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MILITARY SPECIFICATION

FLIGHT CONTROL SYSTEMS - DESIGN, INSTALLATION AND TEST OF PILOTED AIRCRAFT, GENERAL SPECIFICATION FOR

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

1. SCOPE

1.1 Scope. This specification establishes general performance, design, development and quality assurance requirements for the flight control systems of USAF manned piloted aircraft. Flight control systems (FCS) include all components used to transmit flight control commands from the pilot or other sources to appropriate force and moment producers. Flight control commands may result in control of aircraft flight path, attitude, airspeed, aerodynamic configuration, ride, and structural modes. Among components included are the pilot's controls, dedicated displays and logic switching, transducers, system dynamic and air data sensors, signal computation, test devices, transmission devices, actuators, and signal transmission lines dedicated to flight control. Excluded are aerodynamic surfaces, engines, helicopter rotors, fire control devices, crew displays and electronics not dedicated to flight control. The interfaces of flight control systems with related subsystems are defined.

1.2 Classification

1.2.1 Flight control system (FCS) classifications

1.2.1.1 Manual flight control systems (MFCS). Manual Flight Control Systems consist of electrical, mechanical and hydraulic components which transmit pilot control commands or generate and convey commands which augment pilot control commands, and thereby accomplish flight control functions. This classification includes the longitudinal, lateral-directional, lift, drag and variable geometry control systems. In addition, their associated augmentation, performance limiting and control devices are included.

1.2.1.2 Automatic flight control systems (AFCS). Automatic Flight Control Systems consist of electrical, mechanical and hydraulic components which generate and transmit automatic control commands which provide pilot assistance through automatic or semiautomatic flight path control or which automatically control airframe response to disturbances. This classification includes automatic pilots, stick or wheel steering, autothrottles, structural mode control and similar control mechanizations.

FSC 6610

1.2.2 FCS Operational State classifications

1.2.2.1 Operational State I (Normal operation). Operational State I is the normal state of flight control system performance, safety and reliability. This state satisfies MIL-F-8785 or MIL-F-83300 Level 1 flying qualities requirements within the operational flight envelope and Level 2 within the service envelope and the stated requirements outside of these envelopes.

1.2.2.2 Operational State II (Restricted operation). Operational State II is the state of less than normal equipment operation or performance which involves degradation or failure of only a noncritical portion of the overall flight control system. A moderate increase in crew workload and degradation in mission effectiveness may result from a limited selection or normally operating FCS modes available for use; however, the intended mission may be accomplished. This state satisfies at least MIL-F-8785 or MIL-F-83300 Level 2 flying qualities requirements within the operational flight envelope and Level 3 within the service envelope.

1.2.2.3 Operational State III (minimum safe operation). Operational State III is the state of degraded flight control system performance, safety or reliability which permits safe termination of precision tracking or maneuvering tasks, and safe cruise, descent, and landing at the destination of original intent or alternate but where pilot workload is excessive or mission effectiveness is inadequate. Phases of the intended mission involving precision tracking or maneuvering cannot be completed satisfactorily. This state satisfies at least MIL-F-8785 or MIL-F-83300 Level 3 flying qualities requirements.

1.2.2.4 Operational State IV (controllable to an immediate emergency landing). Operational State IV is the state of degraded FCS operation at which continued safe flight is not possible; however, sufficient control remains to allow engine restart attempt(s), a controlled descent and immediate emergency landing.

1.2.2.5 Operational State V (controllable to an evacuable flight condition). Operational State V is the state of degraded FCS operation at which the FCS capability is limited to maneuvers required to reach a flight condition at which crew evacuation may be safely accomplished.

1.2.3 FCS criticality classification

1.2.3.1 Essential. A function is essential if loss of the function results in an unsafe condition or inability to maintain FCS Operational State III.

1.2.3.2 Flight phase essential. A function is flight phase essential if loss of the function results in an unsafe condition or inability to maintain FCS Operational State III only during specific flight phases.

1.2.3.3 Noncritical. A function is noncritical if loss of the function does not affect flight safety or result in control capability below that required for FCS Operational State III.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein. The requirements of this specification shall govern for flight control system design where conflicts exist between this specification and other reference specifications.

SPECIFICATIONS

Military

MIL-T-781	Terminal, Wire Rope, Swaging
MIL-F-3541	Fitting, Lubrication
MIL-U-3963	Universal Joint, Antifriction Bearings
MIL-B-5087	Bonding, Electrical and Lightning Protection, for Aerospace Systems
MIL-W-5088	Wiring, Aircraft, Selection and Installation of
MIL-E-5400	Electronic Equipment, Airborne, General Specification for
MIL-H-5440	Hydraulic Systems, Aircraft Types I and II, Design, Installation, and Data Requirements for
MIL-C-5503	Cylinder, Aeronautical, Hydraulic Actuating, General Requirements for
MIL-P-5518	Pneumatic Systems, Aircraft, Design, Installation, and Data Requirements for
MIL-T-5522	Test Procedure for Aircraft Hydraulic and Pneumatic Systems, General
MIL-S-5676	Splicing, Cable Terminal, Process for, Aircraft
MIL-T-5677	Thimble, Wire Cable, Aircraft
MIL-B-5687	Bearing, Sleeve, Washers, Thrust, Sintered, Metal Powder, Oil-Impregnated
MIL-C-6021	Casting, Classification and Inspection of
MIL-B-6038	Bearing, Ball, Bellcrank, Antifriction, Airframe
MIL-B-6039	Bearing, Double Row, Ball, Sealed, Rod End, Antifriction, Self-Aligning
MIL-E-6051	Electromagnetic Compatibility Requirements, Systems
MIL-T-6117	Terminal, Cable Assemblies, Swaged Type
MIL-J-6193	Joint, Universal, Plain, Light and Heavy Duty
MIL-G-6641	Gearbox, Aircraft Accessory Drive, General Specification for
MIL-P-7034	Pulley, Groove, Antifriction-Bearing, Grease-Lubricated, Aircraft
MIL-I-7064	Indicator, Position, Elevator Trim Tab

MIL-E-7080	Electric Equipment; Aircraft, Selection and Installation of
MIL-F-7190	Forging, Steel, for Aircraft and Special Ordnance Applications
MIL-D-7602	Drive, Turbine, Air, Aircraft Accessory, General Specification for
MIL-B-7949	Bearing, Ball, Airframe, Antifriction
MIL-C-7958	Control, Push-Pull, Flexible and Rigid
MIL-M-7969	Motor, AC, 400 Cycle, 115/200 Volt System, Aircraft, General Specification for
MIL-M-7997	Motor, Aircraft Hydraulic, Constant Displacement, General Specification for
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles
MIL-P-8564	Pneumatic System Components, Aeronautical, General Specifications for
MIL-M-8609	Motor, DC, 28 Volt System, Aircraft, General Specification for
MIL-S-8698	Structural Design Requirements, Helicopters
MIL-H-8775	Hydraulic System Components, Aircraft and Missiles, General Specifications for
MIL-F-8785	Flying Qualities of Piloted Airplanes
MIL-A-8860	Airplane Strength and Rigidity, General Specification for
MIL-A-8861	Airplane Strength and Rigidity, Flight Loads
MIL-A-8865	Airplane Strength and Rigidity; Miscellaneous Loads
MIL-A-8866	Airplane Strength and Rigidity - Reliability Requirements, Repeated Loads, and Fatigue
MIL-A-8867	Airplane Strength and Rigidity, Ground Tests
MIL-A-8870	Airplane Strength and Rigidity Flutter; Divergence, and Other Aeroelastic Instabilities
MIL-T-8878	Turnbuckle, Positive Safetying
MIL-S-8879	Screw Threads, Controlled Radius Root with Increased Minor Diameter; General Specification for
MIL-H-8890	Hydraulic Components, Type III, -65° to +450°F, General Specification for
MIL-H-8891	Hydraulic Systems, Manned Flight Vehicles, Type III, Design, Installation, and Data Requirements for
MIL-A-8892	Airplane Strength and Rigidity, Vibration
MIL-A-8893	Airplane Strength and Rigidity, Sonic Fatigue
MIL-B-8976	Bearing, Plain, Self-Aligning, All-Metal
MIL-S-9419	Switch, Toggle, Momentary, Four-Position On, Center Off
MIL-C-18375	Cable, Steel (Corrosion-Resisting, Nonmagnetic) Flexible, Preformed (for Aeronautical Use)
MIL-A-21180	Aluminum-Alloy Casting, High Strength
MIL-A-22771	Aluminum Alloy Forgings, Heat Treated
MIL-K-25049	Knob, Control, Equipment, Aircraft
MIL-G-25561	Grip Assembly, Controller, Aircraft, Type MC-2

MIL-V-27162	Valve, Servocontrol, Electrohydraulic, General Specification for
MIL-C-27500	Cable, Electrical, Shielded and Unshielded, Aircraft and Missile
MIL-E-38453	Environmental Control, Environmental Protection, and Engine Bleed Air Systems, Aircraft, and Aircraft Launched Missiles, General Specification for
MIL-M-38510	Microcircuit, General Specification for
MIL-B-81820	Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed
MIL-F-83142	Forging, Titanium Alloys, for Aircraft and Aerospace Applications
MIL-F-83300	Flying Qualities of Piloted V/STOL Aircraft
MIL-W-83420	Wire Rope, Flexible, for Aircraft Control
MIL-A-83444	Airplane Damage Tolerance Requirements

STANDARDS

Military

MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-143	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-250	Aircrew Station Controls and Displays for Rotary Wing Aircraft
MIL-STD-421	Chain Roller; Power Transmission and Conveyor, Flat Link Plates, Single Pitch, Single and Multiple Strand, Connective Links and Attachment Links
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Interference Characteristics Requirements for Equipment
MIL-STD-480	Configuration Control - Engineering Changes, Deviations and Waivers
MIL-STD-704	Electric Power, Aircraft, Characteristics and Utilization of
MIL-STD-810	Environmental Test Methods
MIL-STD-838	Lubrication of Military Equipment
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-1530	Aircraft Structural Integrity Program, Airplane Requirements
MIL-STD-1553	Aircraft Internal Time Division Multiplex Data Bus
MS15002	Fittings, Lubrication (Hydraulic) Surface Check, Straight Threads, Steel, Type II

MS15981	Fasteners, Externally Threaded, Self-Locking, Design and Usage Limitations for
MS24665	Pin, Cotter
MS33540	Safety Wiring and Cotter Pinning, General Practices for
MS33572	Instrument, Pilot, Flight, Basic, Standard Agreement for Helicopters
MS33588	Nuts, Self-Locking, Aircraft Design and Usage Limitations of
MS33602	Bolt, Self Retaining, Aircraft Reliability and Maintainability Design and Usage, Requirements for
MS33736	Turnbuckle Assemblies, Clip Locking of

PUBLICATIONS

Military Handbooks

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Plastics for Flight Vehicles

Air Force Systems Command Design Handbooks

AFSC DH 1-2	General Design Factors
AFSC DH 1-4	Electromagnetic Compatibility
AFSC DH 1-5	Environmental Engineering
AFSC DH 1-6	System Safety
AFSC DH 2-1	Airframe
AFSC DH 2-2	Crew Stations and Passenger Accommodations

(Copies of specifications, standards, drawings, publications and handbooks required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

National Aircraft Standard

NAS 516	Fitting, Lubrication - 1/8 Inch Drive, Flush Type

(Copies of National Aircraft Standards may be obtained from the Aircraft Industries Association of America, Inc., Shoreham Building, Washington, D.C.)

SAE Aerospace Recommended Practices

ARP 988	Electrohydraulic Mechanical Feedback Servoactuators
ARP 1281	Servoactuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification for

(Application for copies should be addressed to the American Society of Automotive Engineers, Two Pennsylvania Plaza, New York, New York 10001.)

ICAO Practices

ICAO Annex 10	International Civil Aviation Organization Publication - Aeronautical Telecommunications Vol. II, Communication Procedures, International Standards, Recommended Practices and Procedures for Air Navigation Services

FAA Advisory Circular

FAA Advisory Circular 120-29	Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators

Technical Reports

AFFDL-TR-74-116	Background Information and User Guide for MIL-F-9490D

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 System requirements. The FCS shall comply with the following requirements.

3.1.1 MFCS Performance requirements. The MFCS shall comply with applicable general flying quality requirements of MIL-F-8785 or MIL-F-83300 and the special performance requirements of the procurement detail specification.

3.1.2 AFCS Performance requirements. When the following AFCS functions are used, the following specified performance shall be provided. Unless otherwise specified, these requirements apply in smooth air and include sensor error. Except where otherwise specified, a damping ratio (6.6) of at least 0.3 critical shall be provided for nonstructural AFCS controlled mode responses. Specified damping requirements apply only to the response characteristics for perturbations an order of magnitude greater than the allowable residual oscillation.

3.1.2.1 Attitude hold (pitch and roll). Attitudes shall be maintained in smooth air with a static accuracy of ±0.5 degree in pitch attitude (with wings level) and ±1.0 degree in roll attitude with respect to the reference. RMS attitude deviations shall not exceed 5 degrees in pitch or 10 degrees in roll attitude in turbulence at the intensities specified in 3.1.3.7. When using a flight controller (turn knob) the aircraft shall return to a wings level attitude when the turn control is placed in the detent position. Accuracy requirements shall be achieved and maintained within 3 seconds of mode engagement for a 5 degree attitude disturbance for MIL-F-8785 Class IV aircraft, and within 5 seconds for MIL-F-8785 Classes I, II and III aircraft.

3.1.2.2 Heading hold. In smooth air, heading shall be maintained within a static accuracy of ±0.5 degree with respect to the reference. In turbulence, RMS deviations shall not exceed 5 degrees in heading at the intensities specified in 3.1.3.7. When using a flight controller, heading hold shall automatically engage as the controller is returned to the detent position.

3.1.2.3 Heading select. The aircraft shall automatically turn through the smallest angle to any heading selected or preselected by the pilot and maintain that heading to the tolerances specified for heading hold. The contractor shall determine a bank angle limit which provides a satisfactory turn rate and precludes impending stall. The heading selector shall have 360 degrees control. The aircraft shall not overshoot the selected heading by more than 1.5 degrees with flaps up or 2.5 degrees with flaps down. The roll rate shall not exceed 10 deg/sec and roll acceleration shall not exceed 5 deg/sec/sec for MIL-F-8785 Classes I, II and III aircraft, or double these values for MIL-F-8785 Class IV aircraft.

3.1.2.4 Lateral acceleration and sideslip limits. Except for flight phases using direct side force control, the following performance shall be provided whenever any lateral-directional AFCS function is engaged. Lateral acceleration refers to apparent (measured, sensed) body axis acceleration at the aircraft center of gravity.

3.1.2.4.1 Coordination in steady banked turns. Sideslip angle shall not be greater than 2 degrees and lateral acceleration shall not exceed 0.03g, while at steady bank angles up to the maneuver bank angle limit reached during normal maneuvers with the AFCS engaged. For rotary wing aircraft, only the lateral acceleration limit applies.

3.1.2.4.2 Lateral acceleration limits, rolling. Body axis lateral acceleration at the cg shall not exceed ±0.1g for aircraft with roll rate capability up to 30 deg/sec, ±0.2g for aircraft with roll rate capability of 30 to 90 deg/sec, or ±0.5g for aircraft with roll rates over 90 deg/sec. These limits shall be satisfied for aircraft in essentially constant altitude flight while rolling smoothly from one side to the other at bank rates up to the maximum obtainable through AFCS modes.

3.1.2.4.3 Coordination in straight and level flight. The accuracy while the aircraft is in straight and level flight shall be maintained within a sideslip angle of ±1 degree and a lateral acceleration of ±0.02g at the cg, whichever is lower. For rotary wing aircraft, only the lateral acceleration limit applies.

3.1.2.5 Altitude hold. Engagement of the altitude hold function at rates of climb or descent less than 2,000 fpm shall select the existing indicated barometric altitude and control the aircraft to this altitude as a reference. The resulting normal acceleration shall not exceed 0.2g incremental for MIL-F-8785 Classes I, II and III aircraft, or 0.5g incremental for MIL-F-8785 Class IV aircraft. For engagement at rates above 2,000 feet per minute the AFCS shall not cause any unsafe maneuvers. Within the aircraft thrust-drag capability and at steady bank angles, the mode shall provide control accuracies specified in table I.

TABLE I. MINIMUM ACCEPTABLE CONTROL ACCURACY

<table>
<tr><th>BANK ANGLE (DEG.)
ALT. (FT.)</th><th>0 – 1</th><th>1 – 30</th><th>30 – 60</th></tr>
<tr><td>55,000
to
80,000</td><td>±0.1% at 55,000
varying linearly
to ±0.2% at 80,000</td><td rowspan="3">±60 ft.
or
±0.3%
whichever
is
larger</td><td rowspan="3">±90 ft.
or
±0.4%
whichever
is
larger</td></tr>
<tr><td>30,000
to
55,000</td><td>±0.1%</td></tr>
<tr><td>0
to
30,000</td><td>±30 ft.</td></tr>
</table>

These accuracy requirements apply for airspeeds up to Mach 1.0. Double these values are permitted above Mach 1.0 and triple these values apply above Mach 2.0. Following engagement or perturbation of this mode at 2,000 feet per minute or less, the specified accuracy shall be achieved within 30 seconds. Any periodic residual oscillation within these limits shall have a period of at least 20 seconds.

3.1.2.6 Mach hold. The Mach number existing at the engagement of Mach hold shall be the reference. After engagement and stabilization on Mach hold, the AFCS shall maintain indicated Mach number and the error shall not exceed ±0.01 Mach or ±2 percent of indicated Mach, whichever is larger, with respect to the reference. Any periodic oscillation within these limits shall have a period of at least 20 seconds. The contractor shall establish a mode response or maximum time to capture requirement which is suitable for the mission phase.

3.1.2.7 Airspeed hold. The airspeed existing at the engagement of airspeed hold shall be the reference. Indicated airspeed shall be maintained within ±5 knots or ±2 percent, whichever is greater, of the reference airspeed. Any periodic oscillation within this limit shall have a period of at least 20 seconds. The contractor shall establish a mode response or maximum time to capture requirement which is suitable for the mission phase.

3.1.2.8 Automatic navigation

3.1.2.8.1 VOR/TACAN. When preconditions for radial capture are satisfied the AFCS shall cause the aircraft to maneuver to acquire the radial beam center. Maximum roll rate and attitude commands shall be limited to provide a smooth capture and subsequent tracking of the radial. The following performance requirements for VOR are stated in terms of crosstrack error (feet) and radial error (expressed in μ amps; 1 degree = 15 μ amps) to provide for systems using either ARINC 547 or 579 VOR receivers. For ARINC 547 receivers, only the radial error applies. Crosstrack error applied to the ARINC 579 receiver operating in the primary mode (co-located VOR/DME), and radial error applies in the reversionary mode (DME inoperative or not available).

3.1.2.8.1.1 VOR capture and tracking. Overshoot shall not exceed 5,800 feet (20 μa) beyond the desired ground track line in a no-wind condition for captures 50 miles or more from the station with intercept angles up to 45 degrees. Following capture at 50 miles or more, the aircraft shall remain within an average of 5,800 feet (20 μa) from the VOR radial beam center, with this error allowance decreasing proportional to the distance from the VOR station. Average tracking error shall be measured over a 5 minute period between 50 and 10 miles from the station or averaged over the nominal aircraft flight time between the same distance limits, whichever time is shorter.

3.1.2.8.1.2 TACAN capture and tracking. Overshoot shall not exceed 6,300 feet beyond the desired ground track line in a no-wind condition for captures 120 miles or more from the station with intercept angles up to 30 degrees. The required 0.3 damping ratio shall be exhibited for continuous tracking between 120 miles and 20 miles from the station.

3.1.2.8.1.3 Overstation. The VOR/TACAN mode shall include automatic means for maintaining the aircraft within ±1 degree of aircraft heading or ground track existing at the inbound edge of the VOR zone of confusion (ZOC). During overflight of the ZOC, adjustment of the preset course heading or its equivalent shall cause the roll AFCS to maneuver the aircraft to capture the appropriate outbound radial upon exiting from the ZOC. The VOR/TACAN capture maneuvering limits may be reinstated during overstation operation.

