induced load effects. An air vehicle ECS auxiliary scoop mechanism experienced several problems related to aero-induced loads. Laboratory equipment that could not reproduce transition between externally induced ECS airflow and engine-inlet airflow during testing was a significant cause of incorrect analysis validation.

b. Motive source thermal protection. An air vehicle boarding ladder actuation motor testing failed to reveal possible consequences of thermal protection engagement to control circuit; also, actual operating environment should be fully emulated as possible.

c. Similarity based verification & testing. Use caution when using verification and testing based on similarity. An example air vehicle boarding ladder actuator was tested in an orientation 90 degrees from its air vehicle installation orientation. This caused problems related to limit switch travel requirements on the air vehicle ("sagging" of components that did not appear in tested orientation).

3.4.9.4.1 Ground wind environment.

All actuation subsystems shall be able to (1) be locked and unlocked; (2) provide for folding, unfolding, and deploying; and (3) be folded, unfolded, and deployed within a wind environment that encompasses both atmospheric and weather-induced conditions, wind-over-deck from carrier vessel movement, and downwash and jet wash conditions from other vehicles on or near the carrier vessel deck.

REQUIREMENT RATIONALE (3.4.9.4.1)

The actuation subsystems are intended to operate in, and therefore withstand, an environment that includes loads caused by atmospheric conditions (weather and sea states), wind-over-deck from carrier vessel movement, and downwash and jet wash conditions from other vehicles on or near the carrier vessel deck.

REQUIREMENT GUIDANCE (3.4.9.4.1)

Guidance from ship and land based experience include:

a. Wing fold-wing pivot wind environment. A wing fold-wing pivot system should be able to withstand:

   1. 60 Kt winds from any horizontal direction in the unlocked and folding condition,
   2. 60 Kt winds from any horizontal direction in the unlocked and folded condition, and
   3. 100 Kt winds from any horizontal direction in the locked and folded condition.

It should also be possible to fold and unfold the wings in winds up to 60 Kts from any direction.

b. Blade fold wind environment. Rotorcraft blade fold systems should be able to withstand:

1. 45 Kt winds from any horizontal direction in the unlocked and folding condition,
2. 45 Kt winds from any horizontal direction in the unlocked and folded condition,
3. 100 Kt winds from any horizontal direction in the externally secured and unfolded condition, and
4. 100 Kt winds from any horizontal direction in the locked and folded condition.

It should be possible to fold and unfold the blades repeatedly in winds up to 45 knots from any direction.

c. Tail boom-tail rotor wind environment. Tailboom-tailrotor systems should be able to withstand:

1. 60 Kt winds from any horizontal direction in the unlocked and folding condition,
2. 60 Kt winds from any horizontal direction in the unlocked and folded condition,
3. 100 Kt winds from any horizontal direction in the locked and folded condition, and
4. 100 Kt winds from any horizontal direction in the externally secured and unfolded condition.

It should be possible to repeatedly fold and unfold the tail boom-tail rotor in winds up to 60 knots from any direction.

d. Boarding ladder wind environment. Boarding ladder systems should be able to withstand:

1. 60 Kt winds from any horizontal direction in the unlocked and deploying condition,
2. 60 Kt winds from any horizontal direction in the unlocked and deployed condition, and
3. 100 Kt winds from any horizontal direction in the locked and deployed condition.

It should be possible to deploy and stow the boarding ladder repeatedly in winds up to 60 knots from any direction.

REQUIREMENT LESSONS LEARNED (3.4.9.4.1)

Experience with large rotorcraft near other air vehicles with folding surfaces indicates those downwash-induced loads from such vehicles. Incidental overflight conditions or normal landing/takeoff/hover operations near the folded air vehicles may induce damage.

Jet blast loads are a particular concern with respect to fixed-wing air vehicles and their associated deployable and folding devices and surfaces.

4.4.9.4.1 Ground wind environment.

The ability to meet this constraint shall be verified by analysis and demonstration.

