Home

INCH-POUND

ADS-33E-PRF
21 March 2000
CAGE Code 18876
SUPERSEDING
ADS-33D-PRF
10 May 1996

AERONAUTICAL DESIGN STANDARD

PERFORMANCE SPECIFICATION

HANDLING QUALITIES REQUIREMENTS

FOR MILITARY ROTORCRAFT

AMSC N/A

ADS-33E-PRF

AERONAUTICAL DESIGN STANDARD

PERFORMANCE SPECIFICATION

HANDLING QUALITIES REQUIREMENTS FOR MILITARY ROTORCRAFT

UNITED STATES ARMY AVIATION AND MISSILE COMMAND

AVIATION ENGINEERING DIRECTORATE

REDSTONE ARSENAL, ALABAMA

FUNCTIONAL DIVISION: ______________________

SUBMITTED BY: ______________________

Barry J. Baskett
Director of Aviation Engineering

APPROVED BY: ______________________

FOR Dr. Larry O. Daniel
AMCOM and PEO, Aviation
Standards Executive

DATE: MAR 21 2000

CERTIFICATION RECORD

Board Date:

Document Identifier and Title:

ADS-33E-PRF, Aeronautical Design Standard, Performance Specification, Handling Qualities Requirements for Military Rotorcraft

Rationale for Certification:

Decision:

General Type	Decision (√)	Certification
Specification		Performance
		Detail
Standard		Interface Standard
		Standard Practice
		Design Standard
		Test Method Standard
		Process Standard
Handbook		Handbook (non-mandatory use)
Alternative Action		

	Concur	Nonconcur
Division Chief Samuel T. Crews	√	
AMCOM Standardization Branch Chief William J. Smith	√	
Director, Aviation Engineering Barry J. Baskett	√	
AMCOM and PEO, Aviation Standards Executive Dr. Larry O. Daniel	√	

C O N T E N T S

CONTENTS

PARAGRAPH PAGE

C O N T E N T S

C O N T E N T S

C O N T E N T S

CONTENTS

PARAGRAPH PAGE

C O N T E N T S

T A B L E S

TABLE PAGE

F I G U R E S

FIGURE PAGE

1. SCOPE

1.1 Scope

This specification contains the requirements for the flying and ground handling qualities of rotorcraft. It is intended that the specification should cover land based rotorcraft which have primary missions ranging from scout and attack to utility and cargo. Additional requirements or modified standards may be required for rotorcraft that have to operate from small ships in sea states resulting in more than small ship motion.

Intended use is described in 6.1.

1.2 Application

The requirements of this specification are intended to assure that no limitations on flight safety or on the capability to perform intended missions will result from deficiencies in flying qualities. Flying qualities for the rotorcraft shall be in accordance with the provisions of this specification unless specific deviations are authorized by the Government. 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 Government may, at its discretion, agree to a modified requirement that will maintain an equivalent degree of acceptability.

2. APPLICABLE DOCUMENTS

2.1 Government documents

NA

2.2 Specifications, standards, and handbooks

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the Department of Defense Index of specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Other Government documents, drawings, and publications

NA

2.4 Non-Government publications

NA

2.5 Order of precedence

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 General

3.1.1 Operational missions and Mission-Task-Elements (MTEs)

The system specification will define the operational missions and will specify the Mission-Task-Elements to be considered by the contractor in designing the rotorcraft to meet the requirements of this specification. These Mission-Task-Elements will represent the entire spectrum of intended operational usage and will in most cases be selected from those listed in Table I.

3.1.2 Required agility

Many of the quantitative criteria have multiple boundaries that discriminate between rotorcraft that have to maneuver precisely and aggressively and those that can accomplish their mission tasks with limited agility and maneuverability. Table I indicates which limit shall be met by associating a required agility with the intended MTEs. If no criterion is provided for the required agility, the next available lower value shall apply.

3.1.3 Operational environment

The system specification will specify the operational environment that must be considered by the contractor in designing the rotorcraft to meet the flying qualities requirements of this standard. Parameters to be defined include the following:

Degraded Visual Environment (DVE).

The IMC capability required.

The angle and azimuth for slope take-offs and landings.

The degree of divided attention operation.

Applicability of rotor start and stop capabilities for shipboard operations (3.9.1.1).

Applicability of ditching requirements (3.9.4).

3.1.4 Multi-crew rotorcraft

Unless otherwise stated, all requirements shall apply for the primary pilot station. The system specification will define the Mission-Task-Elements, Degraded Visual Environment, degree of divided attention, and Level of Flying Qualities that are applicable to any other pilot stations.

3.1.5 Levels of handling qualities

The overall rotorcraft Level of handling qualities shall be a combination of the two distinct methods of assessment, Predicted Levels and Assigned Levels.

3.1.5.1 Predicted Levels of handling qualities

To obtain the Predicted Levels of handling qualities, the rotorcraft's flying qualities parameters shall be determined and compared with the criteria limits appropriate to the rotorcraft's operational requirements. For the predicted Level of handling qualities to be Level 1, the rotorcraft shall meet the Level 1 standards for all of the criteria. Violation of any one requirement is expected to degrade handling qualities. Violation of several individual requirements (e.g., to Level 2) could have a synergistic effect so that, overall, the handling qualities degrade to Level 3, or worse.

3.1.5.2 Assigned Levels of handling qualities

To determine the Assigned Level of handling qualities, test pilots shall use the Cooper-Harper Handling Qualities Rating (HQR) Scale (Figure 1) to assess the workload and task performance required to perform the designated MTEs. For the assigned Level of handling qualities to be Level 1, the rotorcraft shall be rated Level 1 for all of the MTEs designated as appropriate to the rotorcraft's operational requirements. With an externally slung load in DVE, the HQRs shall be Level 1 for load mass ratios (6.2.8) less than 0.25, and shall not degrade to worse than 4.0 for load mass ratios up to 0.33. The Government shall judge the acceptability of any degradations when performing a MTE in moderate wind, and with load mass ratios greater than 0.33.

3.1.6 Flight envelopes

The Flight Envelopes shall be defined and shall clearly indicate the effects of rotorcraft configuration, loadings, settings and states.

3.1.6.1 Operational Flight Envelopes (OFE)

The Operational Flight Envelopes shall define the boundaries within which the rotorcraft must be capable of operating in order to accomplish the operational missions of 3.1.1. These envelopes shall be defined in terms of combinations of airspeed, altitude, load factor, rate-of-climb, side-velocity, and any other parameters specified by the system specification, as necessary to accomplish the operational missions. Any warnings or indications of limiting or dangerous flight conditions, required by 3.1.15, shall occur outside the OFEs.

3.1.6.2 Service Flight Envelopes (SFE)

The Service Flight Envelopes shall be derived from rotorcraft limits as distinguished from mission requirements. These envelopes shall be expressed in terms of the parameters used to define the OFEs, plus any additional parameters deemed necessary to define the appropriate limits. The inner boundaries of the SFEs are defined as coincident with the outer boundaries of the OFEs. The outer boundaries of the SFEs are defined by one or more of the following: uncommanded rotorcraft motions, or structural, engine/power-train, or rotor system limits. The magnitude of the differences between the inner and outer boundaries of the SFEs shall be based on the guarantee of adequate margins as required by 3.1.15.

3.1.7 Configurations

The configurations required for performance of the operational missions of 3.1.1 shall be defined.

3.1.8 Loadings

The possible Loadings for the Configurations defined in 3.1.7 shall be determined.

3.1.9 Flight conditions

The flight conditions where significant handling qualities effects or changes occur shall be defined.

3.1.10 Settings

The Settings that are available to the pilot shall be defined.

3.1.11 States

The Settings and Failure States that correspond to failure probabilities allowed by Table II shall be determined.

3.1.12 Rotorcraft status

For each of the Settings and States defined in 3.1.10 and 3.1.11 a set of Loadings, Configurations, and Flight Conditions shall be selected by the contractor for demonstrating compliance with this specification. This selection shall include combinations that are critical from the point of handling qualities, and shall be submitted to the Government for approval.

3.1.13 Levels for Normal States

The minimum Levels of flying qualities shall be Level 1 in the Operational Flight Envelopes and Level 2 in the Service Flight Envelopes.

3.1.13.1 Flight beyond the Service Flight Envelopes

Flight beyond the Service Flight Envelope that does not involve structural failure, or unrecoverable loss of rotor RPM, shall be recoverable to the SFE without undue pilot skill. If such an excursion involves an engine failure, the requirements of 3.7.2 or 3.7.3 shall apply.

3.1.14 Rotorcraft failures

When one or more Rotorcraft Failure States exist, a degradation in rotorcraft handling qualities is permitted. Two methods of assessment shall be used, the first relates the allowable degradation of handling qualities to the probability of encountering the failure, the second must consider specific failures to happen regardless of their probability.

3.1.14.1 Allowable Levels based on probability

The first method involves the following procedure:

a. Tabulate all rotorcraft Failure States.
b. Determine the degree of handling qualities degradation associated with the transient for each Rotorcraft Failure State.
c. Determine the degree of handling qualities degradation associated with the subsequent steady Rotorcraft Failure State.
d. Calculate the probability of encountering each identified Rotorcraft Failure State per flight hour.
e. Compute the total probabilities of encountering Level 2 and Level 3 flying qualities in the Operational and Service Flight Envelopes. (This total is the sum of the rate of each failure only if the failures are statistically independent.)

A degradation in Levels of handling qualities, due to the rotorcraft Failure States, is permitted only if the probability of encountering the degraded Level is sufficiently small. These probabilities shall be less than the values shown in Table II.

3.1.14.2 Allowable Levels for Specific Failures

The second method assumes that certain failures or combinations of failures will occur regardless of their probability of failure. Subject to Government approval, the contractor shall define which Failure States shall be treated as “Specific Failures.” The allowable Level of flying qualities for each Specific Failure will be specified by the Government. Alternatively, the system specification may specify specific piloting tasks and associated performance requirements in the Failure State. As a minimum, the failures in 3.7 shall be treated as Specific Failures.

3.1.14.3 Rotorcraft 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 this section if justification for considering the Failure States as Special is submitted by the contractor and subject to Government approval.

3.1.14.4 Transients following failures

The transient following a failure or combination of flight control system failures shall be recoverable to a safe steady flight condition without exceptional piloting skill. Tests to define the transients for comparison with the values in Table III and the results shall be made available to the Government. For rotorcraft without failure warning and cueing devices, the perturbations encountered shall not exceed the limits of Table III**.**

3.1.14.5 Indication of failures

Immediate and easily interpreted indications of failures shall be provided, if such failures require a change of strategy or crew action.

3.1.15 Rotorcraft limits

Limiting and potentially dangerous conditions may exist where the rotorcraft should not be flown. The pilot shall be provided with clear and unambiguous warnings and indications of approaches to rotorcraft limits. In near-earth operations, the warnings and indications shall be interpretable by the pilot with eyes out of the cockpit.

3.1.15.1 Devices for indication, warning, prevention, and recovery

It is preferred that limiting and dangerous flight conditions be eliminated and the requirements of this specification be met by appropriate aerodynamic and structural design rather than through incorporation of special devices for indication, warning, prevention, and recovery. However, if such devices are used, normal or inadvertent operation shall not create a hazard to the rotorcraft, or prohibit flight within the Operational Flight Envelope.

3.1.16 Pilot-induced oscillations

The rotorcraft shall be designed to have no tendency for pilot-induced oscillations (PIO), that is, unintentional sustained or uncontrollable motions resulting from the efforts of the pilot to control the rotorcraft.

3.1.17 Residual oscillations

Any sustained oscillations in any axis in calm air shall not interfere with the pilot's ability to perform the specified Mission-Task-Elements. For Level 1, oscillations in attitude and in acceleration at the pilot's station greater than 0.5 degrees and 0.05g shall be considered excessive for any Response-Type and Mission-Task-Element. These requirements shall apply with the cockpit controls fixed and free. Residual motions that are classified as a vibration shall be excluded from this requirement. Residual motions that are to be classified as vibrations shall be subject to Government approval.

3.2 Response-Types

The required Response-Types depend on the applicable MTE and the Usable Cue Environment. The specified Response-Types are intended to be minimums, and an upgrade may be provided if superior or equivalent flying qualities can be demonstrated.

3.2.1 Determination of the Usable Cue Environment

The Usable Cue Environment (UCE) shall be obtained from Figure 3 using visual cue ratings (VCRs) obtained from the flight assessments specified below. The VCRs shall be made by at least three pilots using the scale shown in Figure 2. The mean VCRs for each task shall be obtained by separately taking the average of all the pilot ratings in each axis. This will result in five average VCRs for each task: pitch, roll, and yaw attitude, and vertical and horizontal translational rate. This shall be reduced to two VCRs by taking the worst (numerically highest) average VCR among pitch, roll and yaw attitude, and between vertical and horizontal translational rate, for each task. These VCRs for attitude and translational rate shall be plotted on Figure 3 to obtain a UCE for each task. Points falling on a boundary in Figure 3 shall be considered to lie in the region of numerically higher UCE. The largest UCE value obtained in this process shall be used in Table IV to determine the required Response-Type. The visual cue ratings shall be determined using all displays and vision aids that are expected to be operationally available to the pilot, in the Degraded Visual Environments specified in 3.1.3.

3.2.1.1 Characteristics of test rotorcraft

The test rotorcraft shall have response characteristics that rank no higher than a Rate Response-Type as defined in 3.2.6. It shall be shown to be a Level 1 rotorcraft by demonstrating compliance with the applicable MTEs specified in 3.2.1.2, performed to DVE standards but in the GVE (UCE = 1).

3.2.1.2 Applicable Mission-Task-Elements

The following Mission-Task-Elements shall be flown when making the UCE assessments: hover, landing, pirouette, acceleration and deceleration (or depart/abort), sidestep (or lateral reposition), and vertical maneuver. The task descriptions and DVE performance limits specified in 3.11 for each of these maneuvers shall apply when making the VCR determinations.

3.2.1.3 Dispersions among visual cue ratings

Subject to Government approval, a level of UCE shall be assigned or additional pilots shall be used if the standard deviation of the individual visual cue ratings among the pilots is greater than 0.75 .

3.2.2 Required Response-Types

The Response-Types shall be in accordance with Table IV for hover and low speed, and Table V for forward flight. These required Response-Types are intended to be minimums, and an upgrade may be provided if superior or equivalent handling qualities can be demonstrated. If such an upgrade is selected, the requirements in 3.3 and 3.4 pertaining to the upgraded Response-Type apply.

3.2.2.1 Relaxation for Altitude (Height) Hold

A requirement for Vertical Rate Command with Altitude (Height) Hold may be relaxed if the Vertical Translational Rate Visual Cue Rating is 2 or better and divided-attention operation is not required. The vertical response shall meet the definition of a Vertical Rate Response-Type (3.2.10).

3.2.2.2 Additional requirement for Turn Coordination

Turn Coordination (TC) (3.2.11.1) shall be provided as an available Response-Type for the slalom MTE in low-speed flight. TC is not required at airspeeds below 15 knots.

3.2.2.3 Alternative for Attitude Hold in Forward Flight

For divided attention operations in Forward Flight, Attitude Hold may be replaced with an autopilot.

3.2.2.4 Requirement for Autopilot

In IMC the autopilot shall have a heading select/hold function. For decelerating approaches to minimums below 200 feet, the autopilot shall be coupled to the glideslope and localizer.

3.2.3 Response-Type ranking

The rank-ordering of combinations of Response-Types from least to most stabilization shall be defined as:

1. RATE
2. RATE+RCDH+RCHH+PH
3. ACAH+RCDH
4. ACAH+RCDH+RCHH
5. ACAH+RCDH+RCHH+PH
6. TRC+RCDH+RCHH+PH

A specified Response-Type may be replaced with a higher rank of stabilization. For UCE=1 it is important to insure that the higher rank of stabilization does not preclude meeting the moderate and large amplitude requirements.

TRC is not recommended for pitch pointing.

3.2.4 Combinations of degraded Response-Type and dynamics in degraded UCE

In UCE > 1, a combination of Level 2 Response-Type (Table IV or Table V) and Level 2 dynamic characteristics (3.3 or 3.4) shall be interpreted as Level 3.

3.2.5 Rotorcraft guidance

For near-earth operations at night and in poor weather (UCE > 1), sufficient visual cues shall be provided to allow the pilot to navigate over the terrain, and to maneuver the rotorcraft to avoid obstacles while accomplishing the Mission-Task-Elements.

3.2.6 Character of Rate Response-Types

A response that fails to meet the requirements defining the character of an Attitude Command Response-Type (3.2.8) or a Translational Rate Command Response-Type (3.2.9) shall be classified as a Rate Response-Type in that axis. No requirement on the specific shape of the response to control inputs is specified, except that the initial and final cockpit control force required to change from one steady attitude to another shall not be of opposite sign.

3.2.7 Character of Attitude Hold and Heading Hold Response-Types

If Attitude Hold or Heading (Direction) Hold is specified as a required Response-Type in 3.2.2 the response to a pulse input shall be as illustrated in Figure 4. The pulse shall be inserted directly into the control actuator, unless it can be demonstrated that a pulse cockpit controller input will produce the same response.

Pitch attitude shall return to within 10 percent of peak or one degree, whichever is greater, following a pulse input, in less than 20 seconds for UCE=1, and in less than 10 seconds for UCE>1.

Roll attitude and heading shall always return to within 10 percent of peak or one degree, whichever is greater, in less than 10 seconds.

The attitude or heading shall remain within the specified limit for at least 30 seconds for Level 1. The peak attitude and heading excursions for this test shall vary from barely perceptible to at least 10 degrees.

3.2.7.1 Additional requirement for Heading Hold

For Heading Hold, following a release of the directional controller the rotorcraft shall capture the reference heading (in degrees) within 10 percent of the yaw rate at release (in deg/sec) or one degree, whichever is greater, as shown in Figure 4. In no case shall a divergence result from activation of the Heading Hold mode.

3.2.8 Character of Attitude Command Response-Types

If Attitude Command is specified as a required Response-Type in 3.2.2, a step cockpit pitch (roll) controller force input shall produce a proportional pitch (roll) attitude change within 6 seconds. The attitude shall remain essentially constant between 6 and 12 seconds following the step input. However, the pitch (roll) attitude may vary between 6 and 12 seconds following the input, if the resulting ground-referenced translational longitudinal (lateral) acceleration is constant, or its absolute value is asymptotically decreasing towards a constant. A separate trim control shall be supplied to allow the pilot to null the cockpit controller forces at any achievable steady attitude.

3.2.9 Character of Translational Rate Response-Types

If Translational Rate Command is specified as a required Response-Type in 3.2.2, constant pitch and roll controller force and deflection inputs shall produce a proportional steady translational rate, with respect to the earth, in the appropriate direction.

3.2.10 Character of Vertical Rate Response-Types

The rotorcraft shall be defined as having a Vertical Rate Response-Type if a constant deflection (force if an isometric controller is used) of the vertical axis controller from trim produces a constant steady-state vertical velocity. Provision shall be provided for the pilot to null the cockpit controller force at any achievable vertical rate.

3.2.10.1 Character of Vertical Rate Command with Altitude (Height) Hold

If Vertical RCHH (Rate Command with Altitude (Height) Hold) is specified as a required Response-Type in 3.2.2, following an altitude deviation induced by insertion and removal of an input directly into the vertical-axis actuator, the rotorcraft shall return to its original altitude without objectionable delays and with no overshoot. For hover and low speed, the rotorcraft shall automatically hold altitude with respect to a flat surface for land-based operations, or a rough sea for sea-based operations, with the altitude controller free. For Level 1, the altitude deviation shall not exceed desired performance requirements of the hover, hovering turn, pirouette, and sidestep MTEs during the performance of these MTEs as defined for DVE. Engagement of Altitude Hold shall be obvious to the pilot through clear tactile and visual indication. The pilot shall be provided with a means to disengage Altitude Hold, change altitude, and reengage Altitude Hold without removing his hands from the flight controls.

3.2.11 Character of yaw response to lateral controller

3.2.11.1 Turn coordination

For low-speed and forward flight, during banked turns with any available Heading Hold modes disengaged, the rotorcraft heading response to lateral controller inputs shall remain sufficiently aligned with the direction of flight so as not to be objectionable to the pilot. Complex coordination of the yaw and roll controls shall not be required.

3.2.11.2 Rate Command with Direction Hold

For hover, the yaw controller inputs required to maintain constant heading during rolling maneuvers shall not be objectionably large or complex.

3.2.12 Limits on nonspecified Response-Types

It may be desirable, or even necessary, to incorporate Response-Types that are not explicitly defined in this specification. Examples of such Response-Types are Airspeed Hold, Linear Acceleration Command with Velocity Hold, and hybrid responses such as ACAH for small attitudes that blend to Rate for larger commands or attitudes. These Response-Types shall meet the requirements of this specification. In addition, their operation shall not result in excessive excursions in rotorcraft attitudes, or require objectionably complex or unfamiliar control strategies.

3.2.13 Requirements for inputs to control actuator

Control input shaping may be used to achieve the necessary command-response relationship for backup flight control systems. The requirements to check for adequate disturbance rejection via inputs directly into the control actuator (3.2.7, 3.2.10.1, 3.3.2.2, 3.3.7 and 3.4.11) shall be waived for Levels 2 and 3.

3.2.14 Transition between airborne and ground operations

There shall be no tendency for uncommanded, divergent motions of any primary flight control surface when the rotorcraft is in contact with any potential landing platform. This requirement is aimed specifically at integrators in the flight control system that must be turned off when rotorcraft motion is constrained by contact with a fixed object.

3.3 Hover and low speed requirements

The hover and low speed requirements shall apply throughout the applicable portions of the Operational and Service Flight Envelopes for operations up to 45 knots ground speed.

3.3.1 Equilibrium characteristics

The equilibrium pitch and roll attitudes required to achieve a no-wind hover, and to achieve equilibrium flight in a 35 knot relative wind from any direction, shall not result in pilot discomfort, disorientation, or restrictions to the field-of-view that would interfere with the accomplishment of the Mission-Task-Elements of 3.1.1. Nose-up trim attitudes that potentially result in tail boom clearance problems are discouraged.

3.3.2 Small-amplitude pitch (roll) attitude changes

3.3.2.1 Short-term response to control inputs (bandwidth)

The pitch (roll) response to longitudinal (lateral) cockpit control position inputs shall meet the limits specified in Figure 5. The bandwidth (ω_{BW}) and phase delay (τ_p) parameters shall be obtained from frequency responses as defined in Figure 6. It is desirable to also meet this criterion for controller force inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing shall be conducted to determine that the force feel system is not excessively sluggish. For Attitude Command Response-Types, if the bandwidth defined by gain margin is less than the bandwidth defined by phase margin, or is undefined, the rotorcraft may be PIO prone. In this case flight testing shall be performed to determine acceptability.

3.3.2.2 Short-term pitch and roll responses to disturbance inputs

Pitch and roll responses to inputs directly into the control surface actuator shall meet the bandwidth limits based on cockpit controller inputs as specified in 3.3.2.1. If the bandwidth and phase delay parameters based on inputs to the control surface actuator can be shown to meet the cockpit control input bandwidth requirements by analysis, no testing shall be required. This requirement shall be met for Level 1, and relaxed according to 3.2.13 for Levels 2 and 3.

3.3.2.3 Mid-term response to control inputs

The mid-term response characteristics shall apply at all frequencies below the bandwidth frequency obtained in 3.3.2.1. Use of an Attitude Hold Response-Type shall constitute compliance with this requirement, as long as any oscillatory modes following an abrupt controller input have an effective damping ratio of at least $\zeta = 0.35$. If Attitude Hold is not available, the applicable criterion shall depend on the degree of pilot attention according to 3.1.3.

3.3.2.3.1 Fully attended operations

The mid-term response shall meet the limits of Figure 7.

3.3.2.3.2 Divided attention operations

The limits of Figure 7 shall be met, except that the Level 1 damping ratio shall not be less than $\zeta = 0.35$ at any frequency.