3.1.2.9 Automatic instrument low approach system. The approach mode of the AFCS shall respond to localizer signals for lateral guidance and glide slope signals for vertical guidance. The system shall be designed to automatically steer the aircraft to a minimum decision height of 100 feet during ICAO Category II weather minimums. The system shall provide timely warning to permit the pilot to complete the landing if runway visual contact is established or to safely execute a go-around following any single failure or combination of failures not shown to be extremely remote as defined in 6.6. The system shall comply with the tracking requirements of 3.1.2.9.1 through 3.1.2.9.3 for probable combinations of headwinds to 25 knots, tailwinds to 10 knots, and crosswinds to 15 knots, with the probability of occurrence of such winds and associated turbulence and wind shears as specified in 3.1.3.7.3.

3.1.2.9.1 Localizer mode. The AFCS shall cause the aircraft to maneuver to acquire the localizer beam. Heading or roll rate and attitude commands shall be limited to provide a smooth capture and subsequent tracking of the localizer beam. Overshoot shall not exceed 0.5 degrees (37.5 μa) radial error from localizer beam center for captures with initial intercept angles of 45 degrees at 8 miles from runway threshold and increasing linearly to 60 degrees at 18 miles from runway threshold in a no wind condition. During localizer capture the system shall exhibit a damping ratio of at least 0.1 within the noted capture ranges, including the effects of system nonlinearities. The system shall be considered to be tracking whenever the following conditions are satisfied: localizer beam error is 1 degree (75 μa) or less, localizer beam rate is 0.025 deg/sec (2 μa/sec) or less, and roll attitude is 5 degrees or less. During beam tracking the system shall exhibit a damping ratio of 0.2 or greater at a distance of 40,000 feet from the localizer transmitter. The AFCS shall maintain the aircraft 2σ position within 0.33 degrees (25 μa) of localizer beam center whenever the aircraft is between (1) 40,000 feet horizontal distance from the localizer transmitter, and (2) the point where 100 feet above the ground is reached; these criteria shall be based on a Category II localizer ground installation and 10,000 foot runway is defined by ICAO Annex 10.

3.1.2.9.2 Glide slope mode. The pitch AFCS shall cause the aircraft to maneuver to acquire the glide slope beam. Neither the position of the aircraft above or below the glide slope nor vertical speed of the aircraft at time of mode selection shall be incorporated as a precondition for mode engagement. When preconditions are satisfied, overshoot shall not exceed 0.16 degrees (35 μa) of radial error from glide slope beam center when capturing from below the beam in level flight at an altitude greater than 800 feet above the glide slope transmitter datum altitude in a no-wind condition. The system shall exhibit a damping ratio of 0.085 or greater subsequent to the first overshoot for the conditions defined. On a Category II ILS ground facility (including 10,000 foot runway) as defined in ICAO Annex 10, the pitch AFCS shall maintain the aircraft glide slope antenna 2 σ opposition within 0.16 degrees (35 μa) of beam center or within 12 feet of beam center, whichever is greater, between the altitudes of 700 feet and 100 feet above the glide slope transmitter datum.

3.1.2.9.3 Go-around mode. The automatic go-around mode shall be manually engaged only. The AFCS shall be designed such that no single failure, or combination of failures not extremely remote, will cause the aircraft to maneuver to increase the rate of descent upon engaging the go-around mode. If the go-around mode is designed for concurrent operation with other automatic control systems, a single switch location or pilot action shall engage all systems into the appropriate mode for go-around. Should one or any combination of concurrently operating automatic control systems be inoperative at the time of AFCS go-around mode engagement, the AFCS shall comply with the performance requirements based on normal go-around procedures including manual management of thrust, flaps, and landing gear.

3.1.2.9.3.1 Pitch AFCS go-around. The pitch AFCS shall cause the aircraft to smoothly rotate sufficiently to establish a positive rate of climb such that the aircraft will not intersect the obstacle clearances planes defined in FAA Advisory Circular 120-29 more often than 1 in 10^6 events for the wind conditions specified in 3.1.2.9, and including high altitude, hot day conditions as defined by the procuring activity. In the event of inadvertent loss of an engine just prior to or during automatic go-around, the system shall not cause the aircraft to approach stall within 30 seconds of mode engagement, based on design approach speed. If operating procedures require the mode to be disengaged upon inadvertent loss of an engine, a timely warning shall be provided for the pilot to initiate the disengage procedure. Disengagement under this condition shall be accomplished manually.

3.1.2.9.3.2 Lateral-heading AFCS go-around performance standards. The lateral-heading AFCS shall maintain the aircraft 4σ position within the lateral boundaries of the obstacle clearance planes during wind conditions as specified in 3.1.2.9. This capability shall be maintained in the event of the most critical engine failure just prior to or during automatic go-around. If normal procedure is to disengage the go-around mode after inadvertent loss of one engine, under the wind conditions cited a pilot of normal skill shall be able to recover airplane heading such that intersection with the obstacle clearance planes will occur no more than 1 in 10^6 events during recovery.

3.1.2.9.3.3 Minimum go-around altitude. A minimum altitude for engaging automatic go-around shall be established such that the probability of incurring structural damage to the landing gear, wing tips, or control surface is extremely remote. The minimum altitude shall include normal performance under the wind conditions specified in 3.1.2.9 and the probability of inadvertent loss of an engine at any time within 12 seconds preceding mode engagement.

3.1.2.10 All weather landing system. The following all weather landing system requirements pertain to the latter stages of the approach; i.e., that portion of the approach below the decision height or the alert height, as defined in 6.6. All weather landing system shall comply with the following landing accuracies:

a. Longitudinal dispersion of the main landing gear touchdown point shall not exceed 1,500 feet with a 2-sigma probability, with a mean touchdown point beyond the projected glideslope intersection with the runway. The 1,500 foot dispersion need not be symmetrically located about the nominal touchdown point. The aircraft sink rate at touchdown shall not exceed the structural limit of the landing gear except as an extremely remote (6.6) occurrence.

b. The lateral dispersion of the aircraft centerline at the main landing gear at touchdown shall not exceed 27 feet on either side of the runway centerline with a 2-sigma probability. The roll out guidance system (normally used during ICAO Category IIIb or IIIc visibility conditions) shall cause the aircraft to track parallel to or convergent with the centerline of the runway.

c. The systems shall meet these requirements considering reasonable combinations of head winds to 25 knots, tail winds to 10 knots, and crosswinds to 15 knots, according to the probability of encountering these winds and their associated turbulence as specified in 3.1.3.7.3, along with expected variations in aircraft configurations as specified in 3.1.2.10.1, and expected variations in ground facility performance as specified in 3.1.2.10.2.

3.1.2.10.1 All weather landing performance standards - variations or aircraft and airborne equipment configurations. All weather landing performance requirements shall be met while including the effects on performance of the following aircraft and airborne equipment variations expected to occur in normal service.

a. Landing weight and center of gravity variations.

b. Landing flap setting variations.

c. Aircraft approach speed variations.

d. Glide slope and localizer airborne receiver centering errors.

e. AFCS all weather landing system sensor, computer, and servoactuator tolerances.

f. Performance tolerances of automatic control systems operating concurrently with the AFCS all weather landing system; e.g., stability augmentation systems, load alleviation systems.

3.1.2.10.2 Performance standards - ground based equipment variations. Proof of compliance with performance requirements for all weather landing systems shall include the effects of expected variation in type and quality of the ground based equipment. ILS beam structure, associated tolerances and alignment errors, monitoring, touchdown zone lighting, terrain clearances, and controlled or critical taxi zones shall be considered to meet the requirements for Categories II or III operations as defined by ICAO Annex 10.

3.1.2.11 Flight load fatigue alleviation. A fatigue alleviation control system may be used where it is advantageous to the weapon system. The fatigue alleviation system shall comply with applicable requirements of MIL-A-8866 in addition to the requirements of this specification.

3.1.2.12 Ride smoothing. With the ride smoothing AFCS and other FCS in Operational State I, the following short term and applicable long term vertical or lateral axis ride discomfort index levels shall not be exceeded at any crew station during flight in the turbulence level specified in table II.

TABLE II
RIDE DISCOMFORT INDEX LIMITS

Ride Discomfort Index, D_i		Flight Phase Duration (Exposure Time)	Probability of Exceeding RMS Turbulence Intensity
Long Term Requirement	0.10	Over 3 Hours	0.20
	0.13	From 1.5 to 3 Hours	0.20
	0.20	From 0.5 to 1.5 Hours	0.20
Short Term Requirement	0.28	Less than 0.5 Hour	0.01

The requirements apply separately to each of the vertical and lateral axes. For the lateral axis requirement only lateral gusts apply and for vertical acceleration only vertical gusts apply. Effects of attitude hold or other pertinent AFCS modes shall be included where used. This requirement normally applies only where a ride smoothing AFCS is specified by the procuring activity. However, where ride smoothing is not specified and other AFCS modes degrade ride quality, the resulting ride shall not degrade to below the levels specified.

3.1.2.12.1 Ride discomfort index. Ride discomfort index is defined as:

$$D_i = \left[\int_{0.1}^{f_t} |W(f)|^2 |T_{cs}(f)|^2 \phi_u(f) df \right]^{1/2}$$

D_i = Ride Discomfort Index, (vertical or lateral)

$W(f)$ = Acceleration weighting function (vertical or lateral) 1/g

$T_{cs}(f)$ = Transmissibility, at crew station, g/ft/sec

$\phi_u(f)$ = Von Karman gust power spectral density of intensity specified in 3.1.2.12 and form specified in MIL-F-8785

f = Frequency, Hz

f_t = Truncation frequency (frequency beyond which aeroelastic responses are no longer significant in turbulence) (1)

Acceleration weighting functions are defined for vertical and lateral acceleration by figure 1. Probability of exceedance versus turbulence intensity is specified in 3.1.3.7.

3.1.2.13 Active flutter suppression. An active flutter suppression control system may be used where it is advantageous to the weapon system. The flutter suppression control system shall conform to the applicable requirements of MIL-A-8870 in addition to the requirements of this specification.

3.1.2.14 Gust and maneuver load alleviation. An active gust and maneuver load alleviation control system may be used where it is advantageous to the weapon system. The active load alleviation control system shall conform to the applicable requirements of MIL-A-8861 in addition to the requirements of this specification.

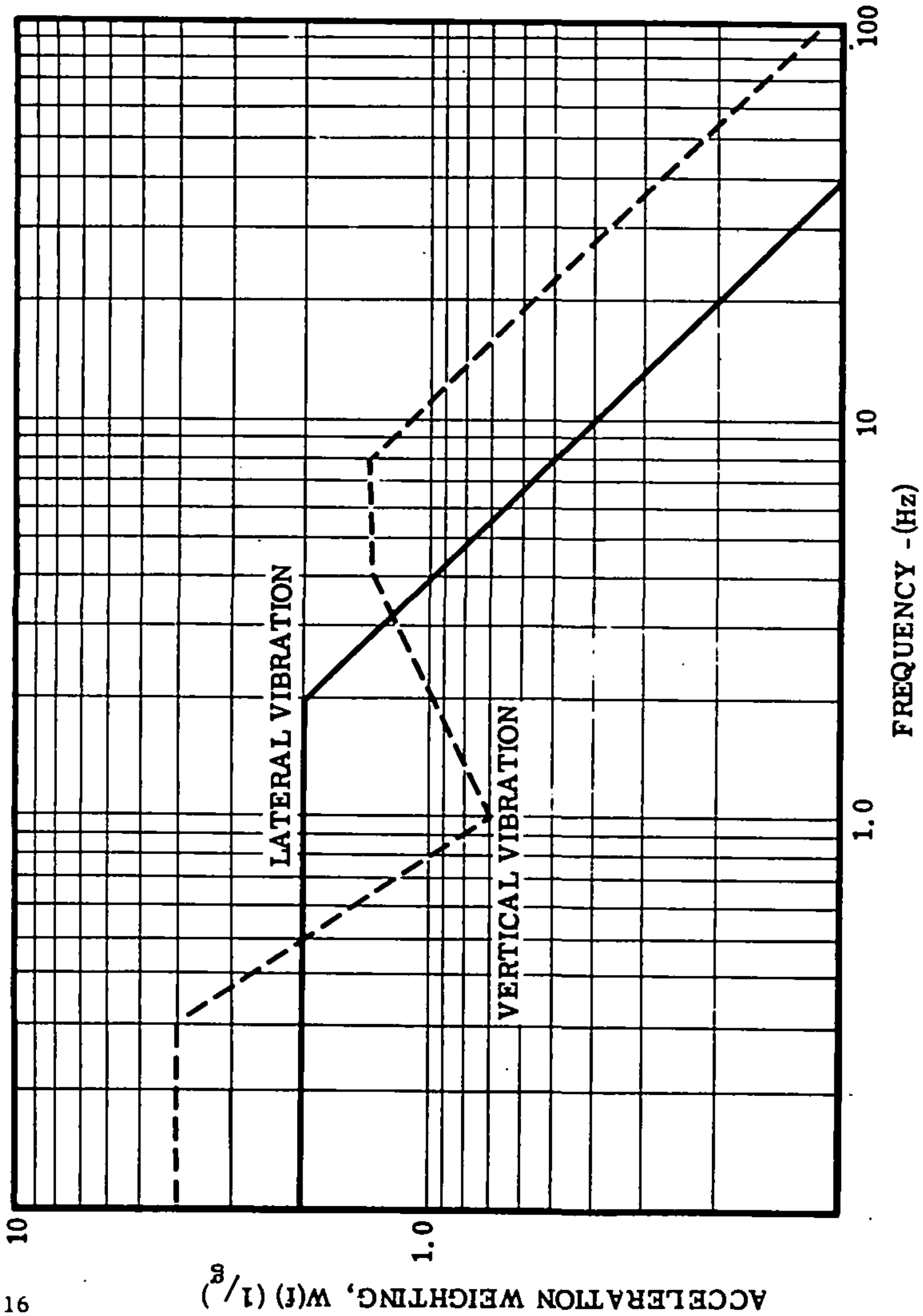

Figure 1. Acceleration weighting functions

3.1.2.15 Automatic terrain following. Performance requirements shall be as specified by the procuring activity.

3.1.2.16 Control stick (or wheel) steering. The pilot shall retain full capability to maneuver the airplane within the applicable control force and maneuver limits of MIL-F-8785 or MIL-F-83300. Automatic disengagement of the AFCS with reversion to manual control is permitted in meeting this requirement.

3.1.3 General FCS design. Flight control systems shall be as simple, direct, and foolproof as possible, consistent with overall system requirements.

3.1.3.1 Redundancy. The contractor shall determine the redundancy approaches and levels required to satisfy the requirements of this specification.

3.1.3.2 Failure immunity and safety. Within the permissible flight envelope, no single failure or failure combination, which is not extremely remote, in the FCS or related subsystems shall result in any of the following effects before a pilot or safety device can be expected to take effective corrective action. For this specification, extremely remote is defined as numerically equal to the maximum aircraft loss rate due to relevant FCS material failures specified in 3.1.7.

a. Flutter, divergence, or other aeroelastic instabilities within the permissible flight envelope of the aircraft, or a structural damping coefficient for any critical flutter mode below the fail-safe stability limit of MIL-A-8870.

b. Uncontrollable motions of the aircraft or maneuvers which exceed limit airframe loads.

c. Inability to land the aircraft safely.

d. Any asymmetric, unsynchronized, unusual operation or lack of operation of flight controls that results in worse than FCS Operational State III.

e. Exceedance of the permissible flight envelope or inability to return to the service flight envelope.

3.1.3.2.1 Automatic terrain following failure immunity. The terrain following system shall detect any potentially critical failure, not shown to be extremely remote, in the command generation scheme, sensors, (including radar and radar altimeter) or terrain following AFCS and provide warning to the pilot. Any failure resulting in loss of the automatic terrain following function or unsafe flying condition shall provide safe exit (automatic fly-up) from the low altitude, high speed environment. Take over or injection of commands by the pilot while the system is operating shall permit a smooth and positive transition without adverse transients. AFCS function accuracy (heading and roll attitude hold) shall be maintained to the degree specified in 3.1.2.

3.1.3.3 System operation and interface. Wherever a noncritical control or any other aircraft subsystem is interfaced with essential or flight phase essential flight control channels, separation and isolation shall be provided to make the probability of propagated or common mode failures extremely remote.

3.1.3.3.1 Warmup. After power is applied to the FCS, the warmup time required to meet this specification shall not be more than 90 seconds for MIL-F-8785 Class IV aircraft and not more than 3 minutes for other types of aircraft.

3.1.3.3.2 Disengagement. Provisions shall be made for positive inflight disengagement of flight phase essential and noncritical electrical controls under all load conditions. No out of trim condition shall exist at disengagement which cannot be easily controlled by the pilot. The pilot shall be informed of automatic disengagement. Disengagement circuitry shall be designed such that a failure of the circuitry itself does not prevent automatic or manual disengagement.

3.1.3.3.3 Mode compatibility. Mode compatibility logic shall provide flexibility of FCS operation and ease of mode selection. The mode selection logic shall:

a. Make correct mode selection by the crew highly probable.

b. Prevent the engagement of incompatible modes that could create an immediate undesirable situation or hazard.

c. Disconnect appropriate previously engaged modes upon selection of higher priority modes.

d. Provide arming of appropriate modes while certain modes are engaged.

e. Provide for the engagement of a more basic FCS mode in the event of a failure of a higher priority mode.

3.1.3.3.4 Failure transients. Aircraft motions following sudden flight control system or component failures shall be such that dangerous conditions can be avoided by pilot corrective action. Time delays between the failure and initiation of pilot corrective action shall be as established by MIL-F-8785. Transients due to failures resulting in FCS Operational States I or II within a redundant FCS shall not exceed ±0.5g incremental normal or lateral acceleration at the center-of-gravity or ±10 deg/sec roll rate. Transients due to failures within the FCS resulting in FCS Operational State III shall not exceed 75 percent of limit load factor or 1.5g's from the initial value, whichever is less, at the most severe flight condition.

3.1.3.4 System arrangement. Systems shall be arranged as required to satisfy the reliability, invulnerability, failure immunity and other general requirements of this specification.

3.1.3.5 Trim controls. Each of the principal control axes shall have trim controls. Wherever worse than Operational State III would result from a power-operated trim control failure that is not extremely remote, the pilot shall be given override capability for the failed control. For series trim control, no worse than Operational State III shall result from a trim control becoming inoperative in any position, except for extremely remote failures. Engagement of the AFCS shall automatically initiate any needed pitch trim. Aircraft subject to short alerts shall have the capability incorporated to return all trim to the takeoff position automatically. Any automatically controlled trim shall incorporate positive means to avoid potentially hazardous adverse trim near stall. In multicrew aircraft with electrical trim systems, interlocks in the circuitry shall prevent simultaneous commands by two aircrew members from causing any operation in opposing directions at the same time.

3.1.3.6 Stability. For FCS using feedback systems, the stability as specified in 3.1.3.6.1 shall be provided. Alternatively, when approved by the procuring activity, the stability defined by the contractor through the sensitivity analyses of 3.1.3.6.2 shall be provided. Where analysis is used to demonstrate compliance with these stability requirements, the effects of major system nonlinearities shall be included.

3.1.3.6.1 Stability margins. Required gain and phase margins about nominal are specified in table III for all aerodynamically closed loop FCS. With these gain or phase variations included, no oscillatory instabilities shall exist with amplitudes greater than those allowed for residual oscillations in 3.1.3.8, and any nonoscillatory divergence of the aircraft shall remain within the applicable limits of MIL-F-8785 or MIL-F-83300. AFCS loops shall be stable with these gain or phase variations included for any amplitudes greater than those allowed for residual oscillations in 3.1.3.8. In multiple loop systems, variations shall be made with all gain and phase values in the feedback paths held at nominal values except for the path under investigation. A path is defined to include those elements connecting a sensor to a force or moment producer. For both aerodynamic and nonaerodynamic closed loops, at least 6 db gain margin shall exist at zero airspeed. At the end of system wear tests, at least 4.5 db gain margin shall exist for all loops at zero airspeed. The margins specified by table III shall be maintained under flight conditions of most adverse center-of-gravity, mass distribution, and external store configuration throughout the operational envelope and during ground operations.