VERIFICATION RATIONALE (4.4.9.4.1)

The ability of the specific system to withstand the specific wind environment for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.1)

The wind environments effects should be validated for the following actuation subsystems:

a. Wing fold-wing pivot.
b. Blade fold wind.
c. Tailboom-tailrotor.
d. Boarding ladder.

VERIFICATION LESSONS LEARNED (4.4.9.4.1)

(TBD)

3.4.9.4.2 Positive locking features.

Mechanisms that provide a structural load path shall incorporate redundant means of locking the mechanism in position. Locking mechanisms shall incorporate a means of operational command interrupt to prevent in-flight actuation of ground-only operating systems.

REQUIREMENT RATIONALE (3.4.9.4.2)

Safety of Flight concerns necessitate the use of redundant means of securing and locking a mechanism in position. Operational command interrupts are necessary because of the hazard inherent in operation of a system not intentionally designed for aerodynamic loads (such as boarding ladder systems and access door actuation systems) in a flight condition which might cause damage or departure of the system from the air vehicle.

REQUIREMENT GUIDANCE (3.4.9.4.2)

Generally, applicable positive locking features are as follows: Provisions should be made for locking folding wings, blades, or other folding/stowing surfaces in the folded/stowed position. Locks should be an integral part of and operate in the sequence of the folding mechanism. Locks should be positive and should not depend on any power source to remain engaged. The control and lock subsystem should be shielded against EMI, and the “fold” sequence should require two separate deliberate pilot actions in the case of flight critical surfaces such as wings/rotor blades. All mechanical and powered locks and actuators should be designed to prevent ground-type system (such as a boarding ladder) deployment in flight or undesired deployment during ground operations. Provisions should be incorporated to prevent inadvertent actuation following the activation and subsequent relief of safety devices such as thermal switches or fuses. The locking arrangement should be positive and easily operable by maintenance personnel providing rapid engagement and disengagement of the locking mechanism. Locks should be capable of withstanding forces created by 100-knot winds from any horizontal direction. All mechanical and powered locks and actuators should be designed to prevent undesired surface positioning in flight. A positive identification of engagement should be provided by the mechanism.

Warning flag and locking feature ice layer penetration. Actuation subsystems that require ground operation should be able to operate successfully with a coating of ice covering any locking mechanism or locked/unlocked indicating mechanism.

REQUIREMENT LESSONS LEARNED (3.4.9.4.2)

Various subsystems have incorporated electromechanical brakes to “lock” actuator/linkage in place when the actuator is not in motion. Experience with air vehicle ECS Auxiliary Scoop Actuator subsystems has shown care must be taken to design the brake to accommodate any uncertainty in loads (such as aerodynamic and friction). Existing brake design had difficulties when aerodynamic loads were higher in actual operation.

Most air vehicle applications utilize a “weight-on-wheels” (WOW) switch to prevent operation of ground-only actuating subsystems, such as a blade fold and wing fold, while in-flight or above a certain ground speed.

An example air vehicle boarding ladder system initial design had a detachable handle to allow maintainers of different height extremes to actuate the ladder. However, it was found that the ladder’s close proximity to an engine intake presented too much of a possibility for foreign object damage (FOD), for example, placing the handle on the intake after use and inadvertently leaving it there.

4.4.9.4.2 Positive locking features.

The ability to meet this constraint shall be validated by test, analysis, and inspection as follows: (TBS).

VERIFICATION RATIONALE (4.4.9.4.2)

The ability of the specific system to provide positive locking for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.2)

TBS should be completed with consideration of the following:

a. Generally applicable positive locking features. The ability to meet this constraint should be validated by test, analysis, and inspection as follows: analysis and qualification testing.

b. Warning flag and locking feature ice layer penetration. Actuation subsystems that require ground operation should demonstrate the ability to operate successfully with a coating of ice covering any locking mechanism or “locked/unlocked” indicating mechanism. The ice should be applied as a mist of water under freezing conditions to allow penetration and subsequent freezing in areas normally accessible to rainwater. The mechanism should then be subjected to low temperatures as specified.

c. Braking devices. The ability to meet this constraint should be validated by test, analysis, and inspection as follows: analysis and qualification testing.

d. In-flight actuation command interrupts. The ability to meet this constraint should be validated by test, analysis, and inspection as follows: analysis and qualification testing.