3.3.3 Moderate-amplitude pitch (roll) attitude changes (attitude quickness)

The ratio of peak pitch (roll) rate to change in pitch (roll) attitude, $q_{pk}/\Delta\theta_{pk}$ $(p_{pk}/\Delta\phi_{pk})$, shall meet the limits specified in Figure 8. The required attitude changes shall be made as rapidly as possible from one steady attitude to another without significant reversals in the sign of the cockpit control input relative to the trim position. The attitude changes required for compliance with this requirement shall vary from 5 deg in pitch (10 deg in roll) to the limits of the Operational Flight Envelope or 30 deg in pitch (60 deg in roll), whichever is less. It is not necessary to meet this requirement for Response-Types that are designated as applicable only to UCE = 2 or 3.

3.3.4 Large-amplitude pitch (roll) attitude changes

The achievable angular rate (for Rate Response-Types) or attitude change from trim (for Attitude Response-Types) shall be at least those specified in Table VI. The specified rates or attitudes shall be achieved in each axis while limiting excursions in the other axes with the appropriate control inputs. Response-Types that are designated as applicable exclusively to UCE = 2 or 3 are only required to meet the Limited agility requirements (3.1.2).

3.3.5 Small-amplitude yaw attitude changes

3.3.5.1 Short-term response to yaw control inputs (bandwidth)

The heading response to directional cockpit control position inputs shall meet the limits specified in Figure 9. The bandwidth ($\omega_{BW\psi}$) and phase delay (τ_{p_ψ}) parameters are obtained from frequency responses as defined in Figure 6. It is desirable to also meet this criterion for controller force inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing shall be conducted to determine that the force feel system is not excessively sluggish.

3.3.5.2 Mid-term response to control inputs

The mid-term response characteristics shall apply at all frequencies below the bandwidth frequency obtained in 3.3.5.1. Use of a Heading Hold Response-Type shall constitute compliance with this paragraph, as long as any oscillatory modes following a cockpit controller pulse input have an effective damping ratio of at least $\zeta = 0.35$. If heading hold is not available, the applicable criterion shall depend on the degree of pilot attention according to 3.1.3.

3.3.5.2.1 Fully attended operations

The mid-term response shall meet the requirements of Figure 7, except that the Level 1 limit on effective damping ratio for oscillations with natural frequencies greater than 0.5 rad/sec is relaxed from 0.35 to 0.19.

3.3.5.2.2 Divided attention operations

The limits of Figure 7 shall be met, except that the Level 1 damping ratio shall not be less than $\zeta = 0.19$ at any frequency.

3.3.6 Moderate-amplitude heading changes (attitude quickness)

The ratio of peak yaw rate to change in heading, $r_{pk}/\Delta\psi_{pk}$, shall meet the limits specified in Figure 10.

The required heading changes shall be made as rapidly as possible from one steady heading to another and without significant reversals in the sign of the cockpit control input relative to the trim position. It is not necessary to meet this requirement for Response-Types that are designated as applicable only to UCE = 2 or 3.

3.3.7 Short-term yaw response to disturbance inputs

Yaw response to inputs directly into the control surface actuator shall meet the bandwidth limits of 3.3.5.1. If the bandwidth and phase delay parameters based on inputs to the control surface actuator can be shown by analysis to meet the cockpit control input bandwidth requirements, no testing is required. This requirement applies for Level 1 only.

3.3.7.1 Yaw rate response to lateral gusts

The peak yaw rate within the first three seconds following a step lateral gust input shall be such that the ratio, r_{pk}/V_g, shall not exceed 0.30 (deg/sec)/(ft/sec) for Level 1 or 1.0 (deg/sec)/(ft/sec) for Level 2. This requirement shall apply for lateral gust magnitudes from 10 to 25 knots in the presence of a steady wind of up to 25 knots from the most critical direction, except that the total wind velocity need not exceed 35 knots. Flight testing for this requirement shall not be required.

3.3.8 Large-amplitude heading changes

The achievable yaw rate in hover shall be at least the values specified in Table VI. The specified angular rates shall be achieved about the yaw axis while limiting excursions in the other axes with the appropriate control inputs, and with main rotor RPM at the lower sustained operating limit. Response-Types that are designated as applicable only to UCE = 2 or 3 shall meet at least the Limited agility requirements (3.1.2).

3.3.9 Interaxis coupling

Control inputs to achieve a response in one axis shall not result in objectionable responses in one or more of the other axes.

3.3.9.1 Yaw due to collective for Aggressive agility

The yaw rate response to abrupt step collective control inputs with the directional controller fixed shall not exceed the boundaries specified in Figure 11. The directional controller may be free if the rotorcraft is equipped with a heading hold function. Pitch and roll attitudes shall be maintained essentially constant. In addition, there shall be no objectionable yaw oscillations following step or ramp collective changes in the positive and negative directions. Oscillations involving yaw rates greater than 5 deg/sec shall be deemed objectionable.

3.3.9.2 Pitch due to roll and roll due to pitch coupling for Aggressive agility

The ratio of peak off-axis attitude response from trim within 4 seconds to the desired (on-axis) attitude response from trim at 4 seconds, $\Delta\theta_{pk}/\Delta\phi_4$ $(\Delta\phi_{pk}/\Delta\theta_4)$, following an abrupt lateral (longitudinal) cockpit control step input, shall not exceed ±0.25 for Level 1 or ±0.60 for Level 2. Heading shall be maintained essentially constant.

3.3.9.3 Pitch due to roll and roll due to pitch coupling for Target Acquisition and Tracking

The pitch due to roll (q/p) and roll due to pitch (p/q) coupling for Target Acquisition and Tracking shall not exceed the limits specified in Figure 12. The average q/p and average p/q are derived from ratios of pitch and roll frequency responses. Specifically, average q/p is defined as the magnitude of pitch-due-to-roll control input (q/δ_{lat}) divided by roll-due-to-roll control input (p/δ_{lat}) averaged between the bandwidth and neutral-stability (phase = -180 deg) frequencies of the pitch-due-to-pitch control inputs (θ/δ_{lon}). Similarly, average p/q is defined as the magnitude (p/δ_{lon}) divided by (q/δ_{lon}) between the roll-axis (ϕ/δ_{lat}) bandwidth and neutral stability frequencies. Off-axis inputs shall be minimized while generating the frequency response data. Multi-input/multi-output frequency response identification techniques shall be used to analyze the frequency responses to account for the effect of inadvertent multiple-axis control inputs which may have been present during the excitation.

3.3.10 Response to collective controller

3.3.10.1 Height response characteristics

The vertical rate response shall have a qualitative first-order appearance for at least 5 seconds following a step collective input. If the most rapid input achievable is not a clear step, the time zero shall be defined as shown in Figure 13. Pitch, roll, and heading excursions shall be maintained essentially constant. The limits on the parameters defined by the following equivalent first-order vertical-rate-to-collective transfer function shall be in accordance with Table VII.

$$\frac{\dot{h}}{\delta_c} = \frac{K e^{-(\tau_{\dot{h}_{eq}} s)}}{T_{\dot{h}_{eq}} s + 1}$$

The equivalent system parameters shall be obtained using the time domain fitting method defined below. The coefficient of determination, r^2, shall be greater than 0.97 and less than 1.03 for compliance with this requirement.

Obtain readings ft/sec from response to step collective input at intervals of no greater than t = 0.05 sec for a time span of 5 sec – a total of $n = 5/\Delta t + 1$ data points (minimum n = 101).

Use a three variable nonlinear least squares algorithm to obtain a best fit curve to this data in the time domain using the following form for the estimated $\dot{h}\left(\dot{h}_{est}\right)$

$$\dot{h}_{est}(t) = K\left[1 - \exp\left[-(t - \tau_{\dot{h}_{eq}})/T_{\dot{h}_{eq}}\right]\right] \qquad \text{for } t > 0$$

where t is time (sec) and K, $1/T_{\dot{h}_{eq}}$ and $\tau_{\dot{h}_{eq}}$ are the variables. (Note: $\tau_{\dot{h}_{eq}}$ may be less than zero.)

The function to be minimized is the sum of squares of the error (e), defined as,

$$e^2 = \sum_{i=1}^{n} \left[\dot{h}(t = t_i) - \dot{h}_{est}(t = t_i)\right]^2$$

where t_i is the time (sec) at the ith observed data point.

The goodness of fit of the estimated curve shall be determined by the coefficient of determination (r^2) which is defined as

$$r^2 = \frac{\sum_{i=1}^{n}\left[\dot{h}_{est}(t = t_i) - \dot{h}_m\right]^2}{\sum_{i=1}^{n}\left[\dot{h}(t = t_i) - \dot{h}_m\right]^2}$$

where $\dot{h}_m$ is the mean of the observed $\dot{h}$, $\dot{h}_m = \sum_{i=1}^{n}\frac{\dot{h}(t = t_i)}{n}$

3.3.10.2 Torque response

Torque, or any other parameter displayed to the pilot as a measure of the maximum allowable power that can be commanded without exceeding engine or transmission limits, shall have dynamic response characteristics that fall within the limits specified in Figure 14. This requirement shall apply if the displayed parameter must be manually controlled by the pilot to avoid exceeding displayed limits.

3.3.10.3 Vertical axis control power

From a spot OGE hover with the wind vector from the most critical speed and direction at a velocity of up to 35 knots, and with the most critical loading and density altitude, for Level 1 it shall be possible to achieve a vertical rate of at least 160 ft/min, 1.5 seconds after initiation of a rapid displacement of the collective control from trim. The minimum vertical rates shall be 55 ft/min for Level 2 and 40 ft/min for Level 3. Pitch, roll, and heading shall be maintained essentially constant. Applicable engine and transmission limits shall not be exceeded.

3.3.10.4 Rotor RPM governing

The rotor RPM shall remain within the limits set by the Service Flight Envelopes during the execution of all Mission-Task-Elements specified in 3.1.1 conducted within the Operational Flight Envelopes.

3.3.11 Position Hold

This requirement shall apply when Position Hold is a required Response-Type. When Position Hold is engaged, the rotorcraft shall automatically hold its position with respect to a ground fixed or shipboard hover reference. The rotorcraft shall maintain its position within a 10 ft diameter circle during a 360 degree turn in a steady wind of up to 35 knots. The 360 degree turn shall be accomplished by the use of the directional controller with the pitch and roll controllers free and collective control as required to maintain constant altitude. The maneuver shall be completed in less than 10 seconds if Aggressive agility is required, 30 seconds if only Moderate agility is required and 45 seconds for Limited agility. The pitch and roll attitudes shall not exceed ±18 degrees at any point in the 360 degree turn. The pitch and roll attitude responses to pitch and roll controller inputs shall meet the requirements of 3.3.2 with the Position Hold system engaged. There shall be a clear annunciation to the pilot indicating status of the Position Hold function.

3.3.12 Translational Rate Response-Type

For Response-Types designated as Translational Rate Command, the translational rate response to step cockpit pitch (roll) control position or force inputs shall have a qualitative first order appearance, and shall have an equivalent rise time, $T_{\dot{x}_{eq}}$ ($T_{\dot{y}_{eq}}$), no less than 2.5 seconds and no greater than 5 seconds. The parameter $T_{\dot{x}_{eq}}$ ($T_{\dot{y}_{eq}}$) is defined in Figure 15a. For Level 1, the following requirements shall apply:

a. The pitch and roll attitudes shall not exhibit objectionable overshoots in response to a step cockpit controller input.

b. Zero cockpit control force and deflection shall correspond to zero translational rate with respect to fixed objects, or to the landing point on a moving ship.

c. There shall be no noticeable overshoots in the response of translational rate to control inputs. The gradient of translational rate with control input shall be smooth and continuous.

In addition, for centerstick controllers, the variation in translational rate with control deflection should lie within the limits of Figure 15b. For sidestick controllers, the variation in translational rate with control force should lie within the limits of Figure 15c.

3.4 Forward flight requirements

The forward flight requirements shall apply throughout the applicable portions of the Operational and Service Flight Envelopes for operations at greater than 45 knots groundspeed.

3.4.1 Pitch attitude response to longitudinal controller

3.4.1.1 Short-term response (bandwidth)

The pitch attitude response to longitudinal cockpit control position inputs shall meet the limits specified in Figure 16. The bandwidth (ω_{BW_θ}) and phase delay ($\tau_{p\theta}$) parameters shall be obtained from frequency responses as defined in Figure 6. It is desirable to also meet this criterion for controller force inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing shall be conducted to determine that the force feel system is not excessively sluggish. For Attitude Command Response-Types, if the bandwidth defined by gain margin is less than the bandwidth defined by phase margin, or is undefined, the rotorcraft may be PIO prone. In this case flight testing shall be performed to determine acceptability.

3.4.1.2 Mid-term response to control inputs

The mid-term response characteristics shall apply at all frequencies below the bandwidth frequency obtained in 3.4.1.1. Use of an Attitude Hold Response-Type shall constitute compliance with this requirement, as long as any oscillatory modes following a pulse controller input have an effective damping ratio of at least $\zeta = 0.35$. If Attitude Hold is not available, the applicable criterion shall depend on the degree of pilot attention according to 3.1.3.

3.4.1.2.1 Fully attended operations

The mid-term response shall meet the requirements of Figure 7.

3.4.1.2.2 Divided attention operations

The limits of Figure 7 shall be met, except that the Level 1 damping ratio shall not be less than $\zeta = 0.35$ at any frequency.

3.4.1.3 Mid-term response – maneuvering stability

The following maneuvering stability requirements shall apply at all airspeeds greater than 45 knots.

3.4.1.3.1 Control feel and stability in maneuvering flight at constant speed

In steady turning flight at constant airspeed, and in pullups and pushovers, for Levels 1 and 2 there shall be no tendency for the rotorcraft pitch attitude or angle of attack to diverge aperiodically. For the above conditions, the incremental control force required to maintain a change in normal load factor and pitch rate shall be in the same sense (aft force – more positive load factor, forward force – more negative load factor) as those required to initiate the change. These requirements shall apply for all local gradients.

3.4.1.3.2 Control forces in maneuvering flight

The variations in longitudinal cockpit control force with steady-state normal acceleration shall have no objectionable nonlinearities throughout the Operational Flight Envelope. At no time shall a negative local gradient be permitted. In addition, deflection of the longitudinal cockpit controller shall not lead the control force at any frequency below 5 rad/sec. For Level 1 the following requirements shall apply:

a. For centerstick controllers, the local force gradient, Fs/n, shall be at least 3 lb/g and no greater than 15 lb/g.

b. For sidestick controllers, the local force gradient shall be at least 3 lb/g and no greater than 6 lb/g.

c. The local slope of Fs vs. n should be relatively constant over the range of normal accelerations within the Operational Flight Envelopes. A variation of more than 50 percent shall be considered as excessive.

3.4.2 Pitch control power

For Level 1, from trimmed, unaccelerated flight the rotorcraft shall achieve the load factor limits specified in the Operational Flight Envelopes during turns or pull-up/push-over maneuvers.

For Level 2, the following requirements shall apply:

a. There shall be sufficient pitch control authority to accelerate from 45 knots to the maximum level flight airspeed, and to decelerate back to 45 knots at constant altitude.

b. Sufficient pitch authority shall be available to maintain altitude if full power is applied at 45 knots and if minimum power is applied at maximum level flight airspeed.

3.4.3 Flight path control

When operating at airspeeds on the frontside of the power required curve, 3.4.3.1 shall apply. For operation at airspeeds on the backside of the power required curve, or when 3.4.3.1 cannot be met, 3.4.3.2 shall apply. For the purpose of this requirement, frontside operation shall be defined when the slope of the steady-state response of flight path angle vs. airspeed, $\Delta\gamma_{ss}/\Delta V_{ss}$, resulting from a step change in pitch attitude, with collective held fixed, is negative. Backside operation shall be defined when this slope is positive or zero.

3.4.3.1 Flight path response to pitch attitude (frontside)

The vertical rate response shall not lag the pitch attitude response, with the collective controller held fixed, by more than 45 degrees at all frequencies below 0.40 rad/sec for Level 1 and 0.25 rad/sec for Level 2.

3.4.3.2 Flight path response to collective controller (backside)

The vertical rate response shall have a qualitative first-order appearance for at least 5 seconds following a step collective input. Pitch attitude excursions shall be limited so that they have a negligible effect on the vertical rate response. The limits on the parameters defined by the following equivalent first-order vertical-rate-to-collective transfer function shall be in accordance with the values specified in Table VIII.

The equivalent system parameters are to be obtained using the time domain fitting method defined in 3.3.10.1. The coefficient of determination, r^2, shall be greater than 0.97 and less than 1.03 for compliance with this requirement.

$$\frac{\dot{h}}{\delta_c} = \frac{K e^{-(\tau_{\dot{h}_{eq}} s)}}{T_{\dot{h}_{eq}} s + 1}$$

3.4.3.3 Rotor RPM governing

The rotor RPM shall remain within the limits set by the Service Flight Envelopes during the execution of all Mission-Task-Elements specified in 3.1.1 conducted within the Operational Flight Envelopes.

3.4.4 Longitudinal static stability

Push (pull) force on the longitudinal controller shall always be required to increase (decrease) speed. Without retrimming, steady state changes in controller force for increased (decreased) speed shall be push (pull) or zero.

3.4.5 Interaxis coupling

Control inputs in one axis shall not result in objectionable responses in one or more of the other axes while performing any of the Mission-Task-Elements specified in 3.1.1.

3.4.5.1 Pitch attitude due to collective control

3.4.5.1.1 Small collective inputs

The peak change in pitch attitude from trim, $\Delta\theta_{peak}$, occurring within the first 3 seconds following a step change in collective causing less than 20% torque change, shall be such that the ratio $\left|\Delta\theta_{peak}/\Delta n_{z_{peak}}\right|$ is no greater than 1.0 deg/ft/sec^2, where $\Delta n_{z_{peak}}$ is the peak incremental normal acceleration from 1 g flight.

3.4.5.1.2 Large collective inputs

The peak change in pitch attitude from trim, $\Delta\theta_{peak}$, occurring within the first 3 seconds following a step change in collective causing greater than or equal to 20% torque change shall be such that the ratio $\left|\Delta\theta_{peak}/\Delta n_{z_{peak}}\right|$ is no greater than 0.5 deg/ft/sec^2 in the up direction and 0.25 deg/ft/sec^2 in the down direction.

3.4.5.1.3 Pitch control in autorotation

During an autorotation to touchdown from any point in the Operational Flight Envelopes, there shall be at least 5 percent of the total (stop-to-stop) pitch controller effectiveness remaining throughout the maneuver.

3.4.5.2 Roll due to pitch coupling for Aggressive agility

The ratio of peak roll attitude response from trim within 4 seconds to the desired pitch attitude response from trim at 4 seconds, $\Delta\phi_{pk}/\Delta\theta_4$, following an abrupt longitudinal cockpit control step input, shall not exceed ±0.25 for Level 1 or ±0.60 for Level 2. Heading shall be maintained essentially constant.

3.4.5.3 Pitch due to roll coupling for Aggressive agility

The pitch response resulting from bank to bank maneuvering with collective held fixed, and the yaw controller used as necessary to achieve turn coordination, shall not be objectionable to the pilot.

3.4.5.4 Pitch due to roll and roll due to pitch coupling for Target Acquisition and Tracking

The pitch due to roll (q/p) and roll due to pitch (p/q) coupling for Target Acquisition and Tracking shall not exceed the limits specified in Figure 12. The average q/p and average p/q are derived from ratios of pitch and roll frequency responses. Specifically, average q/p is defined as the magnitude of pitch-due-to-roll control input (q/δ_{lat}) divided by roll-due-to-roll control input (p/δ_{lat}) averaged between the bandwidth and neutral-stability (phase = -180 deg) frequencies of the pitch-due-to-pitch control inputs (θ/δ_{lon}). Similarly, average p/q is defined as the magnitude (p/δ_{lon}) divided by (q/δ_{lon}) between the roll-axis (ϕ/δ_{lat}) bandwidth and neutral stability frequencies. Off-axis inputs shall be minimized while generating the frequency response data. Multi-input/multi-output frequency response identification techniques shall be used to analyze the frequency responses to account for the effect of inadvertent multiple-axis control inputs which may have been present during the excitation.

3.4.6 Roll attitude response to lateral controller

3.4.6.1 Small-amplitude roll attitude response to control inputs (bandwidth)

The roll attitude response to lateral cockpit control position inputs shall meet the limits specified in Figure 17. The bandwidth (ω_{BW_ϕ}) and phase delay (τ_{p_ϕ}) parameters shall be obtained from frequency responses as defined in Figure 6. It is desirable to also meet this criterion for controller force inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing shall be conducted to determine that the force feel system is not excessively sluggish. For Attitude Command Response-Types, if the bandwidth defined by gain margin is less than the bandwidth defined by phase margin, or is undefined, the rotorcraft may be PIO prone. In this case flight testing shall be performed to determine acceptability.

3.4.6.2 Moderate amplitude attitude changes (attitude quickness)

The ratio of peak roll rate to change in bank angle, $p_{pk}/\Delta\phi_{pk}$, shall meet the limits specified in Figure 18.

The required attitude changes shall be made as rapidly as possible from one steady attitude to another without significant reversals in the sign of the cockpit control input relative to the trim position. The attitude changes required for compliance with this requirement shall vary from 10 deg to the limits of the Operational Flight Envelope or 60 deg, whichever is less. The parameters in Figure 18 are defined in Figure 8.

3.4.6.3 Large-amplitude roll attitude changes

The achievable roll rate (for Rate Response-Types) or attitude change from trim (for Attitude Response-Types) shall be at least those specified in Table IX. Yaw control may be used to reduce sideslip that retards roll rate (not to produce sideslip that augments roll rate).

3.4.6.4 Linearity of roll response

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

3.4.7 Roll-sideslip coupling

The requirements on roll-sideslip coupling shall apply for both right and left lateral control commands of all magnitudes up to the magnitude required to meet the roll performance requirements of 3.4.6.2. The cockpit yaw controller shall be free. The parameters defined in Figure 19 shall be used.

3.4.7.1 Bank angle oscillations

The value of the parameter ϕ_{OSC}/ϕ_{AV} following a pulse lateral control command for Rate Response-Types or step command for Attitude Response-Types shall be within the limits specified in Figure 20 for Levels 1 and 2. The input shall be as abrupt as practical. For Levels 1 and 2, ϕ_{AV} shall always be in the direction of the lateral control command.

3.4.7.2 Turn coordination

The amount of sideslip resulting from abrupt lateral control commands shall not be excessive or require complicated or objectionable directional control coordination. The ratio of the maximum change in sideslip angle to the initial peak magnitude in roll response, $|\Delta\beta/\phi_1|$, for an abrupt lateral control pulse command for Rate Response-Types or step command for Attitude Response-Types, shall not exceed the limit specified on Figure 21. In addition, if the ratio $|\phi/\beta|_d$ exceeds 0.20, the product $0.20 \times |\Delta\beta/\phi_1| \times |\phi/\beta|_d$ shall not exceed the limit specified on Figure 21.

3.4.8 Yaw response to yaw controller

3.4.8.1 Small-amplitude yaw response for Target Acquisition and Tracking (bandwidth)

The heading response to cockpit yaw control position inputs shall meet the limits specified in Figure 22. The bandwidth (ω_{BW_ψ}) and phase delay (τ_{p_ψ}) parameters shall be obtained from frequency responses as defined in Figure 6. It is desirable to also meet this criterion for controller force inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing shall be conducted to determine that the force feel system is not excessively sluggish.

3.4.8.2 Large-amplitude heading changes for Aggressive agility

The heading change in 1 second following an abrupt step displacement of the yaw control shall not be less than:

Level 1: the lesser of 16 degrees or β_L

Level 2: the lesser of 8 degrees or 1/2 β_L

Level 3: the lesser of 4 degrees or 1/4 β_L

where β_L is the sideslip limit of the Operational Flight Envelope in degrees. Other controls should be fixed but may be used to reduce pitch and roll attitude excursions.

3.4.8.3 Linearity of directional response

There shall be no objectionable nonlinearities in the variation of directional response with yaw control deflection or force.