TABLE III
GAIN AND PHASE MARGIN REQUIREMENTS (DB, DEGREES)

Mode Frequency Hz \ Airspeed	Below V_{oMIN}	V_{oMIN} To V_{oMAX}	At Limit Airspeed (V_L)	At 1.15 V_L
f_M <0.06	GM = 6 DB (No Phase Requirement Below V_{oMIN})	GM = ±4.5 PM = ±30	GM = ±3.0 PM = ±20	GM = 0 PM = 0 (Stable at Nominal Phase and Gain)
0.06 ≤ f_M < First Aero-Elastic Mode		GM = ±6.0 PM = ±45	GM = ±4.5 PM = ±30	
f_M > First Aero-Elastic Mode		GM = ±8.0 PM = ±60	GM = ±6.0 PM = ±45	

where:

V_L	=	Limit Airspeed (MIL-A-8860).
V_{oMIN}	=	Minimum Operational Airspeed (MIL-F-8785).
V_{oMAX}	=	Maximum Operational Airspeed (MIL-F-8785).
Mode	=	A characteristic aeroelastic response of the aircraft as described by an aeroelastic characteristic root of the coupled aircraft/FCS dynamic equation-of-motion.
GM = Gain Margin	=	The minimum change in loop gain, at nominal phase, which results in an instability beyond that allowed as a residual oscillation.
PM = Phase Margin		The minimum change in phase, at nominal loop gain, which results in an instability.
f_M	=	Mode frequency in Hz (FCS engaged).
Nominal Phase and Gain	=	The contractor's best estimate or measurement of FCS and aircraft phase and gain characteristics available at the time of requirement verification. (2

3.1.3.6.2 Sensitivity analysis. Tolerances on feedback gain and phase shall be established at the system level based on the anticipated range of gain and phase errors which will exist between nominal test values or predictions and in-service operation due to such factors as poorly defined nonlinear and higher order dynamics, anticipated manufacturing tolerances, aging, wear, maintenance and noncritical material failures. Gain and phase margins shall be defined, based on these tolerances, which will assure satisfactory operation in fleet usage. These gain and phase tolerances shall be established based on variations in system characteristics either anticipated or allowed by component or subsystem specification. The contractor shall establish, with the approval of the procuring agency, the range of variation to be considered based on a selected probability of exceedance for each type of variation. The contractor shall select the exceedance probability based on the criticality of the flight control function being provided. The stability requirements established through this sensitivity analysis shall not be less than 50 percent of the magnitude and phase requirements of 3.1.3.6.1.

3.1.3.7 Operation in turbulence. In Operational State I, while flying in the following applicable random and discrete turbulence environment, the FCS shall provide a safe level of operation and maintain mission-accomplishment capability. For essential and flight phase essential controls, at least Operational State II shall be provided in the specified flight-safety turbulence levels. Noncritical controls shall provide at least Operational State II in turbulence up to the intensities specified in 3.1.3.7.1. Noncritical controls operating in turbulence at intensities above the specified turbulence level, shall not degrade flight safety or mission effectiveness below the level that would exist with the control inactive. Either manual or automatic means to inactivate the control for flight in heavy turbulence may be used, when required. The dynamic analysis or other means used to satisfy this requirement shall include the effects of rigid body motion, significant flexible degrees of freedom and the flight control system. Significant nonlinear effects shall be represented by conservative nonlinear or equivalent linear representations.

3.1.3.7.1 Random turbulence. The RMS turbulence intensity to be used for normal flight and for terrain following shall have a cumulative probability of exceedance as specified in table IV.

TABLE IV
TURBULENCE INTENSITY EXCEEDANCE PROBABILITY

FCS Function Criticality \ Aircraft Class	MIL-F-8785 Class III	MIL-F-8785 Class I, II & IV
Essential	10^{-6}	10^{-5}
Flight Phase Essential	$\frac{1}{T}10^{-6}$	$\frac{1}{T}10^{-5}$
Noncritical	10^{-2}	10^{-2}

where:

T = the longest time spent in essential flight phase segment in any mission/total flight time per mission. (3)

Table V specifies RMS vertical gust amplitude versus altitude for selected exceedance probabilities. The relationship among vertical, lateral and longitudinal RMS intensities and scales as specified in MIL-F-8785 shall be used to establish intensities for lateral and longitudinal gusts. The listed turbulence intensity levels apply at the turbulence penetration airspeed V_G. At the maximum level flight airspeed, V_H these intensity levels are reduced to 38 percent of the specified levels. The mathematical forms of continuous random turbulence to be used in conjunction with the specified intensity levels are as specified in MIL-F-8785 and the airspeeds cited are as specified in MIL-A-8860.

TABLE V
RMS GUST INTENSITIES FOR SELECTED CUMULATIVE EXCEEDANCE PROBABILITIES, FT/SEC TAS

FLIGHT SEGMENT	ALTITUDE (FT – AGL)	PROBABILITY OF EXCEEDANCE						
		2×10^{-1}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
TERRAIN FOLLOWING	UP TO 1000 (LATERAL)	4.0	5.1	8.0	10.2	12.1	14.0	23.1
	UP TO 1000 (VERTICAL)	3.5	4.4	7.0	8.9	10.5	12.1	17.5
NORMAL FLIGHT CLIMB CRUISE AND DESCENT	500	3.2	4.2	6.6	8.6	11.8	15.6	18.7
	1,750	2.2	3.6	6.9	9.6	13.0	17.6	21.5
	3,750	1.5	3.3	7.4	10.6	16.0	23.0	28.4
	7,500	0	1.6	6.7	10.1	15.1	23.6	30.2
	15,000	0	0	4.6	8.0	11.6	22.1	30.7
	25,000	0	0	2.7	6.6	9.7	20.0	31.0
	35,000	0	0	0.4	5.0	8.1	16.0	25.2
	45,000	0	0	0	4.2	8.2	15.1	23.1
	55,000	0	0	0	2.7	7.9	12.1	17.5
	65,000	0	0	0	0	4.9	7.9	10.7
	75,000	0	0	0	0	3.2	6.2	8.4
	OVER 80,000	0	0	0	0	2.1	5.1	7.2

3.1.3.7.2 Discrete gusts. Discrete gust amplitudes to be used shall be established using the relationship between random and discrete gust amplitudes in accordance with MIL-F-8785, and the RMS amplitudes specified in 3.1.3.7.1. The 1-cosine discrete gusts in accordance with MIL-F-8785 shall be applied with wavelengths tuned to provide maximum excitation.

3.1.3.7.3 Wind model for landing and takeoff. The following wind model form shall be used for automatic navigation and all weather landing system design as required by 3.1.2.9 and 3.1.2.10. This model applies for low altitude approach and landing flight phases at conventional airports and shall not be applied at heights greater than 500 feet above mean runway level.

3.1.3.7.3.1 Mean wind. The probability of occurrence of total mean wind and mean crosswind components is shown on figure 2 as a function of wind speed in knots as measured at a reference altitude of 20 feet above mean surface level.

3.1.3.7.3.2 Wind shear. Wind shear shall be included in each simulated approach and landing unless its effect can be accounted for separately. The magnitude of the shear is defined by the expression

$$u = .46\ U \log_{10}(Z) + .4\ U$$

where: u = mean wind at height Z feet in feet/sec (true)

U = mean wind at 20 feet in feet/sec (true)

Z = height above ground (feet) (4)

3.1.3.7.3.3 Wind model turbulence. The longitudinal wind component (in the direction of the mean wind) and vertical and lateral wind components shall each be represented by a Gaussian process having a spectral density, $\Phi(\Omega)$, of:

$$\Phi(\Omega) = \sigma_i^2 \frac{2L_i}{\pi} \frac{1}{(1 + \Omega^2 L_i^2)}, \left(\frac{FT}{SEC}\right)^2 \bigg/ \frac{RAD}{FT}$$

where: σ_i = RMS turbulence level in an axis in feet/sec

L_i = Scale length in an axis, feet

Ω = Spatial frequency in radians/ft. (5)

and the value for σ and L is shown on table VI.

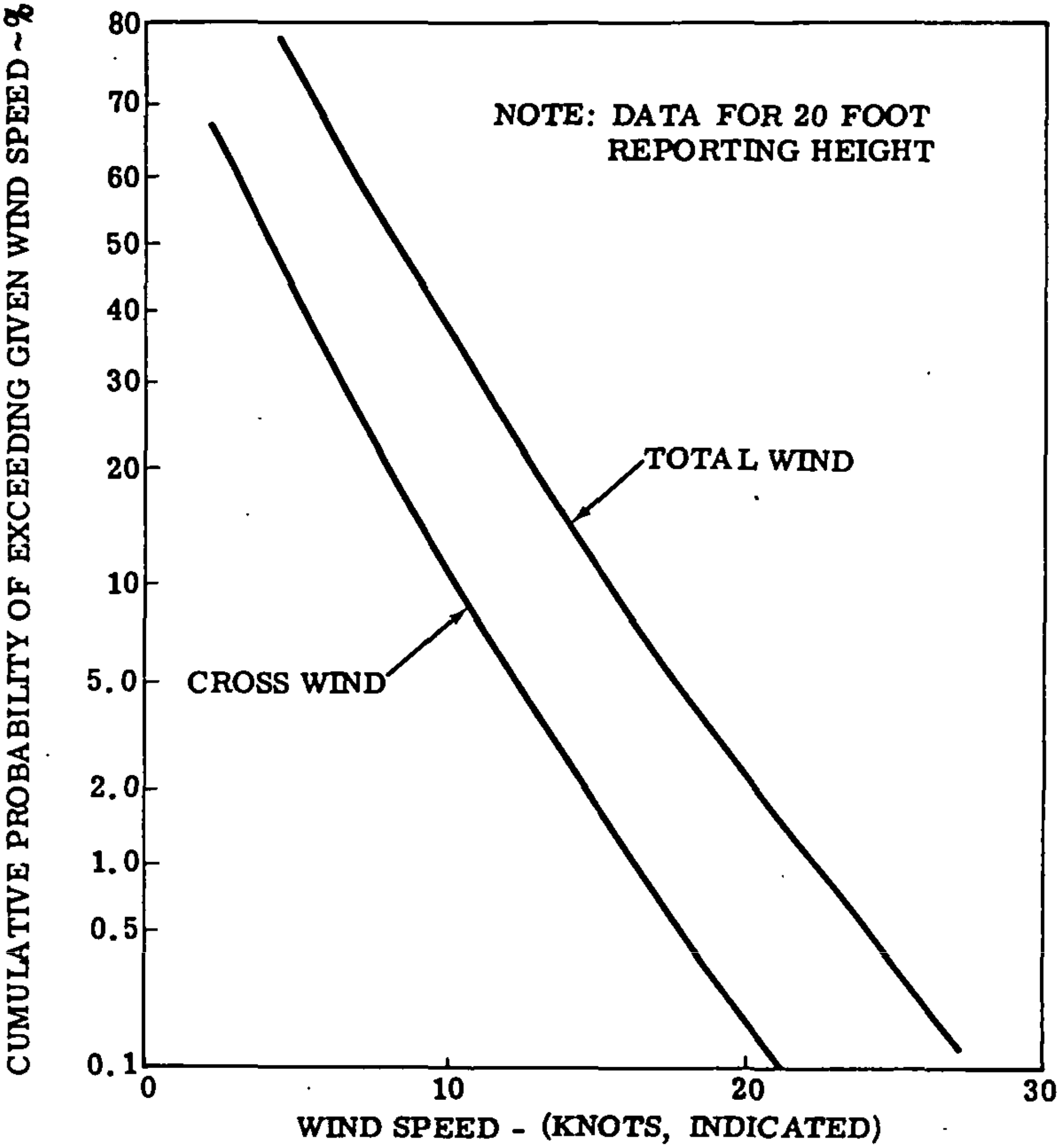

Figure 2. Cumulative probability of report mean wind and crosswind when landing

TABLE VI
RMS TURBULENCE LEVEL AND SCALE LENGTH BY AXIS

	Vertical	Lateral	Longitudinal
σ	0.1 U	0.2 U	0.2 U
L	15 Ft for $Z \leq 30$ Ft .5 Z Ft for $30 \leq Z \leq 1000$	600 Ft 1000 Ft	600 Ft

3.1.3.8 Residual oscillations. For normal operation and during steady flight, FCS induced aircraft residual oscillations at all crew and passenger stations shall not exceed 0.04g's vertical or 0.02g's lateral peak to peak acceleration. Residual oscillations in pitch attitude angle shall satisfy the longitudinal maneuvering characteristic requirements of MIL-F-8785. Residual oscillations in roll and yaw attitude at the pilot's station shall not exceed 0.6 degree peak to peak for flight phases requiring precision control of attitude.

3.1.3.9 System test and monitoring provisions. Test and monitoring means shall be incorporated into the essential and flight phase essential FCS as required to meet the following requirements of this specification:

Mission Reliability	3.1.6
Flight Safety	3.1.7 to 3.1.7.1
Fault Isolation	3.1.10.2 to 3.1.10.2.2
Failure Immunity & Safety	3.1.3.2 to 3.1.3.2.1
Survivability	3.1.8 to 3.1.8.1
Invulnerability	3.1.9 to 3.1.9.7

The effect of detected and undetected FCS failures taken with the probability of occurrence of such failures shall comply with the system reliability and safety requirements. This requirement shall include all failures, both active and latent, and failures in all components of the system, including mechanical, electrical and hydraulic components.

3.1.3.9.1 Built-In-Test equipment (BIT). The total maintenance aid testing, including BIT, and inflight monitoring where used, shall provide an integrated means of fault isolation to the LRU level with a confidence factor of 90 percent or greater. BIT functions shall have multiple provisions to ensure they cannot be engaged in flight. The test equipment shall not have the capability of imposing signals which exceed operating limits on any part of the system or which reduces its endurance capability or fatigue life. Ground test signals shall not be of sufficient magnitude to drive actuators into hard-stop limits.

3.1.3.9.1.1 Preflight or pre-engage BIT. Preflight or pre-engage BIT may be automatic or pilot-initiated, and includes any test sequence normally conducted prior to takeoff or prior to engagement of a control to provide assurance of subsequent system safety and operability. It should be demonstrated that redundant MFCS electronic channels are operating normally without any safety-critical latent failures prior to takeoff. This includes all backup or normally disengaged channels, and fault monitoring and failure isolation elements. The preflight tests shall not rely on special ground test equipment for their successful completion. Any test sequence which could disturb the normal activity of the aircraft in a given mode shall be inhibited when that mode is engaged.

3.1.3.9.1.2 Maintenance BIT. Where required, BIT shall also be provided as a postflight maintenance aid for the FCS. BIT shall be designed to avoid duplicating test features included as part of the preflight test or monitoring functions.

3.1.3.9.2 Inflight monitoring. Continuous monitoring of equipment performance and critical flight conditions shall be active, as a minimum, during essential or flight phase essential modes of operation. False monitoring warnings, including the automatic or normal pilot response thereto, shall not constitute a specific hazard in excess of the system reliability requirements.

3.1.4 MFCS design. The following general requirements apply. References to mechanical or electrical MFCS apply only when the mechanization is used:

a. Augmentation. When used, augmentation systems shall be compatible with all control modes and airframe dynamic considerations. Single failures in a gain scheduling system, not classed as extremely remote, shall not degrade augmentation system performance below Operational State II. Pilot-operated gain changing devices shall only be used as emergency backup equipment. Specific approval shall be obtained from the procuring activity for this feature. Positive mechanical or electrical stops shall be provided in gain schedulers to preclude exceeding limiting gain values.

b. Ratio changing mechanisms. Where ratio changing mechanisms are used, monitors and emergency positioning means shall be provided if improper positioning can result in a safety of flight hazard.

c. Control centering, breakout forces and free play. The corresponding design requirements of MIL-F-8785 or MIL-F-83300 shall be met. Selected sensitivity and breakout forces shall not lead to overcontrol tendencies.

d. Reversion. If a backup mode is provided for a flight control system, at least FCS Operational State III shall be provided following reversion. While disengaged, interaction of backup mode provisions with the normal mode shall not degrade operation below State I. If a single FCS power system is used in an essential or flight phase essential fully powered system, emergency mechanical reversion or an emergency power source shall be provided. On single-engine aircraft, the emergency power source shall be independent of engine operation. It shall be possible to re-engage the normal power source in flight following operation with manual reversion controls or emergency power. Manual or automatic changeover to or from emergency provisons shall not result in capability worse than FCS Operational State III.

e. Controller kinematics. Kinematics shall preclude hazardous unintentional inputs (crosstalk) into one or more axes with normal control motions within the limits of ultimate structural load factor, design maneuver, and turbulence induced accelerations experienced at the crew station.

f. Feedback to crew station controls. The control device motion and force required to accomplish stability and control augmentation shall not be evident at the crew station controls. Vibratory forces or motion acting upon elements downstream of the controller shall not be evident at the crew station controls. Force and motion feedback to crew station controls shall be considered as not evident if the force magnitude is less than half the lowest breakout force of the applicable control.

3.1.4.1 Mechanical MFCS design. In the design of mechanical components, the reliability, strength and simplicity of the system shall be paramount considerations. The signal transmission between the pilot's controls and the control surfaces shall be redundant to the extent required to meet reliability, failure immunity, invulnerability and other requirements of this specification.

3.1.4.1.1 Reversion - boosted systems. In the mechanical reversion mode, at least FCS Operational State III shall be provided. The normal, boosted, control forces shall provide FCS Operational State I. It shall be possible to re-engage boost following operation with mechanical reversion.

3.1.4.2 Electrical MFCS design. Electrical flight control systems (6.6) shall be designed with special consideration to invulnerability to lightning strikes and to the thermal, EMI and other induced environments of 3.1.9.3.

3.1.4.2.1 Use of mechanical linkages. If a separate artificial feel system is used, or if mechanical linkages are used to connect a signal conversion mechanism with the control surface actuators, friction and freeplay shall not result in FCS operation below State I. Longitudinal and directional controls shall be mass balanced in the fore and aft direction and lateral controls shall be provided inboard to outboard balance, consistent with structural mode and longitudinal force requirements. Any residual vertical imbalance shall be consistent with feel requirements.

3.1.5 AFCS design. AFCS shall be provided to the extent specified by the procuring activity.

3.1.5.1 System requirements. When the specified modes are used, the following design requirements apply.

3.1.5.1.1 Control stick (or wheel) steering. If this mode is required, MIL-F-8785, or if applicable, MIL-F-83300, shall be used as the basis for control capability.

3.1.5.1.2 Flight director subsystem. If common mode selection is used, it shall be possible to select control stick steering with flight director operation in place of any of the other AFCS modes. Single-channel flight director operation shall be possible when all but one channel of a redundant system have failed.

3.1.5.2 AFCS interface

3.1.5.2.1 Tie-In with external guidance. Internal FCS switching with zero command signal input from external guidance systems shall not cause transients greater than engage transients in accordance with 3.1.5.2.3. Noise content in usable external guidance signals shall not saturate or bias any component of the FCS, shall not impair the response of the aircraft to the proper guidance signals, and shall not cause objectionable control motion or attitude variation. Steering information transmitted to the AFCS shall be compatible with the accuracy and dynamic performance requirements of the guidance loop. The tie-in provisions shall not degrade performance of other subsystems by causing excessive loading or saturation.

3.1.5.2.2 Servo engage interlocks. Interlocks shall be provided to prevent servo engagement and to provide disengagement in the presence of conditions that render disengagement safer than engagement. Manual override of interlocks shall be provided wherever such override capability will enhance flight safety.

3.1.5.2.3 Engage-Disengage transients. Normal engagement or disengagement of AFCS modes shall not result in transients exceeding the limits set on MFCS engage-disengage transients by MIL-F-8785 and MIL-F-83300. Normal engagement transient requirements shall be met 2 seconds after completion of any maneuver up to the maneuver limits of the aircraft or the limits of sensor equipment being used.

3.1.5.3 AFCS emergency provisions

3.1.5.3.1 Manual override capability. It shall be possible to manually overpower or countermand the automatic control action of the AFCS using the normal pilot controls. Required pilot forces shall not exceed pilot capabilities as defined by MIL-STD-1472. The overpower force for V/STOL aircraft and helicopters shall not exceed the limit cockpit control forces specified for Level 1 operation in MIL-F-83300. Manually overriding the AFCS shall not result in an instability due to force fight between the pilot and the AFCS.

3.1.5.3.2 Emergency disengagement. Positive emergency means of disengagement, in addition to normal mode selection, shall be provided for AFCS. The emergency disengagement means shall also ground the power input side of the servo engage solenoids. No intervening switching mechanism between the point of ground and the solenoid shall exist.