VERIFICATION LESSONS LEARNED (4.4.9.4.2)

Built-in-test: Several example air vehicle programs have demonstrated the need to include postulated lifetime Built-In-Test cycles into the aggregate Lifetime cycles used for Qualification Testing. These seemingly innocuous cycles sometimes cause relatively high loading over a short period of time, even though the actual actuation unit is under low or zero load conditions itself.

3.4.9.4.3 Cockpit positive engagement indication.

The locked-or-unlocked condition of mechanisms used during ground operations or in the interior of the vehicle (cargo or cockpit spaces) shall be displayed in the cockpit.

REQUIREMENT RATIONALE (3.4.9.4.3)

The indication of the locked/unlocked condition is of high importance for both ground and flight safety concerns as well as mission integrity.

REQUIREMENT GUIDANCE (3.4.9.4.3)

Cockpit positive engagement indication systems should be closely coordinated with the parties responsible for cockpit display design.

REQUIREMENT LESSONS LEARNED (3.4.9.4.3)

The use of indicating sensors linked to the actual surface being operated is preferable to having the sensor mounted on the actuating unit itself. Experience with an existing air vehicle has shown that a failed kinematic linkage but operating actuator caused a surface to fail open, yet the cockpit indication showed a "closed" condition since it was receiving a signal from the "healthy" actuator. Such failures are relatively rare and may be mitigated by linkage designs, but they can still occur.

4.4.9.4.3 Cockpit positive engagement indication.

Cockpit positive engagement indication shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.4.3)

The ability of the specific system to provide proper cockpit indication of its operation for its specific application must be verified to ensure a robust and reliable actuation system. In some cases, subsystems may be activated from some other area than the actual pilot location (for example, cargo bay). Demonstration of visibility from a crew viewpoint (pilot or crew chief) in areas around the interior of the air vehicle is very important, especially during night operations.

VERIFICATION GUIDANCE (4.4.9.4.3)

TBS should be filled in with analysis, qualification testing, and ergonomic evaluation.

VERIFICATION LESSONS LEARNED (4.4.9.4.3)

(TBD)

3.4.9.4.4 Actuation control.

Where applicable, a means shall be provided for controlling utility actuation. Where possible, a separate means for "Motion" and "Locking" control may be desired.

REQUIREMENT RATIONALE (3.4.9.4.4)

It is necessary to maintain control over the actuation system for mission success as well as flight and ground safety concerns.

REQUIREMENT GUIDANCE (3.4.9.4.4)

(TBD)

REQUIREMENT LESSONS LEARNED (3.4.9.4.4)

An air vehicle wing fold controller had to be redesigned during the flight test effort to accommodate the need to fold wings independently in certain carrier hangar stowage/maintenance accessibility situations. Better communication with the shipboard reliability and maintainability team would have ensured that this existed in the original design.

An air vehicle had a nose wheel steering gain-control connected to wing fold control handle with separate "unlock" and "fold/unfold" positions. When the wing fold control changed to single unlock/motion position, this caused adverse crew comments. There was a desire to engage higher-gain steering with "unlocked" but not necessarily "folding" wings.

4.4.9.4.4 Actuation control.

The ability to meet this constraint shall be validated by test, analysis, and inspection as follows: analysis, qualification testing, ergonomic evaluation, and EMI Analysis.

VERIFICATION RATIONALE (4.4.9.4.4)

The ability of the specific system to provide proper cockpit control of its operation for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.4)

Any means used to prevent inadvertent actuation of a control (such as guards) should be evaluated by actual pilots to determine suitability as soon as possible in the design process. This also applies to visibility of those controls.