3.4.8.4 Yaw control with speed change

With the rotorcraft initially trimmed directionally, yaw control shall be sufficient to maintain heading constant with the yaw controller, at constant bank angle, when speed is rapidly increased or decreased 30 percent from the trim speed or 20 knots, whichever is less (except where limited by the boundaries of the Service Flight Envelope). For pedal controllers, the yaw control forces shall not be greater than one-half those of Table XIII. For other yaw control types, the forces required shall not be objectionable to the pilot. These requirements shall be satisfied without retrimming and accomplished at constant power (altitude varies), and at constant altitude (power varies).

3.4.9 Lateral-directional stability

3.4.9.1 Lateral-directional oscillations

The frequency, ω_n, and damping ratio, ζ, of the lateral-directional oscillations following a yaw control doublet, shall meet the minimums specified on Figure 23. This requirement shall also be met for a roll control pulse input. 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 nonlinear with amplitude, the requirements shall apply to each cycle of the oscillation.

3.4.9.2 Spiral stability

Following a lateral pulse control input, the time for the bank angle to double amplitude 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 rotorcraft trimmed for straight and level flight. The values specified apply to an exponential divergence and should not depend on the size of the control input. If the variation of roll angle with time is linear following the pulse control input, this requirement is satisfied.

3.4.10 Lateral-directional characteristics in steady sideslips

The requirements of 3.4.10.1 through 3.4.10.3.1 shall be met while performing yaw-control-induced, steady zero-yaw-rate sideslips with the rotorcraft trimmed for straight and level flight.

3.4.10.1 Yaw control in steady sideslips (directional stability)

For the sideslips specified in 3.4.10, right yaw control deflection and force shall be required in left sideslips and left yaw control deflection and force shall be required in right sideslips. For Levels 1 and 2, the following requirements shall apply. Between sideslip angles of ±15 degrees, or the sideslip limit of the Operational Flight Envelopes, whichever is less, the variation of yaw controller deflection and force shall be essentially linear with sideslip. For larger sideslip angles, an increase in yaw control deflection shall always be required for an increase in sideslip, and 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.

3.4.10.2 Bank angle in steady sideslips

For the sideslips specified in 3.4.10, 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.

3.4.10.3 Lateral control in steady sideslips

For the sideslips specified in 3.4.10, right (left) sideslips shall not require left (right) lateral control deflection or force. For Levels 1 and 2, the variation of lateral control deflection and force with sideslip angle shall be essentially linear.

<u>3.4.10.3.1 Positive effective dihedral limit</u>

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 75 percent of the roll control power available to the pilot and no more than 11 pounds of roll control force (for centerstick controllers) are required for sideslip angles that might be experienced in performing the required Mission-Task-Elements. The corresponding limits for Level 2 shall be 90 percent and 13.5 pounds.

3.4.11 Pitch, roll, and yaw responses to disturbance inputs

Pitch, roll, and yaw responses to inputs directly into the control surface actuator shall meet the bandwidth limits based on cockpit controller inputs specified in 3.4.1.1 (pitch), 3.4.6.1 (roll), and 3.4.8.1 (yaw). If the bandwidth and phase delay parameters based on inputs to the control surface actuator can be shown by analysis to meet the cockpit control input requirements, no testing shall be required. This requirement shall apply for Level 1 only.

3.5 Transition of a variable configuration rotorcraft between rotor-borne and wing-borne flight

This paragraph is reserved for future requirements.

3.6 Controller characteristics

3.6.1 Conventional controllers

3.6.1.1 Centering and breakout forces

Pitch, roll, and yaw controls shall exhibit positive centering in flight at any normal trim setting. The combined effects of centering, breakout force, stability, and force gradient shall not produce objectionable flight characteristics or permit noticeable 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 breakout forces shall be within the limits specified in Table X for hover and low speed and Table XI for forward flight. The change in breakout force with speed shall not be objectionable. The minimum collective-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.

3.6.1.2 Force gradients

The pitch, roll, and yaw control force gradients shall be within the range specified in Table XII throughout the range of control deflections. In addition, the force produced by a one 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 shall preferably have zero force gradient unless an autothrottle function such as Height Hold, or envelope cueing, is active.

3.6.1.3 Limit control forces

Unless otherwise specified in particular requirements, the maximum control forces required, without retrimming, for any maneuver consistent with the specified Mission-Task-Elements (3.1.1) shall not exceed the values stated in Table XIII.

3.6.2 Sidestick controllers

This paragraph is reserved for future requirements.

3.6.3 Sensitivity and gradients

The pitch, roll, yaw, and collective controller sensitivities and gradients shall be consistent with the rotorcraft dynamic response characteristics in each axis at all flight conditions. In no case shall the controller sensitivity or gradient produce responses that are objectionably abrupt or sluggish.

3.6.4 Cockpit control free play

The free play in each control, that is, any motion of the cockpit control that does not move the appropriate moment- or force-producing device in flight, shall not be objectionable.

3.6.5 Control harmony

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

3.6.6 Trimming characteristics

It shall be possible to trim controller forces to zero for all unaccelerated flight conditions. Actuation of the trim device to null controller force shall not produce an objectionable change in rotorcraft attitude or translational rate. Operation of the trimmers shall not require a force that is objectionably low or high. The trimmer shall not produce objectionable stick jump, trim rates, or slippage in the trim control position.

3.6.7 Dynamic coupling

There shall be no tendency for dynamic coupling between the rotorcraft and the controller with or without the pilot in the loop. In particular, there shall be no lightly damped, high frequency oscillations that cease when the pilot releases the controller.

3.7 Specific failures

The requirements relating to specific system failures shall apply throughout the Operational and Service Flight Envelopes and are to be treated without regard to their probability of occurrence.

3.7.1 Failures of the flight control system

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

a. Complete or partial loss of any function of the flight control system following any single failure.

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

c. Configuration changes required or recommended following failure.

3.7.2 Engine failures

From any condition within the Service Flight Envelope the rotorcraft shall be capable of:

a. Safely sustaining a single-engine failure.

b. Safely entering into power-OFF autorotation.

c. Safely landing on a level surface from all points outside the height-velocity curve.

3.7.2.1 Altitude loss

For multi-engined rotorcraft, in level flight, at the minimum speed where altitude can be maintained with one engine inoperative, the allowable altitude loss following a single-engine failure shall be no more than 50 ft.

3.7.3 Loss of engine and/or electrical power

Complete or partial loss of engine power and/or loss of an electrical subsystem shall not result in handling qualities worse than Level 2. Engine start during single engine or autorotational flight shall not cause the flight control system(s) to fail or become inoperative.

3.8 Transfer between Response-Types

The transients and trim changes caused by the intentional transfer between Response-Types shall not be objectionable.

3.8.1 Annunciation of Response-Type to the pilot

If more than one Response-Type can be selected in a given axis, there shall be a clear and easily interpretable annunciation to the pilot indicating which of the Response-Types are currently engaged or armed. For near-earth operations, the annunciation shall be located so that it is not necessary for the pilot to significantly shift his eye point of regard from the forward near-field or to look around, or refocus any vision aid.

3.8.2 Control forces during transfer

Following transfer between Response-Types, control forces required to suppress transients shall not exceed one-third of the appropriate limit control forces in Table XIII. The rotorcraft shall initially be trimmed at a fixed operating point, and during the transfer the heading, altitude, rate of climb or descent, and speed shall be maintained without use of the trimmer controls. For blending, the limit forces shall apply over the time interval specified in 3.8.3 following completion of the pilot action initiating the blend. There shall be no objectionable buffeting or oscillations of the control device during the blend.

3.8.3 Control system blending

Blending between Response-Types shall be essentially linear with time and shall occur within the time limitations specified below.

Blending During Deceleration: $2 \text{ sec} < t_{blend} < 10 \text{ sec}$

Blending During Acceleration: $2 \text{ sec} < t_{blend} < 5 \text{ sec}$

When blending from a series to a parallel trim system, a longitudinal or directional trim follow-up may be used as long as the cockpit controller does not move more than 20 percent of its travel in either direction during the blend.

3.9 Ground handling and ditching characteristics

Flight control system and landing gear characteristics shall allow takeoff, landing, and required ground maneuvers to be performed without excessive pilot workload or objectionable characteristics. In particular, the following capabilities shall be provided as required by the system specification.

3.9.1 Rotor start/stop

It shall be possible, while on the ground, to start and stop the rotor blades in mean winds up to at least 45 knots from the most critical direction.

3.9.1.1 Shipboard operation

It shall be possible to bring the engines to idle power without engaging the rotor(s), and to stop the blades within 20 seconds after engine shutdown.

3.9.2 Parked position requirement

It shall be possible, without the use of wheel chocks or skid restraints, to maintain a fixed position on a level paved surface at the normal takeoff rotor speed as power is increased prior to lift-off.

3.9.3 Wheeled rotorcraft ground requirements

The following ground handling conditions shall be met for all operational weather conditions.

a. It shall be possible, without the use of brakes, to maintain a straight path while taxiing or performing rolling takeoffs or landings in a wind of up to 45 knots from any direction.

b. It shall be possible to make complete 360-degree turns in either direction by pivoting on either main landing gear in a wind of up to 45 knots from any direction. These turns shall be made within a radius equaling the major dimension of the rotorcraft.

c. It shall be possible to perform all required maneuvers, including taxiing, rolling takeoffs and landings, and pivoting, without damage to rotor stops and without contact between the main rotor or tail rotor blades and any part of the rotorcraft structure.

3.9.4 Ditching characteristics

The following characteristics shall be provided either as part of the rotorcraft design or in supplementary kit form. The system specification will specify the range of sea states for which the characteristics must be provided.

3.9.4.1 Water landing requirement

In both power-ON and power-OFF autorotative conditions, it shall be possible to make a safe landing on smooth water up to at least 20 knots surface speed with an 8 ft/sec rate of descent and at least 30 knots with a 5 ft/sec rate of descent at angles of yaw up to 15 degrees.

3.9.4.2 Ditching techniques

Attitude and airspeed conditions shall be established for ditching the rotorcraft on water in the event of:

a. The loss of all engine power.

b. The failure of one engine.

Ditching shall not cause immediate injury to the occupants, or make it impossible to exit the rotorcraft through the emergency exits (i.e., due to an adverse static water level on the cabin emergency exits or the blocking of emergency exits by all or part of the flotation system).

3.9.4.3 Flotation requirements

The flotation time and trim attitude characteristics of the rotorcraft shall be such that the crew and passengers are provided with a sufficient length of time to exit the rotorcraft safely and to enter life rafts without application of a rotor brake, sea anchor, or similar device. A sea anchor may be used to assist in deployment of life rafts.

3.9.4.4 Single failures of the flotation equipment

The flotation time and trim attitude requirements of 3.9.4.3 shall also be met with the most critical compartment of the flotation system inoperative (i.e., as caused by a leak deflating the compartment or a failure in actuation of the inflation mechanism).

3.10 Requirements for externally slung loads

3.10.1 Load release

The rotorcraft shall be capable of safely jettisoning external loads from any condition within the External Loads Service Flight Envelope.

3.10.2 Failure of external load system

Within the External Loads Service Flight Envelope, any single failure of a suspension system element (including attachment fittings, slings, pendants, apex fittings, and cargo hooks) shall not result in loss of control of the rotorcraft or cause substantial damage to the airframe. When crew members have the capability to monitor and jettison the load in a fully attended manner, a 1.0 second failure recognition delay time shall be considered when evaluating crew initiated jettison scenarios.

3.11 Mission-Task-Elements

A selection of flight test maneuvers are provided in the form of precisely defined Mission-Task-Elements (MTEs). All MTEs designated by 3.1.1 shall be accomplished. These MTEs provide a basis for an overall assessment of the rotorcraft's ability to perform certain critical tasks, and result in an assigned level of HQ (3.1.5.2). To allow for different standards of precision and aggressiveness, the performance standards for each task are listed separately for different rotorcraft categories and for both Good Visual Conditions (GVE) and Degraded Visual Conditions (DVE). Generally GVE means clear daylight with good cueing and unaided vision. DVE means specifically the operational environment defined in 3.1.1. Typically DVE will be night with some level of illumination (moon and overcast) while using the actual mission equipment vision aid.

Conduct of tests. The applicable MTEs shall be performed with all combinations of manual flight control modes and displays available to the pilot and used as they would normally be used in the conduct of the maneuver. Altitude and position requirements refer to a selected reference point on the rotorcraft that is to be determined by the testing activity. Generally this should be close to the pilot’s eye point, but for small rotorcraft the Hovering Turn and Turn to Target may be performed about the center of gravity. All altitudes given are above ground level. A description of a suggested test course is provided for each maneuver. However, the test course markings and detail are left to the discretion of the testing activity. The terms “calm winds,” “moderate winds,” “stabilized hover,” and “landing gear” are defined in 6.2.

Each MTE shall be assessed by at least three pilots. These pilots shall each assign a subjective rating using the Cooper-Harper Handling Qualities Rating scale (Figure 1). The arithmetic average across all pilots of the Cooper-Harper Handling Qualities Ratings forms the overall rating for the MTE. All individual ratings and associated evaluation commentary shall be documented and supplied to the Government. The maneuvers shall be performed to assess the rotorcraft in configurations and states that are most critical for handling qualities in accordance with 4 Verification.

Performance standards. The use of Cooper-Harper Handling Qualities Ratings requires the definition of numerical values for desired and adequate performance. These performance limits are set primarily to drive the level of aggressiveness and precision to which the maneuver is to be performed. Compliance with the performance standards may be measured subjectively from the cockpit or by the use of ground observers. It is not necessary to utilize complex instrumentation for these measurements. Experience has shown that lines painted on the rotorcraft and markers on the ground are adequate to provide sufficient cues for ground or onboard observers to perceive whether the rotorcraft is within desired or adequate performance parameters. In any event, the contractor shall develop a scheme for demonstrating compliance that uses at least outside observers and in-cockpit observations. This plan will be subject to approval by the Government. The evaluation pilot is to be advised any time his performance fails to meet the desired limits, immediately following the completion of the maneuver, and before the pilot rating is assigned. In cases where the performance does not meet the specified limits, it is acceptable for the evaluation pilot to make as many repeat runs as necessary to insure that this is a consistent result. Repeat runs to improve performance may expose handling qualities deficiencies. Such deficiencies should be an important factor in the assigned pilot rating.

Visual cueing. If the inability to meet a performance standard in GVE is due to a lack of visual cueing, the test course should be modified to provide the required pilot cues. This is allowed in the context that the purpose of these maneuvers is to check rotorcraft handling, not problems associated with a lack of objects on the test course. To accommodate different performance standards the test courses may be modified to conduct the DVE maneuvers. If additional modifications in visual cueing are required to enhance the visual cues in the DVE, the changes shall be defined and submitted to the Government for approval prior to testing.

3.11.1 Hover

a. Objectives.

• Check ability to transition from translating flight to a stabilized hover with precision and a reasonable amount of aggressiveness.

• Check ability to maintain precise position, heading, and altitude in the presence of a moderate wind from the most critical direction in the GVE; and with calm winds allowed in the DVE.

b. Description of maneuver. Initiate the maneuver at a ground speed of between 6 and 10 knots, at an altitude less than 20 ft. For rotorcraft carrying external loads, the altitude will have to be adjusted to provide a 10 ft load clearance. The target hover point shall be oriented approximately 45 degrees relative to the heading of the rotorcraft. The target hover point is a repeatable, ground-referenced point from which rotorcraft deviations are measured. The ground track should be such that the rotorcraft will arrive over the target hover point (see illustration in Figure 24). In the GVE, the maneuver shall be accomplished in calm winds and in moderate winds from the most critical direction. If a critical direction has not been defined, the hover shall be accomplished with the wind blowing directly from the rear of the rotorcraft.

c. Description of test course. The suggested test course for this maneuver is shown in Figure 24. Note that the hover altitude depends on the height of the hover sight and the distance between the sight, the hover target, and the rotorcraft. These dimensions may be adjusted to achieve a desired hover altitude.

d. Performance standards. Accomplish the transition to hover in one smooth maneuver. It is not acceptable to accomplish most of the deceleration well before the hover point and then to creep up to the final position.

Performance – Hover

	Scout/Attack		**Cargo/Utility**		**Externally Slung Load**	
	GVE	DVE	GVE	DVE	GVE	DVE
DESIRED PERFORMANCE						
• Attain a stabilized hover within X seconds of initiation of deceleration:	3 sec	10 sec	5 sec	10 sec	10 sec	13 sec
• Maintain a stabilized hover for at least:	30 sec	30 sec	30 sec	30 sec	30 sec	30 sec
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground:	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft
• Maintain altitude within ±X ft:	2 ft	2 ft	2 ft	2 ft	4 ft	4 ft
• Maintain heading within ±X deg:	5 deg	5 deg	5 deg	5 deg	5 deg	5 deg
• There shall be no objectionable oscillations in any axis either during the transition to hover or the stabilized hover	✓*	✓	✓	✓	✓	NA*
ADEQUATE PERFORMANCE						
• Attain a stabilized hover within X seconds of initiation of deceleration:	8 sec	20 sec	8 sec	15 sec	15 sec	18 sec
• Maintain a stabilized hover for at least:	30 sec	30 sec	30 sec	30 sec	30 sec	30 sec
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground:	6 ft	8 ft	6 ft	6 ft	6 ft	6 ft
• Maintain altitude within ±X ft:	4 ft	4 ft	4 ft	4 ft	6 ft	6 ft
• Maintain heading within ±X deg:	10 deg	10 deg	10 deg	10 deg	10 deg	10 deg

*Note: For all tables, ✓ = performance standard applies; NA = performance standard not applicable

3.11.2 Landing

a. Objectives.

• Check ability to precisely control the rotorcraft position during the final descent to a precision landing point.

• Check pilot-vehicle dynamics when pilot is forced into tight compensatory tracking behavior.

b. Description of maneuver. Starting from an altitude of greater than 10 ft, maintain an essentially steady descent to a prescribed landing point. It is acceptable to arrest sink rate momentarily to make last-minute corrections before touchdown.

c. Description of test course. This task may be performed using the hover course (Figure 24) with the designated landing point being directly under the reference point on the rotorcraft when the pilot's eye is at the hover point.

d. Performance standards.

Performance – Landing

	GVE	DVE
DESIRED PERFORMANCE		
• Accomplish a gentle landing with a smooth continuous descent, with no objectionable oscillations	✓	NA
• Once altitude is below 10 ft, complete the landing within X seconds	10 sec	10 sec
• Touch down within ±X ft longitudinally of the designated reference point	1 ft	1 ft
• Touch down within ±X ft laterally of the designated reference point	0.5 ft	0.5 ft
• Attain a rotorcraft heading at touchdown that is aligned with the reference heading within ±X deg:	5 deg	5 deg
• Final position shall be the position that existed at touchdown. It is not acceptable to adjust the rotorcraft position and heading after all elements of the landing gear have made contact with the pad.	✓	NA
ADEQUATE PERFORMANCE		
• Touch down and remain within ±X ft of the designated landing point	3 ft	3 ft
• Attain a rotorcraft heading at touchdown that is aligned with the reference heading within ±X deg:	10 deg	10 deg

3.11.3 Slope landing

a. Objectives.

• Check adequacy of any stability and control augmentation system changes that respond to partial or full landings.

• Check ability to precisely coordinate control of the heave axis and lateral axis with either the left or right part of the landing gear in contact with the ground.

• Check ability to precisely coordinate control of the heave axis and longitudinal axis with either the aft or forward part of the landing gear on the ground.

b. Description of maneuver. Perform a vertical landing to a sloped surface with the rotorcraft longitudinal axis oriented perpendicular to the fall line. Also perform vertical landings to a sloped surface with the rotorcraft longitudinal axis oriented parallel to the fall line. The landings shall be made with the nose pointed uphill and downhill, and with the up-slope to the left and right. For all of the slope landings, follow the following procedure. Once the upslope landing gear is in contact with the ground, maintain a level rotorcraft attitude for a short period of time, and then gently lower the downslope landing gear to the ground. Raise the downslope landing gear, keeping the upslope landing gear in contact with the ground, and maintain a level rotorcraft attitude for a short time before liftoff.

c. Description of test course. The test area shall consist of sloped terrain that is at least 75% of the rotorcraft slope landing performance limits. The landing area shall be clearly marked on the ground.

d. Performance standards.

Performance – Slope Landing

	GVE	DVE
DESIRED PERFORMANCE		
• Touch down and maintain a final position within an area that is X ft longer than the rotorcraft landing gear	6 ft	6 ft
• Touch down and maintain a final position within an area that is X ft wider than the rotorcraft landing gear	4 ft	4 ft
• Maintain heading within ±X deg:	5 deg	5 deg
• Maintain a level rotorcraft attitude with one part of the landing gear in contact with the ground and the rest in the air for at least X seconds before lowering and raising the downhill part of the landing gear	5 sec	5 sec
• No perceptible horizontal drift at touchdown	✓	✓
• Any load limits shall remain within the OFE	✓	✓
ADEQUATE PERFORMANCE		
• Touch down and maintain a final position within an area that is X ft longer than the rotorcraft landing gear	12 ft	12 ft
• Touch down and maintain a final position within an area that is X ft wider than the rotorcraft landing gear	8 ft	8 ft
• Maintain heading within ±X deg:	10 deg	10 deg
• Maintain a level rotorcraft attitude with one part of the landing gear in contact with the ground and the rest in the air for at least X seconds before lowering and raising the downhill part of the landing gear	1 sec	1 sec
• No perceptible lateral or rearward drift at touchdown	✓	✓
• Any load limits shall remain within the OFE	✓	✓

3.11.4 Hovering Turn

a. Objectives.

- Check for undesirable handling qualities in a moderately aggressive hovering turn.
- Check ability to recover from a moderate rate hovering turn with reasonable precision.
- Check for undesirable interaxis coupling.
- In the DVE, check for undesirable display symbology and dynamics for hover.

b. Description of maneuver. From a stabilized hover at an altitude of less than 20 ft, complete a 180 degree turn. Perform the maneuver in both directions. In the GVE, the maneuver shall be accomplished in calm winds and in moderate winds from the most critical direction. If a critical direction has not been defined, the turn shall be terminated with the wind blowing directly from the rear of the rotorcraft.

c. Description of test course. It is suggested that this maneuver use the test course described for the pirouette (Figure 25) with the rotorcraft located at the center of the pirouette circle. An alternate suggestion is to use the hover course with two extra markers placed in the 6 o'clock position relative to the rotorcraft. The maneuver begins with the rotorcraft lined up on these extra markers and the hover target and board located at the rotorcraft's 6 o'clock position.

d. Performance standards.

Performance – Hovering Turn

	Scout/Attack		**Cargo/Utility**	
	GVE	DVE	GVE	DVE
DESIRED PERFORMANCE				
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground	3 ft	6 ft	3 ft	6 ft
• Maintain altitude within ±X ft:	3 ft	3 ft	3 ft	3 ft
• Stabilize the final rotorcraft heading at 180 deg from the initial heading within ±X deg:	3 deg	5 deg	5 deg	5 deg
• Complete turn to a stabilized hover (within the desired window) within X seconds from initiation of the maneuver	10 sec	15 sec	15 sec	15 sec
ADEQUATE PERFORMANCE				
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground	6 ft	12 ft	6 ft	12 ft
• Maintain altitude within ±X ft:	6 ft	6 ft	6 ft	6 ft
• Stabilize the final rotorcraft heading at180 deg from the initial heading within ±X deg:	6 deg	10 deg	10 deg	10 deg
• Complete turn to a stabilized hover (within the desired window) within X seconds from initiation of the maneuver	15 sec	15 sec	20 sec	20 sec

3.11.5 Pirouette

a. Objectives.

