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See Section 6 for superseding data

MILITARY SPECIFICATION

FLYING QUALITIES OF PILOTED V/STOL AIRCRAFT

1. SCOPE AND CLASSIFICATIONS

1.1 Scope. This specification contains the requirements for the flying qualities of U.S. military piloted vertical and short takeoff and landing (V/STOL) aircraft operating at speeds less than V_{con}.

1.2 Application. The requirements of this specification shall be applied to assure that no limitations on flight safety or on the capability to perform intended missions will result from deficiencies in flying qualities. The flying qualities for all V/STOL aircraft proposed or contracted for shall be in accordance with the provisions of this specification unless specific deviations are authorized by the procuring activity. Guidance on application of these requirements can be found in the Background Information and User Guide (BIUG) referenced in 6.7. Additional or alternate special requirements may be specified by the procuring activity. For example, if the form of a requirement should not fit a particular vehicle configuration or control mechanization, the procuring activity may at its discretion agree to a modified requirement that will maintain an equivalent degree of acceptability. The requirements of MIL-F-8785 shall apply for operation at speeds in excess of V_{con}.

1.2.1 Ground effect. Requirements are not written specifically for operations in or out of ground effect. The height above ground where compliance must be demonstrated is dictated by the requirements for the particular Flight Phase (1.4) of the operational mission under consideration.

1.2.2 Operation under instrument flight conditions. It is assumed that IFR capability is inherent in all military aircraft operational missions, and therefore the detailed requirements are intended to reflect this assumption. Exceptions to this general assumption are noted in specific requirements.

1.3 Classification of aircraft. For the purpose of this specification, an aircraft shall be placed in one of the following Classes:

Class I   Small, light aircraft such as

- Light utility
- Primary trainer
- Light observation

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Class II Medium weight, low-to-medium maneuverability aircraft such as

- Utility
- Search and rescue
- 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 aircraft such as

- Heavy transport/cargo/tanker
- Heavy bomber
- Patrol/early warning/electronic countermeasures/airborne command, control, or communications relay
- Heavy search and rescue
- Trainer for Class III.

Class IV High-maneuverability aircraft such as

- Fighter/interceptor
- Attack
- Tactical reconnaissance
- Observation
- Combat search and rescue
- Trainer for Class IV.

The procuring activity will assign an aircraft to one of these Classes, and the requirements for that Class shall apply. When no Class is specified in a requirement, the requirement shall apply to all Classes. When operational missions so dictate, an aircraft of one Class may be required by the procuring activity to meet selected requirements ordinarily specified for aircraft of another Class.

1.4 Flight Phase Categories. The Flight Phases have been combined into three Categories which are referred to in the requirement statements. These Flight Phases shall be considered in the context of total missions so that there will be no gap between successive Phases of any flight. In certain cases, requirements are directed at specific Flight Phases identified in the requirement. When no Flight Phase or Category is stated in a requirement, that requirement shall apply to all three Categories. Flight Phases descriptive of most military aircraft missions are:

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Nonterminal Flight Phases:

Category A - Those nonterminal Flight Phases that require rapid maneuvering, precision tracking, or precise flight-path control. Included in this Category are:

a. Air-to-air combat (CO)
b. Ground attack (GA)
c. Weapon delivery/launch (WD)
d. Aerial recovery (AR)
e. Reconnaissance (RC)
f. In-flight refueling (receiver) (RR)
g. Terrain following (TF)
h. Antisubmarine search (AS)
i. Close formation flying (FF)
j. Precision hover (PH)

Category B - Those nonterminal Flight Phases that are normally accomplished using gradual maneuvers and without precision tracking, although accurate flight-path control may be required. Included in this Category are:

a. Climb (CL)
b. Cruise (CR)
c. Loiter (LO)
d. In-flight refueling (tanker) (RT)
e. Descent (D)
f. Emergency descent (ED)
g. Emergency deceleration (DE)
h. Aerial delivery (AD)
i. Hover (H)
j. Nonterminal transition (NT)

Terminal Flight Phases:

Category C - Terminal Flight Phases that are normally accomplished using gradual maneuvers and usually require accurate flight-path control. Included in this Category are:

a. Vertical takeoff (VT)
b. Short takeoff (ST)
c. Approach (PA)
d. Wave-off/go-around (WO)
e. Vertical landing (VL)
f. Short landing (SL)
g. Terminal transition (TT)

When necessary, recategorization or addition of Flight Phases or delineation of requirements for special situations will be accomplished by the procuring activity.

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1.5 Levels of flying qualities. Where possible, the requirements of section 3 have been stated in terms of three values of the stability or control parameter specified. Each value is a minimum condition to meet one of three Levels of acceptability related to the ability to complete the operational missions for which the aircraft is designed. The Levels are:

Level 1: Flying qualities clearly adequate for the mission Flight Phase.

Level 2: Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists.

Level 3: Flying qualities such that the aircraft can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate, or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed.

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:

SPECIFICATIONS

Military

MIL-F-9490 Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification for

MIL-C-18244 Control and Stabilization Systems, Automatic, Piloted Aircraft, General Specification for

MIL-F-18372 Flight Control Systems, Design, Installation and Test of, Aircraft (General Specification for)

MIL-W-25140 Weight and Balance Control Data (for Airplanes and Rotorcraft)

MIL-F-8785 Flying Qualities of Piloted Airplanes

STANDARDS

MIL-STD-756 Reliability Prediction

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(Copies of documents required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General requirements

3.1.1 Operational missions. The procuring activity will specify the operational missions to be considered by the contractor in designing the aircraft to meet the flying qualities requirements of this specification. These missions will include the entire spectrum of intended operational usage.

3.1.2 Loadings. The contractor shall define the envelopes of center of gravity and corresponding weights that will exist for each Flight Phase. These envelopes shall include the most forward and aft center-of-gravity positions as defined in MIL-W-25140. In addition, the contractor shall determine the maximum center-of-gravity excursions attainable through failures in systems or components, such as fuel sequencing, hung stores, etc., for each Flight Phase to be considered in the Failure States of 3.1.6.2. Within these envelopes, plus a growth margin to be specified by the procuring activity, and for the excursions cited above, this specification shall apply.

3.1.3 Moments of inertia. The contractor shall define the moments of inertia associated with all loadings of 3.1.2. The requirements of this specification shall apply for all moments of inertia so defined.

3.1.4 External stores. The requirements of this specification shall apply for all combinations of external stores required by the operational missions. The effects of external stores on the weight, moments of inertia, center-of-gravity position, and aerodynamic characteristics of the aircraft shall be considered for each mission Flight Phase. When the stores contain expendable loads, the requirements of this specification apply throughout the range of store loadings. The external stores and store combinations to be considered for flying qualities design will be specified by the procuring activity. In establishing external store combinations to be investigated, consideration shall be given to asymmetric as well as to symmetric combinations, and to various methods of attachment to the airframe (e.g., single-point sling, multi-point sling, rigid, etc.).

3.1.5 Configurations. The requirements of this specification shall apply for all configurations required or encountered in the applicable Flight Phases of 1.4. A (crew-) selected configuration is defined by the positions and adjustments of the various selectors and controls available (except for the pitch, roll, yaw, thrust magnitude, and trim controls), for example, flap setting, wing-angle setting, duct-rotation setting, nozzle setting,

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stability-augmentation-system (SAS)-selector setting, etc. The selected configurations to be examined must consist of those required for performance and mission accomplishment. Additional configurations to be investigated may be defined by the procuring activity.

3.1.6 State of the aircraft. The State of the aircraft is defined by the selected configuration together with the functional status of each of the aircraft components or systems, thrust magnitude, weight, moments of inertia, center-of-gravity position, and external store complement. The trim setting and the positions of the pitch, roll, and yaw controls are not included in the definition of Aircraft State since they are often specified in the requirements. The position of the thrust magnitude control shall not be considered an element of the Aircraft State when the thrust magnitude is specified in a requirement.

3.1.6.1 Aircraft Normal States. The contractor shall define and tabulate all pertinent items to describe the Aircraft Normal (no component or system failure) State(s) associated with each of the applicable Flight Phases. This tabulation shall be in the format and shall use the nomenclature shown in 6.2. Certain items, such as weight, moments of inertia, center-of-gravity position, thrust magnitude and thrust angle control settings, may vary continuously over a range of values during a Flight Phase. The contractor shall replace this continuous variation by a limited number of values of the parameter in question which will be treated as specific States, and which include the most critical values and the extremes encountered during the Flight Phase in question.

3.1.6.2 Aircraft Failure States. The contractor shall define and tabulate all Aircraft Failure States, which consist of Aircraft Normal States modified by one or more malfunctions in aircraft components or systems; for example, a discrepancy between a selected configuration and an actual configuration. Those malfunctions that result in center-of-gravity positions outside the center-of-gravity envelope defined in 3.1.2 shall be included. Each mode of failure shall be considered. Failures occurring in any Flight Phase shall be considered in all subsequent Flight Phases.

3.1.6.2.1 Aircraft Special Failure States. Certain components, systems, or combinations thereof may have extremely remote probability of failure during a given flight. These failure probabilities may, in turn, be very difficult to predict with any degree of accuracy. Special Failure States of this type need not be considered in complying with the requirements of section 3 if justification for considering the Failure States as Special is submitted by the contractor and approved by the procuring activity.

3.1.7 Operational Flight Envelopes. The Operational Flight Envelopes define the boundaries in terms of speed, altitude, and load factor within which the aircraft must be capable of operating in order to accomplish the

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missions of 3.1.1. Additional envelopes in terms of parameters such as rate of descent, flight-path angle, and side velocity may also be specified. Envelopes for each applicable Flight Phase shall be established with the guidance and approval of the procuring activity. In the absence of specific guidance, the contractor shall use the representative conditions of table I for the applicable Flight Phases.

3.1.8 Service Flight Envelopes. For each Aircraft Normal State (but with thrust varying as required), the contractor shall establish, subject to the approval of the procuring activity, Service Flight Envelopes showing combinations of speed, altitude, and load factor derived from aircraft limits as distinguished from mission requirements. Additional envelopes in terms of parameters such as rate of descent, flight-path angle, and side velocity may also be specified. A certain set or range of Aircraft Normal States generally will be employed in the conduct of a Flight Phase. The Service Flight Envelopes for these States, taken together, shall at least cover the Operational Flight Envelope for the pertinent Flight Phase. The speed, altitude, and load factor boundaries of the Service Flight Envelopes shall be based on considerations discussed in 3.1.8.1, 3.1.8.2, 3.1.8.3, 3.1.8.4, and 3.1.8.5.

3.1.8.1 Maximum service speed. The maximum service speed, V_{max}, for each altitude below the service ceiling for the configuration under consideration is the lowest of:

a. The maximum permissible speed

b. The speed which is a safe margin below the value at which intolerable buffet or structural vibration is encountered

c. The speed limited by an extreme nose-down pitch attitude

d. The maximum airspeed, in descents, from which recovery can be made without penetrating a safe margin from loss of control, intolerable buffet, or other dangerous behavior, and without exceeding structural limits.

3.1.8.2 Minimum service speed. The minimum service speed, V_{min}, for each altitude below the service ceiling for the configuration under consideration, in fore and aft flight, is the highest algebraically of:

a. 35 knots rearward (-35 knots)

b. The speed which is a safe margin above the speed at which intolerable buffet or structural vibration is encountered

c. A speed limited by reduced forward field of view or extreme nose-up pitch attitude

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TABLE I

Representative Limits for Operational Flight Envelopes

FLIGHT PHASE CATEGORY	FLIGHT PHASE	AIRSPEED		ALTITUDE		LOAD FACTOR	
		$V_{o_{min}}$	$V_{o_{max}}$	$h_{o_{min}}$	$h_{o_{max}}$	$n_{o_{min}}$	$n_{o_{max}}$
	AIR-TO-AIR COMBAT (CO)	X	V_{con}	MSL	COMBAT CEILING	-1.0	n_L
	GROUND ATTACK (GA)	0	V_{con}	MSL	MEDIUM	-1.0	n_L
	WEAPON DELIVERY LAUNCH (WD)	V_{range}**	V_{con}	MSL	COMBAT CEILING	0.5	*
A	AERIAL RECOVERY (AR)	0	V_{con}	MSL	COMBAT CEILING	0.5	n_L
	RECONNAISSANCE (RC)	35 KT	V_{con}	MSL	COMBAT CEILING	*	*
	IN-FLIGHT REFUELING (RECEIVER) (RR)	35 KT	V_{con}	MSL	COMBAT CEILING	0.5	2.0
	PRECISION HOVERING (PH)	X	35 KT	MSL	COMBAT CEILING	0.9	1.1
	TERRAIN FOLLOWING (TF)	V_{range}**	V_{con}	MSL	10,000 FT	0	3.5
	ANTISUBMARINE SEARCH (AS)	35 KT	V_{con}	MSL	MEDIUM	0	2.0
	CLOSE FORMATION FLYING (FF)	35 KT	V_{con}	MSL	COMBAT CEILING	-1.0	n_L
	CLIMB (CL)	0	V_{con}	MSL	CRUISING CEILING	0.5	2.0
	CRUISE (CR)	V_{range}**	V_{con}	MSL	CRUISING CEILING	0.5	2.0
	HOVER (H)	X	35 KT	MSL	CRUISING CEILING	0.9	1.1
	LOITER (LO)	.85 V_{end}**	1.3 V_{end}**	MSL	CRUISING CEILING	0.5	2.0
B	IN-FLIGHT REFUELING (TANKER) (RT)	35 KT	V_{con}	MSL	CRUISING CEILING	0.5	2.0
	DESCENT (D)	0	V_{con}	MSL	CRUISING CEILING	0.5	2.0
	NONTERMINAL TRANSITION (NT)	X	V_{con}	MSL	SERVICE CEILING*	0.5	2.0
	EMERGENCY DESCENT (ED)	0	V_{con}	MSL	CRUISING CEILING	0.5	2.5
	EMERGENCY DECELERATION (DE)	0	V_{con}	MSL	CRUISING CEILING	0.5	2.0
	AERIAL DELIVERY (AD)	X	V_{con}	MSL	10,000 FT	0	2.0
C	VERTICAL TAKEOFF (VT)	X	45 KT	MSL	10,000 FT	1.0	2.0
	SHORT TAKEOFF (ST)	**	V_{con}	MSL	10,000 FT	0.5	n_L
	APPROACH (PA)	MINIMUM NORMAL APPROACH SPEED	V_{con}	MSL	10,000 FT	0.5	2.0
	WAVE-OFF/ GO-AROUND (WO)	MINIMUM NORMAL APPROACH SPEED	V_{con}	MSL	10,000 FT	0.5	2.0
	VERTICAL LANDING (VL)	X	45 KT	MSL	10,000 FT	0.5	2.0
	SHORT LANDING (SL)	MINIMUM NORMAL LANDING SPEED**	V_{con}	MSL	10,000 FT	0.5	2.0
	TERMINAL TRANSITION (TT)	X	V_{con}	MSL	SERVICE CEILING**	0.5	2.0

* APPROPRIATE TO THE OPERATIONAL MISSION.