3.1.6 Mission accomplishment reliability. The probability of mission failure per flight due to relevant material failures in the flight control system shall not exceed the applicable limit specified below. Failures in power supplies or other subsystems that do not otherwise cause mission failure shall be considered where pertinent. Each mission to which this requirement applies shall be established and defined by the contractor, subject to approval of the procuring activity.

a. Where overall aircraft mission accomplishment reliability is specified by the procurement activity, $Q_{M(fcs)} \leq (1 - R_M)\, A_{M(fcs)}$

b. Where overall aircraft mission accomplishment reliability is not specified, $Q_{M(fcs)} \leq 1 \times 10^{-3}$

where:

$Q_{M(fcs)}$ = Maximum acceptable mission unreliability due to relevant FCS material failures.

R_M = Specified overall aircraft mission accomplishment reliability.

$A_{M(fcs)}$ = Mission accomplishment allocation factor for flight control (chosen by the contractor). (6)

3.1.7 Quantitative flight safety. The probability of aircraft loss per flight, defined as extremely remote, due to relevant material failures in the flight control system shall not exceed:

$$Q_{S(fcs)} \leq (1 - R_S)\, A_{S(fcs)}$$

where: $Q_{S(fcs)}$ = Maximum acceptable aircraft loss rate due to relevant FCS material failures.

$A_{S(fcs)}$ = Flight safety allocation factor for flight control (chosen by the contractor).

R_S = Overall Aircraft Flight Safety Requirements as specified by the procuring activity. (7)

Failures in power supplies or other subsystems that do not otherwise cause aircraft loss shall be considered where pertinent. A representative mission to which this requirement applies shall be established and defined in the FCS specification (4.4.2). If overall aircraft flight safety in terms of R_S is not specified by the procuring activity, the numerical requirements of table VII apply.

TABLE VII
FCS QUANTITATIVE FLIGHT SAFETY REQUIREMENTS

		MAXIMUM AIRCRAFT LOSS RATE FROM FCS FAILURES
OVERALL A/C FLIGHT SAFETY REQUIREMENT NOT SPECIFIED BY PROCURING ACTIVITY	MIL-F-8785 CLASS III AIRCRAFT	$Q_{S(fcs)} \leq 5 \times 10^{-7}$
	ALL ROTARY WING AIRCRAFT	$Q_{S(fcs)} \leq 25 \times 10^{-7}$
	MIL-F-8785 CLASS I, II & IV AIRCRAFT	$Q_{S(fcs)} \leq 100 \times 10^{-7}$

3.1.7.1 Quantitative flight safety - all weather landing system (AWLS). The average hazard due to the use of the all weather landing system shall be less than the risk allowed in the contractor's reliability budget for the all weather landing system. To meet the requirements of 3.1.7, the contractor shall allocate the FCS safety budget among AWLS and other FCS. The specific risk of a hazard due to use of the landing system under an environment limit or operational restriction shall not increase the allowed risk by a factor of more than thirty. An alert height shall be established at an altitude such that, with all systems operative at the alert height, the probability of a hazard occurring during the landing is extremely remote, as defined in 6.6.

3.1.7.1.1 Assessment of average risk of a hazard. The average risk of a hazard due to use of the all weather landing system shall be established considering:

a. The effect of each failure and combination of failures on system performance and the probability of their occurrence.

b. The effect of each revelant failure and combination of failures in systems operating concurrently with the all weather landing AFCS on aircraft performance and the probability of their occurrence.

c. The probability of the system not performing within the required levels as specified in 3.1.2.10 taken in conjunction with the probability that exceedance of those performance levels will result in a hazard.

3.1.7.1.2 Assessment of specific risk. For each environmental limitation or operational restriction which limits the use of the all weather landing system the specific risk shall be established. This evaluation shall comprise the average risk assessment, adjusted for a 1.0 probability of occurrence of environmental limits associated with the operational restriction.

3.1.8 Survivability. FCS Operational State IV or State V shall be provided as required by the procuring activity.

3.1.8.1 All engines out control. For those aircraft which are dependent upon engine generation of flight control system power, supplementary means or power source shall be provided as necessary to supplement the control power available from the engine(s) where engines are unproven, airframe aerodynamics not established in flight, or windmilling power is insufficient to maintain operational State IV control capability anywhere in the aircraft operational envelope. Flight control system design (including power sources) shall be such that unintentional loss of any or all engine thrust shall not result in less than FCS Operational State IV including any necessary transition to emergency source(s) of power. Provision shall be made for inflight reversion to normal power wherein the transition shall not result in a worse FCS operational state.

3.1.9 Invulnerability. Degradation in flight control system operation due to variations in natural environments, adverse events of nature, induced environments, onboard failure of other systems, maintenance error, flight crew error or enemy actions shall be within the following limits.

3.1.9.1 Invulnerability to natural environments. Flight control systems shall be designed to withstand the full range of natural environmental extremes established for the particular vehicle or system without permanent degradation of performance below FCS Operational State I, or temporary degradation below FCS Operational State II. Reductions below State I shall be experienced only at adverse environmental extremes not normally encountered and shall be transient in nature only; and, the function shall be recovered as soon as the aircraft has passed through the adverse environment. System components and clearances with structure and other components shall be adequate to preclude binding or jamming, instability, or out of specification operation of any portion of the system due to possible combinations of temperature effects, ice formations, loads, deflections, including structural deflections, and buildup of manufacturing tolerances.

3.1.9.2 Invulnerability to lightning strikes and static atmospheric electricity. Flight control system shall maintain State II capability or better when subjected to electric field and lightning discharges as specified in MIL-B-5087 and in AFSC Design Handbook DH 1-5, except that a temporary, recoverable, more extensive loss of performance to State III is allowable in the event of a direct lightning strike.

3.1.9.3 Invulnerability to induced environments. Flight control systems shall withstand the full range of worst case induced temperatures and temperature shock, acceleration, vibration, noise and shock, induced pressures, explosive and corrosive atmospheres, electromagnetic interference (EMI), and nuclear radiation, including electromagnetic pulse, projected in missions for the particular aircraft, without permanent degradation or loss of capability to maintain FCS Operational State II capability. These induced environments within structural and crew survival limits shall not result in temporary degradation during the exposure to the environment below FCS Operational State IV capability. The FCS shall meet the requirements of MIL-A-8892, MIL-A-8893, and the applicable requirements of MIL-E-6051 and MIL-STD-461.

3.1.9.4 Invulnerability to onboard failures of other systems and equipment. The FCS shall meet its failure state/reliability budget, as allocated within the weapon system, for self-generated failure (within the FCS) and for those

FCS failures induced by failures of other interfacing systems within the weapons system (3.1.6, 3.1.7). In addition the FCS design shall comply with the following:

a. Essential and flight phase essential flight control systems shall retain FCS capability at Operational State III (minimum safe) or better after sustaining the following failures:

(1) Failure of the critical engine in a two-engine aircraft.

(2) Failure of the two most critical engines in aircraft having three or more propulsive engines.

(3) Failure of any single equipment item or structural member which, in itself, does not cause degradation below State III. This includes any plausible single failure of any onboard electrical or electronic equipment in any subsystem of the aircraft.

b. Flight control systems, including the associated structure and power supplies on MIL-F-8785 Class III aircraft, shall be designed so that the probability of losing the capability of maintaining FCS operation to no less than State IV as a result of an engine or other rotor burst is extremely remote (6.6).

c. Flight control systems, including the associated structure and power supplies on MIL-F-8785 Class I, II, and IV aircraft, shall be designed so that the probability of degrading FCS operation below State V as a result of an engine or other rotor burst is extremely remote (6.6).

3.1.9.5 Invulnerability to maintenance error. Flight control systems shall be designed so that it is physically impossible to install or connect any component item improperly without one or more overt modifications of the equipment or the aircraft. Provisions for adjusting the flight control system on the aircraft, except during initial buildup, major overhaul, or rigging during major maintenance activities, shall be minimized. All line replaceable units (LRU's) shall be designed to permit making internal adjustments only on the bench. The system shall require only a minimum of rerigging following replacement of LRU's. In addition, all control linkages and other flight control mechanisms shall be designed to resist jamming from inadvertent entry of maintenance tools or other material.

3.1.9.6 Invulnerability to pilot and flight crew inaction and error. Flight control systems shall be designed to minimize the possibility of any flight crew member controlling or adjusting system equipment to a condition state which could degrade FCS operation.

a. Protection against improper position and sequencing of controls - Wherever practical, cockpit controls, other than stick or wheel and rudder pedals, shall be equipped with positive action gates to prevent inadvertent positioning which can compromise safe operation of the aircraft. Positive interlocks to prevent hazardous operation or sequencing of switches shall be provided.

b. Protection against inflight engagement of control surface locks.

c. Pilot reaction to failure - Flight control systems shall be designed so that the normal pilot reaction to cues provided by probable failure conditions is instinctively correct.

d. Warning requirements:

(1) Warning information shall be provided to alert the crew to unsafe system operating conditions. Systems, controls, and associated monitoring and warning means shall be designed to preclude crew errors that create additional hazards.

(2) A clearly distinguishable warning shall be provided to the pilot under all expected flight conditions for any failure in a redundant or monitored flight control system which could result in an unsafe condition if the pilot were not aware of the failure.

3.1.9.7 Invulnerability to enemy action. Essential and flight phase essential flight control systems, including associated structure and power supplies, on all aircraft designed for combat operations shall withstand at least one direct encounter from the threat defined by the procuring activity without degradation below Operational State III.

3.1.10 Maintenance provisions. FCS design and installation shall permit normally available maintenance personnel to safely and easily perform required maintenance under all anticipated environmental conditions. Means shall be provided to facilitate the accomplishment of all required maintenance functions including: operational checkouts, system malfunction detection, fault isolation to the LRU (line replaceable unit) level, LRU removal and replacement, inspection, overhaul, servicing, and testing.

3.1.10.1 Operational checkout provisions. Flight control systems shall be designed with provisions for operation on the ground, without operating the main engines, to verify system operation and freedom from failure to the maximum extent practical. They shall be designed to operate with the power generation subsystems supplied by standard Air Force ground carts, as specified by the procuring activity or by self-contained power supplies.

3.1.10.2 Malfunction detection and fault isolation provisions. Means providing a high probability for detecting failures and monitoring critical performance conditions as required to isolate faults to the LRU level shall be incorporated in all flight control electrical and electronic systems required to perform essential and flight phase essential functions. These means may include cockpit instrumentation and built-in test equipment. For the mechanical and fluid power portions of the flight control system, provisions for the use of portable test equipment may also be incorporated as required to meet the maintenance support and operational concept of the particular weapon system.

3.1.10.2.1 Use of cockpit instrumentation. Where acceptable procedures result or are provided, cockpit instrumentation may be used for malfunction detection and fault isolation where it provides readily understandable condition indication either alone or in coordination with built-in test equipment, or with portable test equipment (for nonelectrical and nonelectronic components).

3.1.10.2.2 Provisions for checkout with portable test equipment. Where the use of built-in test equipment would cause excessive penalties and where the use of portable test equipment is compatible with the maintenance support concept, provisions shall be made to permit the use of generally available and commonly used portable test equipment. Components which require peculiar, special, or new items of test equipment shall be avoided.

3.1.10.3 Accessibility and serviceability. Components shall be designed, installed, located, and provided with access so that inspection, rigging, removal, repair, replacement, and lubrication can be readily accomplished. Suitable provisions for rigging pins, or the equivalent, shall be made to facilitate correct rigging of the control system.

3.1.10.4 Maintenance personnel safety provisions. Systems and components shall be designed to preclude injury of personnel during the course of all maintenance operations including testing. Where positive protection cannot be provided, precautionary warnings or information shall be affixed in the aircraft and to the equipment to indicate the hazard, and appropriate warnings shall be included in the application maintenance instructions. Safety pins, jacks, locks, or other devices intended to prevent actuation shall be readily accessible and shall be highly visible from the ground or include streamers which are. All such streamers shall be of a type which cannot be blown out of sight such as up into a cavity in the aircraft.

3.1.11 Structural integrity

3.1.11.1 Strength. The overall flight control system shall be designed to meet the applicable load, strength, and deformation requirements of MIL-A-8860, MIL-A-8861, MIL-A-8865, MIL-S-8698, and MIL-STD-1530. The components of the systems shall be designed in accordance with the strength requirements of MIL-A-8860, MIL-C-6021, MIL-F-7190, MIL-A-21180, MIL-A-22771, MIL-F-83142, MIL-HDBK-5, and MIL-HDBK-17.

3.1.11.1.1 Damage tolerance. Those structural elements of the flight control system that are essential to safety of flight (to control essential and flight phase essential functions) shall meet the damage tolerance requirements of MIL-A-83444.

3.1.11.1.2 Load capability of dual-load-path elements. The load path remaining after a single failure in dual-load-path elements shall meet the following requirements:

a. Where the failure is not evident by visual inspection or by obvious changes in control characteristics, the remaining path shall be capable of sustaining a fatigue spectrum loading based on one overhaul period. The time interval corresponding to an overhaul period shall be established by the contractor. The remaining path shall also withstand, as ultimate load, loading equal to 1.5 times the limit loads specified in MIL-A-8865, or 1.5 times the load from an alternate source, such as a powered actuation system or loads resulting from aerodynamic or other forces, if such load is greater.

b. Where the single failure is obvious, the remaining load path shall be capable of withstanding, as ultimate load, loading equal to 1.15 times limit loads specified in MIL-A-8865, or 1.15 times the load from an alternate source, such as a powered actuation system or loads resulting from aerodynamic or other forces, if such load is greater.

3.1.11.2 Stiffness. The stiffness of flight control systems shall be sufficient to provide satisfactory operation and to enable the aircraft to meet the stability, control, and flutter requirements as defined in the applicable portions of MIL-F-8785, MIL-A-8870, MIL-F-83300 and MIL-A-8865. Normal structural deflections shall not cause undesirable control system inputs or outputs.

3.1.11.3 Durability. Flight control systems shall be designed to meet the durability requirements of MIL-A-8866 and equal to that of the airframe primary structure considering the total number of ground and flight load cycles expected during the specified design service life and design usage of the aircraft from all commands; e.g., from the MFCS, AFCS, servo feedback and from load inputs. The requirements of MIL-A-8892 regarding vibrations and MIL-A-8893 regarding sonic fatigue also apply to the FCS.

3.1.12 Wear life. Mechanical elements of the FCS shall be designed to have wear life equal to the wear life specified for the overall aircraft. Parts subject to wear, such as hydraulic seals, bearings, control cables, sensors and hydraulic actuator barrels, may be replaced or their wearing surfaces renewed after they exceed their useful life. However, all replacements shall be within the FCS wear out-replacement budget established for the overall weapon system. Electronic and other nonmechanical LRU's shall remain economically repairable and shall meet reliability requirements throughout the specified airframe lifetime.

3.2 Subsystem and component design requirements

3.2.1 Pilot controls and displays. Wherever a FCS control, display or annunciator is interfaced with redundant flight control channels, mechanical and electrical separation and isolation shall be provided to make the probability of common mode failures at least extremely remote. FCS controls and displays shall be designed in accordance with MIL-STD-1472.

3.2.1.1 Pilot controls for CTOL aircraft. Pilot's cockpit controls for conventional takeoff and landing (CTOL) aircraft shall be designed and located in accordance with AFSC Design Handbook DH 2-2, DN 2A1, Aircrew Controls; DN 2A5, Flight Controls; and the following subparagraphs. Strict adherence to the prescribed location and maximum range of motion of these controls is required.

3.2.1.1.1 Additional requirements for control sticks. If a control stick is used and is removable, it shall be positively retained in place when installed. It shall be possible to install the stick only in the correct manner, and suitable means shall be provided to prevent rotation of the stick.

3.2.1.1.2 Additional requirement for rudder pedals. Rudder pedals shall be interconnected to insure positive movement of each pedal in both directions.

3.2.1.1.3 Alternate or unconventional controls. If pilot's controls other than the conventional center located sticks, W-type wheels, rudder pedals, trim controls and indicators, wing incidence control, wing sweep control, landing flap control and indicator, speedbrake control, and automatic flight control panels specified in AFSC Design Handbook DH 2-2, DN 2A5, are utilized, demonstration of their adequacy and suitability is required prior to installation in an aircraft.

3.2.1.1.4 Variable geometry cockpit controls. Wing incidence controls and wing sweep controls shall be designed and located in accordance with AFSC Design Handbook DH 2-2, DN 2A5; Flight Controls. Other controls shall be such that actuation in a forward, upward, or clockwise direction results in increased magnitude of the controlled variable except where such motion is in unavoidable conflict with an obvious and direct relationship between the control motion and resulting change of the controlled variable.

3.2.1.1.5 Trim switches. Electrical trim system switches of the five-position, center-off, toggle type shall be in accordance with MIL-S-9419. Control stick grips in accordance with MIL-G-25561 shall already have the trim switches, conforming to MIL-S-9419, installed. Three-position trim switches shall be approved switches similar or equivalent to the MIL-S-9419 switches.

3.2.1.1.6 Two-Speed trim actuator. Two-speed trim actuator systems shall be designed to preclude runaway or inadvertent operation in the high-speed trim mode.

3.2.1.1.7 FCS control panel. The FCS control panel shall provide the pilots with the integrated means to select the MFCS and AFCS functions.

3.2.1.1.8 Normal disengagement means. Means for disengagement of all modes of the AFCS shall be provided which are compatible with the requirements of 3.1.9.6.

3.2.1.1.9 Preflight test controls. Additional controls shall be provided in the cockpit for initiating and controlling the progress of preflight tests, where necessary.

3.2.1.2 Pilot controls for rotary-wing aircraft. The pilot's cockpit controls shall be designed and located in accordance with the applicable portions of AFSC Design Handbook DH 2-2, DN 2A1, SN 1(2), MS33572, MIL-STD-250, and the following subparagraphs. Strict adherence to the prescribed location and range of motions of these controls is required. If a control stick is removable, it shall be positively latched in place when installed. It shall be possible to install the stick only in the correct manner, and suitable means shall be provided to prevent rotation of the stick. Directional pedals shall be interconnected to insure positive movement of each pedal in both directions.

3.2.1.2.1 Interconnection of collective pitch control and throttle(s) for helicopters powered by reciprocating engine(s). The collective pitch control shall be interconnected with the throttle control(s) and synchronized to provide the proper throttle setting(s) as collective pitch is increased or decreased. Means shall also be provided to permit throttle control, independent of collective pitch lever movement, by rotation of the grip on the lever.

3.2.1.2.2 Interconnection of collective pitch control and engine power controls for helicopters powered by turbine engine(s). An engine power level control lever shall be provided for each engine. The power level control lever shall have three discrete positions: off, idle, and fly, which shall establish three operating ranges of engine power. A fourth optional discrete position may be incorporated to provide a contingency emergency power level. The collective pitch controller may be interconnected with the engine power control such that (for a given power level control position) it establishes the approximate power being delivered to the rotor, and also signals power level changes in maneuvering flight to minimize transient rotor speed droop and overspeed. Rotor speed select control shall be provided on the collective pitch controllers. Individual engine power trim or power turbine speed trim controls may be located on the collective pitch controllers or on the engine power level control panel.

3.2.1.2.3 Alternate or unconventional controls. If pilot's controls other than the conventional center located cyclic pitch sticks, left-hand side located collective pitch sticks, directional pedals, control system power boost controls, automatic flight control system controls, and trim controls specified in MIL-STD-250 are utilized, demonstration to the satisfaction of the procuring activity of their accuracy and suitability is required.

3.2.1.3 Pilot controls for STOL aircraft. Pilot's cockpit controls for short takeoff and landing (STOL) aircraft shall be designed and located in accordance with the requirements specified in 3.2.1.1, and subsections, for CTOL aircraft, and MIL-F-83300 for V/STOL aircraft as applicable.

3.2.1.4 Pilot displays

3.2.1.4.1 FCS annunciation. The FCS control panel or associated panels shall provide means to display:

a. AFCS engaged.

b. Mode engaged.

c. That automatic mode switching has occurred - if required.

d. Preselected values for selectable mode parameters.

3.2.1.4.2 FCS warning and status annunciation. FCS warning and status annunciation shall be provided in the cockpit. Annunciation shall be designed to clearly indicate the associated degree of urgency.

a. First degree - Immediate action required (warning may be audible).

b. Second degree - Caution, action may be required.

c. Third degree - Informational, no immediate action required.