• Check ability to accomplish precision control of the rotorcraft simultaneously in the pitch, roll, yaw, and heave axes.
• In the GVE, check ability to control the rotorcraft precisely in a moderate wind that is continuously varying in direction relative to the rotorcraft heading.
• In the DVE, check for degraded display symbology and dynamics during multiple axis maneuvering.

b. Description of maneuver. Initiate the maneuver from a stabilized hover over a point on the circumference of a 100 ft radius circle with the nose of the rotorcraft pointed at a reference point at the center of the circle, and at a hover altitude of approximately 10 ft. Accomplish a lateral translation around the circle, keeping the nose of rotorcraft pointed at the center of the circle, and the circumference of the circle under a selected point on the rotorcraft. Maintain essentially constant lateral groundspeed throughout the lateral translation (note: nominal lateral velocity will be approximately 8 knots for the 45-sec and 6 knots for the 60-sec time around the circle). Terminate the maneuver with a stabilized hover over the starting point. Perform the maneuver in both directions. In the GVE, the maneuver shall be accomplished in calm winds and in moderate winds from the most critical direction at the starting point.

c. Description of test course. The test course shall consist of markings on the ground that clearly denote the circular pathways that define desired and adequate performance. The suggested course shown in Figure 25 is considered adequate for the evaluation. It may also be useful to add objects to assist the pilot with vertical cueing, such as a post at the center of the circle.

d. Performance standards.

Performance – Pirouette

	GVE	DVE
DESIRED PERFORMANCE		
• Maintain a selected reference point on the rotorcraft within ±X ft of the circumference of the circle.	10 ft	10 ft
• Maintain altitude within ±X ft:	3 ft	4 ft
• Maintain heading so that the nose of the rotorcraft points at the center of the circle within ±X deg:	10 deg	10 deg
• Complete the circle and arrive back over the starting point within:	45 sec	60 sec
• Achieve a stabilized hover (within desired hover reference point) within X seconds after returning to the starting point.	5 sec	10 sec
• Maintain the stabilized hover for X sec	5 sec	5 sec
ADEQUATE PERFORMANCE		
• Maintain a selected reference point on the rotorcraft within ±X ft of the circumference of the circle.	15 ft	15 ft
• Maintain altitude within ±X ft:	10 ft	10 ft
• Maintain heading so that the nose of the rotorcraft points at the center of the circle within ±X deg:	15 deg	15 deg
• Complete the circle and arrive back over the starting point within:	60 sec	75 sec
• Achieve a stabilized hover (within adequate hover reference point) within X seconds after returning to the starting point.	10 sec	20 sec
• Maintain the stabilized hover for X sec	5 sec	5 sec

3.11.6 Vertical Maneuver

a. Objectives. For a scout/attack rotorcraft this maneuver is to simulate a rapid unmask/remask maneuver, with an aiming task at the unmask. For a utility or cargo rotorcraft, the maneuver is to assess the heave axis controllability with precision station keeping.

- Check for adequate heave damping, i.e., the ability to precisely start and stop a vertical rate.
- Check for adequate vertical control power.
- Check for undesirable coupling between collective and the pitch, roll, and yaw axes.
- Check the characteristics of the heave axis controller, especially if a non-conventional controller is used, e.g., a four-axis sidestick.
- With an external load, check for undesirable effects between the heave controller and the other axes of the rotorcraft and complications caused by the external load dynamics.

b. Description of maneuver. From a stabilized hover at an altitude of 15 ft, initiate a vertical ascent of 25 ft, stabilize for 2 seconds, then descend back to the initial hover position. With an external load, the maneuver is initiated from a higher altitude to assure a 10 ft load clearance. In the GVE, the maneuver shall be accomplished in calm winds and in moderate winds from the most critical direction. If a critical direction has not been defined, the hover shall be accomplished with the wind blowing directly from the rear of the rotorcraft.

c. Description of test course. The test course shall consist of markings on the ground that clearly define desired and adequate performance. It is suggested that this maneuver use the hover course (Figure 24) with a second reference symbol or hover board set to align at the upper reference.

Performance standards.

Performance – Vertical Maneuver

	Scout/Attack		**Cargo/Utility**		**Externally Slung Load**	
	GVE	DVE	GVE	DVE	GVE	DVE
DESIRED PERFORMANCE						
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground	6 ft	10 ft	3 ft	3 ft	3 ft	3 ft
• Maintain start/finish altitude within ±X ft:	3 ft	3 ft	3 ft	3 ft	4 ft	4 ft
• Maintain heading within ±X ft:	3 deg	3 deg	5 deg	5 deg	5 deg	5 deg
• Complete the maneuver within:	10 sec	13 sec	13 sec	15 sec	13 sec	15 sec
ADEQUATE PERFORMANCE						
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground	10 ft	20 ft	6 ft	6 ft	6 ft	6 ft
• Maintain start/finish altitude within ±X ft:	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft
• Maintain heading within ±X deg:	6 deg	6 deg	10 deg	10 deg	10 deg	10 deg
• Complete the maneuver within:	15 sec	18 sec	18 sec	18 sec	20 sec	20 sec

3.11.7 Depart/Abort

a. Objectives.

- Check pitch axis and heave axis handling qualities during moderately aggressive maneuvering.
- Check for undesirable coupling between the longitudinal and lateral-directional axes.
- Check for harmony between the pitch axis and heave axis controllers
- Check for overly complex power management requirements.
- Check for ability to re-establish hover after changing trim
- With an external load, check for dynamic problems resulting from the external load configuration.

b. Description of maneuver. From a stabilized hover at 35 ft wheel height (or no greater than 35 ft external load height) and 800 ft from the intended endpoint, initiate a longitudinal acceleration to perform a normal departure. At 40 to 50 knots groundspeed, abort the departure and decelerate to a hover such that at the termination of the maneuver, the cockpit shall be within 20 ft of the intended endpoint. It is not permissible to overshoot the intended endpoint and move back. If the rotorcraft stopped short, the maneuver is not complete until it is within 20 ft of the intended endpoint. The acceleration and deceleration phases shall be accomplished in a single smooth maneuver. For rotorcraft that use changes in pitch attitude for airspeed control, a target of approximately 20 degrees of pitch attitude should be used for the acceleration and deceleration. The maneuver is complete when control motions have subsided to those necessary to maintain a stable hover.

c. Description of test course. The test course shall consist of at least a reference line on the ground indicating the desired track during the acceleration and deceleration, and markers to denote the starting and endpoint of the maneuver. The course should also include reference lines or markers parallel to the course reference line to allow the pilot and observers to perceive the desired and adequate longitudinal tracking performance, such as the example shown in Figure 27.

d. Performance standards.

Performance –Depart/Abort

	Cargo/Utility		**Externally Slung Load**	
	GVE	DVE	GVE	DVE
DESIRED PERFORMANCE				
• Maintain lateral track within ±X ft:	10 ft	10 ft	10 ft	10 ft
• Maintain radar altitude below X ft:	50 ft	50 ft	50 ft*	50 ft*
• Maintain heading within ±X deg:	10 deg	10 deg	10 deg	10 deg
• Time to complete maneuver:	25 sec	25 sec	30 sec	30 sec
• Maintain rotor speed within:	OFE	OFE	OFE	OFE
ADEQUATE PERFORMANCE				
• Maintain lateral track within ±X ft:	20 ft	20 ft	20 ft	20 ft
• Maintain radar altitude below X ft:	75 ft	75 ft	75 ft*	75 ft*
• Maintain heading within ±X deg:	15 deg	15 deg	15 deg	15 deg
• Time to complete maneuver:	30 sec	30 sec	35 sec	35 sec
• Maintain rotor speed within:	SFE	SFE	SFE	SFE

* Altitudes refer to height of external load, measured at hover

3.11.8 Lateral Reposition

a. Objectives.

- Check roll axis and heave axis handling qualities during moderately aggressive maneuvering.
- Check for undesirable coupling between the roll controller and the other axes.
- With an external load, check for dynamic problem resulting from the external load configuration.

b. Description of maneuver. Start in a stabilized hover at 35 ft wheel height (or no greater than 35 ft external load height) with the longitudinal axis of the rotorcraft oriented 90 degrees to a reference line marked on the ground. Initiate a lateral acceleration to approximately 35 knots groundspeed followed by a deceleration to laterally reposition the rotorcraft in a stabilized hover 400 ft down the course within a specified time. The acceleration and deceleration phases shall be accomplished as single smooth maneuvers. The rotorcraft must be brought to within ±10 ft of the endpoint during the deceleration, terminating in a stable hover within this band. Overshooting is permitted during the deceleration, but will show up as a time penalty when the pilot moves back within ±10 ft of the endpoint. The maneuver is complete when a stabilized hover is achieved.

c. Description of test course. The test course shall consist of any reference lines or markers on the ground indicating the desired track and tolerances for the acceleration and deceleration, and markers to denote the starting and endpoint of the maneuver. The course should also include reference lines or markers parallel to the course reference line to allow the pilot and observers to perceive the desired and adequate longitudinal tracking performance, such as the example shown in Figure 26.

d. **Performance standards.**

Performance – Lateral Reposition

	Cargo/Utility		**Externally Slung Load**	
	GVE	DVE	GVE	DVE
DESIRED PERFORMANCE				
• Maintain longitudinal track within ±X ft:	10 ft	10 ft	10 ft	10 ft
• Maintain altitude within ±X ft:	10 ft	10 ft	10 ft	10 ft
• Maintain heading within ±X deg:	10 deg	10 deg	10 deg	10 deg
• Time to complete maneuver:	18 sec	20 sec	25 sec	25 sec
ADEQUATE PERFORMANCE				
• Maintain longitudinal track within ±X ft:	20 ft	20 ft	20 ft	20 ft
• Maintain altitude within ±X ft:	15 ft	15 ft	15 ft	15 ft
• Maintain heading within ±X deg:	15 deg	15 deg	15 deg	15 deg
• Time to complete maneuver:	22 sec	25 sec	30 sec	30 sec

3.11.9 Slalom

a. Objectives.

- Check ability to maneuver aggressively in forward flight and with respect to objects on the ground.
- Check turn coordination for moderately aggressive forward flight maneuvering.
- Check for objectionable interaxis coupling during moderately aggressive forward flight maneuvering.

b. Description of maneuver. Initiate the maneuver in level unaccelerated flight and lined up with the centerline of the test course. Perform a series of smooth turns at 500-ft intervals (at least twice to each side of the course). The turns shall be at least 50 ft from the centerline, with a maximum lateral error of 50 ft. The maneuver is to be accomplished below the reference altitude. Complete the maneuver on the centerline, in coordinated straight flight.

c. Description of test course. The suggested test course for this maneuver is shown in Figure 28. Most runways have touchdown stripes at 500-ft intervals that can be conveniently used instead of the pylons. However, if the runway is not 100 ft wide, it will be necessary to use two cones to define each gate (as opposed to one cone and the runway edge as shown in Figure 28).

d. Performance standards.

Performance – Slalom

	GVE	DVE
DESIRED PERFORMANCE		
• Maintain an airspeed of at least X knots throughout the course	60	30
• Accomplish maneuver below reference altitude of X ft:	Lesser of twice rotor diameter or 100 ft	100 ft
ADEQUATE PERFORMANCE		
• Maintain an airspeed of at least X knots throughout the course	40	15
• Accomplish maneuver below reference altitude of X ft:	100 ft	100 ft

3.11.10 Vertical Remask

a. Objectives.

• Check ability to accomplish an aggressive vertical descent close to the ground.

• Check ability to combine vertical and lateral aggressive maneuvering as required to evade enemy fire if observed during a bob-up.

b. Description of maneuver. From a stabilized hover at 75 ft, remask vertically to an altitude below 25 ft. Then rapidly displace the rotorcraft laterally 300 ft and stabilize at a new hover position. During the vertical remask simulate deploying rotorcraft survivability equipment as appropriate. Accomplish the maneuver to the left and to the right.

c. Description of test course. The test course should include markers to denote the desired and adequate performance related to position during the vertical descent and final stabilized hover. It may also be desirable to include a vertical reference to provide cues related to the 25 ft altitude reference. This maneuver assumes that the pilot is remasking behind some object, and such an altitude reference should therefore be available. A suggested test course for this maneuver is shown in Figure 26.

d. Performance standards.

Performance – Vertical Remask

	Desired	Adequate
• Achieve an altitude of X or less within 6 seconds of initiating the maneuver.	25 ft	NA
• During initial stabilized hover, vertical descent, and final stabilized hover, maintain longitudinal and lateral position within ±X ft of a reference point on the ground.	8 ft	12 ft
• Maintain altitude after remask and during displacement within X ft:	±10 ft	+10 and -15 ft
• Maintain lateral ground track within) ±X ft:	10 ft	15 ft
• Maintain heading within ±X deg	10 deg	15 deg
• Achieve a stabilized hover within X sec after reaching the final hover position.	5 sec	10 sec
• Achieve the final stabilized hover within X sec of initiating the maneuver.	15 sec	25 sec

3.11.11 Acceleration and Deceleration

a. Objectives.

• Check pitch axis and heave axis handling qualities:

- (GVE): for aggressive maneuvering near the rotorcraft limits of performance.

- (DVE): for reasonably aggressive maneuvering in the DVE.

• Check for undesirable coupling between the longitudinal and lateral-directional axes.

• Check for harmony between the heave axis and pitch axis controllers.

• Check for adequate rotor response to aggressive collective inputs.

• Check for overly complex power management requirements.

b. Description of maneuver. Start from a stabilized hover. In the GVE, rapidly increase power to approximately maximum, maintain altitude constant with pitch attitude, and hold collective constant during the acceleration to an airspeed of 50 knots. Upon reaching the target airspeed, initiate a deceleration by aggressively reducing the power and holding altitude constant with pitch attitude. The peak nose-up attitude should occur just before reaching the final stabilized hover. In the DVE, accelerate to a groundspeed of at least 50 knots, and immediately decelerate to hover over a defined point. The maximum nose-down attitude should occur immediately after initiating the maneuver, and the peak nose-up attitude should occur just before reaching the final stabilized hover. Complete the maneuver in a stabilized hover for 5 seconds over the reference point at the end of the course.

c. Description of test course. The test course shall consist of a reference line on the ground indicating the desired track during the acceleration and deceleration, and markers to denote the starting point and endpoint of the maneuver. The distance from the starting point to the final stabilized hover position is a function of the performance of the rotorcraft, and shall be determined based on trial runs consisting of acceleration to the target airspeed, and decelerations to hover as described above. The course should also include reference lines or markers parallel to the course centerline to allow the pilot and observers to perceive desired and adequate lateral tracking performance. A suggested test course is shown in Figure 27.

d. Performance standards.

Performance – Acceleration-Deceleration

	GVE	DVE
DESIRED PERFORMANCE		
• Within X seconds from initiation of the maneuver, achieve at least the greater of 95% maximum continuous power or 95% maximum transient limit that can be sustained for the required acceleration, which ever is greater. If the 95% power results in objectionable pitch attitudes, use the power corresponding to the maximum nose-down pitch attitude that is felt to be acceptable. This pitch attitude shall be considered as a limit of the Operational Flight Envelope (OFE) for NOE flying.	1.5 sec	NA
• Achieve a nose-down pitch attitude during the acceleration of at least X deg below the hover attitude:	NA	12 deg
• Maintain altitude below X ft:	50 ft	50 ft
• Maintain lateral track within ±X ft:	10 ft	10 ft
• Maintain heading within ±X deg:	10 deg	10 deg
• Decrease power to less than 5% within X seconds to initiate deceleration.	3 sec	NA
• Significant increases in power are not allowed until just before the final stabilized hover.	✓	✓
• Achieve a nose-up pitch attitude during the deceleration of at least X deg above the hover attitude. The maximum pitch attitude should occur shortly before the hover.	30 deg	15 deg
• Longitudinal tolerance on the final hover point is plus zero, minus a distance equal to X % of the overall rotorcraft length.	50 %	50 %
• Rotor RPM shall remain within the limits of X without undue pilot compensation	OFE	OFE
ADEQUATE PERFORMANCE		
• Within X seconds from initiation of the maneuver, achieve at least the greater of 95% maximum continuous power or 95% maximum transient limit that can be sustained for the required acceleration, whichever is greater. If the 95% power results in objectionable pitch attitudes, use the maximum nose-down pitch attitude that is felt to be acceptable. This pitch attitude shall be considered as a limit of the Operational Flight Envelope (OFE) for NOE flying.	3 sec	NA
• Achieve a nose-down pitch attitude during the acceleration of at least X deg below the hover attitude.	NA	7 deg
• Maintain altitude below X ft:	70 ft	70 ft
• Maintain lateral track within ±X ft:	20 ft	20 ft
• Maintain heading within ±X ft:	20 deg	20 deg
• Decrease power to less than 30% of maximum within X seconds to initiate deceleration.	5 sec	NA
• Significant increases in power are not allowed until just before the final stabilized hover.	✓	✓
• Achieve a nose-up pitch attitude during the deceleration of at least X deg above the hover attitude.	10 deg	10 deg
• Longitudinal tolerance on the final hover point is minus a distance equal to X % of the overall rotorcraft length.	100 %	100 %
• Rotor RPM shall remain within the limits of the:	SFE	SFE

3.11.12 Sidestep

a. Objectives.

- Check lateral-directional handling qualities for aggressive maneuvering near the rotorcraft limits of performance (GVE), for reasonably aggressive lateral maneuvering (DVE).
- Check for objectionable interaxis coupling.
- Check ability to coordinate bank angle and collective to hold constant altitude.

b. Description of maneuver. Starting from a stabilized hover with the longitudinal axis of the rotorcraft oriented 90 degrees to a reference line marked on the ground, initiate a rapid and aggressive lateral acceleration, holding altitude constant with power. Hold target velocity for 5 seconds and then initiate an aggressive deceleration to hover at constant altitude. The peak bank angle during deceleration should occur just before the rotorcraft comes to a stop. Establish and maintain a stabilized hover for 5 seconds. Immediately repeat the maneuver in the opposite direction.

c. Description of test course. The test course shall consist of any reference lines or markers on the ground indicating the desired track and tolerances for the acceleration and deceleration, and markers to denote the starting and endpoint of the maneuver. The course should also include reference lines or markers parallel to the course reference line to allow the pilot and observers to perceive the desired and adequate longitudinal tracking performance, such as the example shown in Figure 26. Note that the end point for this maneuver is not prescribed.

d. Performance standards.

Performance - Sidestep

	GVE	DVE
DESIRED PERFORMANCE		
• Achieve at least 25 degree of bank angle change from trim, or target airspeed, within X seconds of initiating the maneuver:	1.5 sec	NA
• Achieve a target airspeed of X knots:	lesser of 40 or (OFE-5) knots	17 knots
• Achieve at least 30 degrees of bank angle within X seconds of initiating deceleration:	1.5 sec	NA
• Achieve at least X deg of bank angle change from trim during the acceleration and deceleration:	NA	20 deg
• Maintain a selected reference point on the rotorcraft within ±X ft of the ground reference line:	10 ft	10 ft
• Maintain altitude within ±X ft at a selected altitude below 30 ft:	10 ft	10 ft
• Maintain heading within ±X deg:	10 deg	10 deg
• Achieve a stabilized hover within X seconds after reaching the hover point:	5 sec	10 sec
ADEQUATE PERFORMANCE		
• Achieve at least 25 degree of bank angle change from trim, or target airspeed, within X seconds of initiating the maneuver:	3.0 sec	NA
• Achieve a target airspeed of X knots:	lesser of 40 or (OFE-5) knots	17 knots
• Achieve at least 30 degrees of bank angle within X seconds of initiating deceleration:	3.0 sec	NA
• Achieve at least X deg of bank angle during the acceleration and deceleration:	NA	10 deg
• Maintain a selected reference point on the rotorcraft within ±X ft of the ground reference line:	15 ft	15 ft
• Maintain altitude within ±X ft at a selected altitude below 30 ft:	15 ft	15 ft
• Maintain heading within ±X deg:	15 deg	15 deg
• Achieve a stabilized hover within X seconds after reaching the hover point:	10 sec	20 sec

3.11.13 Deceleration to Dash

a. Objectives.

- Check for poor engine governing or overly complex power management requirement.
- Check pitch, heave, and yaw axis handling qualities for aggressive maneuvering.
- Check for undesirable coupling between the longitudinal and lateral-directional axes, and between the heave axis and longitudinal and lateral-directional axes, for maneuvers requiring large power changes.
- Check for harmony between the heave, pitch, and directional axis controllers.
- Check for adequate rotor response to aggressive collective inputs.

b. Description of maneuver. From level unaccelerated flight at the lesser of V_H or120 knots, perform a level deceleration-acceleration. Adjust the pitch attitude to maintain altitude with a full down collective position. As the airspeed decreases to approximately 50 knots, aggressively assume the attitude for maximum acceleration and rapidly increase power to approximately the maximum, and maintain that power until the initial airspeed is reached.

c. Description of test course. Any reference line on the ground will serve as an adequate test course for this maneuver.

d. Performance Standards. The entire maneuver shall be conducted below 200 ft.

Performance – Deceleration to Dash

	Desired	Adequate
• Achieve X% collective within Y sec from the initiation of the deceleration.	0% (full down) 3 sec	Less than 10% 5 sec
• Achieve either X% of maximum continuous power (or X% of the transient limit) within Y sec of initiating the acceleration.	95% 2 sec	80% 3 sec
• During the acceleration, the power shall not exceed any rotorcraft limitation, and shall not fall below X%.	85%	80%
• Without undue pilot compensation, rotor RPM shall remain within the limits of the:	OFE	SFE
• Maintain heading within ±X deg:	5 deg	10 deg
• Maintain altitude below X ft:	200 ft	200 ft
• Maintain altitude within ±X ft:	50 ft	NA
• Any oscillations or coupling shall not be:	undesirable	objectionable

3.11.14 Transient Turn

a. Objectives.

- Insure that handling qualities do not degrade during aggressive maneuvering in all axes.
- Check for undesirable coupling between pitch, roll, and yaw during aggressive maneuvering.

b. Description of maneuver. Starting at the lesser of V_H or 120 knots and an altitude at or below 200 ft, accomplish a 180-degree change in directional flightpath and achieve wings-level attitude in as little time as possible. Use of pedals to induce a lateral acceleration in the direction of the turn is acceptable. Perform the maneuver both to the right and to the left. It is acceptable to reduce collective to increase the rate of speed bleed-off and thereby maximize the turn rate.

c. Description of test course. This maneuver does not require a test course that is marked out on the ground aside from a reference line such as a road or railroad track.

d. Performance standards.

Performance – Transient Turn

	Desired	Adequate
• Achieve a peak normal load factor of at least X% of the OFE $n_L(+)$:	100%-0.2g	80%
• Complete the maneuver within X seconds:	10 sec	15 sec
• Maintain altitude within X ft:	±50 ft	Below 200 ft
• Maintain the rotor RPM within the limit of the:	OFE	SFE

3.11.15 Pullup/Pushover

a. Objectives.

• Check handling qualities at elevated and reduced load factors and during transition between elevated and reduced load factors.

• Check for undesirable coupling between pitch, roll, and yaw for aggressive maneuvering in forward flight.

• Check for ability to avoid obstacles during high-speed NOE operations.

b. Description of maneuver. From level unaccelerated flight at the lesser of V_H or 120 knots, attain a sustained positive load factor in a symmetrical pullup. Transition, via a symmetrical pushover, to a sustained negative load factor. Recover to level flight as rapidly as possible.

c. Description of test course. This maneuver may be accomplished up-and-away, and no test course is required.

d. Performance standards.

Performance – Pullup/Pushover

	Desired	Adequate
• Attain a normal load factor of at least the positive limit of the OFE ($n_L(+)$) within X seconds from the initial control input.	1 sec	2 sec
• Maintain at least $n_L(+)$ for at least X seconds	2 sec	1 sec
• Accomplish transition from $n_L(+)$ pullup to a pushover of not greater than the negative normal load factor limit of the OFE ($n_L(-)$) within X seconds.	2 sec	4 sec
• Maintain a load factor of not greater than $n_L(-)$ for at least X seconds.	2 sec	1 sec
• Maintain angular deviations in roll and yaw within ±X degrees from the initial unaccelerated level flight condition to completion of the maneuver.	10 deg	15 deg

3.11.16 Roll Reversal

a. Objectives.