X - AIRSPEED IS 35 KT IN ANY DIRECTION

** BASED ON SELECTED CONFIGURATION.

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d. Other speed at MAT which is a safe margin above the value where pitch, roll, or yaw control available is insufficient to maintain 1-g level flight.

3.1.8.3 Service side velocity. The service side-velocity boundary for the configuration under consideration is defined by the maximum side velocity associated with each speed between V_{max} and V_{min} (as defined by 3.1.8.1 and 3.1.8.2) from which recovery to straight and level flight can be made without penetrating a safe margin from loss of control or other dangerous behavior.

3.1.8.4 Maximum service altitude. The maximum service altitude, h_{max}, for a given speed is the maximum altitude at which a rate of climb of 100 feet per minute can be maintained in unaccelerated flight with MAT.

3.1.8.5 Service load factors. Maximum [and minimum] service load factors, n(+) [n(-)], shall be established as a function of speed for several significant altitudes. The maximum [minimum] service load factor, when trimmed for 1-g flight at a particular speed and altitude, is the lowest [highest] algebraically of:

a. The positive [negative] structural limit load factor

b. The steady load factor at which the pitch control is in full aircraft-nose-up [nose-down] position with the thrust magnitude control in a position to maximize [minimize] the load factor

c. A safe margin below [above] the load factor at which intolerable buffet or structural vibration is encountered.

3.1.9 Permissible Flight Envelopes. The Permissible Flight Envelopes encompass all regions in which operation of the aircraft is both allowable and possible. These are the boundaries of flight conditions outside the Service Flight Envelope which the aircraft is capable of safely encountering. Transient load factors, power settings, and emergency thrust settings may be representative of such conditions. The Permissible Flight Envelopes define the boundaries of these areas in terms of velocity, altitude, and load factor. Additional envelopes, in terms of parameters such as rate of descent, flight-path angle, and side velocity may also be specified.

3.1.9.1 Maximum permissible speed. The maximum permissible speed for each permissible altitude for the configuration under consideration shall be the lowest of:

a. The limit speed based on structural considerations

b. The limit speed based on engine considerations

c. The speed at which intolerable buffet or structural vibration is encountered

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d. The maximum airspeed, in descents, from which recovery can be made without encountering loss of control, intolerable buffet or structural vibration, and without exceeding structural limits.

3.1.9.2 Minimum permissible speed. The minimum permissible speed for each permissible altitude for the configuration under consideration, in fore and aft flight, shall be the highest algebraically of:

a. 35 knots rearward (-35 knots)

b. The speed, at MAT, below which pitch, roll, or yaw control available is insufficient to maintain 1-g level flight

c. The speed below which intolerable buffet or structural vibration is encountered.

3.1.10 Applications of Levels. Levels of flying qualities as indicated in 1.5 are employed in this specification in realization of the possibility that the aircraft may be required to operate under abnormal conditions. Such abnormalities that may occur as a result of flight outside the Operational Flight Envelope, the failure of aircraft components, or both, are permitted to comply with a degraded Level of flying qualities as specified in 3.1.10.1 through 3.1.10.3.3.

3.1.10.1 Requirements for Aircraft Normal States. The minimum required flying qualities for Aircraft Normal States (3.1.6.1) are as shown in table II.

TABLE II. Levels for Aircraft Normal States

Within Operational Flight Envelope	Within Service Flight Envelope
Level 1	Level 2

3.1.10.2 Requirements for Aircraft Failure States. When Aircraft Failure States exist (3.1.6.2), a degradation in flying qualities is permitted only if the probability of encountering a lower Level than specified in 3.1.10.1 is sufficiently small. The contractor shall determine, based on the most accurate available data, the probability of occurrence of each Aircraft Failure State per flight and the effect of that Failure State on the flying qualities within the Operational and Service Flight Envelopes. These analyses shall be updated at intervals specified by the procuring activity. These determinations shall be based on MIL-STD-756

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except that (a) all aircraft components and systems are assumed to be operating for a time period, per flight, equal to the longest operational mission time to be considered by the contractor in designing the aircraft, and (b) each specific failure is assumed to be present at whichever point in the Flight Envelope being considered is most critical (in the flying qualities sense). From these Failure State probabilities and effects, the contractor shall determine the overall probability, per flight, that one or more flying qualities are degraded to Level 2 because of one or more failures. The contractor shall also determine the probability that one or more flying qualities are degraded to Level 3. These probabilities shall be less than the values shown in table III.

TABLE III. Levels for Aircraft Failure States

Probability of Encountering	Within Operational Flight Envelope	Within Service Flight Envelope
Level 2 after failure	$< 10^{-2}$ per flight	
Level 3 after failure	$< 10^{-4}$ per flight	$< 10^{-2}$ per flight

In no case shall a Failure State (except an approved Special Failure State) degrade any flying quality outside the Level 3 limit.

3.1.10.2.1 Specific failures. The requirements on the effects of specific types of failures, e.g., propulsion (3.8.9) or flight control system (3.5.5), shall be met on the basis that the specific type of failure has occurred, regardless of its probability of occurrence.

3.1.10.3 Exceptions

3.1.10.3.1 Ground operation. Some requirements pertaining to takeoff, landing, and taxiing involve ground operation outside the Operational, Service and Permissible Flight Envelopes. When requirements are stated for these conditions, the Levels shall be applied as if the conditions were in the Operational Flight Envelope.

3.1.10.3.2 When Levels are not specified. Within the Operational and Service Flight Envelopes, all requirements that are not identified with specific Levels shall be met under all conditions of component and system failure except approved Aircraft Special Failure States (3.1.6.2.1).

3.1.10.3.3 Flight outside the Service Flight Envelope. From all points in the Permissible Flight Envelope, it shall be possible readily and safely to return to the Service Flight Envelope without exceptional pilot skill or technique, regardless of component or system failures. The

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requirements of 3.8.1 and 3.8.2 shall also apply.

3.1.10.3.4 Operation in critical height-velocity conditions. Some propulsion system failures in the critical height-velocity regime may be catastrophic. Although the aircraft would not meet the requirements of 3.1.10.3.3 for flight within the Permissible Flight Envelope following such propulsion system failures, there may be cases where the critical height-velocity conditions will fall within the Operational Flight Envelope for all other Aircraft States because flight under these conditions is essential to accomplishment of the operational missions of 3.1.1. Special requirements may be specified by the procuring activity for conditions encountered during and after the propulsion system failure. The size of the critical height-velocity regime is subject to the approval of the procuring activity.

3.1.11 Cockpit controls. Requirements are written on the basis of conventional cockpit controls, e.g., stick or wheel plus rudder pedals, with either a conventional throttle or a helicopter-type collective control. The form of thrust angle control has not been assumed. Aircraft having cockpit controls other than conventional (e.g., side arm control) are excluded from the requirements which reflect the type of control (e.g., response to a 1-inch stick deflection), but not others (e.g., roll performance requirements). The procuring activity will impose alternate requirements for nonconventional cockpit controls.

3.2 Hover and low speed. The hover and low-speed requirements apply to those Flight Phases of the operational missions of the aircraft which include hovering at zero ground speed in steady winds from any direction up to the limits of the Service Flight Envelope, and maneuvering in any direction at speeds up to the limits of the Service Flight Envelope, except that the requirements specified under 3.3 apply for those conditions where the forward speed component is greater than 35 knots TAS. The requirements of 3.5, 3.6, 3.7 and 3.8 are also applicable in this speed regime.

3.2.1 Equilibrium characteristics. Without attaining excessive attitudes, it shall be possible to hover over a spot in steady winds of up to 35 knots from any direction relative to the aircraft heading, except as limited by the boundaries of the Service Flight Envelope.

3.2.1.1 Changing trim. The local slope of the equilibrium attitude-speed relationship shall not exceed 0.6 degrees per knot for speed perturbations of at least 10 knots in either direction about the trim speed. Thirty-five knots or the limits of the Service Flight Envelope, ±10 degrees roll attitude, or an attitude change of ±10 degrees in pitch need not be exceeded. The configuration and trim may be different at each trim condition but they must remain fixed while determining the attitude-speed variations about the trim condition. The fuselage reference bank attitudes must not exceed ±10 degrees at any trim speed. These requirements shall be satisfied at all forward trim speeds, backward trim speeds, and sideward trim speeds

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both to the left and to the right, up to the limits of the Service Flight Envelope or 35 knots, whichever is less in magnitude.

3.2.1.2 Fixed trim. For aircraft required to perform rapid hovering turns in winds up to 35 knots or as otherwise specified by the procuring activity, the local slope of the equilibrium attitude-speed relationship shall not exceed 0.6 degrees per knot. The total fuselage reference pitch attitude change shall not exceed 20 degrees, and the bank attitude shall not exceed ±10 degrees. These requirements apply at all steady forward speeds, backward speeds, sideward speeds both to the left and to the right, up to the limits of the Service Flight Envelope or 35 knots, whichever is less in magnitude, with configuration and trim fixed.

3.2.1.3 Cockpit control gradients. The following requirements shall be satisfied at all forward trim speeds, backward trim speeds, and sideward trim speeds both to the left and to the right, up to the limits of the Service Flight Envelope or 35 knots, whichever is less in magnitude. This requirement shall apply for speed perturbations of at least 10 knots in both directions about the trim speed except that the aircraft need not exceed 35 knots or the limits of the Service Flight Envelope. The configuration and trim may be different at each trim condition, but they must remain fixed while determining the control gradients.

Level 1: The variations of cockpit control force and control position with airspeed shall be smooth and the local gradients stable or zero for both the pitch and roll cockpit controls. The gradients shall be essentially linear with no objectionable changes in the slope of force or position with speed.

Level 2: For those Flight Phases of the operational missions of 3.1.1 for which IFR operation is required, the Level 2 requirement is the same as for Level 1. In all other cases, the Level 2 requirement is the same as Level 3.

Level 3: The Level 1 requirements shall apply for the local control force gradients. The local pitch and roll control position gradients may be unstable, provided the change in cockpit control position does not exceed one-half inch in the unstable direction over the speed range specified.

Stable pitch control gradients mean that incremental pull forces and aft displacement of the cockpit control are required to maintain slower or more rearward airspeeds and the opposite to maintain faster or more forward airspeeds.

Stable roll control gradients mean that incremental right force and right displacement of the cockpit control are required to maintain right translations or right sideslips and the opposite to maintain left translations or left sideslips.

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The term gradient does not include that portion of the control force or control position versus airspeed curve within the preloaded breakout force or friction band.

3.2.2 Dynamic response requirements

3.2.2.1 Pitch [roll]. The following requirements shall apply to the dynamic responses of the aircraft with the cockpit controls free and with them fixed following an external disturbance or an abrupt pitch [roll] control input in either direction. The requirements apply for responses of any magnitude that might be experienced in operational use. If oscillations are nonlinear with amplitude, the oscillatory requirements shall apply to each cycle of the oscillation.

Level 1: All aperiodic responses (real roots of the longitudinal characteristic equation and the lateral-directional characteristic equation) shall be stable. Oscillatory modes of frequency greater than 0.5 radians per second shall be stable. Oscillatory modes with frequency less than or equal to 0.5 radians per second may be unstable provided the damping ratio is less unstable than -.10. Oscillatory modes of frequency greater than 1.1 radians per second shall have a damping ratio of at least 0.3.

Level 2: For those Flight Phases of the operational missions of 3.1.1 for which IFR operation is required, the Level 2 requirement is the same as for Level 1. In all other cases, for Level 2, divergent modes of aperiodic response shall not double amplitude in less than 12 seconds. Oscillatory modes may be unstable provided their frequency is less than or equal to 0.84 radians per second and their time to double amplitude is greater than 12 seconds. Oscillatory modes of frequency greater than 0.84 radians per second shall be stable.

Level 3: Divergent modes of aperiodic response shall not double amplitude in less than 5 seconds. Oscillatory modes may be unstable provided their frequency is less than or equal to 1.25 radians per second and their time to double amplitude is greater than 5 seconds. Oscillatory modes of frequency greater than 1.25 radians per second shall be stable.

3.2.2.2 Directional damping. While hovering at zero airspeed, the yaw mode shall be stable and the time constant shall not exceed the following:

Level 1: 1.0 second
Level 2: 2.0 seconds

For Level 3 operation there shall be no tendency toward aperiodic divergence in yaw.

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3.2.3 Control characteristics. To ensure adequate hover and low-speed control characteristics, the following requirements shall be satisfied starting from flight at constant speed with zero angular rate.

3.2.3.1 Control power. With the wind from the most critical directions relative to the aircraft, control remaining shall be such that simultaneous abrupt application of pitch, roll and yaw controls in the most critical combination produces at least the attitude changes specified in table IV within one second from the initiation of control force application.

TABLE IV. Attitude Change in One Second or Less (Degrees)

Level	Pitch	Roll	Yaw
1	±3.0	±4.0	±6.0
2	±2.0	±2.5	±3.0
3	±2.0	±2.0	±2.0

3.2.3.2 Response to control input. The ratio of the maximum attitude change, occurring within the first second following an abrupt step displacement of the appropriate cockpit control, to the magnitude of the cockpit control command shall lie within the bounds of table V. There shall be no objectionable nonlinearities in aircraft response to control deflections and forces.

TABLE V. Response to Control Input
in One Second or Less (Degrees per Inch)

Level	Pitch		Roll		Yaw	
	Min	Max	Min	Max	Min	Max
1	3.0	20.0	4.0	20.0	6.0	23.0
2	2.0	30.0	2.5	30.0	3.0	45.0
3	1.0	40.0	1.0	40.0	1.0	50.0

3.2.3.3 Maneuvering control margins. When automatic stabilization and control equipment or devices are used to overcome an aperiodic instability of the basic aircraft, both the magnitude of the instability and the installed control power shall be such that at least 50 percent of the nominal control moment can be commanded by the pilot in the critical

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direction through the use of the cockpit controls. This requirement applies throughout the Service Flight Envelope within ±15 knots TAS of the trim speed.

3.2.4 Control lags. Starting from trimmed hovering or low-speed flight, the angular acceleration response in the commanded direction shall be developed within 0.1 seconds after the initiation of step displacements of the pitch, roll and yaw cockpit controls. In addition, the initial maximum angular acceleration shall be achieved within 0.3 seconds after the initiation of the cockpit control command. These requirements apply for input amplitudes of up to 0.5 inches.

3.2.5 Vertical flight characteristics. The requirements of 3.2.5.1 through 3.2.5.3 are applicable to ascending or descending flight with airspeeds up to 35 knots TAS. They shall be met while maintaining in reserve the attitude control power called for in 3.2.3.1.