A panel comprising means for displaying first degree annunciations shall be located within the normal eye scan range of the command pilot. A first degree warning or status indication, which applies only to a particular mode or phase of flight, shall be inhibited or designed to clearly indicate a lesser degree of urgency for all other modes or phases of flight.

3.2.1.4.2.1 Preflight test (BIT) status annunciation. If BIT is used, this display shall:

a. Indicate the progress of the preflight test.

b. Instruct the crew to provide required manual inputs.

c. Indicate lack of system readiness when failure conditions are detected.

3.2.1.4.2.2 Failure status. Failure warnings shall be displayed to allow the crew to assess the operable status of redundant or monitored flight control systems. Automatic disengagement of an AFCS mode shall be indicated by an appropriate warning display. Manual disengagement by the crew shall not result in warning annunciation.

3.2.1.4.2.3 Control authority annunciation. If available manual control authority can be reduced below the level required for maneuver control by a function such as automatic trim or stability augmentation, pilot displays shall be provided to indicate available control authority for essential and flight phase essential FCS. Warning shall be provided if remaining manual control becomes critical.

3.2.1.4.3 Lift and drag device position indicators. Indicators shall be provided in the cockpit to indicate to the pilot(s) the position of each lift or drag device having a separate control. They shall also indicate the correct takeoff, enroute, approach, and landing positions; and, if any extension of the lift and drag devices beyond the landing position is possible, the indicators shall be marked to identify the range of extension. In addition, an indication of unsymmetrical operation or other malfunction in the lift or drag device systems shall be provided whenever necessary to enable the pilot(s) to prevent or counteract an unsafe flight or ground condition.

3.2.1.4.4 Trim indicators. Suitable indicators shall be provided to:

a. Indicate the position and the range of travel of each trim device.

b. Indicate the direction of the control movement relative to the airplane motion.

c. Indicate the position of the trim device with respect to the range of adjustment. (Trim devices such as the magnetic brake used in helicopters to instantaneously relieve pilot's control forces by changing the feel force reference to zero at the control position held by the pilot at the time the trim switch is activated shall not require separate trim indicator.)

d. Provide pilot warning of trim failures which could result in exceeding the State III requirements of 3.1.3.3.4.

Aircraft which require takeoff longitudinal trim setting in accordance with cg location shall have suitably calibrated trim position indicators. Where suitable, trim indicators shall be in accordance with MIL-I-7064. In aircraft requiring quick takeoff capability or certain single pilot aircraft, which use a single trim setting for all takeoff conditions, a trim for takeoff light shall be provided.

3.2.1.4.5 Control surface position indication. Indicators shall be provided in the cockpit for all control surfaces whose positions are indicative of potential flying qualities below Level 3, when the cockpit controls do not provide a positive indication of long term or steady state control surface position, or where the effects of control surface positioning is not readily detectable by other means.

3.2.2 Sensors. Sensors shall be installed in locations which allow adequate sensing of the desired aircraft and flight control system parameters, and which minimize exposure to conditions which could produce failures or undesired output signals.

3.2.3 Signal transmission

3.2.3.1 General requirements

3.2.3.1.1 Control element routing. Within the restrictions and requirements contained elsewhere in this specification, all portions of signal transmission subsystems, including cables, push-pull rods, torque tubes, and electrical wiring shall be routed through the airplane in the most direct manner over the shortest practical distances between points being connected. Protection from use as steps or handholds shall be provided.

3.2.3.1.2 System separation, protection, and clearance. Where redundant cable, pushrod, or electrical wiring are provided, they shall be separated as required to meet the invulnerability requirements of 3.1.9. Advantage shall be taken of the shielding afforded by heavy structural members, existing armor plate, or other equipment for the protection of important components of the control systems. Clearance between flight control system components and structure or other components shall be provided as necessary to insure that no probable combination of temperature effects, air loads, structural deflections, vibrations, build-up of manufacturing tolerances, or wear, can cause binding or jamming of any portion of the control system. In locally congested areas only, the following minimum clearances may be used after all adverse effects are accounted for:

a. 1/8-inch between static elements except those within an LRU where closer clearances can be maintained or where contact cannot be detrimental.

b. 1/8-inch between elements which move in relation to each other and which are connected to or are guided by the same structural or equipment element(s) except those within an LRU where closer clearances can be maintained or where contact cannot be detrimental.

c. 1/4-inch between elements which move in relation to each other and which are connected to or are guided by different structural or equipment elements.

d. 1/2-inch between elements and aircraft structure and equipment to which the elements are not attached.

3.2.3.1.3 Fouling prevention. All elements of the flight control system shall be designed and suitably protected to resist jamming by foreign objects.

3.2.3.1.4 Rigging provisions. The number of rigging positions shall be kept to a practical minimum. They shall be readily accessible and located where space for the rigging function is available. Installed rigging pins shall be highly visible from the ground or include streamers as specified in 3.1.10.4. Control surface actuator outputs shall not be rig pinned.

3.2.3.2 Mechanical signal transmission

3.2.3.2.1 Load capability. Elements of mechanical signal transmission systems subjected to loads generated by the pilot(s) shall be capable of withstanding the loads due to pilot's input limits specified in MIL-A-8865, Section 3.7, Flight Control System Loads, taken as limit loads, unless higher loads can be imposed such as by a powered actuation system or loads resulting from aerodynamic forces. Where higher loads are thusly imposed, they shall be met with the same margins and circumstances as specified in MIL-A-8865.

3.2.3.2.2 Strength to clear or override jammed hydraulic valves. All mechanical elements which transmit input commands to metering valves of hydraulic servoactuators shall have strength to withstand higher loads, above those for normal valve stroking, required to clear foreign material that may occur in projected usage.

3.2.3.2.3 Power control override provisions. Provisions shall be made to permit the pilot(s) to clear or override metering valve jams unless there is sufficient aerodynamic control power from the remaining operative surfaces to override control moments generated by the jammed surface in its most adverse position.

3.2.3.2.4 Control cable installations. Control cable installations shall be designed to accommodate easy servicing and rigging, and the number of adjustments required shall be kept to the practical minimum.

3.2.3.2.4.1 Control cable. Cable used for the actuation of flight controls shall be the most suitable of the following types for each application. Use of carbon steel or other type cable not listed below requires procuring activity approval.

a. Flexible nylon-coated corrosion-resisting steel wire rope in accordance with MIL-W-83420.

b. Preformed flexible corrosion-resisting steel wire rope in accordance with MIL-W-83420.

c. Performed flexible corrosion-resisting nonmagnetic steel cable in accordance with MIL-C-18375.

3.2.3.2.4.2 Cable size. Cable shall be sized to meet the load requirements of the system with ample safety factors to compensate for wear and deterioration where pulleys, fairleads, etc. are encountered. Cable size shall also be adequate in regard to permissible cable stretch, pulley friction values, and other variables which affect system performance. Where substantial loads are carried, cables shall be sized so that limit loads do not exceed 67 percent of the rated breaking strength of the cable and do not exceed the maximum cable limit loads allowed for their pulleys.

3.2.3.2.4.3 Cable attachments. The minimum practical number of interconnections shall be used which allow all cable segments to be connected manually. Cable disconnects shall be located and designed so that it is physically impossible to misconnect in any manner, either cables in the same system or the cables of different systems. Cable disconnects and turnbuckles shall be so located that they will not hang up or interfere with adjacent structure or equipment or on each other and will not snag on cables, wires, or tubing. Corrosion-resistant steel MS swage-type cable fittings in accordance with MIL-T-781, swaged to form cables assemblies in accordance with MIL-T-6117, shall be used wherever possible. Thimble ends in accordance with MIL-T-5677, attached to cable by splicing and wrapping in accordance with MIL-S-5676, may be used in applications where additional joints are needed to prevent bending fatigue failures. Turnbuckles used in flight control cables systems shall be in accordance with MIL-T-8878. Turnbuckle and fittings shall be designed so that they are not subject to bending forces which can cause fatigue failures. Turnbuckle terminals shall not have more than three threads exposed at either end. All turnbuckle assemblies shall be properly safetied in accordance with MS33736.

3.2.3.2.4.4 Cable routing. Control cables shall be arranged in parallel runs, and be accessible to inspection for their entire length. Cable runs located in aeroelastic structure, such as aircraft wings, shall be routed so as to minimize any induced control action, caused by structural flexure. Spacing between adjacent cables shall prevent cables, turnbuckles, and fittings from chafing during all operating conditions including vibration. Slack return cables shall not snag on each other or any other equipment or structure when the controlling cables are loaded to design limit loads at the adverse extremes of temperature, structural deflection, and other operating conditions. Cables shall not be subjected to critical bends at the junction with cable terminals or other attaching points such as on drums and sectors.

3.2.3.2.4.5 Cable sheaves. Cable drums, sectors, and pulleys of adequate capacity and diameter for their function and to meet aircraft life requirements shall be provided. They shall be large enough for the cable wrap angle such that the cable strands are not overstressed. The diameter and number of grooves on cable drums, and the radius and angle of control cable sectors shall be adequate for the required cable travel. Overtravel allowance shall not be less than 5 percent of full travel in either direction and at least 10 degrees. When cable wrap varies with cable travel, the initial wrap with the sheave in the neutral position shall be at least 115 percent of the full cable travel in either direction. If overtravel exceeds the minimum required, cable wrap shall be increased a corresponding amount. All cable grooves on drums and sectors, machined or die cast, shall have root radii properly sized for the cable size used thereon. Specific approval shall be obtained before using plain pulleys in essential applications. Antifriction pulleys used in flight control systems shall be MS standards in accordance with MIL-P-7034, and the design limit load shall not exceed the allowable limit load specified for the applicable standard.

3.2.3.2.4.6 Cable and pulley alignment. Fixed-mounted pulleys shall be aligned with their cables within 2 degrees as specified in AFSC Design Handbook DH 2-1, DN 3B1, Subnote 1.1.3(1), Cable Pull. Where a control cable has an angular motion with respect to the plane of the pulleys, the maximum misalignment resulting from this motion must not exceed 2 degrees, and the cable shall not contact the pulley (or quadrant) flange for the total cable travel.

3.2.3.2.4.7 Pulley-bracket spacers. Loose spacers between pulleys, bearings, and pulley brackets shall not be used.

3.2.3.2.4.8 Sheave guards. Guards shall be installed at all sheaves (pulleys, sectors, drums, etc.) as necessary to prevent the cable from jumping out of the groove of the sheave. Guards shall be installed at the approximate point of tangency of the cable to the sheave. Where the cable wrap exceeds 90 degrees, one or more intermediate guards shall be installed. All guards shall be supported in a way which precludes binding of the sheave due to relative deflections in the aircraft structure. Additional guards shall be installed on sectors as necessary to ensure retention of the cable end in its attachment under slack cable conditions. The design of the rubbing edges of the guard and the selection of materials shall be such as to minimize cable wear and prevent jamming even when the cable is slack.

3.2.3.2.4.9 Sheave spacing. In any given cable run, no portion of the cable shall ever pass over more than one sheave.

3.2.3.2.4.10 Cable tension. Cable rig loads shall insure positive cable tension in control and return legs of closed-loop cable installations under all operating conditions including airframe deflection and differential expansion and contraction between the cable and airframe structure throughout the designed operating temperature range. The cable return leg may be allowed to go slack when the control leg is loaded above the normal operating load, providing it cannot snag, when the control leg is loaded at any load up to limit load, and that there is no hazardous loss of system performance. Cable tension regulators shall be provided only if positive cable tension cannot be maintained in both legs, with reasonable rigging loads.

3.2.3.2.4.11 Cable tension regulators. When used, tension regulators shall maintain required tension at all times. Integral calibration shall be provided to show proper cable tension without the use of external tensionmeters or other equipment.

3.2.3.2.4.12 Fairleads and rubbing strips. Fairleads shall not cause any angular change greater than 3 degrees in the direction of the cable under all conditions including those due to structural deflections in flight. Fairleads shall be split to permit easy removal unless the size of the hole is sufficient to permit the cable with swage terminals to be threaded through.

3.2.3.2.4.13 Pressure seals. Pressure seals shall meet compartment sealing requirements within cable installation friction requirements. They shall be designed to preclude jamming the control system.

3.2.3.2.5 Push-pull rod installations. Push-pull rod installations shall be designed to preclude binding or separating from the mating linkage, and shall permit servicing and rigging.

3.2.3.2.5.1 Push-pull rod assemblies. Push-pull rod assemblies shall be designed and installed such that inadvertent detachment of adjustable terminals is impossible, and such that any change in length due to loosening of the terminals cannot result in an unsafe condition. On any single rod assembly, adjustment shall be possible at one end only. The fixed end of each rod shall be attached to its mating linkage element in a manner which precludes rotation of the installed assembly. The adjustable end shall be of the clevis type or join a clevis type in such a manner that it is also prevented from rotating. When an unsymmetrical rod is used, such as one with a cutaway portion to allow for relative motion of an attached link, the rod end terminals and mating linkage elements shall positively prevent incorrect installation of the rod. Push-pull rods shall have a minimum wall thickness of 0.035 inches and shall be capable of withstanding loads of 1.5 times limit loads in both tension and compression without failure, buckling, or any other form of permanent deformation. All joints shall be made in a manner which precludes loosening and fatigue failure. All closed cavities in rod assemblies installed in unpressurized spaces shall be provided with drain holes adequate to drain ingested water unless cavities are air tight. All push-pull rod terminals shall incorporate antifriction bearings as specified in 3.2.7.2.1.1 or self-lubricating spherical bearings as specified in 3.2.7.2.1.2. All terminal pins shall be retained as specified in 3.2.8.3.2.2. Loose washers or other loose spacers shall not be used to maintain terminal spacing in the connecting linkage.

3.2.3.2.5.2 Levers and bellcranks. Applicable requirements in AFCS Design Handbook DH 1-6; System Safety, Section 3J; Flight Control Systems, Design Note 3J2; Mechanical Flight Controls; Pulleys, Brackets and Bellcranks, and Design Note 3JX; Safety Design Check list, shall be met. Bearings shall have adequate self-aligning capability if necessary to prevent excessive deflection loads on levers and bellcranks, and, their installations shall be designed for easy replacement so that the parent part may be reused. Levers and bellcranks designed with dual load paths having the two sections positively joined by permanent fasteners, such as rivets, shall be bonded with adhesive.

3.2.3.2.5.3 Push-pull rod supports. Where long sections of push-pull rods are utilized in applications where jamming is not extremely remote, guides shall be installed at intervals to preclude fouling in the event of rod failure.

3.2.3.2.5.4 Push-pull rod clearance. Clearance between push-pull rods, and between rods and aircraft equipment and structure, shall be as specified in 3.2.3.1.2 except that it shall also be sufficient to permit removal of adjacent LRU's without disconnecting the rods.

3.2.3.2.6 Control chain. Where used, control chains shall be of standard aircraft quality and conform to MIL-STD-421. Connecting links shall be retained with standard nonhardened cotter pins. Spring clips shall not be used.

3.2.3.2.7 Push-pull flexible controls. Push-pull flexible controls may be used for transmitting control signals in noncritical applications, but specific approval from the procuring activity must be obtained before use in essential and flight phase essential applications. Where used, they shall conform to MIL-C-7958. Installations shall avoid an excessive number of bends to keep friction forces within acceptable values and minimize the possibility of jamming, and the routing shall preclude damage due to personnel using them as steps and handholds. Conduits shall be supported at frequent intervals, but not so tightly that the control is restrained axially.

3.2.3.3 Electrical signal transmission. The following requirements apply to all essential and flight phase essential signal paths. Except for power sources, such systems shall be independent of failure modes associated with any other electrical system. Cross connections between redundant electrical signal paths shall be eliminated, or minimized and electrically isolated. Wire runs and components in redundant control paths shall be physically separated and electrical shielding shall be installed, as necessary, to meet failure immunity and invulnerability requirements. All interconnecting wiring shall be prefabricated, jacketed cable assemblies. The outer jackets shall be identifiable by a unique color or other means. Wiring installation shall be in accordance with MIL-W-5088.

3.2.3.3.1 Electrical flight control (EFC) interconnections. EFC (6.6) wiring in individual channels shall be routed, isolated and protected to minimize the applicable threats to redundancy. Channel loss due to any foreseeable hazard, not extremely remote, shall be limited to a maximum of a single channel. The adequacy of the separation, isolation and protection attainable in any given location for any given hazard shall be evaluated for each aircraft design. Additional protection shall be provided for the EFC wiring where analysis shows that any single hazardous event, not extremely remote, could cause the loss of more than one EFC channel. Primary structural components shall be used to afford this protection where possible. Where it is approved by the procuring activity to route the EFC wiring through wheel wells or other areas subjected, during flight, to the slipstream or impingement of runway fluids, gravel, etc., the wiring shall be protected by enclosures and routed directly through without unnecessary termination or junctions. Where terminations or junctions to equipment in these areas are required, they shall be protected from such impingements. This shall also be done in areas where a high level of maintenance is likely to be required on other systems and equipment.

3.2.3.3.1.1 Cable assembly design and construction. The outer jacketing for EFC wiring shall not create stresses on the wire and connector terminations and shall not stress the wires in a manner which opens the connector grommet seals. During design of the cable assemblies, particular attention shall be paid to the requirements of the circuits within the cable and adequate EMI and EMP control methods, e.g., shielding, twisting, etc., shall be incorporated into the design. Where shielded wires are used provisions shall be made for carrying the shields through the connectors where single point grounding is necessary. A signal return wire shall be provided for each signal level circuit in the cables. All cable assemblies shall be constructed in an area with temperature and humidity controls and positive pressure ventilation and shall be cleaned (all wire cuttings, etc., removed) and inspected after layup and prior to jacketing to assure that no potentially damaging particles have been included, particularly at the entrance to the grommet seal. All cable assemblies shall be constructed, tested and inspected by specially trained and certified personnel. Terminal boards shall not be used in EFC wiring. Splices shall be qualified, permanent-type splices.

3.2.3.3.1.2 Wire terminations. Crimp type wire terminations (spade, lug or connector) shall be used on all EFC cables. Soldered and potted connections shall not be used. With the terminal installed on the wire, the wire shall be visible for inspection at both ends of the crimp barrel. The length of wire visible between the insulation and barrel shall not exceed 1/16 inch.

3.2.3.3.1.3 Inspection and replacement. The EFC wiring shall be installed so that is can be inspected for damage and replaced as necessary. The installation shall provide for visual inspection in critical areas such as hazardous environment areas or areas where a high level of maintenance is required on system or equipment in close proximity.

3.2.3.3.2 Multiplexing. Multiplexed signal transmission circuits shall be the digital time-division-multiplexing type utilizing a twisted shielded pair cable as the transmission media for the multiplex bus. The multiplex data bus line and its interface electronics, multiplex terminal unit shall meet MIL-STD-1553.

3.2.4 Signal computation

3.2.4.1 General requirements

3.2.4.1.1 Transient power effects. Flight control computers shall not suffer adverse effects, which result in operation below FCS Operational State I, due to power source variations within the limits specified for the applicable power system. In the event of power source interruption, no adverse effects shall result which limit operation or performance of flight control computers upon resumption of normal quality power.

3.2.4.1.2 Interchangeability. The requirements of 3.2.7.1.2 shall be met, and tolerances shall be such that interchange of any computer component, module, or LRU with any other part bearing the same part number shall require only minimum resetting of parameters or readjustment of other components in order to maintain overall tolerances.

3.2.4.1.3 Computer signals

3.2.4.1.3.1 Signal transmissions. Signal transmissions between computer components and modules shall be done by using direct mechanical, hydraulic, pneumatic, or electrical connections, as required. Use of light transmission technology or other nonconventional transmission paths requires specific approval of the procuring activity.

3.2.4.1.3.2 Signal path protection. Where redundant computing paths are provided they shall be isolated or separated when required to meet the invulnerability requirements of 3.1.9.

3.2.4.2 Mechanical signal computation

3.2.4.2.1 Element loads. Mechanical computer signal transmission elements subjected to the pilots' input force shall be capable of withstanding the loads specified in 3.2.3.2.1.

3.2.4.2.2 Geared mechanisms. All geared mechanisms used in mechanical computer components shall meet the requirements of MIL-G-6641.

3.2.4.2.3 Hydraulic elements. Hydraulic computing elements shall be designed in accordance with MIL-C-5503, MIL-H-8775, MIL-G-8890 or ARP 1281 as applicable. MIL-V-27162 shall be used as a general guide for the design of control valves used in hydraulic computing components.