VERIFICATION LESSONS LEARNED (4.4.9.4.4)

(TBD)

3.4.9.4.5 Maintainer safety.

Actuation subsystems that have provision for manual operation shall include safety devices to prevent injury to maintainers in case of inadvertent application of power during a manually powered operation. Actuated devices shall also be evaluated with respect to possible APU exhaust impingement hazards during actual use and maintenance operations (for example, built-in-test operations and pre-flight checks). Possible hazards include overheat and overpressure of structural components as well as high temperature hazards to personnel.

REQUIREMENT RATIONALE (3.4.9.4.5)

The safety of the maintainer as well as the equipment and air vehicle itself needs to be safeguarded during operation of the actuation system.

REQUIREMENT GUIDANCE (3.4.9.4.5)

Actuation subsystems such as boarding ladders that require the maintainer to be in very close proximity during stowage or deployment should incorporate some means of controlling deployment speed to a specified safe rate.

REQUIREMENT LESSONS LEARNED (3.4.9.4.5)

This is based on experience with several helicopter programs. The relatively small size of a helicopter fuselage makes APU exhaust routing an important concern during operations such as blade fold.

4.4.9.4.5 Maintainer safety.

The ability to meet this constraint shall be validated by test, analysis, and inspection.

VERIFICATION RATIONALE (4.4.9.4.5)

The ability of the specific system to provide maintainer safety features in its operation for its specific application must be verified to ensure a safe, robust, and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.5)

Analysis, qualification testing, and ergonomic evaluation should be conducted. Thermal and acoustic analyses of areas necessary for maintainer/crew positioning during actuation processes during various operating conditions (for example, the APU on, main power plant on, or ground carts on) should be performed to validate personnel safety.

VERIFICATION LESSONS LEARNED (4.4.9.4.5)

(TBD)

3.4.9.4.6 Ground power operability.

Utility actuation subsystems shall be capable of operating from the ground power supplied to the air vehicle as well as air vehicle supplied power.

REQUIREMENT RATIONALE (3.4.9.4.6)

Utility actuation systems need to operate safely and properly when using ground power to facilitate system checkout and maintenance functions.

REQUIREMENT GUIDANCE (3.4.9.4.6)

Utility actuation subsystems should be designed to accommodate air vehicle and ground power and to safely accommodate transitions between the two states.

REQUIREMENT LESSONS LEARNED (3.4.9.4.6)

(TBD)

4.4.9.4.6 Ground power operability.

The ability to meet this constraint shall be validated by test, analysis, and inspection.

VERIFICATION RATIONALE (4.4.9.4.6)

The ability of the specific system to provide proper ground power operability for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.6)

Analysis, qualification testing, and ergonomic evaluation should be conducted. Analysis or testing should be performed to verify that transitions from ground to air vehicle power could be safely performed without harm to personnel or equipment.

VERIFICATION LESSONS (4.4.9.4.6)

(TBD)

3.4.9.4.7 Actuation time.

All actuation subsystems shall be able to perform their specified function within (TBS) time and cycle. Allowable intervals between actuation cycles shall also be specified as well as total cycles expected during the application lifetime.

REQUIREMENT RATIONALE (3.4.9.4.7)

Specific mission requirements will require a system performance within a specified band of time.

REQUIREMENT GUIDANCE (3.4.9.4.7)

TBS: For example, an air vehicle's wing fold system had actuation time of 10-14 seconds. The air vehicle wing stow system had a total actuation time of 90 seconds (12 seconds to index rotors, 30 seconds to fold blades, 12 seconds to rotate nacelles, and 45 seconds to actually rotate wings to stowed position). Another example is an air vehicle boarding ladder system had actuation time of 7 seconds (3.6 second actuation cycle time plus 3 second ladder deployment time). Example air vehicle blade fold system had powered actuation time of 42 seconds (12 seconds to index rotors; 30 seconds to fold blades).