3.2.5.1 Height control power. Starting from a steady descent rate of not greater than 4 feet per second, sufficient height control power shall be available to produce upward vertical accelerations of not less than those specified in table VI following an abrupt step input of the thrust magnitude control. In any case, the steady state thrust-to-weight ratio available, T/W, shall not be less than that specified in table VI.

TABLE VI. Height Control Power Requirements

Level	Incremental Vertical Acceleration, g's	T/W
1	0.10	1.05
2	0.05	1.02
3		1.01

3.2.5.2 Thrust magnitude control lags. The following requirements shall be satisfied following an abrupt step input of the thrust magnitude control from the nominal setting corresponding to a steady descent rate of between 5 and 10 feet per second:

Level 1: It shall be possible to achieve 63 percent of a commanded incremental thrust of at least 0.05W in not more than 0.3 seconds.

Level 2: It shall be possible to achieve 63 percent of a commanded incremental thrust of at least 0.02W in not more than 0.6 seconds.

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Level 3: It shall be possible to achieve 63 percent of a commanded incremental thrust of at least 0.01W in not more than 0.6 seconds.

3.2.5.3 Response to thrust magnitude control input. Following an abrupt step displacement of the thrust magnitude control, the ratio of the maximum rate of climb occurring within the first second to the magnitude of the cockpit control input shall lie within the bounds of table VII. This requirement is for hovering in still air and for inputs up to the maximum permissible.

TABLE VII. Response to Thrust Magnitude Control Input in One Second or Less (Climb Rate in Feet per Minute per Inch of Control Deflection)

Level	Minimum	Maximum
1	100	750
2	50	1200
3		2000

3.2.5.4 Vertical damping. The translational height damping in vertical flight (i.e., the vertical force proportional to vertical velocity) shall not be in the unstable sense.

3.3 Forward flight. The forward flight requirements apply to those Flight Phases of the operational missions of the aircraft which include equilibrium flight or maneuvering in the speed range of 35 knots TAS to V_{con}. The requirements of 3.5, 3.6, 3.7 and 3.8 are also applicable in this speed regime.

3.3.1 Longitudinal equilibrium. With the aircraft trimmed at speeds from 35 knots forward to V_{con}, the following requirements shall be satisfied for perturbations of ± 10 knots from the trim speed except where limited by the boundaries of the Service Flight Envelope. The configuration and trim may be different at each trim condition, but shall remain fixed while determining the control gradients.

Level 1: The variations of pitch control force and control position with pitch attitude and airspeed shall be smooth and the local gradients stable or zero.

Level 2: For those Flight Phases of the operational missions of 3.1.1 for which IFR operation is required, the Level 2 requirement is the same as for Level 1. In all other cases, the Level 2 requirement is the same as for Level 3.

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Level 3: The Level 1 requirements shall apply except that the local pitch control position gradients may be unstable. However, the change in the pitch control position shall not exceed one-half inch in the unstable direction over the speed range or pitch attitude range associated with the unstable gradient.

Stable pitch control gradients mean that incremental pull force and aft displacement of the cockpit control are required to maintain nose-up attitudes or slower airspeeds and the opposite to maintain nose-down attitudes or higher airspeeds. The term gradient does not include that portion of the control force or control position versus pitch attitude or airspeed curve within the preloaded breakout force or friction band.

3.3.2 Longitudinal dynamic response. The following requirements shall apply to the dynamic response of the aircraft with the pitch control free and with it fixed. These requirements apply following a disturbance in smooth air, and following abrupt pitch control inputs in each direction, for responses of any magnitude that might be experienced in operational use. If the oscillations are nonlinear with amplitude, the requirements shall apply to each cycle of the oscillation.

Level 1: The response of the aircraft shall not be divergent (i.e., all roots of the longitudinal characteristic equation of the aircraft shall be stable). In addition, the undamped natural frequency, ω_n, and damping ratio, ζ, of the second-order pair of roots (real or complex) that primarily determine the short-term response of angle of attack following an abrupt pitch control input shall meet the Level 1 requirements of figure 1.

Level 2: For those Flight Phases of the operational missions of 3.1.1 for which IFR operation is required, the Level 2 requirement is the same as for Level 1. In all other cases, for Level 2, divergent modes of aperiodic response shall not double amplitude in less than 12 seconds. Oscillatory modes may be unstable provided their frequency is less than or equal to 0.84 radians per second and their time to double amplitude is greater than 12 seconds. In addition, the undamped natural frequency and damping ratio of the second-order pair of roots (real or complex) that primarily determine the short-term response of angle of attack following an abrupt pitch control input shall meet the Level 2 requirements of figure 1.

Level 3: Divergent modes of aperiodic response shall not double amplitude in less than 5 seconds. Oscillatory responses shall be stable; however, an instability will be permitted provided its frequency is less than 1.25 radians per second and its time to double amplitude is greater than 5 seconds.

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3.3.3 Residual oscillations. Any sustained residual oscillations shall not interfere with the pilot's ability to perform the tasks required in operational use of the aircraft. For Levels 1 and 2, oscillations in normal acceleration at the pilot's station greater than $\pm 0.05g$ will be considered excessive for any Flight Phase. These requirements shall apply with the pitch control fixed and with it free.

3.3.4 Pitch control feel and stability in maneuvering flight. In steady turning flight, and in pullups at constant speed, increased pull forces and aft displacement of the cockpit pitch control shall be required to maintain increases in angle of attack, normal acceleration and nose-up pitch rate throughout the range of angle of attack and load factor in the Service Flight Envelope. Increases in push forces and forward displacement of the cockpit pitch control shall be required to maintain reductions of angle of attack and normal acceleration in pushovers at constant speed.

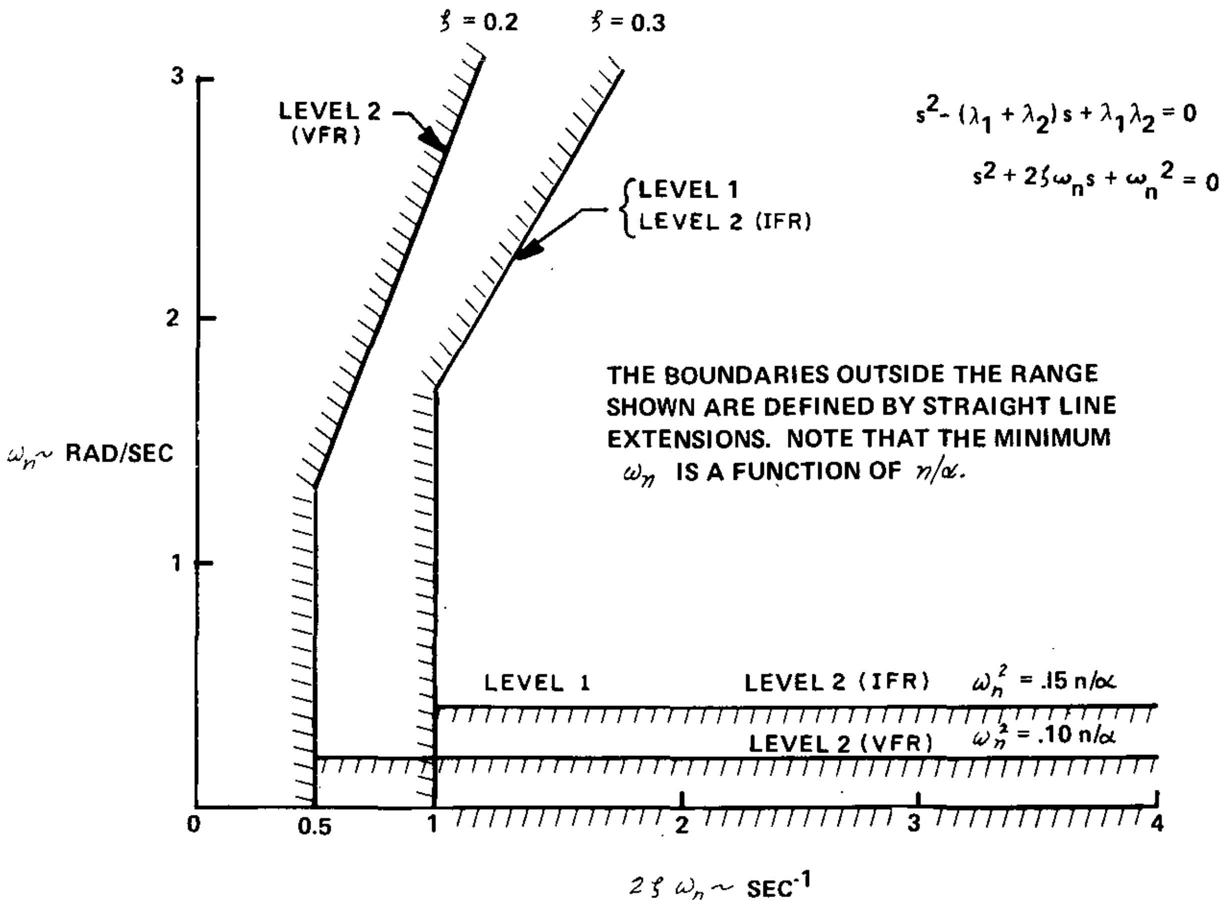

Figure 1. SHORT-TERM LONGITUDINAL RESPONSE REQUIREMENTS

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3.3.4.1 Pitch control forces in maneuvering flight. In steady turning flight, in pullups, and in pushovers, at constant speed, the variation in pitch control force with steady-state normal acceleration or angle of attack shall be approximately linear. In general, a departure from linearity resulting in a local gradient which differs from the average gradient for the maneuver by more than 50 percent is considered excessive. For Levels 1 and 2 the local value of the pitch control force gradient with normal acceleration shall never be less than 3 pounds per g. There shall be no undesirable inputs to the pitch control system due to changes in linear or angular accelerations produced by gusts or thrust magnitude control inputs. The term gradient does not include that portion of the force versus normal-acceleration or angle-of-attack curve within the preloaded breakout force or friction band.

3.3.5 Pitch control effectiveness in maneuvering flight. When the aircraft is trimmed in unaccelerated flight at any speed and altitude in the Operational Flight Envelope, it shall be possible to develop at the trim speed the limiting attitude or angle of attack of the Operational Flight Envelope.

3.3.5.1 Maneuvering control margins. When automatic stabilization and control equipment or devices are used to overcome an aperiodic instability of the basic aircraft, both the magnitude of the instability and the installed control power shall be such that at least 50 percent of the nominal control moment is available to the pilot in the critical direction through the use of the pitch control. This requirement applies throughout the Service Flight Envelope within ±15 knots TAS or 15 percent of the trim speed, whichever is greater.

3.3.5.2 Speed and flight-path control. The aircraft dynamic characteristics, together with the effectiveness and response times of the pitch, thrust magnitude, and thrust angle controls, shall be such that adequate control of the flight path and airspeed can be maintained at all permissible angles of attack and load factors.

3.3.6 Pitch control in sideslips. With the aircraft trimmed for straight flight with zero sideslip, the pitch control force required to maintain constant speed in steady, constant-heading sideslips, shall not exceed one-third of the limits of 3.5.3 in the pull direction or one-sixth of the limits of 3.5.3 in the push direction. This requirement shall be met for sideslips up to the magnitude specified in 3.3.11 or the magnitude which can be generated by 50 pounds of yaw control force, whichever is less. If a variation of pitch control force with sideslip does exist, it is preferred that increasing pull force accompany increasing sideslip, and that the magnitude and direction of the force change be similar for right and left sideslips. In addition, in the steady sideslip conditions specified above, a margin of at least 20 percent of the nominal control moment in pitch shall be available as an allowance for the control of gust disturbances. This requirement applies in level flight and in climbs and descents to the limits of the appropriate Flight Envelopes.

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3.3.7 Lateral-directional characteristics

3.3.7.1 Lateral-directional oscillations (Dutch roll). The frequency, ω_{n_d} and damping ratio, ζ_d, of the lateral-directional oscillations following a disturbance input, for example a yaw control doublet, shall exceed the minimums specified on figure 2. The requirements shall be met with controls fixed and with them free for oscillations of any magnitude that might be experienced in operational use. If the oscillation is non-linear with amplitude, the requirements shall apply to each cycle of the oscillation. Residual oscillations may be tolerated only if the amplitude is sufficiently small that the motions are not objectionable and do not impair mission performance. With control surfaces fixed, $\omega_{n_d}{}^2$ shall always be greater than zero.

3.3.7.2 Roll mode time constant. The roll mode shall be stable and the time constant, τ_R, shall be less than the following:

Level 1:	1.4 seconds
Level 2:	3.0 seconds
Level 3:	10.0 seconds

3.3.7.3 Spiral stability. The combined effect of spiral stability, flight-control system characteristics, and trim change with speed shall be such that following a disturbance in bank of up to 10 degrees, the time for the bank angle to double shall be greater than the following:

Level 1:	20.0 seconds
Level 2:	12.0 seconds
Level 3:	4.0 seconds

These requirements shall be met with the cockpit controls free and the aircraft trimmed for zero-bank-angle, zero-yaw-rate flight.

3.3.8 Roll-sideslip coupling. The requirements on roll-sideslip coupling are stated in terms of allowable bank angle oscillations, sideslip excursions, roll control forces and yaw control forces that occur during specified rolling and turning maneuvers. The requirements of 3.3.8.1 and 3.3.8.2 apply for both right and left roll control commands of all magnitudes up to the magnitude required to meet the roll performance requirements of 3.3.9, unless otherwise stated.

3.3.8.1 Bank angle oscillations. The value of the parameter $\phi_{OSC}/\phi AV$ following a yaw-control-free impulse roll control command shall be within the limits specified in figure 3 for Levels 1 and 2. The impulse shall be as abrupt as practical within the strength limits of the pilot and the rate limits of the roll control system. For Levels 1 and 2, ϕ_{AV} shall always be in the direction of the roll control command.