- Check handling qualities while maneuvering with load factors close to the OFE limits.
- Check the roll damping and roll authority during elevated and reduced load factor.
- Check for undesirable coupling between axes during aggressive maneuvering.
- Check the maneuvering stability of the rotorcraft close to the OFE limits.

b. Description of maneuver. Starting in a dive, conduct a series of pullups and pushovers to achieve normal accelerations within 0.10g of the positive [n_L(+)] and negative [n_L(-)] boundaries of the Operational Flight Envelope. The target normal acceleration should occur as the rotorcraft passes through the level attitude. At this time execute an aggressive roll to a minimum of 45 degrees of bank, and back to zero while maintaining incremental load factor. The maneuvers should be conducted so that the airspeed at the start of the rolling maneuvers is the lesser of V_H or 120 knots.

c. Description of test course. This maneuver may be accomplished up-and-away, and no test course is required.

d. Performance standards.

Performance – Roll Reversal

	Desired	Adequate
• Achieve a peak roll rate of at least X percent of the maximum steady state roll rate achievable at one g:	50%	30%
• Maintain target normal acceleration within X % of the incremental load factor:	50%	50%
• No oscillation in any axis that is:	Undesirable	Uncontrollable or persistent
• Any change in roll or pitch response shall not be:	Sudden	Objectionable or reversals

3.11.17 Turn to Target

a. Objectives.

- Check for undesirable handling qualities during a maximum effort, rapid hovering turn.
- Check ability to recover from a rapid hovering turn with sufficient precision to fire a weapon.
- Check for undesirable interaxis coupling.

b. Description of maneuver. From a stabilized hover at an altitude of less than 20 ft, complete a 180 degree turn. Turns shall be completed in both directions. The final heading tolerance should be based on a sight mounted on the rotorcraft, preferably the same sight to be used for operational missions.

c. Description of test course. The test course can consist of any convenient target.

d. Performance standards.

Performance – Turn to Target

	Desired	Adequate
• Maintain longitudinal and lateral position of a selected point on the rotorcraft within ±X ft of a reference point on the ground.	6 ft	12 ft
• Maintain altitude within ±X ft	3 ft	6 ft
• Stabilize final rotorcraft heading within a tolerance based on the firing constraints of the weapon system to be deployed on the rotorcraft.	✓	NA
• Stabilize final rotorcraft heading within ±X deg:	NA	3 deg
• Complete the turn so that a firing solution has been achieved within X from initiation of the maneuver.	5 sec	10 sec

3.11.18 High Yo-Yo

a. Objectives.

- Check handling qualities during reduced and elevated load factors.
- Check the short term-response characteristics of the rotorcraft through aggressive pitch pointing tasks.
- Check for undesirable coupling between pitch, roll, and yaw during aggressive maneuvering.

b. Description of maneuver. Two aircraft are required to perform this air-combat maneuver. The maneuver is initiated from level unaccelerated flight with both aircraft at a constant airspeed equal to the V_H of the test rotorcraft. The test rotorcraft is positioned at least 500 ft in trail behind the target aircraft. The target aircraft then decelerates 20 knots, to (V_H - 20), causing the test rotorcraft to close on the target. When the range between the two aircraft decreases to approximately 300 ft, the target aircraft initiates a 45-degree banked turn at constant altitude, and holds the turn to roll out after 180 deg heading change. The test rotorcraft delays until the line-of-sight reaches 30 degrees, at which time the pilot initiates a climbing turn toward the target, with a nose-up pitch attitude of 15 to 30 degrees. The resulting deceleration causes a decrease in the rate of closure from above. When the closure rate is no longer apparent, and the range to the target is approximately 200 to 500 ft, the test rotorcraft rapidly lowers the nose to achieve a firing solution within missile launch constraints.

c. Description of test course. This maneuver may be accomplished up-and-away, and no test course is required.

d. Performance standards.

Performance – High Yo-Yo

	Desired	Adequate
• Interaxis coupling shall not be:	Undesirable	Objectionable
• Maintain the missile launch constraints for X sec:	7 sec	4 sec
• Acquire the target with no tendency for pitch overshoots	✓	✓

3.11.19 Low Yo-Yo

a. Objectives.

- Check handling qualities during reduced and elevated load factors.
- Check the short-term response characteristics of the rotorcraft through aggressive pitch pointing tasks.
- Check for undesirable coupling between pitch, roll, and yaw during aggressive maneuvering.

b. Description of maneuver. Two aircraft are required to perform this air-combat maneuver, and the target aircraft must be capable of achieving airspeeds of at least V_H of the test rotorcraft The maneuver is initiated from level unaccelerated flight, with both aircraft at an airspeed equal to (V_H - 20 knots)of the test rotorcraft. The test rotorcraft is positioned approximately 200 ft in trail behind the target aircraft. The target aircraft then accelerates 20 knots to V_H, resulting in a steady increase in range between the two aircraft. When the range between the two aircraft increases to approximately 300 ft, the target aircraft executes a 45-degree banked turn at constant altitude and holds the turn to roll out after 180 deg heading change. The test rotorcraft delays until the line-of-sight reaches 30 degrees, at which time the pilot initiates a diving turn in the direction of the target with a nose-down pitch attitude of 15 to 30 degrees. The resulting acceleration causes the test rotorcraft to begin to close on the target from below. When a rate of closure on the target is apparent, and the range to the target is within 500 ft, the test rotorcraft rapidly raises the nose and tracks the target to achieve a firing solution within missile launch constraints.

c. Description of test course. This maneuver may be accomplished up and away, and no test course is required.

d. Performance standards.

Performance – Low Yo-Yo

	Desired	Adequate
• Interaxis coupling shall not be:	Undesirable	Objectionable
• Maintain the missile launch constraints for X sec:	7 sec	4 sec
• Acquire the target with no tendency for pitch overshoots	✓	✓
• Maintain power within the transient range for as long as possible, without exceeding the time limit specified for the rotorcraft, or until simulated missile launch. Maintain at least 95% of maximum continuous power when rotorcraft limitations prohibit operation in the transient range.	✓	NA
• Maintain power within ±10% of maximum continuous. If +10% exceeds a limit, do not exceed that limit.	NA	✓

3.11.20 Decelerating Approach

a. Objectives.

• Check ability to perform precision glideslope and localizer tracking to very low decision height and groundspeed with a reasonable pilot workload.

• Check ability to precisely control airspeed and to perform a deceleration while descending on the glideslope.

b. Description of maneuver. Starting on a 4-degree glideslope at an airspeed of 100 knots, perform a manual deceleration to an airspeed of 25 knots at an altitude of 50 ft. Guidance commands may be generated using onboard sensors, or from ground-based transmitters.

c. Performance standards.

Performance – Decelerating Approach in IMC Conditions

	Desired	Adequate
• Maintain glideslope within ±X ft:	12.5 ft	25 ft
• Maintain localizer within ±X ft:	50 ft	75 ft
• Maintain airspeed within ±X knots of the reference:	5 knots	10 knots

3.11.21 ILS Approach

a. Objective.

• Check ability to perform precise flight path and speed control.

b. Description of Maneuver. Start the maneuver eight miles from the runway with an offset from the localizer of 1 nm, on a 45 degree intercept to the localizer. At an airspeed of 120 knots or V_H and altitude of 1500 ft, intercept the localizer and slow the rotorcraft to 90 knots prior to glideslope intercept. Track the ILS to a 200 ft decision height at an airspeed of 90 knots.

c. Performance standards.

Performance – ILS Approach

	Desired	Adequate
• Maintain airspeed of 90 knots within ±X knots:	5 knots	10 knots
• Prior to glideslope intercept, maintain altitude within ±X ft:	100 ft	200 ft
• Maintain glideslope and localizer within X dots:	1 dot	2 dots

3.11.22 Missed Approach

a. Objective.

• Check longitudinal flight control variations in a high-workload, divided-attention task.

b. Description of Maneuver. After performing an ILS approach to Decision Height, initiate a climb on runway heading to an altitude of 500 ft at an airspeed of 80 knots. At 500 ft, turn right to a heading 90 degrees from runway heading. Level off at 1,000 ft and accelerate to 100 knots. Once steady at this condition, turn right to a heading of 180 degrees from runway heading and climb to 2,000 ft. Once level at 2000 ft and steady on 100 knots, accelerate to 130 knots or V_H.

c. Performance standards.

Performance – Missed Approach

	Desired	Adequate
• Maintain target altitudes within ±X ft:	100 ft	200 ft
• Maintain target airspeeds within ±X knots:	5 knots	10 knots

3.11.23 Speed Control

a. Objective.

- Investigate airspeed control to assess adequacy of stick force gradient with airspeed.

b. Description of Maneuver. From trimmed level flight at 90 knots, decelerate to 70 knots and retrim for hands-off flight. Then accelerate to 90 knots and retrim for hands off flight. Finally, accelerate to 110 knots and retrim.

c. Performance standards.

Performance – Speed Control Task

	Desired	Adequate
• Maintain altitude within ±X ft:	100 ft	200 ft
• Trim hands-off at target airspeed within ±X knots:	3 knots	5 knots
• Change from one trim airspeed to another within X minutes:	1 minute	2 minutes
• Maintain heading within ±X deg:	5 deg	10 deg

4. VERIFICATION

4.1 General

Compliance with the requirements of this specification shall be demonstrated using analysis, simulation, and flight test at appropriate milestones during the rotorcraft design and development. In absence of other guidance from the system specification, Table XIV and Table XV shall be observed. Table XIV indicates the appropriate milestones for analysis, simulation and flight test. Table XV indicates the range of Rotorcraft Status and Flight Conditions from which specific combinations shall be selected to demonstrate compliance with this specification. Complexity and scope of these demonstrations are defined in 4.1.1, 4.1.2, and 4.1.3.

4.1.1 Analysis

Initially the quantitative flying qualities criteria shall be assessed analytically (non-piloted) using available math models that represent the aerodynamic, flight control system, and engine/fuel control characteristics of the rotorcraft.

By PDR, and thereafter, analytical checks shall be accomplished using full nonlinear math models including best estimates of engine/fuel controls, rotor system, and SCAS elements. The Configurations, Loadings, and SCAS modes should be well defined. HQ shall be evaluated at selected conditions throughout the OFE, at least for Normal States. By CDR the Failure States shall be defined and included in the analyses. Analysis shall be continued throughout the development program to supplement the simulation and flight testing.

4.1.2 Simulation

Piloted simulation with representative cockpit controls and displays including the feel system shall be used by the CDR milestone. The simulator shall include a visual attachment, but does not require a motion system unless such a system is specified by the system specification. The simulation shall include a validated representation of all controls and displays that will be available to the pilot for control of the rotorcraft. Rotorcraft Status to be tested shall include all mission-required Configurations at nominal and critical Loadings. All Settings shall be available and evaluated. In addition, failure transients and steady state Failure States shall be investigated. Although the piloted simulation environment is primarily to investigate the MTEs, many of the quantitative tests are intended to include the pilot-rotorcraft interface and so a sample shall be repeated in the piloted simulator environment. Any discrepancies between the piloted simulator results and the off-line math model results shall be investigated and resolved.

It has been found that tests should be performed to determine the Simulated Day Usable Cue Environment of the simulator (SIMDUCE), using the test methodology specified in 3.2.1 for determination of the UCE. If the SIMDUCE is greater than one, it is likely that the pilot ratings (HQRs) will be in the Level 2 range (HQR between 4 and 6), even though the actual rotorcraft would be Level 1. The key indicator of acceptable Level 1 HQ is that the pilot comments clearly associate the Level 2 deficiencies with deficient visual cueing.

Simulated vision aids shall be calibrated to insure that the visual acuity is consistent with the estimated performance of that vision aid in the DVE specified as part of the operating environment. It should be possible to achieve Level 1 pilot ratings in the simulated DVE, when employing the flight control modes designed for operations in DVE.

Validation of the simulator shall include comparisons of the response of the math model and the visual scene with responses obtained from the validated non-real-time simulation to identical cockpit controller inputs. The lag between the cockpit control input and the out-the-window visual scene response shall not cause a change from the rotorcraft's true Bandwidth and Phase Delay that is equivalent to more than ½ a point in estimated HQR. The increment of HQR is obtained by interpolation on the appropriate Bandwidth criteria figure. If the out-the-window scene is generated by a remotely located sensor, the head tracking dynamic response and the image source location shall be represented.

4.1.3 Flight

For SVR verification, flight tests shall be performed to demonstrate both the quantitative and subjective requirements of this specification and to show that the predicted Levels of HQ and the assigned Levels of HQ are as required.

Based on the analysis and simulation results the contractor shall develop a test plan to adequately demonstrate the full-mission capability and define limiting conditions. The test plan shall be subject to approval by the Government.

All of the quantitative criteria shall be tested. The tests shall be performed for a sample of Configurations and Loadings, all Normal States and selected Failure States, at a range of Flight Conditions. The sample shall be sufficient to assess validity of the analysis and simulation results, and if adequate fidelity is demonstrated further testing may be limited in scope. Emphasis shall be on data points that are critical from the standpoint of handling qualities and safety, but shall also demonstrate performance at important nominal mission conditions.

Qualitative flight test evaluations shall be performed to provide an overall check of the HQ. All applicable MTEs shall be demonstrated in primary mission configuration, with primary or augmented SCAS mode in normal state(s) with Loadings that are most critical for HQ. Selected MTEs shall be performed to evaluate the HQ with secondary SCAS mode (or configurations corresponding to $Pf > 10^{-5}$). All ground-referenced MTEs shall be performed in calm winds. In addition, the hover, hovering turn, pirouette, and vertical maneuver shall be performed in the GVE in moderate winds. The Government will decide if the extent of HQR degradation due to moderate winds is acceptable. It shall not be required to flight test in moderate winds with externally slung loads.

All of the quantitative testing, and the flight tests of the GVE MTEs, shall be conducted in day good visual conditions (GVE). The DVE MTEs shall be tested in real DVE when evaluating the primary or augmented SCAS in normal state. The Secondary SCAS may be tested in simulated DVE.

It is not necessary to perform the MTE evaluations in a high density altitude environment unless the rotorcraft has been shown to not meet one or more of the quantitative boundaries, and satisfactory results in the MTE tests are being used to support a deviation.

4.2 Levels of handling qualities

Handling qualities depend on the aircraft's flying characteristics, the piloting task being performed, the Usable Cue Environment, wind and turbulence, and any additional demands on the pilot. Levels of handling qualities are defined by the 1 to 3, 4 to 6, and 7 to 8 ranges of the Cooper-Harper Handling Qualities Rating (HQR) Scale (Figure 1). This specification uses two distinct methods of establishing Levels of handling qualities, Predicted Levels and Assigned Levels. Predicted Levels are obtained from quantitative criteria that are based on HQR data from engineering in-flight and ground-based simulation. This knowledge is not complete; data are not available to fully define the required limit for all flying qualities parameters which taken together will ensure good handling qualities for all mission tasks. Assigned Levels are obtained from test pilots using the HQR Scale (Figure 1) to assess the workload and task performance required to perform designated MTEs. The MTE flight test maneuvers are not sufficiently comprehensive to represent all mission maneuvers in all environments that a particular rotorcraft may be called upon to perform, nor is it practical to perform the designated MTEs throughout the OFE for all loadings. Since neither the Predicted Levels nor the Assigned Levels provide a complete comprehensive assessment of handling qualities, compliance with both methods is necessary to maximize the likelihood of an accurate assessment of the Level of handling qualities. If there are conflicts between the Predicted Levels and Assigned Levels, the quantitative criteria and the MTE results shall be scrutinized to determine the cause of the discrepancy. On the basis of this investigation, the Government will determine whether or not compliance has been achieved or if further testing is required.

4.3 Testing with externally slung loads

Testing of applicable MTEs with externally slung loads shall be accomplished with a load mass ratio (6.2.8) of 0.33 or the maximum load that will be used for operational missions, whichever is less. If load mass ratios of greater than 0.33 will be used operationally, a configuration with the maximum load mass shall also be tested. The government will decide if HQR degradations at high load mass ratios are acceptable. Testing shall be accomplished in both GVE and DVE if required by 3.1.1.

4.4 Interpretation of subjective requirements

In several instances throughout the specification, subjective terms such as essentially constant, objectionable delays, excessively sluggish, and complex coordination, have been employed where insufficient information exists to establish quantitative criteria. Such requirements shall be interpreted with due regard to the intent of the Level definitions of 3.1.5. Final determination of compliance with requirements so worded shall be determined through flight test or other suitable means subject to Government approval.

5. PACKAGING

For acquisition purposes, the packaging requirements shall be as specified in the contract or order.

6. NOTES

This section contains information of a general or explanatory nature which may be helpful but is not mandatory.

6.1 Intended use

This performance specification establishes requirements for the flying and ground handling qualities of military rotorcraft. It is intended that the specification should cover land-based rotorcraft that have primary missions ranging from scout and attack to utility and cargo. Additional requirements or modified standards may be required for rotorcraft that operate from small ships in sea states resulting in more than small ship motion.

The requirements are intended for application in development of a new system, or for a major system upgrade. If met, they should assure that no limitations on flight safety, or on the capability to perform intended missions, will result from deficiencies in flying qualities. The criteria and MTEs can also be used as a development tool since they provide quantitative benchmarks and calibrated maneuver standards which may be valuable for assessing the need for upgrades, or for diagnosing the cause of deficient performance.

Application of this specification to a specific system requires minimal tailoring. This tailoring basically consists of selecting the appropriate MTEs corresponding to the operational missions, and defining several aspects of the operational environment. All of the topics to be specified in the system specification have been gathered into 3.1. Guidance on tailoring these topics will be provided in a separate handbook.

6.2 Definitions

6.2.1 Acronyms

The acronyms used in this specification are defined as follows:

A - Analysis method for verification

ACAH - Attitude Command/Attitude Hold Response-Type

AH - Attitude Hold

CDR - Critical Design Review – Midterm project milestone

DH - Direction [Heading] Hold

DVE - Degraded Visual Environment to be defined by system specification, but typically night with some form of visual aid such as night vision goggles

FFR - First Flight Readiness Review – Project milestone

F_s/n - Control force per g

GVE - Good Visual Environment, typically clear daylight with adequate visual cues

HH - Height [Altitude] Hold

HQ - Handling Qualities

HQR - Cooper-Harper Handling Qualities Rating

IMC - Instrument Meteorological Conditions

MTE - Mission-Task-Element, specifically refers to the maneuvers defined in 3.11

NA - Not Applicable

$n_L(+)$ - Positive load factor limit of the Operational Flight Envelope

$n_L(-)$ - Negative load factor limit of the Operational Flight Envelope

OFE - Operational Flight Envelope

OGE - Out of Ground Effect

PDR - Preliminary Design Review – Early project milestone

Pf - Probability of encountering a failure, typically expressed as failures per flight hour

PH - Position Hold

PIO - Pilot-Induced Oscillation

RATE - Rate Response-Type

RCAH - Rate Command/Attitude Hold Response-Type

RCDH - [Yaw] Rate Command/Direction [Heading] Hold Response-Type

RCHH - [Vertical] Rate Command/Height [Altitude] Hold Response-Type

RPM - Revolutions per minute

SCAS - Stability and Control Augmentation System

SFE - Service Flight Envelope

SFR - Systems Functional Review – Early milestone in project evolution

S - Simulation method for verification

SVR - Systems Verification Review – Late milestone in project evolution

T - Test method for verification

TC - Turn Coordination

TRC - Translational Rate Command Response-Type

UCE - Usable Cue Environment

VCR - Visual Cue Rating

V_H - Maximum level flight airspeed at maximum continuous power

✓ - Specification requirement is applicable

6.2.2 Configurations

A configuration is defined by the external geometry. This includes the positions of variable systems such as landing gear or flaps, location of external stores and carriage of sling loads.

6.2.3 Degree of pilot attention

Some requirements depend on whether or not the pilot must attend to tasks other than flying the rotorcraft.

6.2.3.1 Fully attended operation

The pilot flying the rotorcraft can devote full attention to attitude and flight path control. Requirements for divided attention are minimal.

6.2.3.2 Divided attention operation

The pilot flying the rotorcraft is required to perform non-control-related sidetasks for a moderate period of time.

6.2.4 Flight Condition

Flight Condition is defined by a unique combination of the parameters which define the Operational Flight Envelope.

6.2.5 IMC operations

Instrument Meteorological Conditions (IMC) operations imply control of the rotorcraft solely with reference to the flight instruments. Occurs when the rotorcraft is clear of all obstacles.

6.2.6 Landing gear

Wheels or skids used to support the rotorcraft while on the ground.

6.2.7 Levels of handling qualities

Levels of handling qualities are defined by the 1 to 3, 4 to 6, and 7 to 8 ranges of the Cooper-Harper Handling Qualities Rating (HQR) Scale (Figure 1). This specification uses two distinct methods of establishing Levels of handling qualities, Predicted Levels and Assigned Levels. Predicted Levels are obtained by comparing the rotorcraft's flying qualities parameters with the boundaries appropriate to the rotorcraft's operational requirements. Assigned Levels are obtained from test pilots performing the designated MTEs. The results of these two methods are combined to determine the overall Level of handling qualities.

6.2.8 Load mass ratio

For externally slung loads, the load mass ratio is the ratio of external load mass to mass of rotorcraft plus external load.

6.2.9 Loadings

Loadings refer to the mass properties of a configuration and will be reflected in the total mass or weight, the center of gravity location, and the various moments of inertia.

6.2.10 Mission-Task-Element (MTE)

An element of a mission that can be treated as a handling qualities task.

6.2.11 Near-earth operations

Operations sufficiently close to the ground or fixed objects on the ground, or near water and in the vicinity of ships, oil derricks, etc., that flying is primarily accomplished with reference to outside objects.

6.2.12 Response-Type

A characterization of the rotorcraft response to a control input in terms of well recognized stability augmentation systems (i.e., Rate, Rate Command/Attitude Hold, etc.). However, it is not necessary to use a stability augmentation system to achieve the specified characteristics.

6.2.13 Rotorcraft Status

The Rotorcraft Status is defined by a unique combination of Configuration, Loading, Setting and State.

6.2.14 Settings

Settings refers to the selected functionality of rotorcraft components or systems that affect rotorcraft response, or UCE, which can be activated or deactivated by the pilot.

6.2.15 Speed ranges

6.2.15.1 Ground Speed

Ground speed is defined to be the speed with respect to a hover reference which may itself be moving, such as for shipboard operations.

6.2.15.2 Hover

Hovering flight is defined as all operations occurring at ground speeds less than 15 knots.

6.2.15.3 Low speed

Low-speed flight is defined as all operations occurring at ground speeds between 15 and 45 knots.

6.2.15.4 Forward flight

Forward flight is defined as all operations with a ground speed greater than 45 knots.

6.2.16 Stabilized hover

A stabilized hover is one in which there are no objectionable oscillations in rotorcraft attitude or position.

6.2.17 States

Rotorcraft States are Normal when the various systems are functioning as selected. Failure States exist when the functionality is modified by one or more malfunctions in rotorcraft components or systems that affect rotorcraft response or UCE.

6.2.18 Step input

A step input is defined as a rapid change in the controller force or position from one constant value to another. The input should be made as rapidly as possible without exciting undesirable structural or rotor modes, or approaching any rotorcraft safety limits. This differs from the classical definition, where the change occurs in zero time.

6.2.19 Winds

6.2.19.1 Calm winds

Winds with a steady component of less than 5 knots.

6.2.19.2 Light Winds

Winds with a steady component of between 10 and 15 knots

6.2.19.3 Moderate winds

Winds with a steady component of between 20 and 35 knots.

6.3 Changes from Previous Issues

Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes. Following are brief descriptions of the most significant changes in this revision.

This document has been rearranged to comply with the structure defined in MIL-STD-961D (March 1995). The primary changes resulting from this are as follows:

All the requirements are located in 3.0 Requirements. This means the quantitative criteria can no longer be referred to as the “section 3 requirements” and the flight test maneuvers or MTEs as the “section 4 requirements.” As an alternative the terms “criteria” and “MTEs” are suggested for simple reference.

A new section 4.0 Verification has been added. This provides guidance on the manner and extent of demonstration that is required as the project evolves.

Definitions and other background material are located in section 6.0 Notes.