REQUIREMENT LESSONS LEARNED (3.4.9.4.7)

(TBD)

4.4.9.4.7 Actuation time.

The ability to meet this constraint shall be validated by test, analysis, and inspection.

VERIFICATION RATIONALE (4.4.9.4.7)

The ability of the specific system to provide proper actuation time performance during its operation for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.7)

Actuation time should be validated by test in an environment that is representative of the actual air vehicle installation and air vehicle loads; if the loads change during the actuation process this should be accounted for also.

VERIFICATION LESSONS LEARNED (4.4.9.4.7)

(TBD)

3.4.9.4.8 Surface interference prevention.

Utility actuation subsystems shall incorporate some means to prevent damage to adjacent movable surfaces (for example, flaps) during folding and unfolding operations. Also, a means shall be incorporated to allow any movable control surface to be in any position on the panel being folded/unfolded.

REQUIREMENT RATIONALE (3.4.9.4.8)

Damage to adjacent surfaces or to the system itself is not acceptable during system operation because of safety and maintainability/reliability concerns.

REQUIREMENT GUIDANCE (3.4.9.4.8)

(TBD)

REQUIREMENT LESSONS LEARNED (3.4.9.4.8)

Most existing air vehicle wing fold systems utilize some mechanical interlock to prevent ailerons on the outer, folding wing panel from interfering with the flaps on the inner, non-folding portion of the wing during the wing fold process.

For example, air vehicles require aileron interlock to prevent damage to inboard flaps during wing fold operations.

4.4.9.4.8 Surface interference prevention.

The ability to meet this constraint shall be validated by test, analysis, and inspection.

VERIFICATION RATIONALE (4.4.9.4.8)

The ability of the specific system to provide proper surface interference prevention through design or specific features for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.8)

Analysis, qualification testing, and ergonomic evaluation should be conducted. It is important to consider adjacent structural areas during the design of the actuation subsystem to prevent damage during operation. Verification by demonstration may provide results too late to be of much benefit.

VERIFICATION LESSONS LEARNED (4.4.9.4.8)

(TBD)

3.4.9.4.9 Replaceable attachments.

The actuation subsystem attachment shall not be an integral part of the air vehicle structure, such as wing rib. It shall be a replaceable attachment designed so that in case of an overload or fatigue failure event, failure of the attachment shall occur in lieu of air vehicle primary structural component failure.

REQUIREMENT RATIONALE (3.4.9.4.9)

Damage to the primary air vehicle structure itself is usually not acceptable during system operation because of safety and maintainability/reliability concerns. Damage to the actuation system is preferable to air vehicle structural damage because of cost, flight safety, and ground safety concerns.

REQUIREMENT GUIDANCE (3.4.9.4.9)

It is desirable to have the attachment point of the actuation subsystem function as a “structural fuse,” an overload/jam condition would fail the attachment prior to the much more costly air vehicle primary structure.

REQUIREMENT LESSONS LEARNED (3.4.9.4.9)

(TBD)

4.4.9.4.9 Replaceable attachments.

Replaceable attachments shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.4.9)

The inclusion of replaceable attachments in the specific system must be verified to ensure a robust, maintainable, and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.9)

TBS should be filled in with test, analysis, and inspection.

VERIFICATION LESSONS LEARNED (4.4.9.4.9)

(TBD)

3.4.9.4.10 Folded and stowed position clearance.

Clearance shall be 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.

REQUIREMENT RATIONALE (3.4.9.4.10)

Damage to adjacent surfaces or to the system itself are not acceptable during system operation because of safety and maintainability/reliability concerns. Therefore, positive clearance values must be maintained for a variety of conditions.