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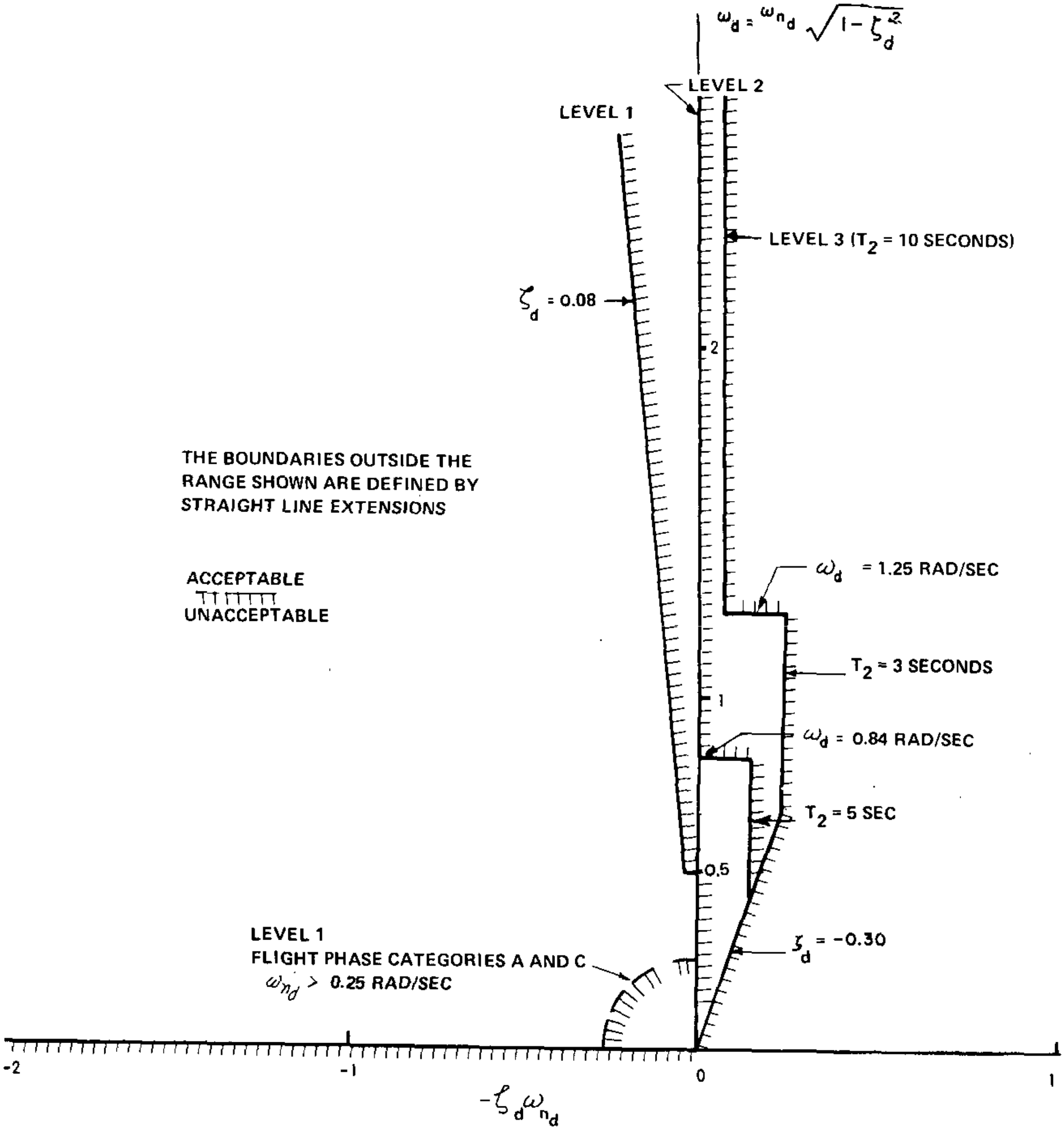

Figure 2. LATERAL-DIRECTIONAL OSCILLATORY REQUIREMENTS

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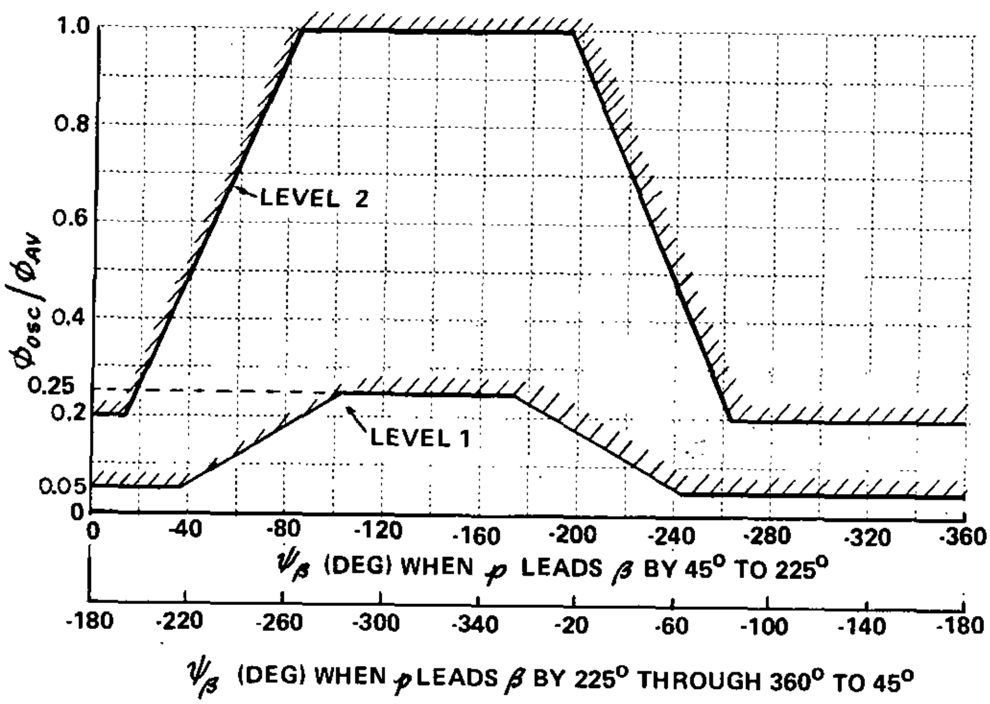

Figure 3. BANK ANGLE OSCILLATION LIMITATIONS

3.3.8.2 Sideslip excursions. The amount of sideslip resulting from abrupt roll control commands shall not be excessive or require complicated or objectionable rudder coordination. For Flight Phase Categories A and C, the ratio of the maximum change in sideslip angle to the initial peak magnitude in roll response, $|\Delta\beta/\phi_1|$, for an abrupt roll control pulse command shall not exceed the limit specified on figure 4. In addition, $|\Delta\beta/\phi_1|$ x $|\phi/\beta|_d$ shall not exceed the limit specified on figure 5.

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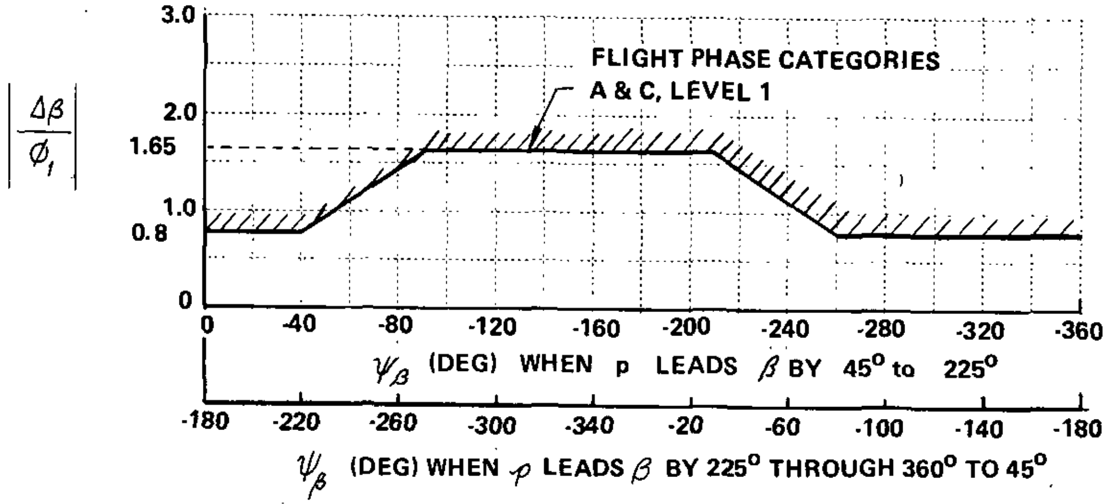

Figure 4. SIDESLIP EXCURSION LIMITATIONS

(BOUNDARY for $\left|\frac{\Delta\beta}{\phi_1}\right|$)

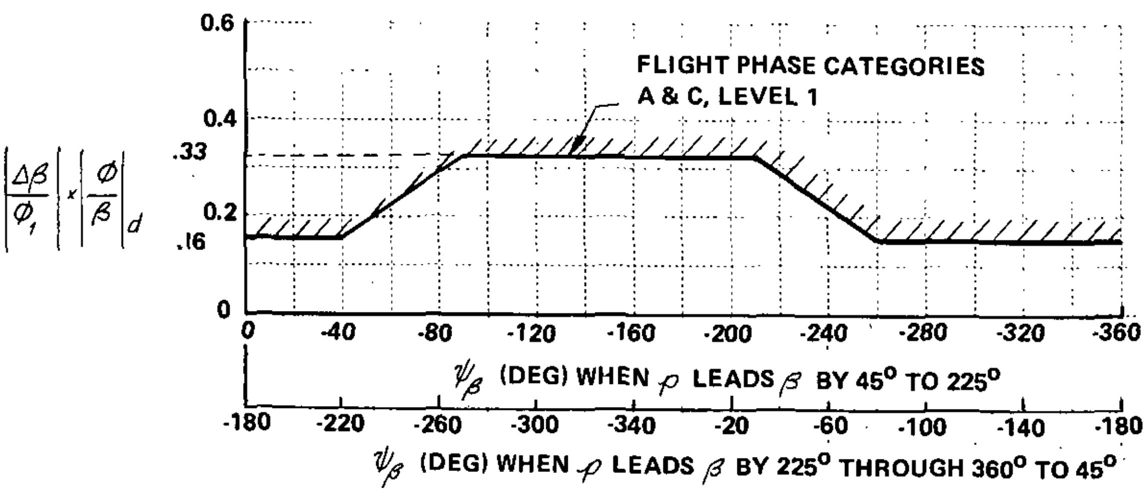

Figure 5. SIDESLIP EXCURSION LIMITATIONS

(BOUNDARY FOR $\left|\frac{\Delta\beta}{\phi}\right| x \left|\frac{\phi}{\beta}\right|_d$)

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3.3.8.3 Control of sideslip in rolls. In the rolling maneuvers described in 3.3.9, yaw-control effectiveness shall be adequate to maintain zero sideslip with yaw control forces not exceeding those of 3.5.3. This requirement applies to rolling maneuvers of magnitude up to the required roll performance of 3.3.9. For inputs smaller than those required to meet the roll performance requirements of 3.3.9, the resultant forces shall be divided by the ratio of the bank angle obtained at the time specified in 3.3.9 to the bank angle required, and the results compared with the limits of 3.5.3 for compliance.

3.3.8.4 Turn coordination. It shall be possible to maintain steady constant-altitude coordinated turns in either direction, using bank angles up to either that required to produce a turn rate of 10 degrees per second or a bank angle of 60 degrees for Class IV aircraft, 45 degrees for Class I and Class II aircraft, or 30 degrees for Class III aircraft. Yaw control forces shall not exceed 40 pounds and roll control forces shall not exceed 5 pounds. This requirement applies to Level 1, with the aircraft trimmed for zero-bank-angle straight flight.

3.3.9 Roll control effectiveness. The time to change bank angle by 30 degrees (t_{30}) to the right or left from a trimmed zero-roll-rate condition shall not exceed the value specified in table VIII. The time shall be measured from the initiation of roll control force application. Yaw control may be used to reduce sideslip that retards roll rate (not to produce sideslip that augments roll rate), provided that yaw control inputs are simple, easily coordinated with roll control inputs, and are consistent with piloting techniques for the aircraft in its mission. Roll control shall be sufficiently effective, in combination with other normal means of control, to balance the aircraft laterally throughout the Service Flight Envelope in the atmospheric environments of 3.7.

TABLE VIII. Roll Control Effectiveness

Class	t_{30} - seconds		
	Level 1	Level 2	Level 3
I	1.3	1.8	2.6
II	1.8	2.5	3.6
III	2.5	3.2	4.0
IV	1.0	1.3	2.0

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3.3.9.1 Roll control forces. The roll control forces required to obtain the rolling performance specified in 3.3.9 shall lie between the maximums and minimums of table IX.

TABLE IX. Roll Control Forces (Pounds)

	Level 1	Level 2	Level 3
Maximum	15.0	20.0	25.0
Minimum	3.3	3.0	0.5

3.3.9.2 Linearity of roll response. There shall be no objectionable nonlinearities in the variation of roll response with roll control deflection or force.

3.3.9.3 Wheel control throw. For all aircraft with wheel controllers, the wheel throw necessary to meet the roll performance requirements specified in 3.3.9 shall not exceed 60 degrees in either direction. For completely mechanical systems, the requirements may be relaxed to 80 degrees.

3.3.9.4 Yaw-control-induced rolls. For Levels 1 and 2 the application of right yaw control force shall not result in left rolls and the application of left yaw control force shall not result in right rolls.

3.3.10 Directional control effectiveness. Yaw control shall be sufficiently effective, in combination with other normal means of control, to balance the aircraft directionally throughout the Service Flight Envelope in the atmospheric environments of 3.7.

3.3.10.1 Directional response to yaw control input. The yaw attitude change within the first second following an abrupt step displacement of the yaw control shall not be less than:

Level 1:	6.0 degrees
Level 2:	3.0 degrees
Level 3:	1.0 degree

This requirement applies with all other cockpit controls fixed.

3.3.10.2 Linearity of directional response. There shall be no objectionable nonlinearities in the variation of directional response with yaw control deflection or forces. Excessive sensitivity or sluggishness in response to small yaw control deflections or forces shall be avoided.

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3.3.10.3 Directional control with speed change. With the aircraft initially trimmed directionally with symmetric power, it shall be possible to maintain zero-bank-angle straight flight over a speed range of ±30 percent of the trim speed or ±20 knots whichever is less (except where limited by the boundaries of the Service Flight Envelope). The yaw control forces shall not be greater than those of table XIII for propeller-driven aircraft and not greater than one-half those of table XIII for other aircraft. These requirements must be satisfied without retrimming.

3.3.10.3.1 Directional control with asymmetric loading. With the aircraft initially trimmed directionally with any asymmetric loading specified in the contract at any speed in the Operational Flight Envelope, it shall be possible to maintain a straight flight path throughout the Operational Flight Envelope with yaw control forces not exceeding those of table XIII, without retrimming.

3.3.11 Lateral-directional characteristics in steady sideslips. The requirements of 3.3.11.1 through 3.3.11.3.1 are expressed in terms of characteristics in yaw-control-induced steady zero-yaw-rate sideslips with the aircraft trimmed for zero-bank-angle straight flight. Sideslip angles to be demonstrated shall be the lesser of 25 degrees or $\sin^{-1}$ (30/airspeed in knots), or those limited by structural limitations, or the yaw control and roll control force limits of table XIII. In any event, the minimum sideslip to be demonstrated shall be the lesser of 15 degrees or $\sin^{-1}$ (30/airspeed in knots).

3.3.11.1 Yawing moments in steady sideslips. For the sideslips specified in 3.3.11, right yaw control deflection and force shall be required in left sideslips and left yaw control force and deflection shall be required in right sideslips.