3.2.4.2.4 Pneumatic elements. All pneumatic computing elements shall be designed in accordance with MIL-P-8564 and AFSC Design Handbook DH 1-6, Section 3G, Pressurization and Pneumatic Systems, as applicable.

3.2.4.3 Electrical signal computation

3.2.4.3.1 Analog computation. Redundant electrical signal paths within a computer shall be isolated as required by failure immunity and invulnerability requirements specified herein. For failures which may cause a hazardous deviation in the aircraft flight path, the computer shall have provisions for rapidly disabling its command outputs or servos unless other fail-safe provisions exist.

3.2.4.3.2 Digital computation. At the time of aircraft acceptance by the procuring activity, the total time used in flight control computations for worst case conditions shall not exceed 75 percent of the available computation time allocated for flight control use. Resident and bulk storage shall be sized such that at least 25 percent of each type is available for growth at the time of aircraft acceptance. Computation and sample rate shall be established at a level which ensures that the digital computation process will not introduce unacceptable phase shift, round off error, nonlinear characteristics, and frequency foldover or aliasing into the system response.

3.2.4.3.2.1 Memory protection. Memory protection features shall be provided to avoid inadvertent alternation of memory contents. Memory protection shall be such that neither electrical power source transients within the limits specified nor EMI as specified in 3.2.5.4.1 shall cause loss of program memory, memory scramble, erroneous commands, or loss of ability for continued operation. The transients shall be as specified in MIL-STD-704 for Category C utilization equipment. For applications where system failures could be hazardous to safety of flight, the levels for normal, abnormal, and emergency electric system operation shall apply. For applications which are not critical to safety of flight, the levels for normal operation shall apply. These transient requirements shall apply to cases when all or only one of the redundant power sources are operating.

3.2.4.3.2.2 Program scaling. Parameter scaling, word size, input limiting, and overflow protection shall ensure correct processing and continuous safe operation for all possible combinations of maneuvering demand and gust or other plausible disturbance within the service envelop of the system. Any condition capable of producing an overflow in an essential or flight phase essential function shall be precluded by hardware overflow detection and software or firmware that provides for data recovery and continuous safe operation following an overflow. Scaling shall provide satisfactory resolution to prevent the granularity due to digitizing processes from introducing, into the system response, unacceptable levels of nonlinear characteristics or instabilities.

3.2.4.3.2.3 Software support. For programmable computers a software support package shall be provided to aid in generation and validation of new programs. This support package shall be designed to be executable, either on the airborne computing system for which it was designed or on a large scale digital computer specified by the procuring agency. The support package shall include the necessary software and appropriate peripheral devices in accordance with the contractor data requirements list (DD 1423).

3.2.5 Control power

3.2.5.1 Power capacity. Sufficient electrical, hydraulic, and pneumatic power capacity shall be provided in all flight phases and with all corresponding engine speed settings such that the probability of losing the capability to maintain at least FCS Operational State III airplane performance shall be not greater that extremely remote when considering the combined probability of system and component failure and the cumulative exceedance probability of turbulence. Hydraulic power shall be used to actuate powered essential and flight phase essential MFCS.

3.2.5.2 Priority. Essential and flight phase essential flight controls shall be given priority over noncritical controls and other actuated functions during simultaneous demand operation. However, no specific priority provisions, such as hydraulic priority valves, are required unless there is a likelihood of simultaneous demands which could prevent one or more essential or flight phase essential actuation systems from meeting their performance requirements. Where provided, priority controls shall be highly resistant to deterioration, binding, or failure while dormant under normal aircraft operations so that they will function as required when conditions dictate. If flight safety can be endangered by failure of such controls, ground checkout means for ready determination of their operability shall be provided and procedures specified.

3.2.5.3 Hydraulic power subsystems. All hydraulic power generated and distribution systems normally used for flight control shall be designed in accordance with MIL-H-5440 and MIL-H-8891 as applicable. The FCS shall operate in accordance with this specification when supplied with such hydraulic power. Applicable requirements in AFSC Design Handbook DH 1-6, Systems Safety, Section 3F, Hydraulic Systems, shall also be met.

3.2.5.4 Electrical power subsystems. All electrical power generation and distribution subsystems used for flight control shall provide electrical power in accordance with MIL-STD-704. The FCS shall operate in accordance with this specification when supplied with power in accordance with MIL-STD-704. Applicable requirements in the following AFSC design handbooks shall be met:

a. DH 1-4: Electromagnetic Compatibility.

b. DH 1-6: System Safety.

c. DH 2-1: Airframe

d. DH 2-2: Crew Stations and Passenger Accommodations.

Electrical systems which provide power to essential or flight phase essential controls, shall insure uninterruptible, isolated redundant power of adequate quality to meet FCS requirements after any malfunction not considered extremely remote. Such electrical systems shall, except for basic power source, be independent of failure modes associated with any other electrical system. Essential and flight phase essential FCS shall be automatically provided alternate sources of power where interruption could result in operation below FCS Operational State III. A protected alternate source of power shall be provided for all essential or flight phase essential control signal transmission paths sufficient to continuously maintain at least FCS Operational State III performance in the event of loss of all electrical power supplied from engine-driven generators. Control systems employing both ac and dc power inputs shall normally have interlocks incorporated to disconnect both power inputs should either type of power be lost. However, if the loss of either power source can be shown to be equivalent to loss of both or FCS Operational State III or better is maintained with either power source, interlocks are not required.

3.2.5.4.1 Electromagnetic interference limits. The FCS shall operate within the limits of MIL-E-6051 and MIL-STD-461 environment. Electromagnetic interference created by the systems and components during normal operation shall be within the limits of MIL-E-6051 and MIL-STD-461, respectively. Failure modes of all onboard systems and equipment, including flight controls, wherein these limits may be exceeded shall be identified in addition to sources of conducted EMI that may be detrimental to FCS operation. Additionally, the estimated magnitude of EMI generated by these failure modes shall be provided for the assessment of the safety of the EFCS.

3.2.5.4.2 Overload protection. Overload protection of the primary power wiring to the system or component shall be provided by the airplane contractor. Installation requirements of the system or component specification shall specify the values of starting current versus time, surge currents if applicable, normal operating current, and recommended protective provisions. Additional protection as necessary shall be provided within the system or component. Such circuit protection shall not be provided in signal circuits or other circuits where opening of the protective devices will result in unsafe motion of the aircraft.

3.2.5.4.3 Phase separation and polarity reversal protection. In systems affecting flight safety, phase reversal and polarity reversal shall be prevented as far as practical by keying, physical restraints or other positive means.

3.2.5.5 Pneumatic power subsystems. Pneumatic power using ram-air, engine bleed air, stored gas, mechanically compressed air, or generated gas may be used for noncritical flight control functions and for driving hydraulic pumps and electric generators. High pressure pneumatic systems used for FCS functions shall conform to MIL-P-5518, the applicable requirements in AFSC Design Handbook DH 1-6; System Safety, Section 3G; Pressurization and Pneumatic Systems, and the applicable requirements under 3.2.5.1, herein. Engine bleed air systems used for FCS functions shall conform to MIL-E-38453.

3.2.6 Actuation

3.2.6.1 Load capability

3.2.6.1.1 Load capability of elements subjected to pilot loads. Elements of actuation systems subjected to loads generated by the pilot(s) shall be capable of withstanding the loads due to the pilot's input limits specified in MIL-A-8865, Section 3.7, Flight Control System Loads, taken as limit loads unless higher loads can be imposed such as by a powered actuation system or loads resulting from aerodynamic forces. Control signal boost actuator outputs may be load limited by spring cartridges.

3.2.6.1.2 Load capability of elements driven by power actuators. Elements subjected to loads generated by a powered actuation system, including all parts of the actuator shall be capable of withstanding the maximum output of the actuation system, including loads due to bottoming, or the maximum blowback load, as controlled by pressure relief valves or other load limiting provisions, whichever is greater, as the limit load. Ultimate load capability shall be 1.5 times limit load. In dual load path design, each path shall be capable of sustaining load as specified in 3.1.11.1.2 without failure.

3.2.6.2 Mechanical force transmitting actuation. For control cable actuation, the requirements specified in 3.2.3.2.4 and subparagraphs apply. For push-pull rod actuation, the requirements specified in 3.2.3.2.5 and subparagraphs apply.

3.2.6.2.1 Force transmitting powerscrews. Powerscrews with rotary input and linear output motion may be used to actuate relatively low-duty-cycle flight control surfaces, such as wing flaps and trimmable stabilizers, but specific approval from the procuring activity shall be obtained before use in high-duty-cycle applications. Nonjamming mechanical stops shall be provided at both ends of the screw to limit travel of the nut; and, they shall be designed to withstand all possible loads, including possible impact loading, without failure. Provisions shall be incorporated into the nut to minimize entry of sand, dust, and other contaminants; to retain its lubricant; and to preclude the entry or retention of water. However, positive sealing is not required if the screw is installed such that it is protected from such contamination or is inherently resistant to wear and jamming by contamination.

3.2.6.2.1.1 Threaded powerscrews. Standard thread forms only shall be used, and the thread roots shall be rounded as necessary to preclude stress cracking. Lubrication provisions shall be adequate for controlling efficiency, wear, and heating to acceptable values. Where in service lubrication is necessary, lube fittings in accordance with 3.2.7.2.5 shall be provided. If the design is dependent on inherent friction to maintain irreversibility, this characteristic must be adequate under all expected operating conditions, including the full range of loads, both steady loads and reversing or variable-magnitude loads which may be encountered due to control surface buffeting or buzz, temperatures, and environmental vibration over the full service life of the unit.

3.2.6.2.1.2 Ballscrews. An adequate number of balls and ball circuits shall be provided to keep individual ball loading within allowable nonbrinelling limits. On units used in essential and flight phase essential applications, at least two separate independent ball circuits and a secondary load path with load capability in accordance with 3.1.11.1.2 shall be incorporated.

3.2.6.3 Mechanical torque transmitting actuation. Specific approval from the procuring activity must be obtained before use of such provisions is essential and flight phase essential applications. Backlash accumulation shall not prevent the system from performing its required function throughout the service life of the airplane.

3.2.6.3.1 Torque tube systems. Torque tubes which are exposed to possible misuse, such as support for maintenance personnel, shall be shielded from such misuse or shall be of adequate stiffness to prevent damage to the installation. Each torque tube, in a linked run of tubes shall be removable and reinstallable in the aircraft without disturbing the support, component, or other interfacing system element at either end of the torque tube. Guards which are capable of containing a broken torque tube against thrashing shall be installed in appropriate locations to prevent damage to wiring, tubing, and other equipment. The rated operating speed of a torque tube system shall be no greater than 75 percent of the critical speed.

3.2.6.3.1.1 Torque tubes. Torque tubes shall have a minimum wall thickness of 0.035 inch and shall be seamless, except that steel tubes, seam welded by the electrical resistance method, may be used.

3.2.6.3.1.2 Universal joints. Universal joints shall be in accordance with MIL-J-6193 or MIL-U-3963, as specified in AFSC Design Handbook DH 1-2, General Design Factors, Section 4C, Universal Joints, and shall not be used for angularities greater than specified therein or recommended for the specific component by the manufacturer.

3.2.6.3.1.3 Slip joints. Adequate engagement shall be provided to insure that disengagement will not occur under all expected operating conditions, or due to buildup of adverse manufacturing and installation tolerances.

3.2.6.3.2 Gearing. All gear boxes used in actuating systems shall meet the requirements specified in MIL-G-6641.

3.2.6.3.3 Flexible shafting. Flexible shafting may be used providing that minimum bend radii, rated rotational speed, and rated torque are not exceeded, and that extreme temperatures and other operational variations and environments do not cause binding. Flexible shafts shall be installed with the fewest possible bends and shall be securely fastened to supporting structure at close intervals.

3.2.6.3.4 Helical splines. Involute helical splines shall use only the ASA standard tooth forms Numbers 1 through 5. Ballsplines shall meet the requirements specified in 3.2.6.2.1.2 for ballscrews.

3.2.6.3.5 Rotary mechanical actuators. Rotary mechanical actuators used with a through shaft which attaches to torque tubes at both ends, thus serving as a portion of the torque distribution system, shall be capable of reacting full system torque in both the forward direction (due to a jam anywhere in the system) or in the backdriving direction (due to overrunning load), unless provided with a torque limiter and no-back brake or other devices which would preclude such loading.

3.2.6.3.6 Torque limiters. Where used, torque limiters designed to slip or lock to adjacent structure shall be properly located in the transmission system to prevent drive loads in excess of control surface limit load from being transmitted past the limiter in the event of overload or jamming. The rate of application of the limiter(s) and the spring rate of the transmission system shall be matched so that the stress in any member due to sudden application does not exceed its yield strength.

3.2.6.3.7 No-Back brakes. No-back brakes shall prevent back driving (or feedback) forces imposed on the output of an actuating mechanism from being converted to torques which can cause the input shaft to rotate. In no-back brakes of the heat dissipative type, provisions shall be included to distribute heat generated by the brake so that temperature limitations are not exceeded.

3.2.6.4 Hydraulic actuation. Hydraulic actuation components shall be designed in accordance with MIL-H-8775 or MIL-H-8890, and specific component specifications as applicable. If hydraulic bypass provisions are necessary to prevent fluid lock or excessive friction load or damping, bypassing and resetting shall occur automatically when system pressure drops below or returns to the minimum acceptable value for actuation. In actuation systems designed for manual control following hydraulic failure, provisions shall be made to permit bypassing of the hydraulic systems for checkout purposes and to permit pilot training with the emergency manual system.

3.2.6.4.1 Hydraulic servoactuators. Hydraulic servoactuators shall be designed in accordance with ARP 1281. Electrohydraulic servovalves shall be designed in accordance with MIL-V-27162. If electrical-input hydraulic servovalves having mechanical feedback of actuator position are used, the applicable requirements of ARP 988 shall be met.

3.2.6.4.2 Motor-pump - servoactuator (MPS) package. This is defined as an integrated servoactuator package which incorporates an electric motor driving a hydraulic pump, a hydraulic fluid reservoir, a servoactuator, and necessary accessories packaged in a single, self-contained LRU. Individual components within the integrated package shall be designed in accordance with the applicable requirements of the corresponding component specifications. Essential of flight phase essential applications require specific approval from the procuring activity.

3.2.6.4.3 Actuating cylinders. Actuating cylinders without control valves and feedback provisions in the same LRU shall be designed in accordance with MIL-C-5503, except that the life cycling requirements shall be modified to reflect the specific usage. (See 3.1.12.)

3.2.6.4.4 Force synchronization of multiple connected hydraulic servoactuators. In essential and flight phase essential flight control actuator installations employing multiple connected servoactuators, the actuators shall be synchronized as necessary to assure specified performance and durability as specified in 3.1.11.3 in the structure between actuators without undue structural weight penalties.

3.2.6.4.5 Hydraulic motors. Hydraulic motors may be used to actuate relatively low-duty-cycle, noncritical flight control surfaces, such as wing flaps, but specific approval from the procuring activity must be obtained before use in high duty cycle noncritical applications or in any essential or flight phase essential application. They shall be designed in accordance with MIL-M-7997.

3.2.6.5 Electromechanical actuation. Electric power may be used to actuate relatively low-duty-cycle, noncritical flight control functions, such as for trim and in the AFCS, but specific approval from the procuring activity must be obtained before use in essential and flight phase essential applications. Electromechanical actuation components shall be designed in accordance with MIL-E-7080, and specific component specifications as applicable, and the following. Performance requirements shall be adequate for intended application.

3.2.6.6 Pneumatic actuation. Pneumatic power may be used to actuate relatively low-duty-cycle, noncritical flight control surfaces, such as wing flaps, but specific approval from the procuring activity must be obtained before use in essential and flight phase essential applications.

3.2.6.6.1 High-pressure pneumatic actuation. High-pressure pneumatic actuation components shall be designed in accordance with MIL-P-8564.

3.2.6.6.2 Pneumatic drive turbines. Pneumatic drive turbines shall be designed in accordance with MIL-D-7602 when used for FCS purposes.

3.2.6.7 Interfaces between actuation systems, support structure, and control surfaces

3.2.6.7.1 Control surface stops. Surface stops shall be provided each flight control surface to positively limit its range of motion. Stops shall be located so that wear, slackness, or takeup adjustments will not adversely affect the control characteristics of the airplane because of a change in the range of surface travel. Each stop shall be able to withstand any loads corresponding to the design conditions for the control system. Where power control actuators are attached directly to the control surface, stops shall be provided within the actuator. Such actuators shall not only be designed for maximum impact loads, but also for the cumulative fatigue damage due to load cycling predicted during flight and due to bottoming during ground checkout and taxiing. Where control valve command input stops are provided, the actuators shall be designed for maximum impact stop loads, and not for fatigue damage due to bottoming, except as normally encountered with the input stops and feedback provisions functioning.

3.2.6.7.1.1 Adjustable stops. All adjustable stops shall be positively locked or safety wired in the adjusted position. Jam nuts (plain or self-locking type) are not considered adequate as locking devices for this application.

3.2.6.7.2 Control surface ground gust protection. All flight control surfaces shall have provisions to prevent damage from ground wind loads as specified in MIL-A-8865. However, no separate provisions are required if the damping characteristics of installed flight control actuators suffice for gust protection.

3.2.6.7.2.1 Control surface locks. Where control surface locks are used, the lock system shall be internal within the airplane. External locks may be used for helicopter rotors. The locks shall either engage the surfaces directly or lock the controls as near to each surface as practicable and shall be spring loaded to the unlocked position. Control surface locks shall be designed to preclude attempting takeoff with controls locked.

3.2.6.7.2.2 Protection against inflight engagement of control surface locks. Control surface ground gust locks and their controls shall be designed to preclude their becoming engaged during flight.

3.2.6.7.3 Control surface flutter and buzz prevention. All flight control surface actuation systems controlling surfaces which are not dynamically balanced shall be effectively irreversible or provided with sufficient damping to prevent flutter, buzz, or other relative dynamic instabilities for all operating modes and meet the requirements of MIL-A-8870. No active powered compensation technique or mechanization designed to artifically increase effective stiffness, damping, or natural frequency shall be used without prior approval of the procuring activity.

3.2.7 Component design

3.2.7.1 Common requirements

3.2.7.1.1 Standardization. Where practical, contractor designed equipment which has been approved for use in some models of aircraft shall also be used in later model airplanes if the installation and requirements are similar.

Tolerances shall be such that interchange of any LRU with any other part bearing the same part number shall not require resetting of parameters or readjustment of other components in order to maintain overall tolerances and performance.

3.2.7.1.2 Interchangeability. Like assemblies, subassemblies, and replaceable parts shall meet the requirements of MIL-I-8500 regardless of manufacturer or supplier. Items which are not functionally interchangeable shall not be physically interchangeable unless specifically approved by the procuring activity.

3.2.7.1.3 Selection of specifications and standards. Specifications and standards for necessary commodities and services not specified herein shall be selected in accordance with MIL-STD-143.

3.2.7.1.4 Identification of product. Equipment components, assemblies, and parts of flight control systems shall be identified in accordance with MIL-STD-130.

3.2.7.1.5 Inspection seals. Corrosion resistant metallic seals shall be provided at all strategic locations to indicate assembly inspection and any unauthorized disassembly.

3.2.7.1.6 Moisture pockets. All components shall avoid housing designs which result in pockets, wells, traps, and the like into which water, condensed moisture, or other liquids can drain or collect. If such designs are unavoidable, provisions for draining shall be incorporated.

3.2.7.2 Mechanical components. Mechanical components not covered by design requirements specified elsewhere within this specification shall be designed in accordance with applicable requirements in: Government and Industry specifications, in the order of precedence specified in MIL-STD-143; in AFSC Design Handbooks DH 2-1, DN 3B1, Mechanical Flight Controls; and DH 1-2, General Design Factors; and the following:

3.2.7.2.1 Bearings. Flight control system bearings shall be selected in accordance with AFSC Design Handbook DH 2-1, Chapter 6, Airframe Bearings, and the following.

3.2.7.2.1.1 Antifriction bearings. Approved type ball bearings in accordance with MIL-B-6038, MIL-B-6039, and MIL-B-7949 shall be used throughout the flight control system, except as indicated in the following paragraphs. Bearing installation shall be arranged in such a manner than failure of the rollers or balls will not result in a complete separation of the control. Where direct axial application of control forces to a bearing cannot be avoided, a fail-safe feature shall be provided.