REQUIREMENT GUIDANCE (3.4.9.4.10)

Conditions that include special maintenance positions or equipment location should be examined. Unsymmetrical landing gear deflections, in the case of one surface such as a wing or rotor blade being folded before the others, should be combined with a flat tire or compressed landing-gear-ground-interface-device (skid, air cushions) on the low side in determining critical clearances. With the surfaces folded, swept, or stowed, it should be possible to retract and extend the landing gear for maintenance purposes. Except when the landing gear retracts into the folded portion of the wings, a complete retraction and extension cycle, including up-lock operation, should be possible.

REQUIREMENT LESSONS LEARNED (3.4.9.4.10)

(TBD)

4.4.9.4.10 Folded and stowed position clearance.

Folded and stowed position clearance shall be verified by (TBS).

VERIFICATION RATIONALE (4.4.9.4.10)

The ability of the specific system to provide proper deployed and stowed position clearance during its operation for its specific application must be verified to ensure a safe, robust, and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.10)

TBS should be filled in with test, analysis, and inspection.

VERIFICATION LESSONS LEARNED (4.4.9.4.10)

(TBD)

3.4.9.4.11 Manual deployment and drive input.

Utility actuation mechanisms used during ground operations shall 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). Subsystems used for purely in-flight applications shall also have means incorporated to allow cockpit controlled activation for ground maintenance actions.

REQUIREMENT RATIONALE (3.4.9.4.11)

Manual backup for deploying and stowing an actuated surface or device is necessary for maintenance power-off conditions as well as to accommodate emergency conditions in situations where the operation of other air vehicles may also be impacted as well (such as hangar deck obstructed by air vehicle(s) with spread wings/rotor blades with failed power units).

REQUIREMENT GUIDANCE (3.4.9.4.11)

Wing folding and spreading operation should be accomplished by both manual and powered means. Wings folded/pivoted by power should permit decoupling of the wing locking mechanism and should have manual or other alternate provision for folding and spreading the wings. Provisions should be made to prevent hazards to maintenance personnel, wing-mounted equipment (such as pylons), or damage critical components that could cause wing/tail control surface damage as well as control loss or damage to electrical connectors, control lines, or such during normal, manual, or externally powered wing folding and spreading.

Blade folding should be accomplished by manual or powered means. Provisions should be made to prevent hazards to maintenance personnel or damage critical components that could cause blade/wing/tail surface control loss or damage to electrical connectors, control lines, or such during normal, manual, or externally powered blade folding and spreading.

REQUIREMENT LESSONS LEARNED (3.4.9.4.11)

Manual operation of example air vehicle folding mechanism caused damage through the use of unauthorized, but frequently used, ammunition-loading power tools. A torque-limiting mechanism was later incorporated to address this problem.

4.4.9.4.11 Manual deployment and drive input.

The ability to meet this constraint shall be validated by test, analysis, and inspection.

VERIFICATION RATIONALE (4.4.9.4.11)

The inclusion within the specific system of manual deployment and drive input features and their operation for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.11)

Wing fold/wing pivot manual deployment and drive input should be validated by test, analysis, and inspection.

Blade fold manual deployment and drive input should be validated by test, analysis, and inspection.

VERIFICATION LESSONS LEARNED (4.4.9.4.11)

(TBD)

3.4.9.4.12 External securing.

Removable surface securing devices shall only be used in lieu of integral locks when specifically authorized by the Government. These devices shall be capable of withstanding rough handling without damage and shall have strength equal to or exceeding that of the air vehicle. The removable devices shall be such that one man can secure the surface in winds up to 60 knots from any horizontal direction.

REQUIREMENT RATIONALE (3.4.9.4.12)

External securing provisions are necessary to accommodate situations where high wind/sea state conditions occur and it is not feasible to move the air vehicle to a safer location or within a hangar.

REQUIREMENT GUIDANCE (3.4.9.4.12)

Actuation subsystem external securing devices should be designed to reduce or eliminate the possibility of foreign object damage (FOD) during removal/installation.

Due to the nature of rotorcraft operations, it is desirable that external blade fold securing devices be transportable within the air vehicle to remote staging and operating areas.