For Levels 1 and 2, the following requirements apply. The variation of sideslip angle with yaw control deflection and force shall be essentially linear for sideslip angles between +15 and -15 degrees. For larger sideslip angles, an increase in yaw control deflection shall always be required for an increase in sideslip and, although a reduction of yaw control force gradient is acceptable outside this range, the following requirements shall apply:

Level 1: The gradient of sideslip angle with yaw control force shall not reverse slope

Level 2: The gradient of sideslip angle with yaw control force is permitted to reverse slope provided the sign of the yaw control force does not reverse.

The term gradient does not include that portion of the yaw control force versus sideslip-angle curve within the preloaded breakout force or friction band.

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3.3.11.2 Bank angle in steady sideslips. For the sideslips specified in 3.3.11, an increase in right bank angle shall accompany an increase in right sideslip, and an increase in left bank angle shall accompany an increase in left sideslip.

3.3.11.3 Rolling moments in steady sideslips. For the sideslips specified in 3.3.11, left roll control deflection and force shall be required in left sideslips, and right roll control deflection and force shall be required in right sideslips. For Levels 1 and 2, the variation of roll control deflection and force with sideslip angle shall be essentially linear.

3.3.11.3.1 Positive effective dihedral limit. For Level 1, positive effective dihedral (right roll control for right sideslip and left roll control for left sideslip) shall never be so great that more than 50 percent of the roll control power available to the pilot or 7.5 pounds of roll control force are required for sideslip angles which might be experienced in service employment. The corresponding limits for Level 2 shall be 75 percent and 10 pounds.

3.4 Transition. The transition requirements are applicable to the accelerating or decelerating transition maneuver itself, and not to the maneuvering capability when operating about a fixed operating point defined by some trim speed lying in the range between hover and V_{con}. For operation around such fixed operating points, the requirements of 3.2 and 3.3 shall apply. Compliance shall be demonstrated when performing transition profiles as defined by the mission requirements. The transition maneuver requirements shall be met for all applicable Aircraft States except Aircraft Special Failure States.

3.4.1 Acceleration-deceleration characteristics. From every possible fixed operating point at speeds below V_{con}, with the aircraft trimmed at the operating point, it shall be possible to accelerate rapidly and safely to V_{con} at approximately constant altitude and also on any other flight path as required by the operational missions of 3.1.1. From trimmed steady, level, unaccelerated flight at V_{con}, it shall be possible to decelerate rapidly and safely, at approximately constant altitude and also on any other flight path as required by the mission, to all fixed operating points at speeds below V_{con}. The time taken for these maneuvers and the altitudes flown shall be those designated by the mission requirements. It shall be possible to execute these maneuvers without restriction due to factors such as pitch, roll, or yaw control power, pitch trim, stalling or buffeting, or thrust response characteristics. All controls required to effect a transition shall be easily operated by one pilot.

3.4.2 Flexibility of operation. At any time during a transition it shall be possible for the pilot to quickly and safely stop the transition maneuver and reverse its direction.

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3.4.3 Tolerance in transition program. It shall be possible to change from hover or minimum speed to conventional flight, and vice versa, safely and easily. There shall be no need for precise programming by the pilot of engine power, fuselage attitudes, wing or lift engine tilt, etc., in terms of speed or time, such as to demand excessive pilot skill and attention.

3.4.4 Control margin. To allow for disturbances and for maneuvering, the margin of control power remaining at any stage in the transition shall not be less than 50 percent of the nominal pitch, roll and yaw control moments available.

3.4.5 Trim changes. All trim changes throughout the transition shall be small. Without retrimming, the pitch control forces shall not exceed 15 pounds pull or 7 pounds push.

3.4.6 Rate of pitch control movement. During transition, with the maximum available rate of change of forward speed, the rate of pitch control movement to maintain trim shall not exceed 1 inch per second.

3.5 *Characteristics of the flight control system.* These requirements are concerned with those aspects of the flight control system which are directly related to flying qualities, and are imposed in addition to the requirements of the applicable control system design specifications, e.g., MIL-F-9490 for Air Force procurements or MIL-C-18244 for Navy procurements. Meeting the following requirements separately will not necessarily ensure that the overall system will be satisfactory; the mechanical characteristics must be compatible with the nonmechanical portions of the control system and with the aircraft dynamic characteristics. The requirements apply at all speeds up to V_{con}.

3.5.1 Mechanical characteristics. Some of the important mechanical characteristics of control systems (including servo valves and actuators) are: friction and preload, lost motion, flexibility, mass imbalance and inertia, nonlinear gearing, and rate limiting. Requirements for these characteristics are contained in 3.5.1.1 through 3.5.1.7.

3.5.1.1 Control centering and breakout forces. Pitch, roll, and yaw controls shall exhibit positive centering in flight at any normal trim setting. Absolute centering is not required. The combined effects of centering, breakout force, stability, and force gradient shall not produce objectionable flight characteristics, such as poor precision-tracking ability, or permit large departures from trim conditions with controls free. Breakout forces, including friction, preload, etc., refer to the cockpit control force required to start movement of the control surface in flight. The requirements for breakout force are given in tables X and XI. Table X applies for all speeds less than 35 knots. At V_{con}, the values shown in table XI apply for Levels 1 and 2; for Level 3 the maximum values may be doubled. Between 35 knots and V_{con}, the breakout force may increase to but not exceed the V_{con} value provided the change in breakout force with speed is not objectionable.

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TABLE X. Allowable Breakout Forces, Pounds, V<35 knots

Cockpit Control		Level 1 min/max	Level 2 min/max	Level 3 max
Pitch		0.5/1.5	0.5/3.0	6.0
Roll		0.5/1.5	0.5/2.0	4.0
Yaw		2.0/7.0	2.0/7.0	14.0
Thrust Magnitude	throttle type	1.0/3.0	1.0/3.0	3.0
	collective type	1.0/3.0	1.0/3.0	6.0

TABLE XI. Allowable Breakout Forces at V_{con}, Pounds

Control	Classes I, II, IV		Class III	
	min	max	min	max
Pitch	0.5	3.0	0.5	5.0
Roll	0.5	2.0	0.5	4.0
Yaw	2.0	7.0	2.0	14.0

The minimum thrust-magnitude-control breakout force may be measured with adjustable friction set. Measurement of breakout forces on the ground will ordinarily suffice in lieu of actual flight measurement, provided qualitative agreement between ground measurement and flight observation can be established.

3.5.1.2 Cockpit control force gradients. At speeds up to 35 knots, the pitch, roll and yaw control force gradients shall be within the range specified in table XII throughout the range of control deflections. From 35 knots to V_{con}, transition of the gradients to the values required to comply with MIL-F-8785 at V_{con} is allowed in any manner which is not objectionable to the pilot. In addition, the force produced by a 1-inch travel from trim by the gradient chosen shall not be less than the breakout force. For the remaining control travel, the local gradients shall not change by more than 50 percent in one inch of travel. The thrust magnitude control should preferably have zero force gradient.

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TABLE XII. Allowable Control Force Gradients, Pounds/Inch

Control	Level 1		Level 2	
	min	max	min	max
Pitch	0.5	3.0	0.5	5.0
Roll	0.5	2.5	0.5	5.0
Yaw	5.0	10.0	5.0	20.0

3.5.1.3 Cockpit control free play. The free play in each control, that is, any motion of the cockpit control which does not move the appropriate moment- or force-producing device in flight, shall be compatible with the required Level of flying qualities.

3.5.1.4 Rate of control displacement. The ability of the aircraft to perform the operational maneuvers required of it, and to operate in an atmospheric disturbance environment consistent with the operational missions of 3.1.1, shall not be limited by the rate of movement of the moment- or force-producing devices. For powered or boosted controls, the effect of engine speed and duty cycle of any part of the flight control system, together with pilot control techniques, shall be included when establishing compliance with this requirement.

3.5.1.5 Adjustable controls. When a cockpit control is adjustable for pilot physical dimensions or comfort, the control forces defined in 6.2.4 shall refer to the mean adjustment. A force referred to any other adjustment shall not differ by more than 10 percent from the force referred to the mean adjustment.

3.5.1.6 Control harmony. The control forces, displacements, and sensitivities of the pitch, roll and yaw controls shall be compatible, and their responses shall be harmonious.

3.5.1.7 Mechanical cross-coupling. Displacement of one cockpit control shall not produce objectionable forces or displacements at any of the other cockpit controls.

3.5.2 Dynamic characteristics. The control deflection shall not lead the control force for any frequency or force amplitude. This requirement applies to the pitch, roll, yaw and thrust magnitude controls.

3.5.2.1 Damping. All control system oscillations shall be well damped, unless they are of such an amplitude, frequency, or phasing that the

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cockpit-control or airframe oscillations resulting from abrupt maneuvers or flight in atmospheric disturbances are compatible with the required Level of flying qualities as determined from 3.1.10.

3.5.3 Limit cockpit control forces. Unless otherwise specified in particular requirements, the maximum control forces required, without retrimming, for any maneuver consistent with service use, shall not exceed the values stated in table XIII.

TABLE XIII. Limit Cockpit Control Force Values, Pounds

Cockpit Control	V<35 Knots			35 Knots<V<V_{con}		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Pitch	10.0	20.0	40.0	30.0	35.0	40.0
Roll	7.0	15.0	20.0	15.0	20.0	25.0
Yaw	30.0	40.0	80.0	75.0	100.0	125.0
Thrust Magnitude Throttle type	3.0	3.0	3.0	3.0	3.0	3.0
Collective type	7.0	7.0	7.0	7.0	7.0	7.0

3.5.4 Augmentation systems. Normal operation of stability augmentation and control augmentation systems and devices shall not introduce any objectionable flight or ground handling characteristics.

3.5.4.1 Performance of augmentation systems. Any degradation of the performance of augmentation systems during flight in a severe atmospheric disturbance environment consistent with the operational missions of 3.1.1, or because of structural vibrations, shall be taken into account in demonstrating compliance with the required Level of flying qualities. In addition, any limits on the authority of augmentation systems or saturation of equipment shall not produce flying characteristics inconsistent with the required Level of flying qualities.

3.5.5 Failures. Special provisions shall be incorporated to preclude any critical single failure of the flight control system including trim devices or stability augmentation system which may result in flying qualities which are dangerous or intolerable. Failure-induced transient motions and trim changes resulting either immediately after failure or upon subsequent transfer to alternate control modes shall be small and

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and easily interpreted indications whenever failures occur in the flight control system.

3.5.5.1 Control force to suppress transients. Without retrimming, the cockpit control forces required to suppress transients following a failure in any part of the flight control system shall not exceed one-half the Level 1 limit control force values in table XIII.

3.5.6 Transients and trim changes. This requirement applies to all Aircraft State changes made under conditions representative of operational procedure by activation of the Aircraft State selectors and controls available to the pilot. With the aircraft initially trimmed at a fixed operating point, the peak pitch, roll, and yaw control forces required to suppress the transient aircraft motions resulting from the change and maintain the desired heading, attitude, altitude, rate of climb or descent, or speed without use of the trimmer control, shall not exceed one-third of the appropriate limit control force in table XIII. This applies for a time interval of at least 5 seconds following completion of the pilot action initiating the change. The magnitude and rate of trim change after this period shall be such that the forces can be trimmed as required in 3.5.7. There shall be no objectionable buffeting or oscillations of the control device during the change.

3.5.6.1 Transfer to alternate control modes. The transients and trim changes caused by the intentional engagement or disengagement of any portion of the flight control system consistent with normal service use, such as selection of a particular augmentation mode, shall not be objectionable. Additional requirements are contained in MIL-F-9490 for Air Force procurements.

3.5.7 Trim system. At all steady flight conditions within the Operational Flight Envelope, the trimming devices shall be capable of reducing the pitch, roll, and yaw control forces to zero for Levels 1 and 2. At all steady flight conditions within the Service Flight Envelope, the untrimmable cockpit control forces shall not exceed 10 pounds pitch, 5 pounds roll, and 20 pounds yaw. For Level 3, the untrimmed cockpit control forces shall not exceed 10 pounds pitch, 5 pounds roll, and 20 pounds yaw. The failures to be considered in applying the Level 2 and 3 requirements shall include trim sticking and runaway in either direction. It is permissible to meet the Level 2 and 3 requirements by providing the pilot with alternate trim mechanisms or override capability. Additional requirements on trim rate and authority are contained in MIL-F-9490 for Air Force procurements and MIL-F-18372 for Navy procurements.

3.5.7.1 Rate of trim operation. Trim devices shall operate rapidly enough to enable the pilot to maintain the pitch and roll control forces less than one-third of the appropriate limit forces in table XIII during any maneuver consistent with service use, but not ever to operate so rapidly as to cause oversensitivity or trim precision difficulties.

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3.5.7.2 Trim system irreversibility. All trimming devices shall maintain a given setting indefinitely unless changed by the pilot, by a special automatic interconnect such as to the flaps, or by the operation of an augmentation device. If an automatic interconnect or augmentation device is used in conjunction with a trim device, provision shall be made to ensure the accurate return of the device to its initial trim position on completion of each interconnect or augmentation operation.

3.6 Takeoff, landing and ground handling. These requirements shall be satisfied within the Operational Flight Envelope for all applicable Category C Flight Phases.

3.6.1 Pitch control effectiveness in takeoff. The effectiveness of the pitch control shall not restrict the takeoff performance of the aircraft and shall be sufficient to prevent over-rotation to undesirable attitudes. Satisfactory takeoffs shall not be dependent on the use of the trimmer control or on complicated control manipulation by the pilot.

3.6.2 Pitch control forces in takeoff. With the trim setting optional but fixed, the cockpit pitch control forces shall not exceed one-half of the limits of table XIII in the pull direction or one-fourth of the limits of table XIII in the push direction at any time during the takeoff Flight Phases.

3.6.3 Pitch control effectiveness in landing. For Levels 1 and 2 the pitch control shall be sufficiently effective that the geometry-limited attitude or the guaranteed landing speed can be obtained at touchdown in the landing Flight Phase. For rolling landings this requirement must be met with the aircraft trimmed at the recommended approach speed for the approach Flight Phase. For Level 3 the pitch control shall be sufficiently effective to permit a safe landing.

3.6.4 Pitch control forces in landing. The cockpit pitch control forces required to meet the landing requirements of 3.6.3 shall not exceed one-half of the limits of table XIII in the pull direction or one-fourth of the limits of table XIII in the push direction at any time during the landing Flight Phase.

3.6.5 Crosswind operation

3.6.5.1 Landing and takeoff. It shall be possible to execute all of the takeoff and landing Flight Phases in crosswinds by using normal pilot skill and technique. The pitch, roll and yaw controls in conjunction with other means of control shall be adequate to maintain a straight path on the landing surface during takeoff runs and landing rollouts with cockpit control forces not exceeding the values specified in table XIII. These requirements apply in 90-degree crosswinds, right and left, of 30 knots.