The primary change to the technical content is addition of MTEs for cargo and utility rotorcraft types. To go along with this, the MTE task descriptions have been consolidated across rotorcraft type and visual environment, with tables to prescribe the performance standards.

A new table is provided listing the recommended MTE for each rotorcraft type (scout, attack, utility or cargo). The MTEs are related to the quantitative criteria in two ways. First, the table of MTEs has a column which indicates the degree of agility implied by the MTE (Limited, Moderate, Aggressive, and Target Acquisition and Tracking), and thereby specifies which criteria boundary must be used when there is a choice. Second, a separate table links the MTE with the required Response-Types. These designations replace the “maneuvering” groupings used in many of the ADS-33D-PRF requirements (for example, “Limited maneuvering” is now “Limited agility,” etc., with “Target Acquisition and Tracking” replacing both the category with the same name, and “Air Combat,” in ADS-33D-PRF).

6.3.1 Operational missions and Mission-Task-Elements (MTEs) (3.1.1)

This paragraph requires the system specification to specify which MTEs apply. For guidance, a table of all MTEs is provided along with a recommended selection for each of the basic Army rotorcraft types. ADS-33D-PRF had a similar paragraph, but included topics which have now been separated into individual paragraphs.

6.3.2 Required agility (3.1.2)

This paragraph draws attention to the fact that each MTE has an associated degree of agility and effectively defines which criteria boundary applies when there is a multiple choice.

6.3.3 Operational environment (3.1.3)

All of the mission related capabilities that have to be specified for a specific application are referenced in this paragraph, and in 3.1.1 and 3.1.4. In ADS-33D-PRF the same characteristics had to be specified, but they were spread around throughout the document. Defining these details forms the basis for specifying which requirements apply, and forms the basis for tailoring this generic specification for use in a specific procurement. It is assumed that this tailoring information will be provided in the system specification.

6.3.4 Levels of handling qualities (3.1.5)

No changes have been made to the overall concepts, but new definitions have been introduced to clarify that the quantitative criteria result in a “predicted Level of HQ” and the MTE evaluations result in an “assigned Level of HQ.” Determination of both predicted and assigned Levels is required to maximize the likelihood of an accurate assessment of the rotorcraft’s handling qualities.

6.3.5 Configurations, loadings, flight conditions, settings, states, and status (3.1.7 – 3.1.12)

Definitions have been slightly modified to clarify the conditions under which compliance shall be demonstrated, and is coordinated with the procedures outlined in 4.0 Verification.

6.3.6 Levels for Normal States (3.1.13)

Table 1(3.1) of ADS-33D-PRF has been eliminated with the requirements incorporated directly into the text.

6.3.7 Rotorcraft failures (3.1.14)

A flight safety reliability level has been added. The probability of encountering loss of control no more than 2.5×10^{-7} per flight hour is based on recent system procurement requirements.

6.3.8 Rotorcraft limits (3.1.15)

A subparagraph in ADS-33D-PRF, "Warning and Indication of Rotorcraft Limits," has been removed and some of the words of that subparagraph absorbed into this requirement. The ADS-33D-PRF requirements implied some burden on the pilot, rather than the rotorcraft, as is the intent of this specification.

6.3.9 Required Response-Types (3.2.2)

The tables have been modified to explicitly relate the MTE to Response-Type. Reference to generic mission tasks that are not MTEs has been deleted. Ancillary requirements that were included only as footnotes to the tables in ADS-33D-PRF have been converted to explicit requirements (3.2.2.1 through 3.2.2.4). This provides for a more direct method of reference and confirmation of compliance. Specific reference to heading and height control Response-Types in forward flight has been removed. Turn coordination is the expected yaw response to lateral control inputs if the sideslip requirements (3.4.7) are to be met. There is no explicit Response-Type for yaw response to yaw controller in forward flight, but the requirements of 3.4.8 must be met. Similarly, height response in forward flight must meet the requirements of 3.4.3.

6.3.10 Combinations of degraded Response-Type and dynamics in degraded UCE (3.2.4)

Besides a title change for clarity, Table 3(3.2) of ADS-33D-PRF has been removed and its requirements incorporated directly into the text. The table was redundant (entries for UCE = 2 were identical to those for UCE = 3), stated the obvious (that a Level 1 Response-Type with Level 2 dynamics would Level 2 and vice versa), and had only a single new requirement (that a combination of Level 2 Response-Type and Level 2 dynamics will be interpreted as Level 3).

6.3.11 Rotorcraft guidance (NA)

This requirement, 3.2.4 in ADS-33D-PRF, has been removed. It required sufficient visual cues to maneuver – already required by other paragraphs – and the determination of envelopes for maneuvering, which can be overly complex to generate. The best modification to this paragraph was its removal entirely.

6.3.12 Character of Attitude Hold and Heading Hold Response-Types (3.2.7)

A minimum of ±1 deg has been added to the hold accuracy. This is to eliminate unreasonable accuracy tolerances resulting from returning to ±10% of displacement, when the displacement is small.

6.3.13 Character of Vertical Rate Command with Altitude (Height) Hold (3.2.10.1)

In ADS-33D-PRF the altitude hold performance requirement was specified as 3.3 ft for bank angles less than 30 deg and 6.6 ft for larger bank angles regardless of the applicable MTE. In some cases this is more stringent than the performance desired while performing the MTE. The requirement has therefore been modified to apply to performance standards for four specific MTEs.

6.3.14 Hover and low speed requirements (3.3)

The preamble to this major section has been modified to exploit the overall concept of OFE and SFE. Specifically, the requirements apply throughout applicable portions of the OFE and SFE for ground speeds up to 45 knots. The term "applicable portions" of the OFE and SFE is used to recognize that most of the quantitative requirements actually apply in and around equilibrium; no investigations have ever been performed to investigate parameters such as bandwidth requirements at elevated load factors.

6.3.15 Short-term response to control inputs (bandwidth) (3.3.2.1, 3.4.1.1, and 3.4.6.1)

For hover and low speed, the Level 2 limit for All Other MTEs – UCE > 1 (Figure 5e) has been increased from 0.5 rad/sec (at low phase delay) to 1.0 rad/sec. This increase is based on recent piloted simulation data. The corresponding forward-flight pitch (Figure 16c) and roll (Figure 17c) Level 2 limits have been changed accordingly.

6.3.16 Short-term response to control inputs (bandwidth) (3.3.2.1, 3.3.5.1, 3.4.1.1, 3.4.6.1, and 3.4.8.1)

All bandwidth requirements are explicitly referenced to control position inputs. It is desirable to also comply with respect to force inputs. If the response to force inputs fails, flight testing will be required to check the dynamics of the force feel system.

6.3.17 Moderate-amplitude pitch (roll) attitude changes (attitude quickness) (3.3.3)

The statement has been changed to clarify the amplitudes to be tested. The stated ranges now correspond to the ranges in the figures given for the criteria.

6.3.18 Yaw rate response to lateral gusts (3.3.7.1)

The requirements of Table 2(3.3) in ADS-33D-PRF have been incorporated directly into the text and the table removed.

6.3.19 Interaxis coupling (3.3.9)

In ADS-33D-PRF the general requirement applied "for inputs up to and including those required to achieve the moderate amplitude responses..." This has been removed since by definition the requirement applies throughout the OFE. In addition, the specific coupling requirements on yaw-due-to-collective, and pitch-due-to-roll and roll-due-to-pitch, have been made applicable only to rotorcraft which have to meet the Aggressive and Target Acquisition and Tracking agility levels. This excludes the Limited and Moderate agility levels and is consistent with the research simulations on which the criteria were based.

6.3.20 Pitch due to roll and roll due to pitch coupling for Target Acquisition and Tracking (3.3.9.2)

This new requirement uses frequency response criteria developed as described in Ref. 1. Ref. 2 found these criteria to be more discriminating than the time-domain criteria and provided consistent results for hover and forward flight. Because the task used to derive the criteria was essentially a tight ground tracking task, the requirement is limited to the most demanding MTEs.

6.3.21 Height response characteristics (3.3.10.1) and vertical axis control power (3.3.10.3)

The wording has been changed to clarify that pitch, roll, and heading should be maintained essentially constant while testing the height response. This is clearly the situation that needs to be quantified since it is unlikely that heave maneuvers would ever be conducted without control of the other axes. The significantly different result that can be obtained if controls are fixed was shown in Ref. 2. Requirements on vertical axis control power, Table 5(3.3) of ADS-33D-PRF, have been incorporated directly into the text and the table removed.

6.3.22 Rotor RPM governing (3.3.10.4)

The requirement to meet all directional control requirements at the lowest sustained operating RPM limit has been deleted. It is possible that low RPM could be selected to minimize noise signature, and that restricted maneuvering may be acceptable during such situations. The change allows such situations to be treated explicitly.

6.3.23 Position hold (3.3.11)

The statement has been modified to define how the other controls shall be used while performing the turn. This now states that the collective shall be used as necessary to maintain altitude, not be left "free."

6.3.24 Forward flight requirements (3.4)

The preamble to this major section has been modified to exploit the overall concept of OFE and SFE. Specifically, the requirements apply throughout applicable portions of the OFE and SFE for ground speeds greater than 45 knots. The term "applicable portions" of the OFE and SFE is used to recognize that most of the quantitative requirements actually apply in and around equilibrium; no investigations have ever been performed to investigate such parameters as bandwidth variations or requirements at elevated load factors.

6.3.25 Short-term response to control inputs (bandwidth) (3.4.1.1, 3.4.6.1, and 3.4.8.1)

All bandwidth requirements are explicitly referenced to control position inputs, not force. If the response to force inputs fails, flight testing will be required to check the dynamics of the force feel system.

6.3.26 Pitch control power (3.4.2)

Based on the recommendation in Ref. 3 an extra requirement was added for Level 2 pitch control effectiveness.

6.3.27 Flight path control (3.4.3)

The flight path control requirement in ADS-33D had two significant shortcomings. First, it did not include a requirement for the use of longitudinal-cyclic for vertical rate response; it is very common to control flight path exclusively with pitch attitude in forward flight. Second, it is nearly impossible to accomplish a pure collective input without a small attitude change in forward flight. Even small attitude changes in forward flight result in a significant vertical rate response. Because of this, it was very difficult to test the ADS-33D-PRF criterion. The revised criteria account for the fact that acceptable flight path control requires the use of collective as primary when on the backside of the power-required curve. When on the frontside of the power-required curve, it most efficient to hold power (collective) constant and regulate altitude with pitch attitude. Separate criteria are provided for backside ($\Delta\gamma_{ss}/\Delta V_{ss} > 0$) and frontside ($\Delta\gamma_{ss}/\Delta V_{ss} < 0$) flight. The criterion for backside operation is the same as for low speed and hover.

6.3.28 Longitudinal static stability (3.4.4)

A new requirement on speed stability has been added. No specific limits are placed on stick force per knot, other than that it be stable.

6.3.29 Pitch control in autorotation (3.4.5.1.3)

A requirement has been added to assure that the inputs required to autorotate do not saturate the pitch controller.

6.3.30 Roll due to pitch and pitch due to roll coupling for Aggressive agility (3.4.5.2, 3.4.5.3)

Two requirements have been created. Any reference to specific MTEs and operational mission tasks has been deleted from the text. The requirement on roll due to pitch is essentially unchanged. For pitch due to roll, however, it has been noted that some coupling will occur during normal maneuvering and the limits need to somehow allow for natural coupling. Because such a requirement would be quite complex to define and apply, the current requirement is purely qualitative.

6.3.31 Pitch due to roll and roll due to pitch coupling for Target Acquisition and Tracking (3.4.5.2)

The frequency response criteria were developed as described in Ref. 1. Ref. 2 found these criteria to be more discriminating than the time-domain criteria and provided consistent results for hover and forward flight.

6.3.32 Turn coordination (3.4.7.2)

There is no change to the requirement, but figure 7(3.4) of ADS-33D-PRF has been deleted since it was exactly figure 6(3.4) with the ordinate scaled by 0.2. This factor is now incorporated into the limit definition.

6.3.33 Large amplitude heading changes for aggressive agility (3.4.8.2)

The requirement has been modified to demand the sideslip changes be achieved in 1 second. This was the original intent of the requirement, see Ref. 4. In addition, the requirement has now been made applicable to only Aggressive agility rather than all degrees of agility since it is assumed that only such categories will need such rapid maneuvering.

6.3.34 Lateral control in steady sideslips (3.4.10.3)

This requirement now allows neutral lateral control in sideslips.

6.3.35 Centering and breakout forces (3.6.1.1)

Small changes have been made to the yaw (2.0 reduced to 1.0 lb) and collective (1.0 reduced to 0.75 lb) Level 2 minimum breakout forces. These changes were stimulated by the BO 105 data in Ref. 2, and did not conflict with data quoted in the BIUG, Ref. 4.

6.3.36 Force gradients (3.6.1.2)

The minimum force gradient for yaw has been reduced to 3.0 lb/in. (from 5.0) for Level 1, and 2.0 lb/in. (from 5.0) for Level 2. These numbers are closer to the Apache data (1.1 lb/in.) quoted in Ref. 3, and rated not objectionable.

6.3.37 Trimming characteristics (3.6.6)

This is a new requirement to cover an important topic that had been overlooked.

6.3.38 Engine failures (3.7.2)

For clarification, the ability to land following an engine failure has been modified by adding the clause "on a level surface."

6.3.39 Control forces during transfer (3.8.2)

Text has been reworded for clarity.

6.3.40 Requirements for externally slung loads (3.10)

A considerable amount of simulation and flight testing has been conducted to investigate the complex interactions between the dynamics of slung loads and handling qualities. The outcome of this testing has been overwhelming evidence that quantitative criteria will be extremely difficult to derive. Test results to date show that, for load mass ratios (defined in 6.2.8) of about 0.33 or less, rotorcraft that are Level 1 without the load will generally be Level 1 when the slung-load MTEs of 3.11 are performed and the sling and hook-to-cg lengths are reasonable. At this time the prudent step is to acknowledge the issues involved, through a limited set of requirements in 3.10 and verification in 4.3. Any rotorcraft that is expected to carry externally slung loads must of course meet the specification without a load.

6.3.41 Mission-Task-Elements (3.11)

To emphasize the specific maneuver definitions, the title has been changed from "Flight Test Maneuvers" to "Mission-Task-Elements." The preamble to this section has been modified slightly to introduce the new arrangement for defining the MTEs. Also, references to conditions, or rotorcraft status, under which the tests shall be performed have been moved to section 4.0 Verification.

The primary change to the specific maneuvers is addition of MTEs for cargo and utility rotorcraft. Since this could mean up to six sets of standards for some MTEs it was decided to develop a new layout. The MTE task descriptions have been consolidated to apply across rotorcraft type and visual environment, and tables used to prescribe the differing performance standards. Where different standards apply for different rotorcraft types the appropriate performance standards are identified by the general classes scout/attack, cargo/utility, and externally slung loads. In most cases different standards are provided for GVE and DVE.

The tasks and standards for cargo and utility and external loads are new, basically as developed during the flight tests described in Ref. 5. Only changes made to the task description or performance standard applicable to scout/attack, i.e., as defined in ADS-33D-PRF, will be mentioned below.

6.3.42 Landing (3.11.2)

The basic maneuver is unchanged, but the landing pad required in ADS-33D-PRF has been replaced by a simple reference point. This is to eliminate the difficulty of building a pad suitable for large rotorcraft, and to remove the possible hazard of such a structure blowing around.

6.3.43 Pirouette (3.11.5)

The maneuver has been extended to include a steady 5 second hover at the end, in accordance with the recommendation in Ref. 5.

6.3.44 Vertical Maneuver (3.11.6)

The ADS-33D-PRF bob-up/bob-down maneuver has been combined with the vertical maneuver developed in Ref. 5. The incremental height is clearly spelled out as 25 ft and the DVE time has been adjusted to 13 and 18 seconds. The previous DVE times (20 and 30 sec) were estimates based on extending the Ref. 3 tests to a larger height change, but were clearly out of line when the Ref. 5 tests were performed.

6.3.45 Acceleration and deceleration (3.11.11)

This task description has been modified to recognize that rotorcraft with large power margins may not be able to hold altitude with full collective without going to dangerously large pitch angles.

6.3.46 Sidestep (3.11.12)

The task description has been modified based on the comment (Ref. 2) that the target bank angle could not be achieved before the side velocity was reached. Thus the OFE has been prescribed as an alternate limit.

6.3.47 Deceleration to dash (3.11.13)

Based on the recommendations in Ref. 2, the speed for initiating this maneuver was defined as the lesser of 120 knots or V_H.

6.3.48 Transient turn (3.11.14)

Based on the recommendations of Refs. 2 and 3 the following modifications were made: the starting speed is 120 knots or V_H; the maneuver is to end in wings-level flight; and peak normal load factor for desired performance is specified to be within 0.2g of limit load factor.

6.3.49 Pull-up/pushover (3.11.15)

Based on the recommendation in Ref. 3, the target speed was defined as 120 kt or V_H, and the termination was to level flight, not the original airspeed.

6.3.50 Roll reversal at reduced and elevated load factors (3.11.16)

Based on the recommendations in Ref. 3, the target speed was changed to 120 kt or V_H, and the target load factor is allowed to fall off 50% during the rolling maneuver.

6.3.51 Turn to Target (3.11.17)

Reference to winds has been removed. The maneuver does not have to be performed in moderate winds.

6.3.52 High Yo-Yo (3.11.18)

Based on the experiences described in Ref. 2 the following modifications have been made: Reduce the target aircraft turn to a 45 deg bank, from 60 deg, to minimize chance of losing sight of the target. Terminate the target turn to roll out after 180 deg heading change to minimize the chance of a collision.

6.3.53 Low Yo-Yo (3.11.19)

Based on the experiences described in Ref. 2 the following modifications have been made: Reduce the initial speed to V_H – 20 knots to provide more margin for acceleration. Reduce the target aircraft turn to a 45 deg bank, from 60 deg, to minimize chance of losing sight of the target. Terminate the target turn to roll out after 180 deg heading change to minimize the chance of a collision.

6.3.54 Verification (4.)

This is a completely new section provided in accordance with MIL-STD-961D (March 1995). It outlines the requirements for verification. In particular, it defines the appropriate use of analysis, simulation, and testing as the project evolves through the development cycle. In addition, it provides a structure for determining the combinations of rotorcraft status and flight conditions for which the various requirements shall be demonstrated to be satisfied.

6.3.55 References cited in 6.3

1. Blanken, C. L., C.J. Ockier, H-J. Pausder, R. C. Simmons. "Rotorcraft Pitch-Roll Decoupling Requirements from a Roll Tracking Maneuver." *Journal of the American Helicopter Society*, July 1997.

2. Ockier C. J. *Evaluation of the ADS-33D Handling Qualities Criteria Using the BO 105 Helicopter*. DLR Report Forschungsbericht 98-07, 1998.

3. Abbott W. C., *et al*. *Engineering Evaluation of Aeronautical Design Standard (ADS)-33C, Handling Qualities Requirements for Military Rotorcraft, Utilizing an AH-64A Apache Helicopter*. US Army Aviation Technical Test Center Final Report AVSCOM Project No. 87-17. November 1991.

4. Hoh, R. H., D. G. Mitchell, B. L. Aponso, D. L. Key, C. L. Blanken. *Background Information and User's Guide for Handling Qualities Requirements for Military Rotorcraft*. USAAVSCOM TR 89-A-008, December 1989.

5. Woratschek R., *et al*. *Engineering Evaluation of the Cargo Helicopter Requirements of Aeronautical Design Standard 33C/D.* US Army Aviation Technical Test Center Final Report ATCOM Project No. 93-02, May 1997.

Table I. Mission-Task-Elements (MTEs)

MTE	RE-QUIRED AGILITY	ROTORCRAFT CATEGORY				EXTER-NALLY SLUNG LOAD
		ATTACK	SCOUT	UTILITY	CARGO	
Tasks in GVE						
Hover	L	✓	✓	✓	✓	✓
Landing	L	✓	✓	✓	✓	
Slope Landing	L	✓	✓	✓	✓	
Hovering Turn	M	✓	✓	✓	✓	
Pirouette	M	✓	✓	✓	✓	
Vertical Maneuver	M	✓	✓	✓	✓	✓
Depart/Abort	M			✓	✓	✓
Lateral Reposition	M			✓	✓	✓
Slalom	M	✓	✓	✓	✓	
Vertical Remask	A	✓	✓			
Acceleration and Deceleration	A	✓	✓			
Sidestep	A	✓	✓			
Deceleration to Dash	A	✓	✓	✓		
Transient Turn	A	✓	✓	✓		
Pullup/Pushover	A	✓	✓	✓		
Roll Reversal	A	✓	✓	✓		
Turn to Target	T	✓	✓			
High Yo-Yo	T	✓	✓			
Low Yo-Yo	T	✓	✓			
Tasks in DVE						
Hover	L	✓	✓	✓	✓	✓
Landing	L	✓	✓	✓	✓	
Hovering Turn	L	✓	✓	✓	✓	
Pirouette	L	✓	✓	✓	✓	
Vertical Maneuver	L	✓	✓	✓	✓	✓
Depart/Abort	L			✓	✓	✓
Lateral Reposition	L			✓	✓	✓
Slalom	L	✓	✓	✓		
Acceleration and Deceleration	L	✓	✓			
Sidestep	L	✓	✓			
Tasks in IMC						
Decelerating Approach	L	✓	✓	✓	✓	✓
ILS Approach	L	✓	✓	✓	✓	
Missed Approach	L	✓	✓	✓	✓	
Speed Control	L	✓	✓	✓	✓	

Notes: ✓ = Suggested maneuvers to apply with appropriate performance standards.