3.2.7.2.1.2 Spherical bearings. Where space or other design limitations preclude the use of antifriction bearings, spherical-type, self-lubricating plain bearings in accordance with MIL-B-81820, or spherical or special-type all-metal bearings in accordance with MIL-B-8976 with adequate and accessible provisions for lubrication, may be used.

3.2.7.2.1.3 Sintered bearings. Sintered type, or oil impregnated bearings shall not be used in those parts of the flight control systems which have slow moving or oscillating motions. Their use in fast moving rotating applications, such as in qualified motors and actuators, is permissible. Bearings shall conform to MIL-B-5687.

3.2.7.2.2 Controls and knobs. Aircrew controls shall be shaped and located per the requirements of AFSC Design Handbook DH 2-2. Control knobs shall be designed and spaced per the requirements of AFSC Design Handbook DH 2-2 and MIL-K-25049.

3.2.7.2.3 Dampers. Each damper shall be completely defined by a detail specification. Control stick dampers shall be designed so that they can be overpowered by the pilot in the event of failure or malfunction. Damping requirements for surface dampers shall be based upon the anticipated flutter frequency, but the endurance requirements shall be based upon the same criteria established for the surface control actuators. Detail design of hydraulic dampers shall conform to the applicable requirements of MIL-C-5503. All joints, connections, and bearings shall be designed to prevent the degree of wear which can cause unacceptable freeplay.

3.2.7.2.4 Structural fittings. All structural fittings used in flight control systems shall comply with the design requirements specified in AFSC Design Handbook DH 1-2, Design Note DN 4B1, Design Requirements, and where applicable, the design considerations specified in Design Note DN 4B2, Forgings and Castings.

3.2.7.2.5 Lubrication. Where applicable, lubrication fittings in accordance with MIL-F-3541, MS15002-1 and -2, or NAS 516 shall be installed to provide for lubrication in accordance with MIL-STD-838. NAS 516 fittings are restricted to nonstressed areas only.

3.2.7.3 Electrical and electronic components. Electrical and electronic components not covered by design requirements specified elsewhere within this specification shall be designed in accordance with MIL-E-5400, MIL-E-7080, MIL-STD-454, MIL-STD-461, MIL-W-5088, MIL-M-7969, MIL-M-8609, and the following:

3.2.7.3.1 Dielectric strength. Leakage current shall not exceed 10 milliamps when a dielectric stress voltage of 1,200 volts, 60 Hz, is applied for 1 minute between insulated circuits and between circuits and case; and there shall be no insulation breakdown. When 500V DC is applied between isolated circuits and the case or connector shell for a period of 10 seconds, the resistance shall be at least 50 megohms. When a component or connector has a lower design voltage limitation, the test shall be run at an appropriate lower voltage as defined by the component specification.

3.2.7.3.2 Microelectronics. When used, microelectronic devices shall conform to the provisions of MIL-M-38510.

3.2.7.3.3 Burn-In. All electronic LRUs shall receive a minimum of 50 hours burn-in operation and testing prior to assembly, or after assembly if such is more meaningful, prior to installation. Performance after burn-in shall be within specified tolerances.

3.2.7.3.4 Switches. The design of special electric/mechanical switches, other that toggle switches, shall be subject to the approval of the procuring activity.

3.2.7.3.5 Thermal design of electrical and electronic equipment. Wherever feasible, components shall be designed with heat-dissipating efficiency adequate to allow simple conductive, radiation, and free convection cooling utilizing the ambient heat sink to maintain the components within their permissible operating temperature limits. Operation under specified conditions shall not result in damage or impairment of component performance.

3.2.7.3.6 Potentiometers. Resistive variable voltage dividers shall not be used in dynamic motion applications such as sensor outputs or feedback output devices without specific approval by the procuring agency.

3.2.8 Component fabrication. The selection and treatment of materials processing, and assembly, may be in accordance with established contractor techniques, in lieu of the following requirements, upon approval by the procuring activity.

3.2.8.1 Materials. When Government specifications exist for the type material being used, the materials shall conform to these specifications. Nonspecification materials may be used if it is shown that they are more suitable for the purpose than specification materials. These materials shall have no adverse effect upon the health of personnel when used for their intended purposes. This requirement shall be met for all probable failure modes and in the required environments.

3.2.8.1.1 Metals. Metals used in flight control system components shall be selected in accordance with the criteria and requirements specified in AFSC Design Handbook DH 1-2, Design Note DN 7A1, Metals.

3.2.8.1.2 Nonmetallic materials. Nonmetallic materials, shall conform to the requirements specified in AFSC Design Handbook DH 1-2, Design Note DN 7A2, Nonmetals.

3.2.8.1.3 Electric wire and cable. Electrical wire cables containing up to seven conductors shall be constructed in accordance with MIL-C-27500. Airframe wire bundles may be constructed in accordance with contractor developed techniques provided such construction is approved by the procuring activity.

3.2.8.2 Processes

3.2.8.2.1 Construction processes. Heat treating, adhesive bondings, welding, brazing, soldering, plating, drilling, and grinding of high strength steels, materials inspection, castings, forgings, sandwich assemblies, and stress corrosion factors used in the fabrication of flight control system components shall comply with the requirements specified in AFSC Design Handbook DH 1-2, Design Note DN7B1, Construction.

3.2.8.2.2 Corrosion protection. All flight control system component parts, except those inherently resistant to corrosion in the operational environments, shall be finished per AFSC Design Handbook DH 1-2, Design Note DN7B2, Corrosion.

3.2.8.2.3 Fabrication of electrical and electronic components. The applicable requirements in AFSC Design Handbook DH 1-6, Design Note DN3H1, Electrical/Electronic Safety Design Considerations, relating to the fabrication of electrical and electronic components shall be met.

3.2.8.3 Assembling

3.2.8.3.1 Mechanical joining. Individual parts may be mechanically joined with removable fasteners, or by riveted or threaded connections, or by qualified methods for permanent joining.

3.2.8.3.1.1 Joining with removable fasteners. All removable fasteners shall be selected and used in accordance with the applicable requirements specified in AFSC Design Handbook DH 1-2, Design Notes 4A1, General Requirements, 4A3, Bolts, Nuts, and Washers; 4A4, Screws; 4A5, Pins; and 4A6, Other Fasteners except as follows:

a. Bolts smaller than 1/4 inch in diameter shall not be used to make single-bolt connections or connections essential to proper functioning of the component.

b. Each removable bolt, screw, nut, pin, or other removable fastener, the loss of which would degrade operation below FCS Operational State III, shall incorporate two separate locking or retention devices either of which must be capable of preventing loss of the fastener by itself and retain it in its proper installation with the other locking or retention device missing, failed, or malfunctioning. Where self-retaining bolts are used, their selection and installation shall be within the limitations of MS33602, and only one type shall be used in any given system.

c. No self-locking nut may be used on any bolt subject to rotation in operation unless a nonfriction locking device is used in addition to self-locking device.

d. Lockbolts listed in AFSC Handbook DH 1-2, Design Note 4A5, Swaged-Collar-Headed Straight Pins and Collars, may be used for fastening applications not requiring removal on the aircraft.

3.2.8.3.1.2 Joining with rivets. Rivets for all riveted joints shall be selected and used in accordance with the requirements specified in AFSC Design Handbook DH 1-2, Design Note 4A2, Rivets.

3.2.8.3.1.3 Threaded joints. All threaded joints shall be provided with adequate wrenching and holding provisions for assembly and disassembly of the joint before and after service use. Internal screw threads and external rolled threads shall be in accordance with the thread form requirements of MIL-S-8879. Pipe threads shall not be used.

3.2.8.3.2 Joint retention. All adjoining parts shall be secured in a manner that will preclude loosening when subjected to internal or external loads or vibration.

3.2.8.3.2.1 Retention of threaded joints. All threaded joints which carry critical loads shall be positively locked in the assembled position so that load reversal at the threads is prevented. The use of jam locknuts alone is not a positive locking means unless lockwired or otherwise restrained.

3.2.8.3.2.2 Retention of removable fasteners. Unless restrained from moving by the attachment of adjoining parts, all removable fasteners shall be positively locked in place. Self-locking externally threaded fasteners shall not be used except within the limitations specified in MS15981, and self-locking nuts shall not be used except within the limitations specified in MS33588. All other types shall incorporate positive locking means or be safetied with cotter pins in accordance with MS24665, where temperature and strength permit, or be safety wired. Cotter pins and safety wiring shall be installed in accordance with MS33540.

3.2.8.3.2.3 Use of retainer rings. Retainer rings shall not be used to retain loaded parts unless the rings are positively confined by a means other than depending on internal pressure or external loads. They shall not allow freeplay which could result in structurally destructive action or fatigue failure of the retained parts or failure of gaskets or packings. Where used, retainer rings shall be commercially available types which can be installed and removed with standard tools.

3.2.8.3.3 Assembly of electronic components

3.2.8.3.3.1 Electrical and electronic part mounting. Electronic parts shall be mounted so that ease of producibility and maintainability is assured. Whenever feasible, parts such as resistors, capacitors, etc. shall be mounted in an even, regular, row-type arrangement. These parts shall be mounted on a base so that the leads do not cross other leads or connections. Heavy electronic parts and assemblies shall be solidly mounted so that adverse effects when subjected to vibration and shock are minimized.

3.2.8.3.3.2 Shielding and bonding on finished surfaces. Nonconductive oxides or other nonconductive finishes shall be removed from the actual contact area of all surfaces required to act as a path for electric current and from local areas to provide continuity of electrical shielding or bonding. All mating surfaces shall be clean and shall be carefully fitted, as necessary, to minimize radio frequency impedance at joints, seams, and mating surfaces. The resultant exposed areas, after assembly at such joints or spots, shall be kept to a minimum.

3.2.8.3.3.3 Isolation of redundant circuits. Redundant circuits shall be isolated from each other to preclude failure of one portion of the circuit from affecting any other circuit.

3.2.8.3.3.4 Electrical connector installation. The number of electrical connectors shall be kept to a minimum within the required limitations for separation of redundant circuits. Connectors shall be mounted to preclude nuisance warning indications and intermittent operation when subjected to applicable temperature differentials, vibration, and shock. They shall be polarized so that it is impossible to mismate them on a particular piece of equipment.

3.2.8.3.3.5 Cleaning of electrical assemblies. All electrical assemblies shall be thoroughly cleaned of loose, spattered, or excess solder, metal chips, or other foreign material after assembly. Burrs, sharp edges and resin flash shall be removed.

3.2.9 Component installation

3.2.9.1 Basic requirements. Flight control system components shall be installed in compliance with the applicable requirements specified in AFSC Design Handbook DH 1-6, Section 3J, Flight Control Systems, including Design Note 3JX, Safety Design Check List, and as specified herein.

3.2.9.2 Locating components. System components shall be located to provide direct routing of the control system signal and power transmission elements (cables, rods, lines, wires, etc.) in accordance with Design Note 3J1, Routing and Separation, only to the extent that the components and transmission elements are not exposed to undue hazards.

3.2.9.3 Installation in fuel system areas. All component installations in fuel system areas shall preclude the generation of sparks both during normal operations and possible abnormal and failure conditions.

3.2.9.4 Electrical and electronic component installation. In addition to the requirements specified in AFSC Design Handbook DH 1-6, Section 3J, the applicable requirements in Design Notes DN 3H1, Electrical/Electronic Safety Design Considerations and DN 3H2, Installation Safety Objectives, shall be met.

3.2.9.5 Electrical and electronic equipment cooling. If cooling augmentation is required, the installation of flight control electrical and electronic equipment cooling shall be integrated with the cooling provisions for other electrical and electronic equipment. The requirements specified in AFSC Design Handbook DH 1-6, DN 3H1, Temperature shall be met.

3.3 Rotary wing performance and design.* All requirements of this specification shall be satisfied by rotary wing aircraft except where specifically noted to apply to other types of aircraft, for example, 3.2.1.1, Pilot Controls for CTOL Aircraft, or where modified by requirements denoted by an asterisk specifically for rotary wing aircraft. Special rotary wing performance and design requirements are as follows:

3.3.1 Special manual FCS performance requirements.* Rotary wing aircraft shall meet the flying qualities requirements specified in MIL-F-83300.

3.3.2 Special automatic FCS performance requirements.* The attitude and heading hold accuracies specified in the following paragraph apply under conditions of fixed collective pitch control only. Allowable magnitudes and settling times of perturbations induced by variations in collective pitch control shall be as specified by the procuring activity.

3.3.2.1 Attitude hold (pitch, roll, and yaw).* During the attitude hold mode, the attitude, in calm air, shall be maintained within ±1 degree of the reference attitude. The dynamic requirements of 3.1.2.1 shall be met.

3.3.2.2 Heading hold and heading select.* The automatic flight control shall maintain heading within ±1 degree of commanded heading in forward flight at speeds above 40 knots indicated. The aircraft shall not overshoot the selected heading by more than 2.5 degrees at speeds above 60 knots. The roll rate shall not exceed 5.0 degrees per second and roll acceleration shall not exceed 3.0 degrees per second for MIL-F-83300 Class II and III aircraft or double these values for MIL-F-83300 Class I and IV aircraft.

3.3.2.3 Altitude hold*

3.3.2.3.1 Barometric altitude stabilization.* The requirements of 3.1.2.5 shall be met when the helicopter is outside the ground effect as defined for the specific helicopter.

3.3.2.3.2 Stabilization of altitude above the terrain.* The operational range of the absolute altitude control mode shall be as specified in the applicable system specification. Within this range, the helicopter shall be controlled to the indicated absolute altitude with an accuracy, in calm air while over flat terrain, of ±7 feet ±sensor error.

3.3.2.4 Hover hold.* For MIL-F-83300 Class II helicopters, position shall be maintained with a drift of less than 20 feet plus sensor error over a 2 minute period. Altitude shall be maintained in ground effect within ±5 feet over a 5 minute period. Where special mission requirements dictate, the contractor shall establish further requirements, subject to procuring activity approval.

3.3.2.5 Vernier control for hovering.* Vernier control shall be provided for accurate positioning of the aircraft during hovering, unless control commensurate with minimum accuracy requirements can be obtained with the regular controls.

3.3.2.6 Groundspeed hold.* Where groundspeed hold is a system requirement, provisions shall be made to insert groundspeed signals to the cyclic pitch and roll controls. After engagement of the groundspeed hold mode, the ground speed existing at the time of engagement shall be held in steady flight in calm air within ±3 knots.

3.3.3 Special design requirements *

3.3.3.1 Manual FCS design *

3.3.3.1.1 Control feedback.* The control device motion and force required to accomplish stability and control augmentation shall not be reflected at the aircraft's cockpit control. Force feedback shall be considered as not reflected at the controls if the magnitude is less than half the breakout force of the control with lowest breakout force. If other control device motions are not to be reflected at the cockpit controls, the proposed system shall be approved by the procuring activity. Full freedom of operation of cockpit controls shall be possible at all times stability augmentation is in use. Provisions shall be made in cockpit control motions so that recovery from an augmentation actuation hardover is possible under all flight conditions. The cockpit control position may shift under this condition.

3.3.3.1.2 Feel augmentation.* The pilot and copilot shall have the capability of overriding the feel system at all times. Upon failure of the feel augmentation system the control feel shall revert to a breakout force and a force gradient versus deflection required by MIL-F-83300.

3.3.3.2 AFCS design.* Integration of the automatic flight control system with the manual flight control system shall not cause the control feel to depart from that specified in MIL-F-83300. Subsystems that trim control forces to zero shall not introduce control transients that degrade flying qualities.

3.3.3.3 Swashplate power actuators *

3.3.3.3.1 Redundancy.* Swashplate power actuators which are essential to flight of the aircraft shall be redundant. Where redundant actuators are used, the control valves shall also be redundant.

3.3.3.3.2 Jamming.* The swashplate power actuator in aircraft subject to combat damage shall be jamproof. The treat shall be specified by the procuring activity.

3.3.3.3.3 Frequency response.* The swashplate power actuator frequency response shall be adequate to meet the flying qualities requirements of MIL-F-83300 when operated in series with the direct linkage and rotating controls.

3.3.3.4 Actuation stiffness.* The stiffness of the swashplate support, in conjunction with rotor blade torsional stiffness, shall be adequate to minimize control loads and shaking forces generated by the rotor.

3.3.3.5 Fatigue life design.* Components shall be designed to a minimum safe-life of 3,600 hours, except for seals. Seals shall be designed for a minimum life of 1,200 hours. Fatigue lives shall be substantiated by component bench testing and flight strain survey. Fatigue lives shall be determined using actual bench test strengths and measured flight loads.

3.3.3.5.1 Fail-safe.* Components subject to fatigue loads shall not only be designed to safe-life but also shall be designed fail-safe. Fail-safe design shall be achieved through either a redundant load path, a failure warning system, or a damage tolerant/free design.

3.3.3.5.2 Display.* Subsystems that continuously display on cockpit indicators the fatigue loading or rotor or dynamic system components shall be redundant if an erroneous display due to a subsystem failure could result in advertent accumulation of fatigue damage.

3.3.3.6 Built-in test. * Rotary wing aircraft with powered control systems shall have provisions for checking single system operation of the redundant flight control systems during flight and during ground operation in accordance with MIL-T-5522. This requirement does not apply to single power systems using manual reversion for emergency operation.

* Special rotary wing aircraft requirements.

4. QUALITY ASSURANCE

4.1 General requirements

4.1.1 Methods for demonstration of compliance. Flight control system compliance with each of the applicable design requirements of this specification or the FCS specification defined by 4.4.2 shall be verified using one or more of the following methods. Except where a specific method is required, selection of the method of proof shall be made by the contractor subject to concurrence of the procuring activity.

4.1.1.1 Analysis. Compliance with requirements in cases where testing or inspection would be hazardous or otherwise impractical may be verified through analyses. These analyses may be linear or nonlinear and may include piloted and nonpiloted simulations, as defined by the FCS development plan.

4.1.1.2 Inspection. Compliance with requirements associated with referenced component specifications, the physical arrangement of parts, or the physical relationship of parts shall be verified by inspection of documentation or inspection of the physical installation. Documentation may include documents showing the qualification status of components which have been qualified to the requirements specifications, or drawings showing clearances or other physical relationships. The FCS development plan shall define those requirements to be verified through inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1.3 Test. To the maximum extent feasible, compliance with the quantitative requirements of the FCS specification shall be demonstrated by tests. Tests shall include the laboratory, airplane ground and flight tests defined in the FCS development plan.

4.2 Analysis requirements. Where compliance with specification requirements through analytical predictions is used, the contractor shall define the major assumptions and approximations used and verify that the modeling and analysis procedures used are conservative. Verification shall normally require prior use and validation through comparison with flight, wind tunnel or ground testing data. In all cases the contractor shall establish tolerances on analytical predictions used to demonstrate compliance with specification requirements. These tolerances shall reflect anticipated variations in system or component characteristics such as:

a. Parameters that change with temperature, atmospheric pressure and other environmental factors.

b. Parameters that change with failures or manufacturing tolerances.

c. Parameters that critically affect system performance or stability.

d. Parameters that are not accurately known (if they are significant).

e. Parameters that change as a result of aging or wear.

4.2.1 Piloted simulations. Piloted simulations shall be performed during FCS development. As a minimum, the following simulations shall be accomplished:

a. Piloted simulations using computer simulation of the FCS prior to hardware availability.

b. Piloted simulations using actual FCS hardware prior to first flight.

4.3 Test requirements

4.3.1 General test requirements

4.3.1.1 Test witness. Before conducting a required test, the contractor shall notify an authorized procurement activity representative. An orientation briefing on specific test goals and procedures shall be given procuring activity observers prior to any required test sequence to be monitored by an observer.

4.3.1.2 Acceptance tests. Appropriate FCS acceptance tests will be defined by the procurement detailed specification.

4.3.1.3 Instrumentation. Accuracy of instruments and test equipment used to control or monitor test parameters shall have been verified since its last use prior to initiation of the sequence of design verification tests. All instruments and test equipment used in conducting design verification tests shall:

a. Conform to laboratory standards whose calibration is traceable to the prime standards at the U.S. Bureau of Standards.

b. Be accurate to within one third the tolerance for the variable to be measured.

c. Be suitable for measuring the test parameter(s).

d. Be verified no less frequently than every 12 months.