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3.6.5.2 Final approach. Yaw and roll control shall be adequate to permit development of at least 15 degrees of steady, zero-yaw-rate sideslip in the power approach with yaw control forces not exceeding the values specified in table XIII. Roll control shall not exceed either 7.5 pounds of force or 50 percent of available control power (for the same configuration and flight condition), as applied manually or automatically or both, for Level 1. The limits are 10 pounds or 75 percent for Level 2. For Level 3, the roll control force shall not exceed 20 pounds.

3.6.5.3 Cold- and wet-weather operation. The requirements of 3.6.5.1 shall be applicable on wet runways for all aircraft, and on snow-packed and icy runways for aircraft intended to operate under such conditions. If the demonstration for specification compliance is not accomplished under these adverse runway conditions, directional control shall be maintained by use of pitch, roll and yaw controls alone for all airspeeds above 30 knots. For very slippery runways, the requirement need only apply for cross-wind components up to that at which the force tending to blow the aircraft off the runway is equal to the opposing tire-runway frictional force with the tires supporting all the aircraft's weight.

3.6.6 Power run-up. In all vertical takeoff configurations it shall be possible, without the use of wheel chocks or other restraints, to maintain a fixed position on a level surface during power run-up using only cockpit controls, in wind conditions to be specified by the procuring activity.

3.6.7 Ground handling. It shall be possible to perform all required ground handling maneuvers, including taxiing, without damage to rotating components or any part of the structure. In addition, in winds up to 35 knots it shall be possible to taxi in a straight line at any angle to the wind and to make 360-degree taxiing turns in either direction within a circle whose radius equals the major dimension of the aircraft.

3.7 Atmospheric disturbances. Some requirements are written in terms of a steady wind speed, in which case, compliance with the requirement should be demonstrated in flight, in that wind condition. Other requirements are written with reference to operation in all potential atmospheric environments. For such cases the atmospheric disturbances such as discrete gusts, wind shear and turbulence to be used shall be chosen by the contractor subject to the approval of the procuring activity. Compliance shall be demonstrated by suitable analysis, test, or both, as determined by the procuring activity.

3.8 Miscellaneous requirements

3.8.1 Approach to dangerous flight conditions. Dangerous conditions may exist where the aircraft should not be flown. When approaching these flight conditions, it shall be possible by clearly discernible means for the pilot to recognize the impending dangers and take preventive action.

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Final determination of the adequacy of all warning of impending dangerous flight conditions will be made by the procuring activity, considering functional effectiveness and reliability. Devices may be used to prevent entry to dangerous conditions only if the criteria for their design, and the specific devices, are approved by the procuring activity.

3.8.1.1 Warning and indication. Warning or indication of approach to a dangerous condition shall be clear and unambiguous. For example, a pilot must be able to distinguish readily among: warning of loss of aerodynamic lift (which may require increased thrust), engine acceleration buffet (which may require decreased thrust) and normal aircraft vibration (which may not require a thrust change). If a warning or indication device is required, functional failure of the device shall be indicated to the pilot.

3.8.1.2 Prevention. As a minimum, dangerous-condition-prevention devices shall perform their function whenever needed, but shall not limit flight within the Operational Flight Envelope. Hazardous operation of these devices, normal or inadvertent, shall never be possible. For Levels 1 and 2, neither hazardous nor nuisance operation shall be possible. For Level 3, hazardous inadvertent operation shall not be possible.

3.8.2 Loss of aerodynamic lift. These requirements are related to those conditions where a loss of lift would result in a loss of altitude or partial loss of control.

3.8.2.1 Warning. The approach to a loss of aerodynamic lift shall be accompanied by an easily perceptible warning. Such a warning shall be provided artificially, subject to approval by the procuring activity, when natural warning is not feasible. The increase in warning intensity with further loss of lift shall be sufficiently marked to be noted by the pilot.

3.8.2.2 Prevention of loss of aerodynamic lift. It shall be possible to prevent loss of aerodynamic lift by normal use of the controls at the onset of the warning indication.

3.8.2.3 Control and recovery following loss of aerodynamic lift. In the event of loss of aerodynamic lift, it shall be possible to maintain control and recover by normal use of the controls, with control forces not exceeding the Level 3 requirements of table VIII. Recovery shall be accomplished without experiencing pitch, roll, or yaw attitude changes in excess of 20 degrees or excessive loss of altitude or buildup of speed. It is desired that no pitch-up tendencies occur; however, a mild nose-up pitch may be acceptable if no pitch control force reversal occurs and if no dangerous, unrecoverable, or objectionable flight conditions result.

3.8.3 Pilot-induced oscillations. There shall be no tendency for pilot-induced oscillations, that is, sustained or uncontrollable oscillations resulting from the efforts of the pilot to control the aircraft about any control axis or combination of control axes.

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3.8.4 Buffet. Within the boundaries of the Operational Flight Envelope, there shall be no objectionable buffet which might detract from the effectiveness of the aircraft in executing its intended missions.

3.8.5 Release of stores. The intentional release of any stores shall not result in objectionable flight characteristics for Levels 1 and 2. However, the intentional release of stores shall never result in dangerous or intolerable flight characteristics. This requirement applies for all flight conditions and store loadings at which normal or emergency store release is structurally permissible.

3.8.6 Effects of armament delivery and special equipment. Operation of movable parts such as bomb bay doors, cargo doors, armament pods, refueling devices, rescue equipment, or firing of weapons, release of bombs, extension of lift engines, or delivery or pickup of cargo shall not cause buffet, trim changes, or other characteristics which impair the tactical effectiveness of the aircraft under any pertinent flight condition. These requirements shall be met for Levels 1 and 2.

3.8.7 Cross-coupled effects. Control inputs or aircraft motions about a given aircraft axis shall not induce objectionable control forces or aircraft motions about any other axis. Specifically, the requirements of 3.8.7.1 and 3.8.7.2 shall apply.

3.8.7.1 Gyroscopic effects. Gyroscopic moments caused by rotating components shall not result in objectionable flight or ground handling characteristics. In flight, the elimination of the cross-coupled response during the maneuvers required to demonstrate compliance with this specification shall require less than 10 percent of the maximum control moment available about the cross-coupling axis for Level 1, and less than 20 percent for Level 2.

3.8.7.2 Inertial and aerodynamic cross-coupling. The application of any cockpit control input necessary to meet any pitch, roll or yaw performance requirement of this specification shall not result in any objectionable aircraft attitudes or angular rates about the axes not under consideration. In addition, undesired altitude changes shall be minimal.

3.8.8 Failures. No single failure of any component or system shall result in dangerous or intolerable flying qualities; Special Failure States (3.1.6.2.1), including certain propulsion failures (3.1.10.3.4 and 3.8.9) are excepted. The crew members concerned shall be provided with immediate and easily interpreted indications whenever failures occur that require or limit any flight-crew action or decision.

3.8.8.1 Transients following failures. The aircraft motions following sudden aircraft system or component failures which might occur during maneuvering flight or unattended trimmed flight shall be such that dangerous conditions can be avoided by pilot corrective action.

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A realistic time delay between the failure and initiation of pilot corrective action shall be incorporated when determining compliance. This time delay should include an interval between the occurrence of the failure and the occurrence of a cue such as acceleration, rate, displacement, or sound that will definitely indicate to the pilot that a failure has occurred, plus an additional interval which represents the time required for the pilot to diagnose the situation and initiate corrective action.

3.8.9 Control following loss of thrust/powered lift. Thrust, powered lift, or both may be lost from many factors including engine failure, inlet unstart, propeller failure, propeller-drive failure and boundary-layer control system failure. The requirements of 3.8.9.1 through 3.8.9.2.3 apply to loss of thrust or lift on one or more engines, propellers and segments of a powered lift system, caused by all single factors except structural failure of propellers or rotors. The effect of the failure or malperformance of all powered or driven subsystems shall also be included. In demonstrating compliance with 3.8.9.1 through 3.8.9.2.3, a realistic time delay (3.8.8.1) shall be incorporated between the thrust loss and pilot action.

3.8.9.1 Thrust/powered lift loss on the ground. During all takeoffs and landings of the aircraft, it shall be possible without exceptional pilot skill to maintain control following a sudden loss of thrust, powered lift, or both. No failures, beyond those required by 3.8.9, need be considered. For running takeoffs and landings it shall further be possible, after loss, to achieve and maintain a straight path while on the ground without a deviation of more than 30 feet from the path originally intended. Control forces shall not exceed the values for Level 3 in table XIII.

Additional controls such as nosewheel steering if operated by the yaw control, differential braking, and automatic devices which normally operate in the event of a thrust loss may be used. For aborted takeoffs, the requirements apply up to the maximum takeoff speed for the configuration. For continued takeoffs these requirements apply to thrust/powered lift loss at speeds from the lowest refusal speed for the configuration to the maximum takeoff speed, and the requirements of 3.8.9.2 apply once the aircraft is airborne.

3.8.9.2 Thrust/powered lift loss in flight. The aircraft motions following a sudden loss of thrust, powered lift, or both shall be such that dangerous conditions can be avoided by corrective action without undue pilot skill. From considerations of operational requirements, the procuring activity will designate which of the following requirements apply after the loss.

3.8.9.2.1 Continued mission. Aircraft required to proceed from Category C Flight Phases to Category A or B Flight Phases shall meet at least Level 2 flying qualities requirements following the thrust or

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powered lift loss. Aircraft required to complete Category A Flight Phases shall meet at least Level 2 flying qualities requirements following the thrust or powered lift loss. Aircraft required to terminate Category A Flight Phases and to complete Category B Flight Phases shall meet at least Level 3 flying qualities requirements following the thrust loss.

3.8.9.2.2 Safe landing. Aircraft required to perform a safe landing shall meet at least Level 3 flying qualities requirements following the thrust loss. If the landing is completed using autorotation, the autorotation requirements of 3.8.10 through 3.8.10.3 must also be satisfied.

3.8.9.2.3 Crew escape. When there are no operational requirements after a loss of thrust/powered lift, the aircraft shall not diverge so rapidly that the ability of the crew to escape is impaired.

3.8.10 Autorotation. All aircraft required by the procuring activity to demonstrate an autorotative capability shall meet the following requirements.

3.8.10.1 Autorotation entry. The aircraft shall be capable of entry into autorotation (power off) at all speeds from hover to V_{con}. Following power failure a delay of 1 second prior to pilot corrective action is mandatory, and a delay of 2 seconds is desired. During the delay, no dangerous flight conditions or excessive changes in aircraft attitude or altitude shall occur. Changes in aircraft attitudes shall be considered excessive if they exceed 20 degrees in 2 seconds following complete loss of power with controls fixed. During the transition from powered flight to autorotative flight, the control forces shall not exceed the Level 2 maximums of table XIII, and 20 percent of the nominal control power must remain for maneuvering.

3.8.10.2 Autorotative descent and landing. All aircraft with an autorotative capability requirement shall be capable of descending and landing (power off) safely. The pitch, roll and yaw dynamic stability requirements of this specification shall apply in autorotation at any speed. Touchdown speeds and landing zone environment will be specified by the procuring activity.

3.8.11 Vibration characteristics. Throughout the Operational Flight Envelope, the aircraft shall be free of objectionable shake, vibration, or roughness. In addition, throughout the Operational Flight Envelope the aircraft shall not exhibit mechanical or aeroelastic instabilities (i.e., ground resonance, flutter, etc.) that degrade the flying qualities.

4. QUALITY ASSURANCE PROVISIONS

4.1 Determination. Quality assurance shall be determined through:

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Analysis
Simulation
Ground test
Flight test.

The contract end item specification for each procurement will delineate, for each requirement of section 3, which of these methods shall be used. In order to restrict the number of design and test conditions, representative flight conditions, configurations, external store complements, loadings, etc., shall be determined for detailed investigation. The selected design points must be sufficient to allow extrapolation to the other conditions at which the requirements apply. The required analyses shall be thorough, excepting only approved Special Failure States (3.1.6.2.1).

4.2 Interpretation of qualitative requirements. Requirements which are not stated in terms of quantitative value of a particular stability or control parameter are to be interpreted with due regard to the intent of the Level definitions of 1.5. Final determination of compliance with such qualitative requirements will be made by the procuring activity through flight test or other suitable means.

5. PREPARATION FOR DELIVERY

Section 5 is not applicable to this specification.

6. NOTES

6.1 Intended use. This specification contains the flying qualities requirements for military piloted V/STOL aircraft operating at speeds up to V_{con} and shall form one of the bases for determination, by the procuring activity, of aircraft acceptability. The specification shall serve as design requirements and as criteria for use in stability and control calculations, analysis of wind-tunnel test results, flying qualities simulation tests, and flight testing and evaluation. To the extent possible, this specification should be met by providing an inherently good basic airframe. Where that is not feasible, or where inordinate penalties would result, a mechanism is provided herein to assure that the flight safety, flying qualities and reliability aspects of dependence on stability augmentation and other forms of system complication will be considered fully.

6.2 Definitions. Terms and symbols used throughout this specification are defined in the following subparagraphs.

6.2.1 General

s - Laplace transform variable

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MSL	- mean sea level
Aircraft Normal States	- the nomenclature and format of table XIV shall be used in defining the Aircraft Normal States (3.1.6.1)
service ceiling	- altitude at a given airspeed at which the rate of climb is 100 ft/min at stated weight and engine thrust
combat ceiling	- altitude at a given airspeed at which rate of climb is 500 ft/min at stated weight and engine thrust
cruising ceiling	- altitude at a given airspeed at which rate of climb is 300 ft/min at NRT at stated weight
h_{max}	- maximum service altitude (defined in 3.1.8.4)
$h_{o_{max}}$	- maximum operational altitude (3.1.7)
$h_{o_{min}}$	- minimum operational altitude (3.1.7)
c.g.	- aircraft center of gravity
hover	- to remain stationary relative to either the air mass or a point on the ground as specified in the applicable requirement

6.2.2 Speeds

refusal speed	- the maximum speed to which the aircraft can accelerate and then stop in the available runway length
TAS	- true airspeed
V	- airspeed along the flight path
$V_{max}(X)$, $V_{min}(X)$	- short-hand notation for the speeds V_{max}, V_{min} for a given configuration, weight, center-of-gravity position, and external store combination associated with Flight Phase X
V_{end}	- speed for maximum endurance
V_{range}	- speed for maximum range in zero wind conditions
V_{MAT}	- high speed, level flight, maximum augmented thrust

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TABLE XIV. Aircraft Normal States

Flight Phase		Weight	C.G.	External Stores	Thrust Magnitude	Thrust Angle	High Lift Devices	Wing Sweep	Wing Incidence	Landing Gear	Speed Brakes	Bomb Bay or Cargo Doors	Stability Augmentation	Other
Vertical Take-off	VT													
Short Take-off	ST													
Hover	H													
Precision Hover	PH													
Climb	CL													
Cruise	CR													
Loiter	LO													
Descent	D													
Emergency Descent	ED													
Emergency Deceleration	DE													
Non-terminal Transition	NT													
Terminal Transition	TT													
Approach	PA													
Wave-off/Go-around	WO													
Vertical Landing	VL													
Short Landing	SL													
Air-to-air Combat	CO													
Ground Attack	GA													
Weapon Delivery/Launch	WD													
Aerial Delivery	AD													
Aerial Recovery	AR													
Reconnaissance	RC													
In-flight Refuel (Receiver)	RR													
In-flight Refuel (Tanker)	RT													
Terrain Following	TF													
Antisubmarine Search	AS													
Close Formation Flying	FF													

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V_{max}	- maximum service speed (defined in 3.1.8.1)
V_{min}	- minimum service speed (defined in 3.1.8.2)
$V_{o_{max}}$	- maximum operational speed (3.1.7)
$V_{o_{min}}$	- minimum operational speed (3.1.7)
V_{con}	- the speed which establishes the upper limit of applicability of the requirements of this specification and the lower limit of applicability of the requirements of MIL-F-8785. No more precise definition of V_{con} will be attempted as it is assumed that V_{con} will be chosen by the contractor subject to approval by the procuring activity. Factors to be considered in the selection of V_{con} are discussed in the Background Information and User's Guide (BIUG); see 6.7.