L = Limited agility

M = Moderate agility

A = Aggressive agility

T = Target Acquisition and Tracking

Table II. Levels for Rotorcraft Failure States

PROBABILITY OF ENCOUNTERING	WITHIN OPERATIONAL FLIGHT ENVELOPE	WITHIN SERVICE FLIGHT ENVELOPE
Level 2 after failure	< 2.5 x 10^{-3} per flight hr	
Level 3 after failure	< 2.5 x 10^{-5} per flight hr	< 2.5 x 10^{-3} per flight hr
Loss of control	< 2.5 x 10^{-7} per flight hr	

Table III. Transients following failures

LEVEL	FLIGHT CONDITION		
	HOVER AND LOW SPEED	FORWARD FLIGHT	
		NEAR-EARTH	UP-AND-AWAY
1	3° roll, pitch, yaw 0.05g n_x, n_y, n_z No recovery action for 3.0 sec	Both Hover and Low Speed and Forward Flight Up-and-Away requirements apply	Stay within OFE. No recovery action for 10 sec
2	10° attitude change or 0.2g acceleration. No recovery action for 3.0 sec	Both Hover and Low Speed and Forward Flight Up-and-Away requirements apply	Stay within OFE. No recovery action for 5.0 sec
3	24° attitude change or 0.4g acceleration. No recovery action for 3.0 sec	Both Hover and Low Speed and Forward Flight Up-and-Away requirements apply	Stay within OFE. No recovery action for 3.0 sec

Table IV. Required Response-Types for hover and low speed – near earth

MTE	UCE = 1		UCE = 2		UCE = 3	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Required Response-Type for all MTEs. Additional requirements for specific MTEs are given below.	**RATE**	**RATE**	**ACAH**	**RATE + RCDH**	**TRC+RCDH + RCHH+PH**	**ACAH**
Hover			RCDH + RCHH			RCDH + RCHH
Landing			RCDH			RCDH
Slope landing			RCDH			RCDH
Hovering turn			RCHH			RCHH
Pirouette			RCHH			RCHH
Vertical Maneuver			RCDH			RCDH
Depart/Abort			RCDH + RCHH			RCDH + RCHH
Lateral Reposition			RCDH + RCHH			RCDH + RCHH
Slalom	NA	NA	RCHH			RCHH
Vertical remask			RCDH			RCDH
Acceleration and deceleration			RCDH + RCHH			RCDH + RCHH
Sidestep			RCDH + RCHH			RCDH + RCHH
Turn to target			RCDH + RCHH			RCDH + RCHH
Divided attention required	RCDH + RCHH + PH		RCDH + RCHH			RCDH + RCHH

Table V. Required Response-Types for forward flight (pitch and roll)

MTE	VMC		IMC and UCE = 2,3	
	Level 1	Level 2	Level 1	Level 2
Decelerating approach in IMC conditions	NA	NA	AH + 3-cue flight director	Rate
ILS Approach	NA	NA	Rate	Rate
Missed Approach	NA	NA	Rate	Rate
Speed Control	NA	NA	Rate	Rate
Divided attention required	AH	Rate	Autopilot	Autopilot
Slalom	Rate	Rate	NA	NA
Deceleration to Dash	Rate	Rate	NA	NA
Transient Turn	Rate	Rate	NA	NA
Pullup/Pushover	Rate	Rate	NA	NA
Roll Reversal	Rate	Rate	NA	NA
High Yo-yo	Rate	Rate	NA	NA
Low Yo-yo	Rate	Rate	NA	NA

Table VI. Requirements for large-amplitude attitude changes – hover and low speed

AGILITY CATEGORY MTE	RATE RESPONSE-TYPES						ATTITUDE COMMAND RESPONSE-TYPES			
	ACHIEVABLE ANGULAR RATE (deg/sec)						ACHIEVABLE ANGLE (deg)			
	LEVEL 1			LEVELS 2 AND 3			LEVEL 1		LEVELS 2 AND 3	
	Pitch	Roll	Yaw	Pitch	Roll	Yaw	Pitch	Roll	Pitch	Roll
<u>Limited Agility</u> Hover Landing Slope Landing	±6	±21	±9.5	±3	±15	±5	±15	±15	±7	±10
<u>Moderate Agility</u> Hovering Turn Pirouette Vertical Maneuver Depart/Abort Lateral Reposition Slalom	±13	±50	±22	±6	±21	±9.5	+20 -30	±60	±13	±30
<u>Aggressive Agility</u> Vertical Remask Acceleration Deceleration Sidestep <u>Target Acquisition and Track</u> Turn to Target	±30	±50	±60	±13	±50	±22	±30	±60	+20 -30	±30

Table VII. Maximum values for height response parameters – hover and low speed

LEVEL	$T_{\dot{h}_{eq}}$ (sec)	$\tau_{\dot{h}_{eq}}$ (sec)
1	5.0	0.20
2	∞	0.30

Table VIII. Maximum values for flight path response parameters – forward flight

LEVEL	$T_{\dot{h}_{eq}}$ (sec)	$\tau_{\dot{h}_{eq}}$ (sec)
1	5.0	0.20
2	10.0	0.30

Table IX. Requirements for large-amplitude roll attitude changes – forward flight

AGILITY CATEGORY MTE	RATE RESPONSE-TYPES ACHIEVABLE ROLL RATE (deg/sec)		ATTITUDE RESPONSE-TYPES ACHIEVABLE BANK ANGLE (deg)	
	LEVEL 1	LEVEL 2	LEVEL 1	LEVEL 2
Limited Agility Decel Approach in IMC ILS Approach Missed approach Speed Control	±15	±12	±25	±15
Moderate Agility Slalom	±30	±15	±25	±15
Aggressive Agility Deceleration to Dash Transient Turn Pullup/Pushover Roll Reversal	±50	±21	±90	±30
Target Acquisition and Track High Yo-yo Low Yo-yo	±90	±50	Unlimited	±60

Table X. Allowable breakout forces, pounds – hover and low speed

COCKPIT CONTROL	LEVEL 1	LEVEL 2	LEVEL 3
	min/max	min/max	max
Pitch (Centerstick)	0.5/1.5	0.5/3.0	6.0
Roll (Centerstick)	0.5/1.5	0.5/2.0	4.0
Yaw (Pedals)	2.0/7.0	1.0/7.0	14.0
Collective	1.0/3.0	0.75/4.5	6.0

Table XI. Allowable breakout forces, pounds – forward flight

COCKPIT CONTROL	CARGO min	CARGO max
Pitch (Centerstick)	0.5	5.0
Roll (Centerstick)	0.5	4.0
Yaw (Pedals)	2.0	14.0

NOTE: The values in Table XI are for Levels 1 and 2.
For Level 3 the maximum values may be doubled.

Table XII. Allowable control force gradients, pounds/inch

COCKPIT 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	3.0	10.0	2.0	20.0

Table XIII. Limit cockpit control forces, pounds

COCKPIT CONTROL	HOVER AND LOW SPEED			FORWARD FLIGHT		
	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 1	LEVEL 2	LEVEL 3
Pitch (Centerstick)	15.0	20.0	40.0	30.0	35.0	40.0
Roll (Centerstick)	10.0	15.0	20.0	15.0	20.0	25.0
Yaw (Pedals)	30.0	40.0	80.0	75.0	100.0	125.0
Collective	10.0	10.0	10.0	10.0	10.0	10.0

Table XIV. Requirements/verification matrix

PARAGRAPH NO.	REQUIREMENT	VERIFICATION METHOD/EVENT				
		SFR	PDR	CDR	FFR	SVR
3.1.14	Rotorcraft Failures	A	A	A	S	T
3.1.15	Rotorcraft Limits			A	S	F
3.1.16	Pilot-Induced Oscillations				S	F
3.1.17	Residual Oscillations					F
3.2.2	Required Response-Type	A	T	T	T	F
3.3	Hover and Low Speed					
3.3.1	Equilibrium Characteristics		A	A	A	F
3.3.2	Small-Amplitude Pitch (Roll) Attitude	A	A	A	A	F
3.3.2.2	Short-Term Pitch and Roll Responses to Disturbances		A	A	A	F
3.3.3	Moderate-Amplitude Pitch (Roll) Attitude Changes	A	A	A	A	F
3.3.4	Large-Amplitude Pitch (Roll) Attitude Changes	A	A	A	A	F
3.3.5	Small-Amplitude Yaw Attitude Changes	A	A	A	A	F
3.3.6	Moderate-Amplitude Heading Changes	A	A	A	A	F
3.3.7	Short-Term Yaw Response to Disturbances		A	A	A	F
3.3.8	Large-Amplitude Heading Changes	A	A	A	A	F
3.3.9	Interaxis Coupling		A	A	A	F
3.3.10	Response to Collective Controller	A	A	A	A	F
3.3.11	Position Hold		A	A	A	F
3.3.12	Translational Rate Response-Type		A	A	A	F
3.4	Forward Flight					
3.4.1	Pitch Attitude Response to Longitudinal Controller	A	A	A	A	F
3.4.2	Pitch Control Power	A	A	A	A	F
3.4.3	Flight Path Control				A	F
3.4.4	Longitudinal Static Stability	A	A	A	A	F
3.4.5	Interaxis Coupling		A	A	A	F
3.4.6	Roll Attitude Response to Lateral Controller	A	A	A	A	F
3.4.7	Roll-Sideslip Coupling		A	A	A	F
3.4.8	Yaw Response to Yaw Controller	A	A	A	A	F
3.4.9	Lateral-Directional Stability	A	A	A	A	F
3.4.10	Lateral-Directional Characteristics in Sideslips		A	A	A	F
3.4.11	Pitch, Roll, Yaw Responses to Disturbances		A	A	A	F
3.6	Controller Characteristics	A	A	S	T	F
3.7	Specific Failures	A	A	S	S	T
3.8	Transfer Between Response-Types		A	A	S	F
3.9	Ground Handling and Ditching		A	A	A	F
3.10	Requirements for Externally Slung Loads				A	T
3.11	Mission-Task-Elements			S	S	F

Methods of Verification:
- A – Analysis
- S - Piloted Simulation
- F - Flight Test
- T - Testing, miscellaneous

Events:
- SFR - System Functional Review
- PDR - Preliminary Design Review
- CDR - Critical Design Review
- FFR - First Flight Readiness Review
- SVR - System Verification Review

Table XV. Rotorcraft status and flight conditions for verification

<table>
<tr><th rowspan="2">HQ LEVEL REQD</th><th colspan="4">ROTORCRAFT STATUS</th><th rowspan="2">FLIGHT CONDITIONS</th><th colspan="2">REQTS TO BE SATISFIED</th></tr>
<tr><th>CONFIG-URATIONS</th><th>LOADINGS</th><th>SETTINGS</th><th>STATES</th><th>FQ CRITERIA</th><th>APPLIC-ABLE MTE</th></tr>
<tr><td rowspan="2">1</td><td rowspan="9">As required by the opera-tional missions</td><td rowspan="9">Possible range for applicable Configns</td><td>Primary SCAS</td><td rowspan="3">Normal and Pf $>2.5 \times 10^{-3}$</td><td>GVE OFE</td><td rowspan="8">All for rotorcraft category</td><td rowspan="5">All for mission</td></tr>
<tr><td>Primary or Augmented SCAS</td><td rowspan="2">DVE OFE</td></tr>
<tr><td rowspan="2">2</td><td>Primary SCAS</td></tr>
<tr><td rowspan="2">Secondary SCAS</td><td rowspan="2">Normal and Pf $>2.5 \times 10^{-5}$</td><td>GVE OFE</td></tr>
<tr><td>3</td><td>DVE OFE</td></tr>
<tr><td rowspan="2">2</td><td>Primary SCAS</td><td>Normal</td><td>GVE SFE</td><td rowspan="2">NA</td></tr>
<tr><td>Primary or Augmented SCAS</td><td>Normal</td><td>DVE SFE</td></tr>
<tr><td>3</td><td rowspan="2">Backup</td><td rowspan="2">Pf $>2.5 \times 10^{-7}$</td><td>GVE</td><td>NOE Egress</td></tr>
<tr><td>Con-trol-lable</td><td>DVE</td><td>NA</td><td>Up-&-away egress</td></tr>
</table>

Pf = Probability of encountering a failure per flight hour.

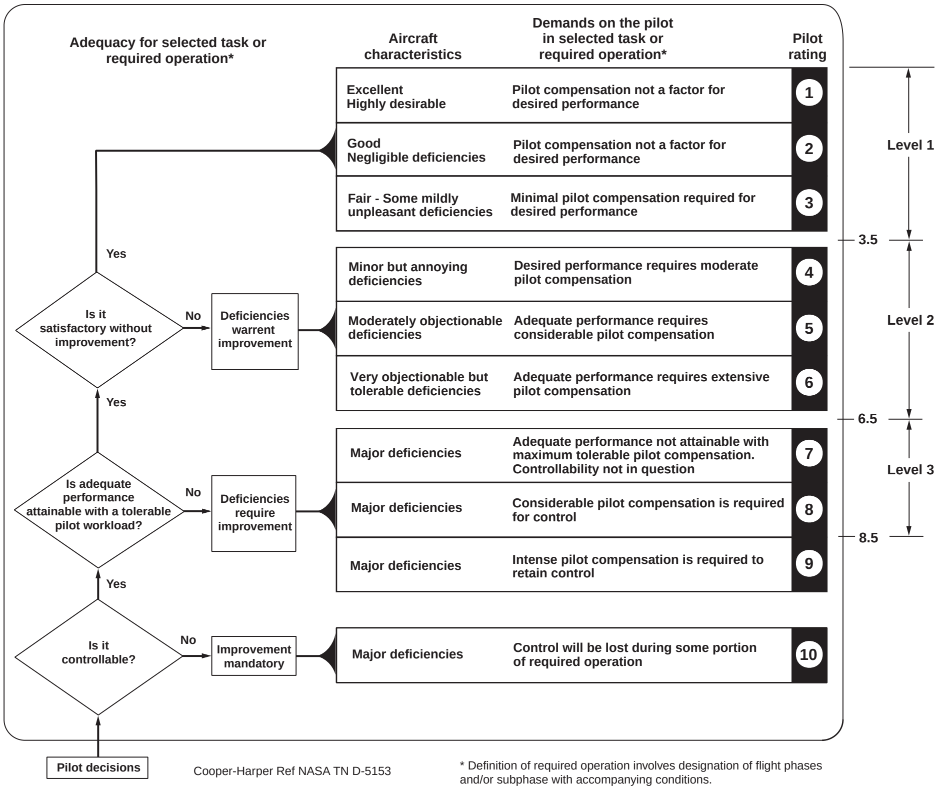
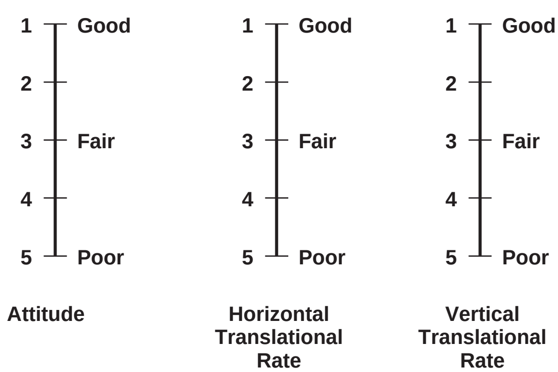


Figure 1. Definition of handling qualities Levels



Pitch, roll and yaw attitude, and lateral-longitudinal, and vertical translational rates shall be evaluated for stabilization effectiveness according to the following definitions:

Good : Can make aggressive and precise corrections with confidence and precision is good.

Fair : Can make limited corrections with confidence and precision is only fair.

Poor: Only small and gentle corrections are possible, and consistent precision is not attainable.

Figure 2. Visual cue rating scale

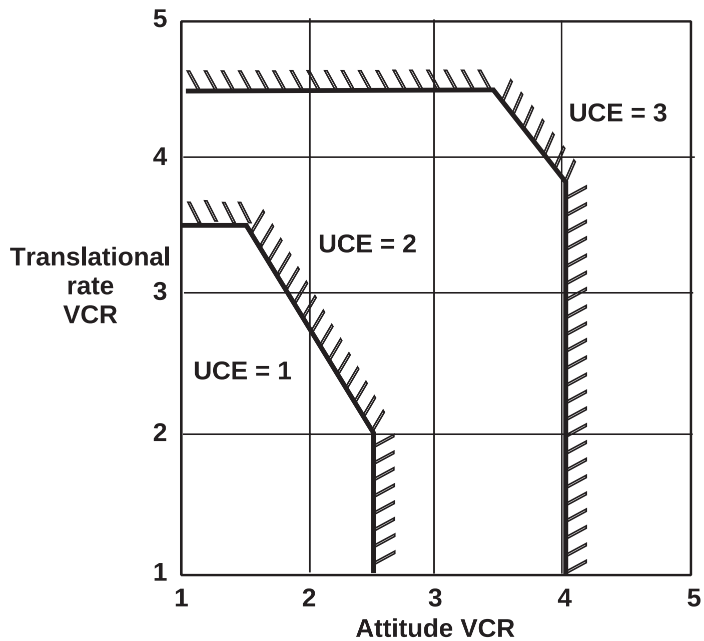


Figure 3. Usable Cue Environments for Visual Cue Ratings

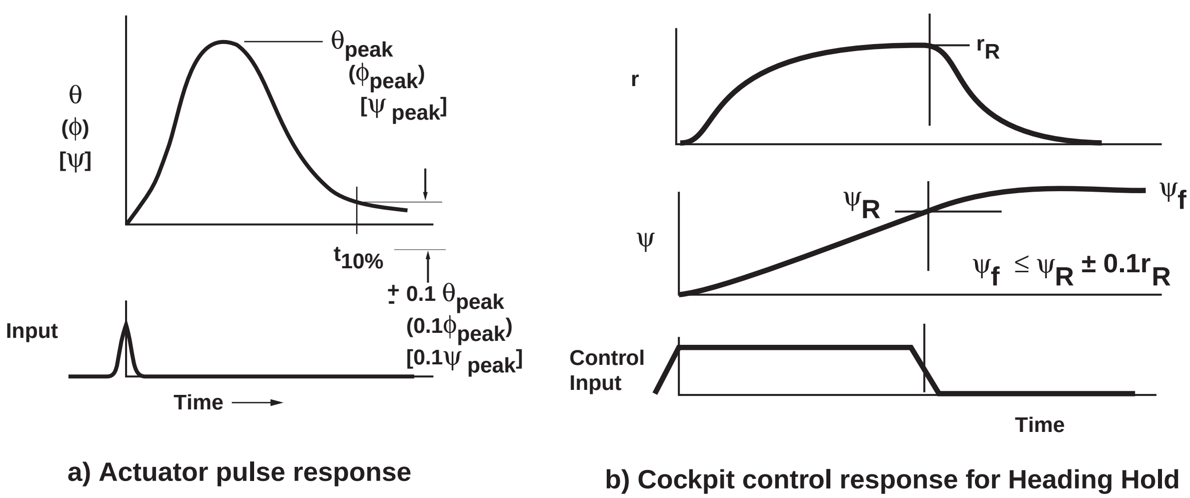
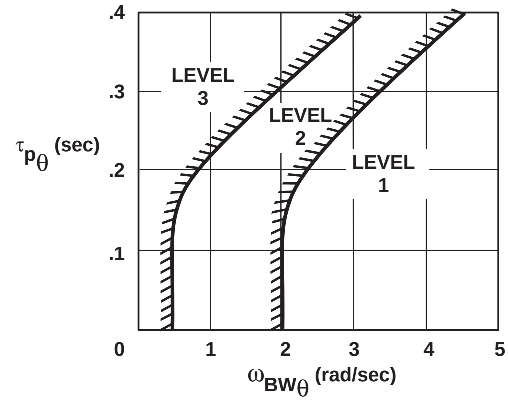
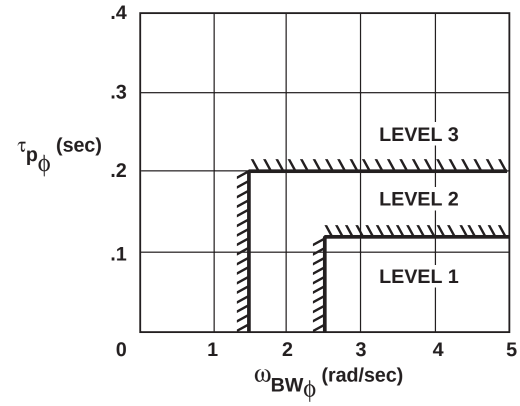


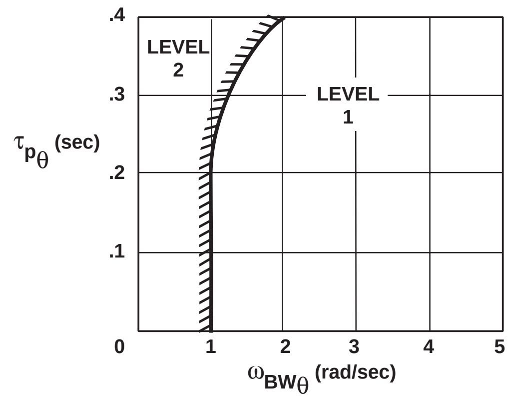
Figure 4. Responses for Attitude Hold and Heading Hold Response Types



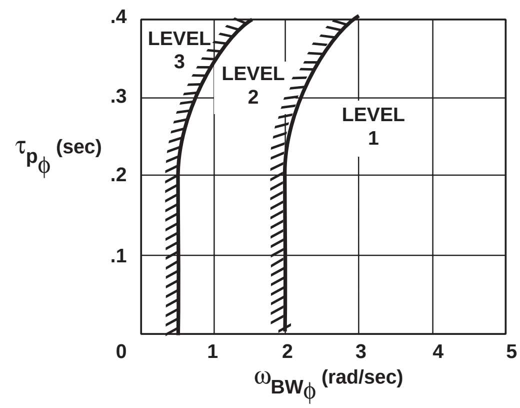
a) Target Acquisition and Tracking (pitch)



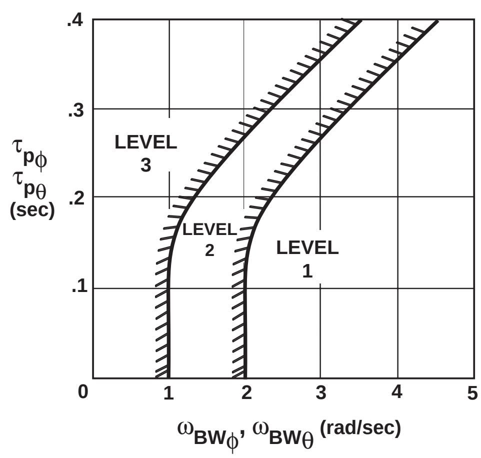
b) Target Acquisition and Tracking (roll)



c) All other MTEs - UCE=1 and Fully Attended operations (pitch)



d) All other MTEs - UCE=1 and Fully Attended operations (roll)



e) All other MTEs - UCE > 1 and/or Divided Attention operations (pitch and roll)

Figure 5. Requirements for small-amplitude pitch (roll) attitude changes – hover and low speed

Phase delay:

$$\tau_p = \frac{\Delta\Phi 2\omega_{180}}{57.3\,(2\omega_{180})}$$

Note:	**If phase is nonlinear between ω_{180} and 2 ω_{180}, τ_p shall be determined from a linear least squares fit to phase curve between ω_{180} and 2 ω_{180}**

> **Caution:**
> **For ACAH, if $\omega_{BW_{gain}} < \omega_{BW_{phase}}$, or if $\omega_{BW_{gain}}$ is indeterminate, the rotorcraft may be PIO prone for super-precision tasks or aggressive pilot technique.**

Rate response-types:

ω_{BW} is lesser of $\omega_{BW_{gain}}$ and $\omega_{BW_{phase}}$

Attitude Command/Attitude Hold Response-Types (ACAH):