REQUIREMENT LESSONS LEARNED (3.4.9.4.12)

As an example, an air vehicle boarding ladder system initial design had a detachable prop to lock the ladder in place and function as a deployment assistance handle. It was found that the ladder's close proximity to an engine intake presented too much of a possibility for FOD (for example, placing the handle on the intake after use and inadvertently leaving it there).

4.4.9.4.12 External securing.

The ability to meet this constraint shall be validated by test, analysis, and inspection as follows: analysis and qualification testing.

VERIFICATION RATIONALE (4.4.9.4.12)

The ability of the specific system to provide proper external securing during operation for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.12)

Wing fold/wing pivot external securing should be validated by test, analysis, and inspection.

Blade fold external securing should be validated by test, analysis, and inspection.

Detachable securing devices should be tested with regard to maintainer induced loads (including potential jam/forcing conditions) as well as normal environmental loads, such as wind, or shipboard movement.

VERIFICATION LESSONS LEARNED (4.4.9.4.12)

An air vehicle wing fold system suffered component failures due to excessive force applied during manual fold operations. The design did not take into account normal-usage-induced increase in friction creating temporary high load conditions at manual input location.

3.4.9.4.13 Visual positive engagement identification.

The locked-unlocked condition of mechanisms used during ground operations or in the interior of the vehicle (cargo or cockpit spaces) shall be displayed visually, externally, internally, or both if required, by purely mechanical, non-electric means. This is in addition to the “cockpit positive engagement indication” in this specification guide.

REQUIREMENT RATIONALE (3.4.9.4.13)

Indication of positive engagement of locking mechanisms is necessary to ensure safe operation of an actuating system.

Cockpit and external indication means are both necessary because of the possibility of purely manual deployment, such as when no one is in the cockpit.

REQUIREMENT GUIDANCE (3.4.9.4.13)

Engagement identification devices should be designed to allow visibility during day or night conditions. These devices should be visible from any area that a maintainer could be expected to be during the actuation cycle; they should not become occluded during any portion of the actuation cycle.

Flags, distinctively colored cylinders, and distinctively colored portions of the air vehicle surface that are revealed by the actuating mechanism itself are suitable means of external indication.

REQUIREMENT LESSONS LEARNED (3.4.9.4.13)

Several different means of positive engagement identification are in use including mechanical striped "barber poles," rotating colored or uncolored discs, and exposed or covered brightly painted areas.

4.4.9.4.13 Visual positive engagement identification.

The ability to meet this constraint shall be validated by test, analysis, and inspection.

VERIFICATION RATIONALE (4.4.9.4.13)

The ability of the specific system to provide proper positive engagement identification during its operation for its specific application must be verified to ensure a robust and reliable actuation system.

VERIFICATION GUIDANCE (4.4.9.4.13)

Positive engagement identification should be verified my maintainer demonstrations as early in the program as possible, including the use of partial mockups (real or virtual) when available.

VERIFICATION LESSONS LEARNED (4.4.9.4.13)

(TBD)

5. PACKAGING

5.1 Packaging.

For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

The mechanical subsystem descriptions in this specification guide are intended for use in air vehicle systems developed to perform combat and combat-support missions in environments unique to military weapon systems.

6.2 Acquisition requirements.

Acquisition documents should specify the following:

a. Title, number, and date of this specification.

6.3 Acronyms.

The following list contains the acronyms/abbreviations contained within this specification guide:

PPSL	Program Parts Selection List
QPL	Qualified Products List
SRB	Self-retaining Bolt

6.4 Subject term (key word) listing.

Bearing

Door

Fastener

Latch

Lock

Seals

Weapons bay

6.5 Change notations.

The margins of this specification guide are marked with vertical lines to indicate where changes from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the previous issue.

CONCLUDING MATERIAL

Custodians:
Navy –AS
Air Force – 11

Review activity:
Air Force – 70

Preparing activity:
Air Force – 11
(Project 15GP-2018-006)

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 https://assist.dla.mil.