6.2.3 Thrust and power

NRT	- normal rated thrust, which is the maximum thrust at which the engine can be operated continuously
MRT	- military rated thrust, which is the maximum thrust at which the engine can be operated for a specified period
MAT	- maximum augmented thrust: maximum thrust, augmented by all means available for the Flight Phase
T/W	- the ratio formed by dividing the thrust available by the aircraft's weight

6.2.4 Control parameters

Pitch, Roll, Yaw Controls	- the stick or wheel and rudder pedals manipulated in the cockpit by the pilot to produce pitching moments, rolling moments and yawing moments, respectively
Thrust Magnitude Control	- the lever which is manipulated in the cockpit by the pilot to produce changes in the magnitude of the thrust vector
Thrust Angle Control	- the lever or switch manipulated by the pilot to produce changes in the thrust angle, for example, wing-tilt angle control

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Pitch Control Force	- component of applied force, exerted by the pilot on the cockpit control, in or parallel to the plane of symmetry, acting at the center of the stick grip or wheel in a direction perpendicular to a line between the center of the stick grip or wheel and the stick or control column pivot
Roll Control Force	- for a stick control, the component of control force exerted by the pilot in a plane perpendicular to the plane of symmetry, acting at the center of the stick grip in a direction perpendicular to a line between the center of the stick grip and the stick pivot. For a wheel control, the total moment applied by the pilot about the wheel axis in the plane of the wheel, divided by the average radius from the wheel pivot to the pilot's grip
Thrust Magnitude Control Force	- component of applied force, exerted by the pilot on the cockpit control, in or parallel to the plane of symmetry acting at the center of the lever grip in a direction perpendicular to a line between the center of the lever grip and the lever column pivot
Yaw Control Force	- difference of push-force components of forces exerted by the pilot on the rudder pedals, lying in planes parallel to the plane of symmetry, measured perpendicular to the pedals at the normal point of application of the pilot's instep on the respective rudder pedals
Control Surface	- a surface or device which is positioned by a cockpit control or by stability augmentation, and which produces aerodynamic or jet-reaction type forces in such a manner as to control the forces, moments, or both, on the aircraft. As used in this specification, the pitch control surface, roll control surface, and yaw control surface are the control surfaces or devices which are controlled by the pitch, roll and yaw controls respectively
Nominal Control Moment	- one-half of the total control moment change available to the pilot using only the pitch, roll or yaw control at the given flight condition
Control Power	- the angular or linear acceleration available to the pilot with full cockpit control displacement from the given trim condition

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6.2.5 Longitudinal parameters

n	- normal load factor
n_L	- symmetrical flight limit load factor for a given Aircraft Normal State, based on structural considerations
n_{max}, n_{min}	- maximum and minimum service load factors (defined in 3.1.8.5)
$n(+)$, $n(-)$	- for a given altitude, the upper and lower boundaries of n in the V-n diagrams depicting the Service Flight Envelope
$n_{o_{max}}$, $n_{o_{min}}$	- maximum and minimum operational load factors (3.1.7)
$n_o(+)$, $n_o(-)$	- for a given altitude, the upper and lower boundaries of n in the V-n diagrams depicting the Operational Flight Envelope (see figures 6 and 7)
n/α	- the steady-state normal acceleration change per unit change in angle of attack for an incremental pitch control deflection at constant speed

6.2.6 Lateral-directional parameters

δ_{AS}	- roll control displacement
τ_R	- first-order roll mode time constant
δ_{RP}	- yaw control displacement
ω_{n_d}	- undamped natural frequency of the Dutch roll oscillation; $\omega_{n_d}^2$ greater than zero is indicative of positive weathercock stability (3.3.7.1)
ζ_d	- damping ratio of the Dutch roll oscillation
T_d	- damped period of the Dutch roll, $T_d = \dfrac{2\pi}{\omega_{n_d}\sqrt{1-\zeta_d^2}}$
ϕ	- bank angle
ϕ_1, ϕ_2, ϕ_3	- bank angles at the first, second and third peaks, respectively (figures 8 and 9)
p	- roll rate

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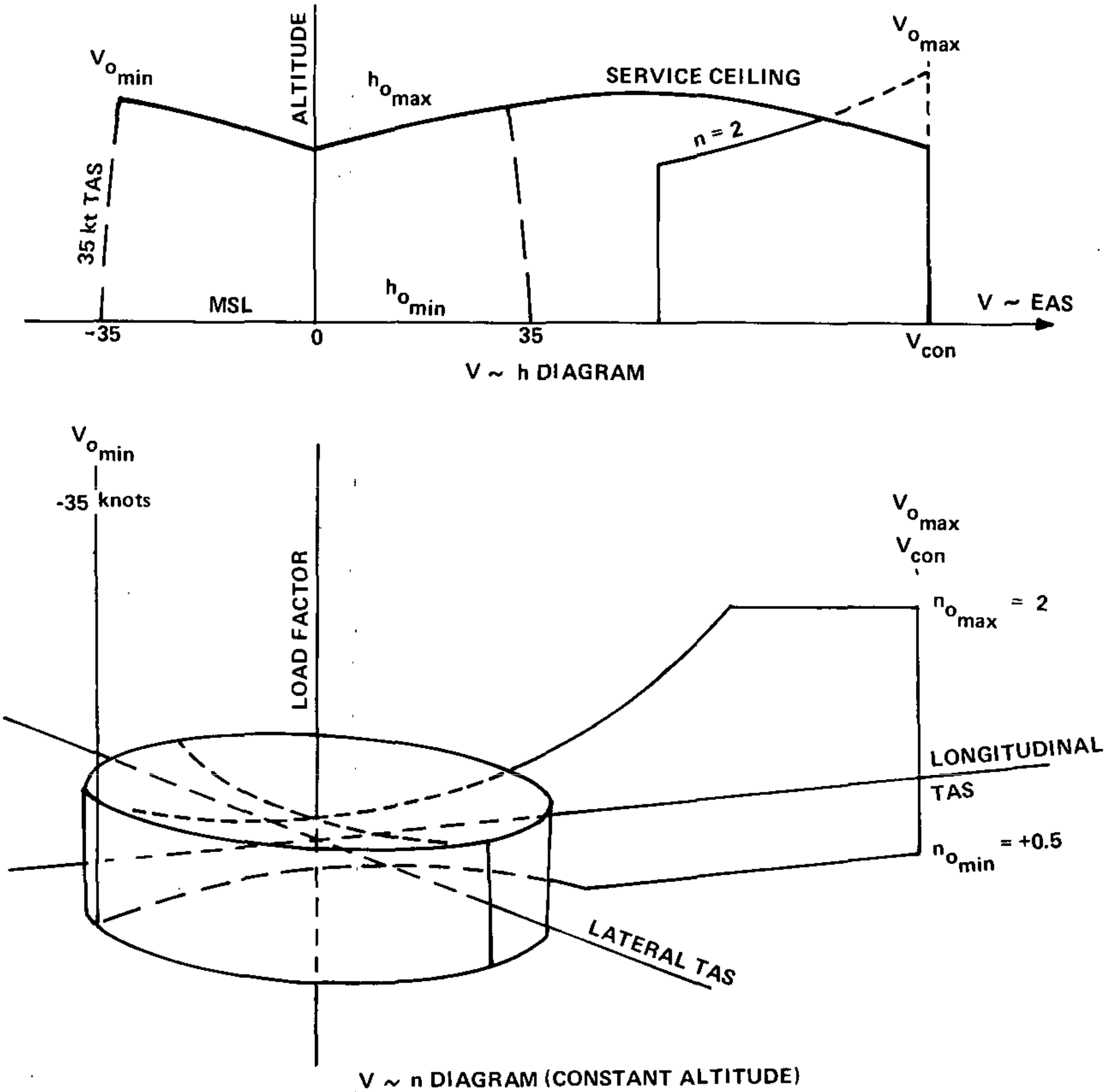

Figure 6.

TYPICAL OPERATIONAL FLIGHT ENVELOPE FOR FLIGHT PHASE CATEGORY B, NON-TERMINAL TRANSITION (NT), BASED ON LIMITS OF TABLE I

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SKETCH SHOWING TYPICAL RELATIONSHIP BETWEEN OPERATIONAL ENVELOPE AND SERVICE FLIGHT ENVELOPE FOR A GIVEN FLIGHT PHASE WHICH REQUIRES TWO NORMAL STATES.

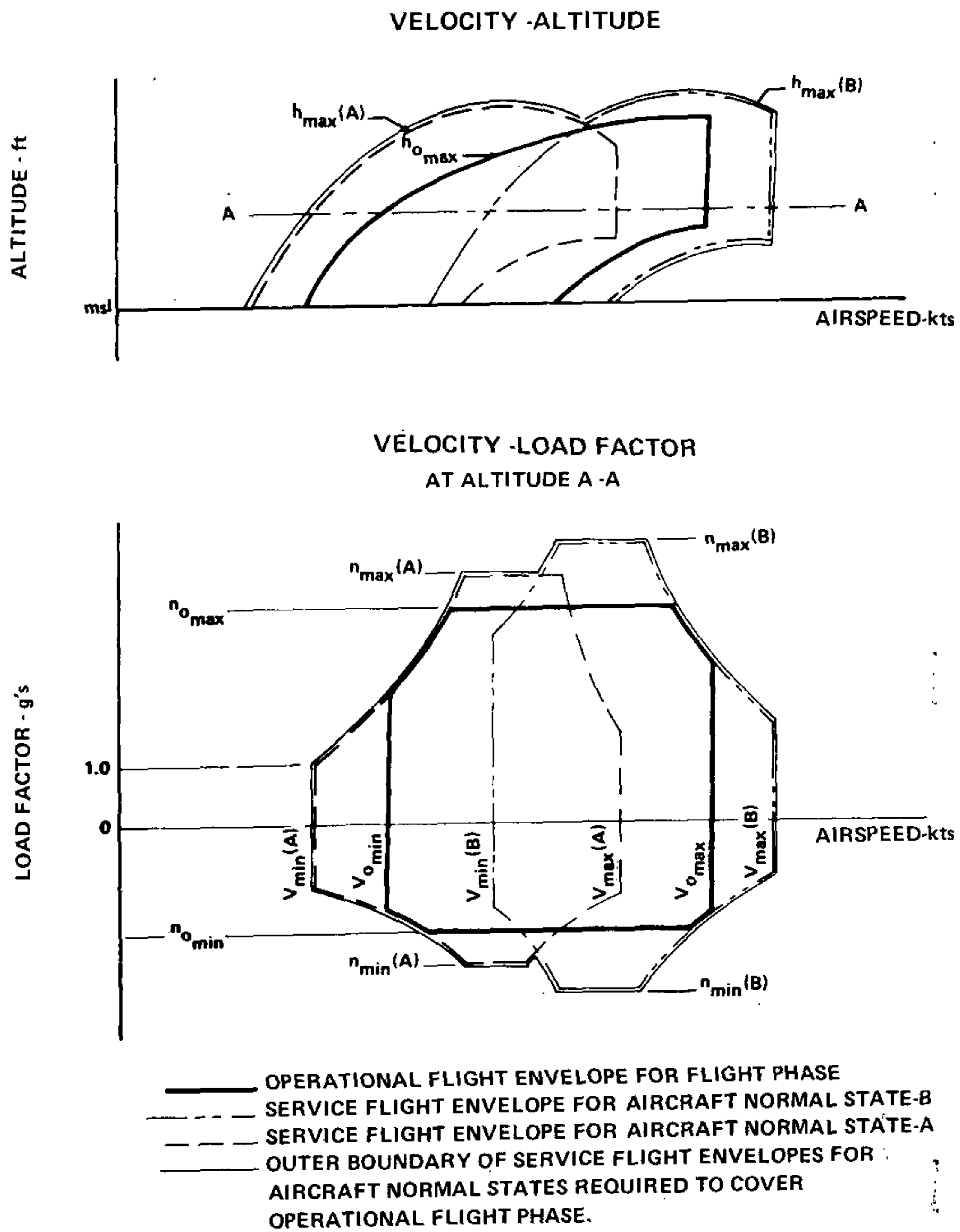

Figure 7 TYPICAL RELATIONSHIP BETWEEN OPERATIONAL ENV. AND SERVICE FLIGHT ENV. FOR A GIVEN FLIGHT PHASE REQUIRING TWO NORMAL STATES

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$\frac{\phi_{OSC}}{\phi_{AV}}$ - a measure of the ratio of the oscillatory component of bank angle to the average component of bank angle following an impulse roll control command with yaw control free:

$$\zeta_d \leq 0.2: \quad \frac{\phi_{OSC}}{\phi_{AV}} = \frac{\phi_1 + \phi_3 - 2\phi_2}{\phi_1 + \phi_3 + 2\phi_2}$$

$$\zeta_d > 0.2: \quad \frac{\phi_{OSC}}{\phi_{AV}} = \frac{\phi_1 - \phi_2}{\phi_1 + \phi_2}$$

ϕ_{AV}

$$\zeta_d \leq 0.2: \quad \phi_{AV} = 1/4\ (\phi_1 + \phi_3 + 2\phi_2)$$

$$\zeta_d > 0.2: \quad \phi_{AV} = 1/2\ (\phi_1 + \phi_2)$$

β - sideslip angle at the center of gravity, angle between undisturbed flow and plane of symmetry. Positive or right sideslip corresponds to incident flow approaching from the right side of the plane of symmetry.

$\Delta\beta$ - the maximum change in sideslip following an abrupt roll control pulse command within time $t_{\Delta\beta}$ where $t_{\Delta\beta}$ is the lesser of 6 seconds or one-half the Dutch roll period, and is measured from a point halfway through the duration of the pulse command (figures 8 and 9)

t_{n_β} - time for the Dutch roll oscillation in the sideslip response to reach the n^{th} local maximum for a right pulse roll control command, or the n^{th} local minimum for a left command (figures 8 and 9). The control shall be moved as abruptly as practical and, for purposes of this definition, time shall be measured from a point halfway through the duration of the pulse.