4.3.1.4 Test conditions. The contractor shall establish operation test conditions which accurately represent system in-service usage throughout the applicable flight phases and flight envelopes defined in accordance with MIL-F-8785 or MIL-F-83300.

4.3.2 Laboratory tests

4.3.2.1 Component tests. All components shall be qualified to the applicable component specification by individual tests, by proof of similarity to qualified components which are qualified under conditions applicable to the specified operating conditions, by testing in system design verification tests, or suitable combinations of these methods. Component qualification requirements shall be based upon their use in the specific vehicle and its associated environment. Environmental test methods and procedures shall be selected from MIL-STD-461, or MIL-STD-810. The contractor shall generate additional methods and procedures where MIL-STD-461 or MIL-STD-810 are inadequate for the planned aircraft usage. Wear life 3.1.12 shall be demonstrated at the component level except where system wear life is more meaningful due to component interaction.

4.3.2.2 Functional mockup and simulator tests. Where one of the first airplanes in a new series of aircraft will not be available for extensive testing of the FCS prior to flight of that model, an operational mockup which functionally, statically and dynamically duplicates the flight control system shall be constructed. For essential and flight phase essential flight controls, an accurate electrical representation shall also be provided. Production configuration components shall be used for all flight control system parts, and the hydraulic system shall be compatible with MIL-H-5440 test requirements. Primary aircraft structure need not be duplicated; however, production configuration mounting brackets shall be used and shall be attached to structure which simulates actual mounting compliance. Mechanical components of the FCS shall be duplicated dimensionally. Inertia and compliance of flight control surfaces shall be duplicated or accurately simulated. The operational mockup shall be coupled with a computer simulation of aircraft characteristics and external inputs to the flight control system. The following minimum testing shall be conducted on the operational mockup, or other appropriate test facility when approved by the procuring activity.

a. Power supply variation tests to demonstrate satisfactory operation over the range of allowable variations specified in the applicable control power specifications referenced in 3.2.5.

b. System fatigue tests (where system installation geometry or dynamic characteristics are critical to fatigue life) in accordance with MIL-A-8867 to demonstrate compliance with the requirements of 3.1.11.3. The duty cycle required shall be established by the contractor as representative of flight and ground usage.

c. Stability margin tests to verify those requirements of 3.1.3.6 which can be verified by test using an aircraft simulation or the operational mockup, but which cannot be economically or safely demonstrated in flight.

d. Tests to determine the effects of single and multiple failures on performance, safety, and mission completion reliability; and the development of emergency procedures to counteract the effects of failures.

e. Miscellaneous tests to demonstrate FCS performance, and compatibility among FCS systems and with interfacing systems.

f. System wear life 3.1.12 where component wear life is interactive.

4.3.2.3 Safety-of-flight tests. Prior to first flight, sufficient testing shall be accomplished to ensure that the aircraft is safe for flight. These shall be defined in the FCS development plan and shall include, but not be limited to, the following:

4.3.2.3.1 Component safety-of-flight tests. All system components shall successfully demonstrate satisfactory performance and satisfactory operation under the environmental extremes expected in the flight test program. Certification that a component is safe for flight because of prior qualification and use on other aircraft may be allowed provided that the component design is identical to the previously qualified part in all significant respects and that its capability to operate under all conditions specified for its new application has been proven.

4.3.2.3.2 System safety-of-flight tests. The complete system shall successfully pass all of the operational mockup tests specified in 4.3.2.2 prior to first flight except that only 20 percent of the required fatigue life demonstration need be completed.

4.3.3 Aircraft ground tests. Prior to first flight the following minimum testing shall be performed.

a. Gain margin tests to demonstrate the zero airspeed 6 dB stability margin requirements of 3.1.3.6 for feedback systems depending on aerodynamics for loop closure and to demonstrate stability margins for nonaerodynamic loops. Primary and secondary structure shall be excited, with special attention given to areas where feedback sensors are located with loop gains increased to verify the zero airspeed requirement.

b. Functional, dynamic and static tests to demonstrate that all FCS equipment items are properly installed and that steady state responses meet FCS specification requirements. These tests shall include integrated FCS and test instrumentation as installed on the prototype airplane. Compliance with the applicable residual oscillation requirements of 3.1.3.8 shall be demonstrated.

c. Electromagnetic interference (EMI) tests to demonstrate compliance with the requirements of 3.2.5.4.1. Measurement of interference limits shall be made in accordance with MIL-STD-461 and MIL-E-6051.

d. An integrity test to insure soundness of components and connections, adequate clearances, and proper operation in accordance with MIL-A-8867.

4.3.4 Flight tests. Flight tests shall be conducted, as defined in the FCS development plan, to demonstrate compliance with requirements where compliance cannot reasonably be demonstrated by other tests or analyses. The design and test condition guidelines tabulated in MIL-F-8785 shall be considered in establishing the flight test plan. Flight test data shall be used to verify the analytical trends predicted and shall be compared to the performance and design requirements of the FCS specification. Comparable data trends shall be required for verification where analytical data is used to extend or extrapolate flight test data to show compliance. In addition, tests shall be conducted to assure that the flight control system, in all operational states, does not violate the flutter requirements of MIL-A-8870.

4.4 Documentation. FCS data submittal and approval requirements for each specific model aircraft shall be in accordance with contract requirements. The data shall be furnished in accordance with appropriate line items of the Contractor Data Requirements List (DD Form 1423). Typical information and data items are listed in this section.

4.4.1 Flight control system development plan. A flight control system development plan shall be prepared by the contractor for approval by the procuring activity. This plan shall be revised and updated at intervals as specified by the procuring activity until it is mutually agreed that no further revision is required. The plan shall include a minimum of:

a. A detailed milestone chart showing the interrelationship between phases of development work to be accomplished. Design reviews shall be identified and scheduled and an outline of the progressive design verification process to be used by the contractor shall be included. Starting and completion dates for all work items and due dates for all reports shall be identified.

b. A FCS synthesis and analysis plan describing the general approach and analytical procedures to be used. Analyses planned to generate requirements for the FCS specification shall be described.

c. A verification plan defining the means selected by the contractor for verifying that the design meets each of the requirements of the FCS specification. Verification means shall be specifically correlated with each specification requirement.

d. Flight safety, reliability, maintainability, and vulnerability analysis plans to include a description of the analytical or other means selected by the contractor for design verification in these areas.

e. A functional mockup test plan, including the test procedures to be used and a listing of requirements to be satisfied by each test.

f. A ground test plan and ground test procedures defining the ground tests and functional checks to be performed prior to first flight.

g. A flight test plan and detailed flight test procedures. Each procedure shall be correlated with one or more requirements of the FCS specification.

4.4.2 Flight control system specification. The contractor shall prepare a flight control system specification incorporating:

a. Applicable general system, implementation, and test requirements of this specification.

b. Special requirements of the procurement air vehicle detail specification.

c. Special requirements determined by the contractor, as required by the general specification.

A preliminary FCS specification shall be prepared within 90 days of contract award and progressively updated, as requirements are finalized.

4.4.3 Design and test data requirements. If applicable design data are available the contractor shall, in lieu of preparing new design data, use these available data supplemented by sufficient information to substantiate their applicability.

4.4.3.1 FCS analysis report. A report describing FCS analysis shall be prepared using an outline prepared by the contractor, subject or procuring activity approval. This report shall be initially prepared immediately following the preliminary FCS analysis and synthesis and periodically updated throughout the development period. The final update shall include as a minimum:

a. Design requirements and criteria used during the FCS analysis and synthesis.

b. Block diagrams of the FCS. These diagrams shall include transfer or describing functions and indicate normal control paths, redundancy, manual overrides, emergency provisions, location and type of sensors and control device used.

c. A general description of the FCS. The various modes of operation shall be described and the theory of operation discussed.

d. Discussions of unusual or difficult design features and problems.

e. A description of the stability and performance of the FCS and a correlation of system characteristics with the requirements of the FCS specification. Data shall be presented for both linear, small perturbation analyses and for non-linear simulations or analyses which consider nonlinearities such as actuator rate, electronic amplifier saturation, and actuator position limits. Where analytical predictions are used to satisfy specification requirements, the assumptions, analytical approximations and the tolerances placed on these analytical predictions by the contractor shall be documented and justified.

f. Results of the FCS flight safety, reliability, maintainability and vulnerability analyses. The reliability analysis results shall include a detailed listing of possible failure modes. The approach and sources of data used shall be discussed and the results compared to and correlated with requirements of the FCS specification. Analytical methods used shall be documented and justified by the contractor.

g. A general control system layout or series of layouts showing control surfaces, actuation systems, feel systems, pilot's controls and control panel organization. Means of providing redundancy and emergency provisions shall be illustrated. Layouts shall include wiring schematics for all electrical and electronic portions or the FCS and attendant electrical, hydraulic, and pneumatic power inputs to the FCS.

h. A description of piloted simulations performed, as required by 4.2.1. Where piloted simulation data is used to verify specification requirements, the simulator and flight configurations simulated shall be described and the data compared to and correlated with the requirements of the FCS specification.

i. Mathematical models of the FCS, the unaugmented airplane and other data required to allow the procuring activity to independently simulate the FCS at any point during or following the aircraft development process. Mathematical models, block diagrams, stability and performance data and layouts shall be updated following flight tests to incorporate modifications made during testing.

4.4.3.2 FCS qualification and inspection report. The contractor shall document results of inspections used to demonstrate compliance with requirements of the FCS specification. Where inspection of component qualification status documentation is used to verify compliance with the FCS specification, the contractor prepared component specification shall be submitted as a part of the FCS inspection report.

4.4.3.3 FCS test report. A report describing and correlating tests performed and data generated to verify requirements of the FCS specification shall be prepared by the contractor. This report may be prepared in volumes, and shall include a minimum of:

a. A detailed description of the operational mockup including part numbers and the test conditions under which data was generated and a comparison of the FCS specification. Inclusion or exclusion of control surface aerodynamic hinge moments, simulation of aircraft structural compliance in lieu of airframe parts or use of other approximations in operational mockup construction shall be justified. All discrepancies or corrective actions arising from operational mockup testing shall be reported.

b. A description of the airplane ground tests performed and data generated and a discussion of any system adjustments or modifications required to satisfy requirements of the FCS specification.

c. A comparison of flight test data with requirements of the FCS specification and a description of the airplane configurations and flight conditions tested. Modifications to the FCS made during the flight test phase to meet FCS specification requirements shall be documented and justified.

5. PREPARATION FOR DELIVERY

5.1 Packaging requirements. In the event of direct purchases by or shipments to the Government, the packaging shall be in accordance with the contract or the approved component or subsystem specification, as applicable. Components shall be delivered complete, tested, and ready for installation.

6. NOTES

6.1 Intended use. This is a general requirements specification applicable to flight control systems and is based upon service experience to date. Deviations to the requirements of the specification may be granted following presentation and approval of substantiating data.

6.2 Procedure for requesting deviations. The requirements of MIL-STD-480 shall be met. Substantiating data shall be in the form of a test, simulation or analytical data generated by the contractor during design tradeoffs.

6.3 Reordered equipment or second source procurement. Where models or drawings of components of systems are furnished by the procuring activity on a contract to facilitate interchangeable construction, or where procurement is for equipment to provide interchangeable use with equipment previously procured, and the requirements for interchangeability contradict the current requirements of one or more MIL specifications, the contract requirements for interchangeability govern.

6.4 User's guide. A background information and user's guide, AFFDL-TR-74-116, provides explanations of the justification for the requirements of this general specification.

6.5 Abbreviations

AFCS	-	Automatic Flight Control System
BIT	-	Built-in-Test
CDRL	-	Contractual Data Requirements List
C.G.	-	Center of Gravity
CTOL	-	Conventional Takeoff and Landing
EFCS	-	Electrical Flight Control System
EMI	-	Electromagnetic Interference
EMP	-	Electromagnetic Pulse
FCS	-	Flight Control System
g	-	Gravitational Constant
LRU	-	Line Replaceable Unit
MFCS	-	Manual Flight Control System
MPS	-	Motor-Pump-Servoactuator Package
TAS	-	True Airspeed
VOR	-	Very High Frequency Omnidirectional Range
V/STOL	-	Vertical/Short Takeoff and Landing

6.6 Definitions

Airspeeds. Airspeeds referenced within this specification are as defined in either MIL-F-8785 or MIL-A-8860. MIL-F-8785 defines airspeeds associated with flying qualities and MIL-A-8860 defines airspeeds related to loading and flutter.

Alert height. A height (100 feet or less above the highest elevation in the touchdown zone), based upon the characteristics of the aircraft and the particular airborne Category III system above which a Category III approach would be discontinued and a missed approach executed if a failure occurred in one of the required redundant operational systems in the aircraft or in the ground equipment.

All weather landing system. An all weather landing system includes specifically all the elements of airborne equipment and more generally includes the ground-based equipment necessary for completion of the all weather landing. All weather landings comprise the operations and procedures required to conduct approaches and landings during Category II and III visibility conditions defined by the International Civil Aviation Organization.

Automatic flight control system. See 1.2.1.2

Automatic landing system. A landing system which provides automatic flight control to touchdown or to touchdown and beyond.

Built-in test (BIT). Integral onboard testing devices which enable rapid isolation on the ground of a faulty Line Replaceable Unit (LRU) (either manual or automatic), without removing the LRU from the aircraft. Usually a warning of malfunction is given by an external device on the LRU.

Category I operations. An instrument approach procedure which provides for approaches to a decision height (DH) of not less than 200 feet and visibility of not less than 1/2 mile or RVR (Runway Visual Range) 2,500 feet (RVR 1,800 feet with operative touchdown zone and runway centerline lights).

Category II operations. An instrument approach procedure which provides approaches to minima of less than DH 200 feet/RVR 2,400 feet to as low as DH 100 feet/RVR 1,200 feet.

Category IIIa operations. Operations with no decision height limitation, to and along the surface of the runway with external visual reference during the final phase of the landing and with runway visual range not less than 700 feet.

Category IIIb operations. Operations with no decision height, to and along the surface of the runway with runway visual range not less than 150 feet and with reliance on the system for part or all of the rollout along the runway and with external visual reference for guidance along the taxiway.

Category IIIc operations. Operation with no decision height, to and along the surface of the runway and taxiways without reliance on external visual reference.

Channel. The term describing a single signal or control path within a device or system that may contain many paths. A channel is an entity within itself and contains elements individual to that channel. A model may be used as a reference channel in a detection-correction system.

Classes. Airplane classes are defined using the MIL-F-8785 definitions for the following classes.

Class I Small, light airplanes such as
- Light utility
- Primary trainer
- Light observation

Class II Medium weight, low-to-medium maneuverability airplanes such as
- Heavy utility/search and rescue
- Light or medium transport/cargo/tanker
- Early warning/electronic countermeasures/airborne command, control, or communications relay
- Antisubmarine
- Assault transport
- Reconnaissance
- Tactical bomber
- Heavy attack
- Trainer for Class II

Class III Large, heavy, low-to-medium maneuverability airplanes such as
- Heavy transport/cargo/tanker
- Heavy bomber
- Patrol/early warning/electronic countermeasures/airborne command, control, or communications relay
- Trainer for Class III

Class IV High-maneuverability airplanes such as
- Fighter/interceptor
- Attack
- Tactical reconnaissance
- Observation
- Trainer for Class IV

Where MIL-F-83300 applies, the corresponding MIL-F-83300, Class I, II, or III or IV applies.

Comparison monitor. A device which compares signals and warning outputs from two or more sources and provides its own signal to indicate that the two or more outputs are within or outside specified tolerances.

Control wheel (stick) steering. An AFCS mode which permits pilot manual control inputs to be introduced into the system through the wheel or stick when the AFCS is engaged and controlling the airplane.

Damping ratio. The equivalent second order viscous damping ratio. The critical damping ratio is defined as unity.

Decision height. Decision height, with respect to operation of aircraft means the height at which a decision must be made during an ILS (Instrument Landing System) or PAR (Precision Approach Radar) instrument approach to either continue the approach or to execute a missed approach. This height is expressed in feet above runway datum altitude and for Category II ILS operations, the height is additionally expressed as a radio altimeter reading.

Dual load path. A type of passive paralleling wherein two separate load carrying paths exist. Each load path is capable of carrying sufficient load such that failure of either member will not jeopardize system performance.

Electrical flight control system (EFCS). A flight control system wherein one or more axes of vehicle control is, at one point or another, completely electrical. Non-electrical backup or other reversion means may exist. Electrical flight control is commonly referred to as fly-by-wire, especially where the application is either manual or essential.

Essential FCS. See 1.2.3.1

Extremely remote. The probability of an event occurring which, although theoretically possible, is not expected in the life of an individual aircraft. For the purpose of this specification, the extremely remote probability for a specific aircraft is defined as numerically equal to the maximum aircraft loss rate due to relevant FCS material failures specified in 3.1.7.

Failure. The inability of an item to perform within previously specified limits.

Failure rate. The number of failures of an item per unit measure of life (flights, time, cycles, events, miles, etc.) as applicable for the item.

FCS operational states. See 1.2.2

Firmware. A set of binary machine language instructions stored in read-only memory in a computer for the purpose of providing a step-by-step control of the processor.

Flight control system. See 1.1

Flight director subsystem. A subsystem which provides the pilot a display of actual and desired flight parameters. When operating in a flight director mode, the pilot's task is to minimize the difference between the displayed actual and desired values through control actions.

Flight envelopes. Flight envelopes referred within this specification are defined in MIL-F-8785 and MIL-F-83300.

Flight phase essential FCS. See 1.2.3.2.

Fully-powered control system. See power-operated control

Inflight monitoring. Continuous automatic monitoring of system performance normally performed inflight as a safety check.

Manual flight control system. See 1.2.1.1

Nonaerodynamic loops. Inner feedback loops within an FCS which do not rely on aerodynamics for loop closure. Examples include AFCS servo loops and actuator feedback loops.

Noncritical FCS. See 1.2.3.3

Power-boosted control. A reversible control wherein pilot effort is exerted through mechanical linkages and is boosted, directly in proportion to the input, by a power source.

Power-operated control. An irreversible control wherein the pilot, through mechanical linkages or other means, actuates a power control package to control an aerodynamic surface or other device.

Random failure. Any failure whose occurrence is unpredictable in an absolute sense which is predictable only in a probabilistic or statistical sense. Random failures are those which cannot be attributed to wearout, defective design, or abnormal stress, and can occur at any time within the equipment's useful life.

Redundancy. A design approach such that two or more independent failures, rather than a single failure, are required to produce a given undesirable condition. Redundancy may take the form:

a. Providing two or more components, subsystems, or channels, each capable of performing the given function.

b. Monitoring devices to detect failures and accomplish annunciation and automatic disconnect or automatic switching.

c. Combination of the two above features.

Relevant failure. Any random or normal wearout failure occurring in service prior to end of specified service life when the equipment is properly operated within design load and environmental limits. A normal wearout failure is relatively improbable on a new part, but undergoes a relatively rapid rise in probability of occurrence after an extended period of service (operating hours or calendar time). Wearout is typical of seals, bearings, motor brushes, fatigue-critical structure, etc. A realistic system reliability computation must include proper allowance for such failures wherever they are not avoided by scheduled replacement/overhaul procedures in service.

Reversion. The capability to revert to a backup or alternate control from the normal control means. The alternate control may use mechanical or electrical signal transmission and powered actuation.

Software. A set of instructions intended to be stored in programmable memory of a computer for the purpose of providing step-by-step control to the processor. This includes source program instructions requiring assembly or compilation as well as binary machine language instructions.

Turbulence cumulative exceedance probability. The cumulative probability of experiencing turbulence at an intensity equal to or exceeding a given level. This probability accounts for both the probability or encountering turbulence and the distribution of the RMS intensity of the turbulence, if encountered.

Variable geometry control system. Those components and subsystems which transmit control commands from the pilot(s) and which produce forces and moments to change the aerodynamic configuration of the aircraft. Variable geometry controls include those for changing wing sweep angle and wing incidence angle, folding wing tips, deploying canard surfaces, and varying the angle of the nose of the aircraft with the body.

6.7 Use of limited coordination specifications. Limited coordination Military Specifications may be used when such are in effect on the date of invitation for bid or request for proposal. These specifications carry prefixes, such as MIL-A-008860A(USAF) in lieu of MIL-A-8860(ASG).

6.8 Identification of changes. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

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