ψ_β - phase angle expressed as a lag for a cosine representation of the Dutch roll oscillation in sideslip, where

$$\psi_\beta = \frac{-360}{T_d} t_{n_\beta} + (n-1)360 \text{ (degrees)}$$

with n as in t_{n_β} above

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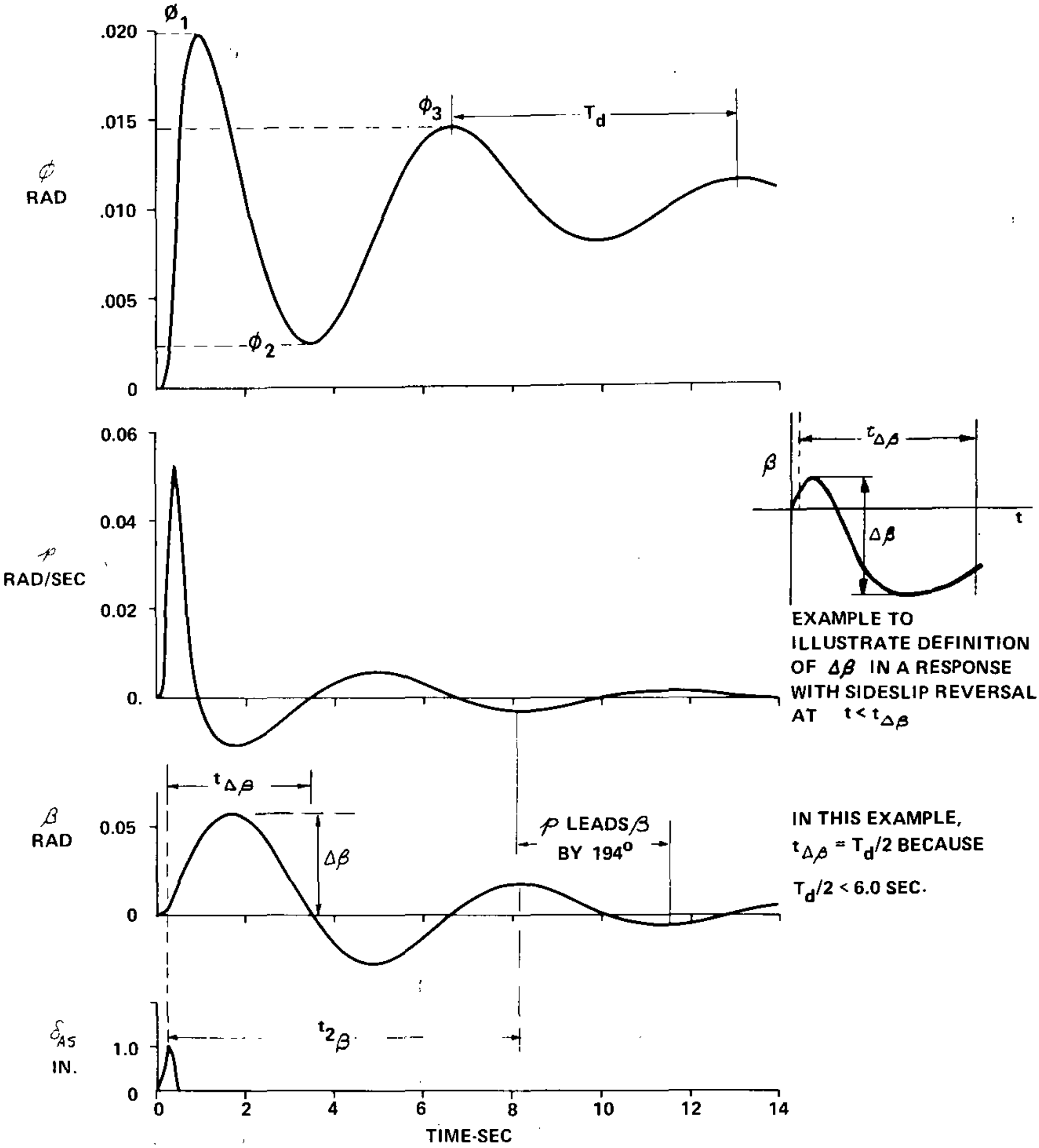

Figure 8 ROLL-SIDESLIP COUPLING PARAMETERS RIGHT ROLLS

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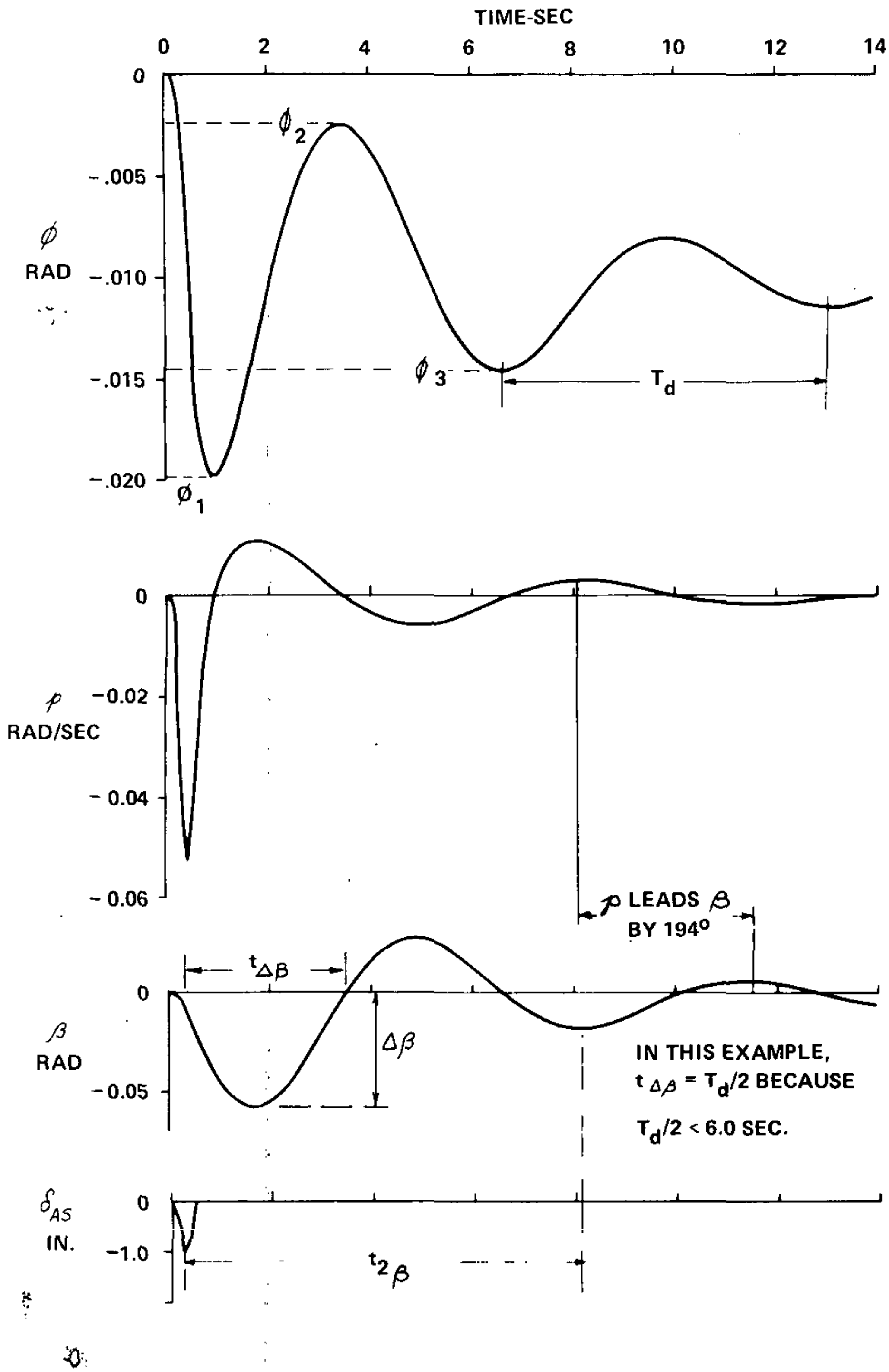

Figure 9 ROLL-SIDESLIP COUPLING PARAMETERS
LEFT ROLLS

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$|\phi/\beta|_d$ - at any instant, the ratio of amplitudes of the bank-angle and sideslip angle envelopes in the Dutch roll mode

Examples showing measurement of roll-sideslip coupling parameters are given in figure 8 for right rolls and figure 9 for left rolls. It should be noted that since ψ_β is the phase angle of the Dutch roll component of sideslip, care must be taken to select a peak far enough downstream that the position of the peak is not influenced by the roll mode. In practice, peaks occurring one or two roll mode time constants after the roll control input will be relatively undistorted. Care must also be taken when there is ramping of the sideslip trace, since ramping will displace the position of a peak of the trace from the corresponding peak of the Dutch roll component. In practice, the peaks of the Dutch roll component of sideslip are located by first drawing a line through the ramping portion of the sideslip trace and then noting the times at which the vertical distance between the line and the sideslip trace is the greatest.

6.3 Gain scheduling. Changes of mechanical gearings and stability augmentation gains in the flight control system are sometimes accomplished by scheduling the changes as a function of the settings of thrust lift angle or devices such as flaps or wing sweep. This practice is generally acceptable, but gearings and gains normally should not be scheduled as a function of trim control settings since pilots do not always keep aircraft in trim.

6.4 Effects of aeroelasticity, control equipment, and structural dynamics. Since aeroelasticity, control equipment, and structural dynamics may exert an important influence on the aircraft flying qualities, such effects should not be overlooked in calculations or analyses directed toward investigation of compliance with the requirements of this specification.

6.5 Application of Levels. Part of the intent of 3.1.10 is to ensure that the probability of encountering significantly degraded flying qualities because of component or subsystem failures is small. For example, the probability of encountering very degraded flying qualities (Level 3) must be less than specified values per flight.

6.5.1 Theoretical compliance. To determine theoretical compliance with the requirements of 3.1.10.2, the following steps must be performed:

a. Identify those Aircraft Failure States which have a significant effect on flying qualities (3.1.6.2).

b. Define the longest flight duration to be encountered during operational missions (3.1.1).

c. Determine the probability of encountering various Aircraft Failure States, per flight, based on the above flight duration (3.1.10.2).

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d. Determine the degree of flying qualities degradation associated with each Aircraft Failure State in terms of Levels as defined in the specific requirements.

e. Determine the most critical Aircraft Failure States (assuming the failures are present at whichever point in the Flight Envelope being considered is most critical in a flying qualities sense), and compute the total probability of encountering Level 2 flying qualities in the Operational Flight Envelope due to equipment failures. Likewise, compute the probability of encountering Level 3 flying qualities in the Operational Flight Envelope, etc.

f. Compare the computed values above with the requirements in 3.1.10.2 and 3.1.10.3.

If the requirements are not met, the designer must consider alternate courses such as:

(a) Improve the aircraft flying qualities associated with the more probable Failure States, or

(b) Reduce the probability of encountering the more probable Failure States through equipment redesign, redundancy, etc.

Regardless of the probability of encountering any given Aircraft Failure States (with the exception of Special Failure States) the flying qualities shall not degrade below Level 3.

6.5.2 Level definitions. To determine the degradation in flying qualities parameters for a given Aircraft Failure State the following definitions are provided:

a. Level 1 is better than or equal to the Level 1 boundary, or number, given in section 3.

b. Level 2 is worse than Level 1, but no worse than the Level 2 boundary, or number.

c. Level 3 is worse than Level 2, but no worse than the Level 3 boundary, or number.

When a given boundary, or number, is identified as Level 1 and Level 2, this means that flying qualities outside the boundary conditions shown, or worse than the number given, are at best Level 3 flying qualities. Also, since Level 1 and Level 2 requirements are the same, flying qualities must be within this common boundary, or number, in both the Operational and Service Flight Envelopes for Aircraft Normal States (3.1.10.1). Aircraft Failure States that do not degrade flying qualities beyond this

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common boundary are not considered in meeting the requirements of 3.1.10.2. Aircraft Failure States that represent degradations to Level 3 must, however, be included in the computation of the probability of encountering Level 3 degradations in both the Operational and Service Flight Envelopes. Again, degradation beyond the Level 3 boundary is not permitted, except for Special Failure States.

6.5.3 Computational assumptions. Assumptions a and b of 3.1.10.2 are somewhat conservative, but they simplify the required computations in 3.1.10.2 and provide a set of workable ground rules for theoretical predictions. The reasons for these assumptions are:

a. "...components and systems are...operating for a time period per flight equal to the longest operational mission time..." Since most component failure data are in terms of failures per flight hour, even though continuous operation may not be typical (e.g., yaw damper on during supersonic flight only), failure probabilities must be predicted on a per flight basis using a "typical" total flight time. The "longest operational mission time" as "typical" is a natural result. If acceptance cycles-to-failure reliability data are available (MIL-STD-756), these data may be used for prediction purposes based on maximum cycles per operational mission, subject to procuring activity approval. Also, finite wearout life components, such as engines at maximum take-off thrust, may be considered as exceptions and failure calculations shall be based on maximum normal operating time per flight in these cases, again subject to procuring activity approval. In any event, compliance with the requirements of 3.1.10.2, as determined in accordance with section 4, is based on the probability of encounter per flight.

b. "...failure is assumed to be present at whichever point...is most critical...." This assumption is in keeping with the requirements of 3.1.6.2 regarding Flight Phases subsequent to the actual failure in question. In cases that are unrealistic from the operational standpoint, the specific Aircraft Failure States might fall in the Aircraft Special Failure State classification (3.1.6.2.1).

6.6 Superseding data. This specification supersedes Military Specification MIL-H-8501A for U.S. Air Force use.

6.7 Related documents. The documents listed below, while they do not form a part of this specification, are so closely related to it that their contents should be taken into account in any application of this specification.

SPECIFICATIONS

Military

MIL-C-5011 Charts; Standard Aircraft Characteristics and Performance, Piloted Aircraft

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MIL-S-5711	Structural Criteria, Piloted Airplanes, Structural Tests, --Flight
MIL-M-7700	Manual, Flight
MIL-G-38478	General Requirements for Angle of Attack Based Systems
MIL-S-25015	Spinning Requirements for Airplanes

STANDARDS

MIL-STD-882	System Safety Program for Systems and Associated Subsystems, and Equipment; Requirement for

PUBLICATIONS

AFSC Design Handbook, Series 1-0 and 2-0

Background Information and User Guide for MIL-F-83300 - Military Specification--Flying Qualities of Piloted V/STOL Aircraft, AFFDL TR 70-88, March 1971

Custodians:
Army - AV
Navy - AS
Air Force - 11

Preparing activity:
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