$\omega_{BW} = \omega_{BW_{phase}}$

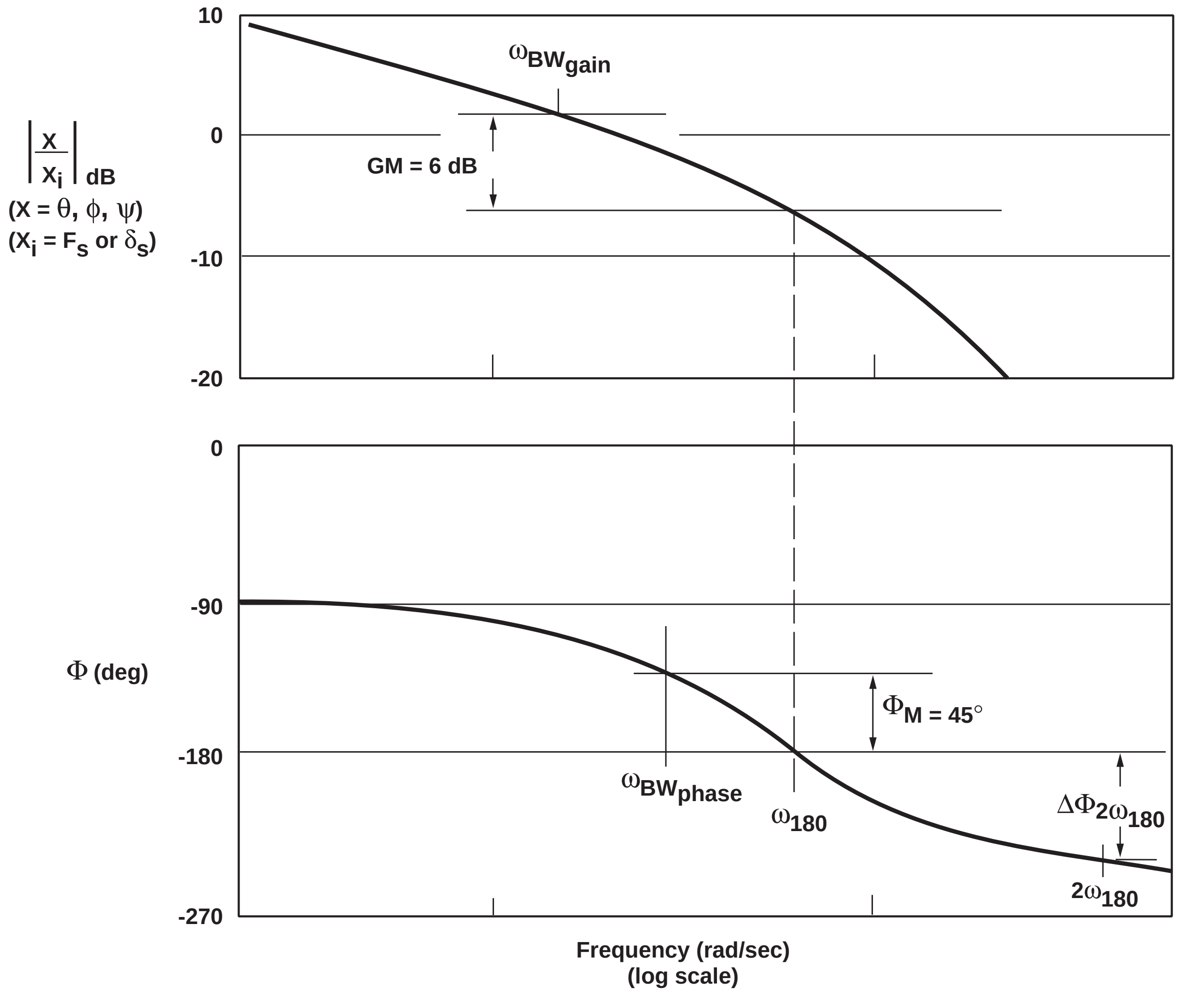


Figure 6. Definitions of bandwidth and phase delay

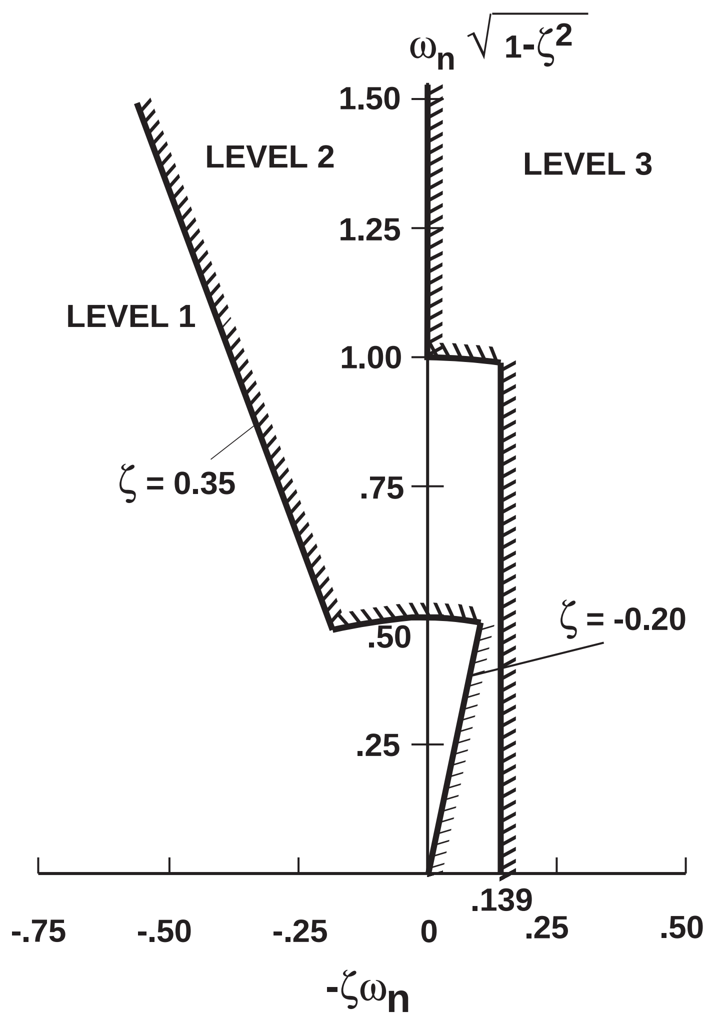
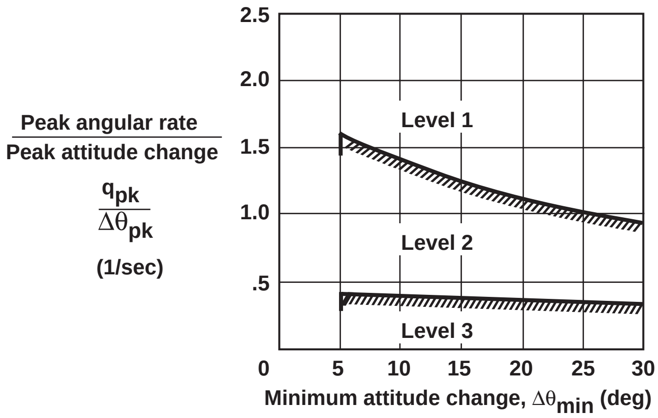
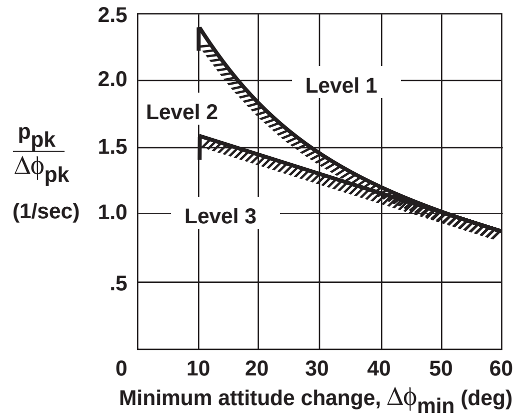


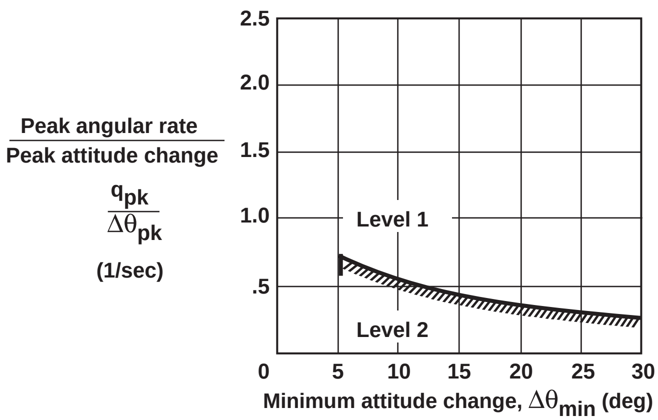
Figure 7. Limits on pitch (roll) oscillations – hover and low speed



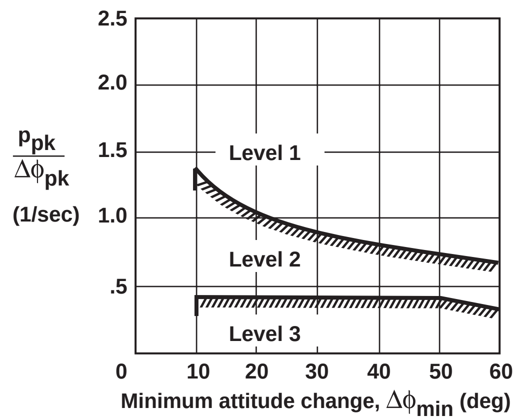
a) Target Acquisition and Tracking (pitch)



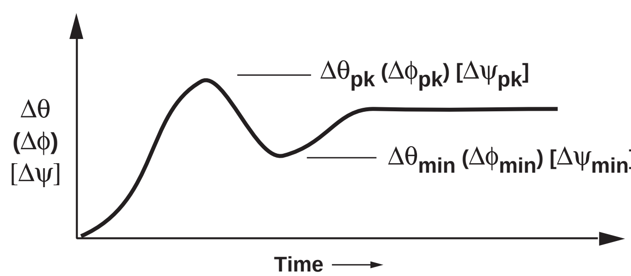
b) Target Acquisition and Tracking (roll)



c) All Other MTEs (pitch)

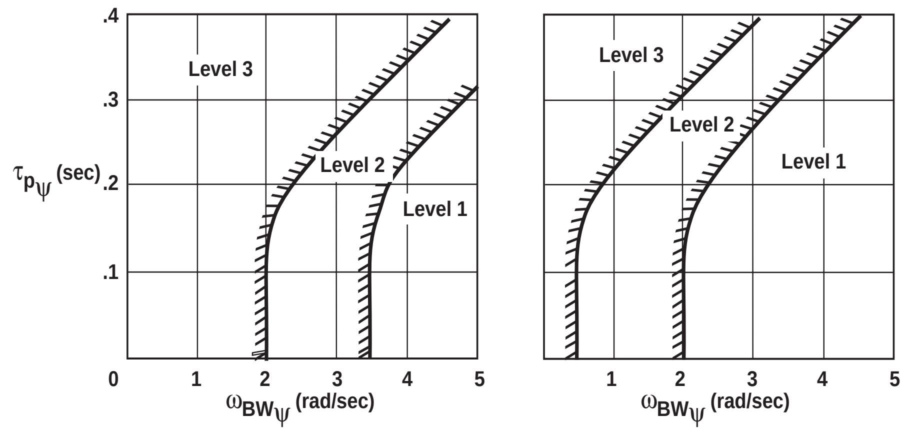


d) All Other MTEs (roll)



e) Definition of Moderate-Amplitude Criterion Parameters

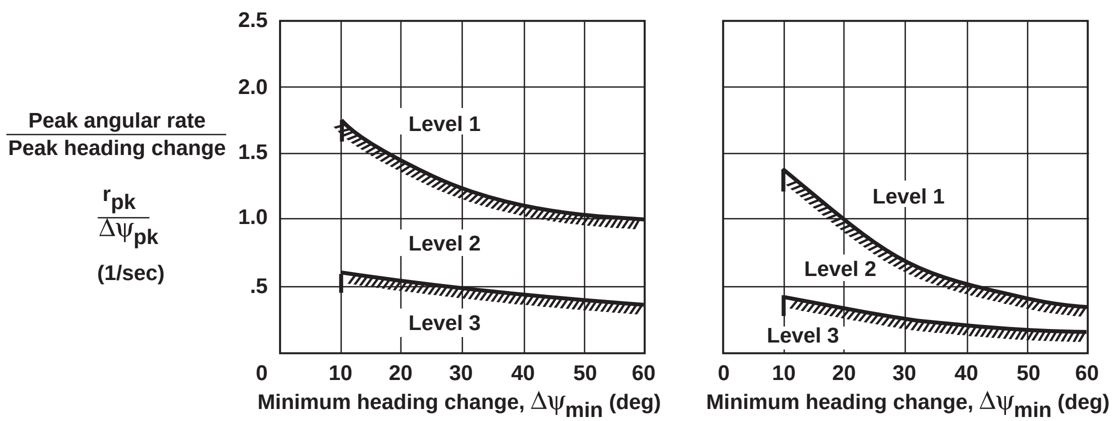
Figure 8. Requirements for moderate-amplitude pitch (roll) attitude changes – hover and low speed



a) Target Acquisition and Tracking

b) All Other MTEs

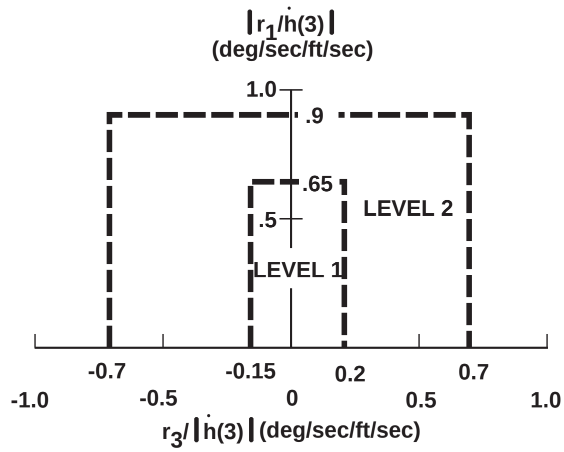
Figure 9. Requirements for small-amplitude heading changes – hover and low speed



a) Target Acquisition and Tracking

b) All Other MTEs

Figure 10. Requirements for moderate-amplitude heading changes – hover and low speed



Where:

r_1 = first peak (before 3 seconds) or r(1) if no peak occurs before 3 seconds

r_3 = r(3) - r_1 for $r_1 > 0$, or r_1 - r(3) for $r_1 < 0$

r(1) and r(3) are yaw rate responses measured at t = 1 and 3 seconds, respectively, following a step collective input at t = 0

In the unlikely event of more than one peak before 3 seconds, the largest peak (by magnitude) should be designated as r_1

Figure 11. Yaw-due-to-collective coupling requirements

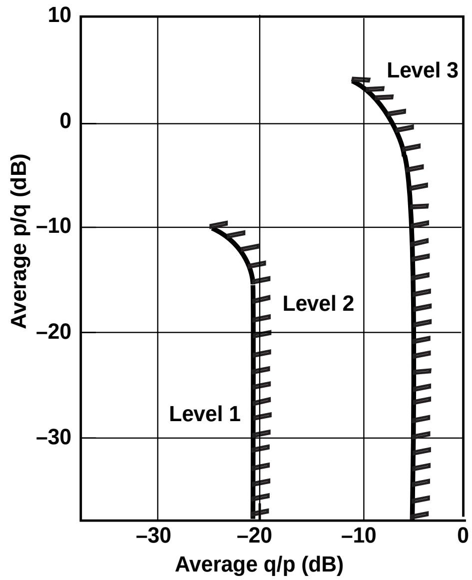


Figure 12. Requirements for pitch due to roll and roll due to pitch coupling for Aggressive agility

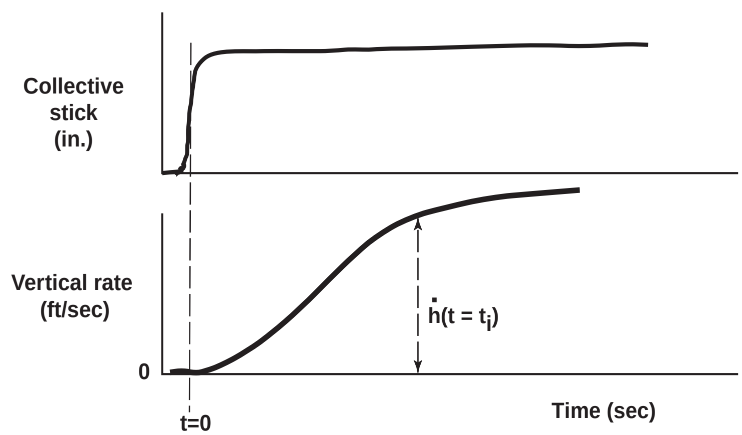
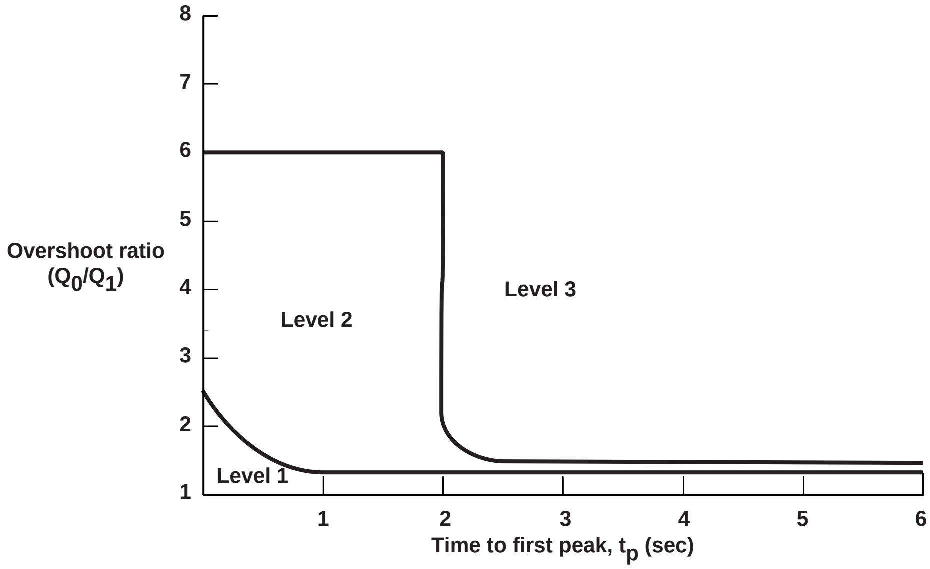
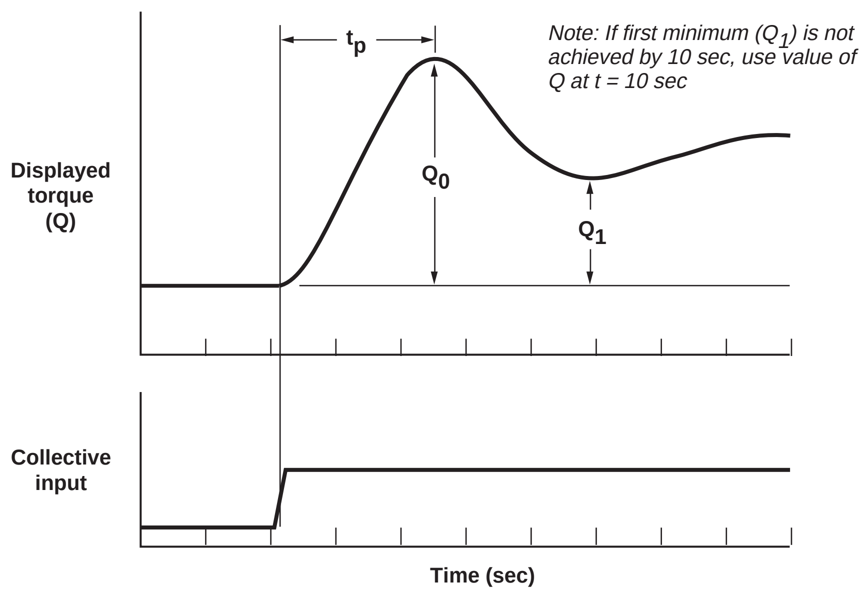


Figure 13. Procedure for obtaining equivalent time domain parameters for the height response to collective controller

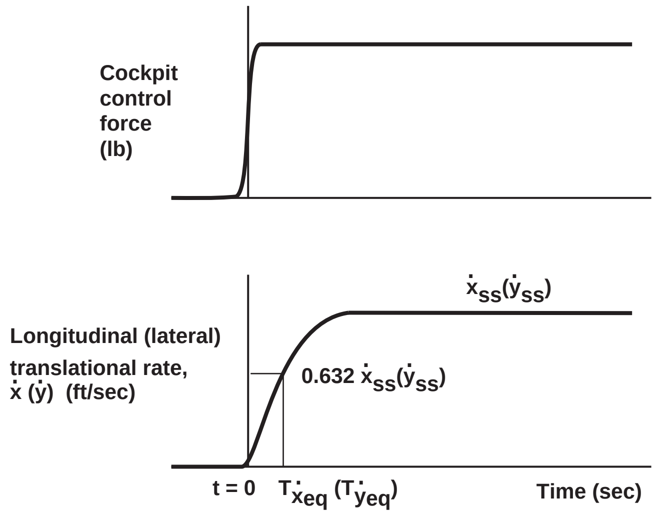


a) Requirement on dynamics of displayed torque based on step collective change

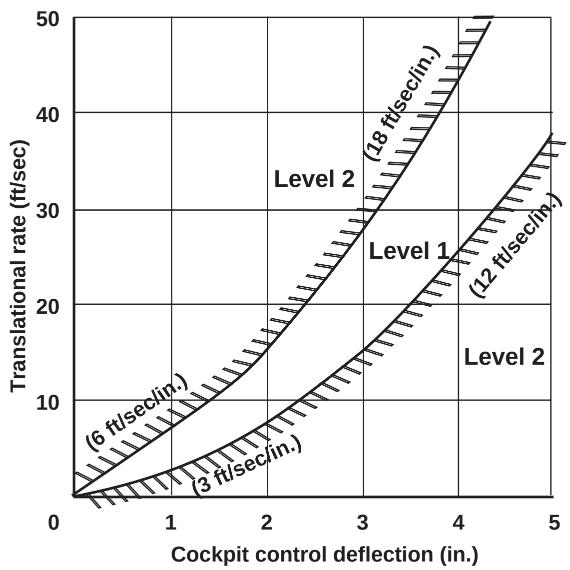


b) Definition of Q_0/Q_1 and t_p for displayed torque requirement

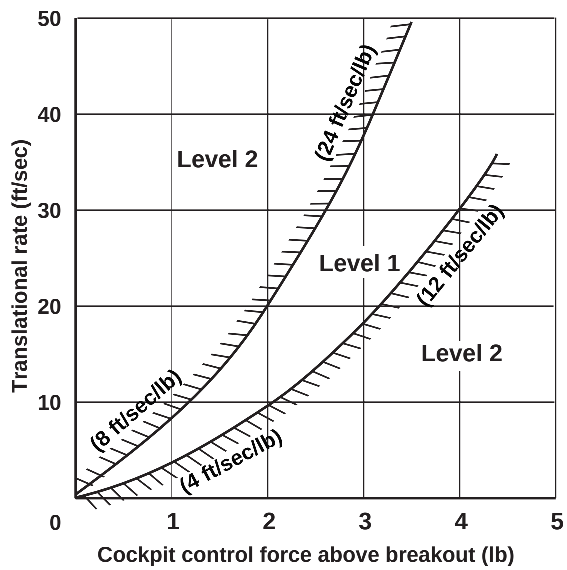
Figure 14. Displayed torque response requirement



a) Definition of equivalent rise time, $T_{\dot{x}_{eq}}$ ($T_{\dot{y}_{eq}}$)

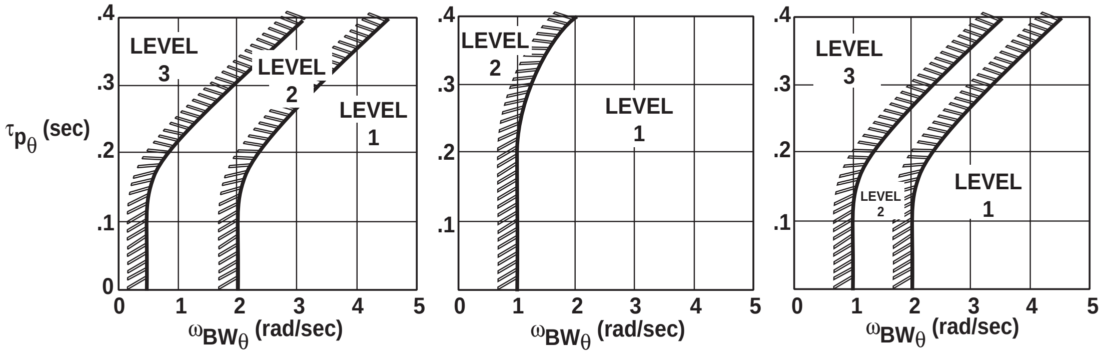


b) Control/response requirement for centerstick controllers



c) Control/response requirement for sidestick controllers

Figure 15. Requirements for longitudinal (lateral) Translational Rate Response-Types – hover and low speed

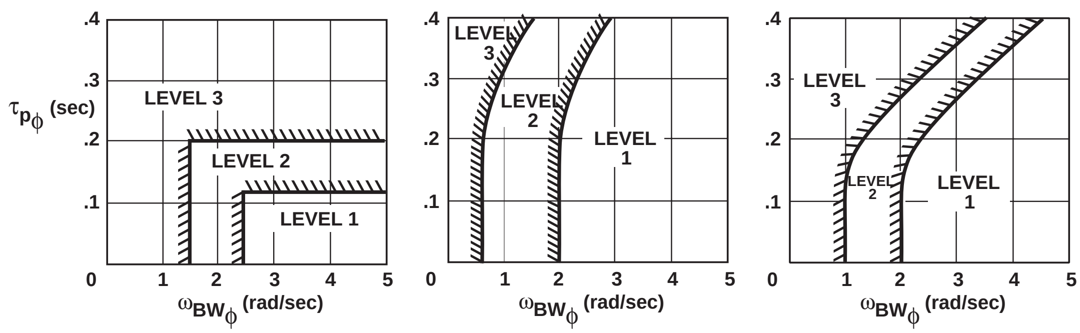


a) Target Acquisition and Tracking

b) All Other MTEs - VMC and Fully Attended Operations

c) All Other MTEs - IMC and/or Divided Attention Operations

Figure 16. Requirements for small-amplitude pitch attitude changes – forward flight

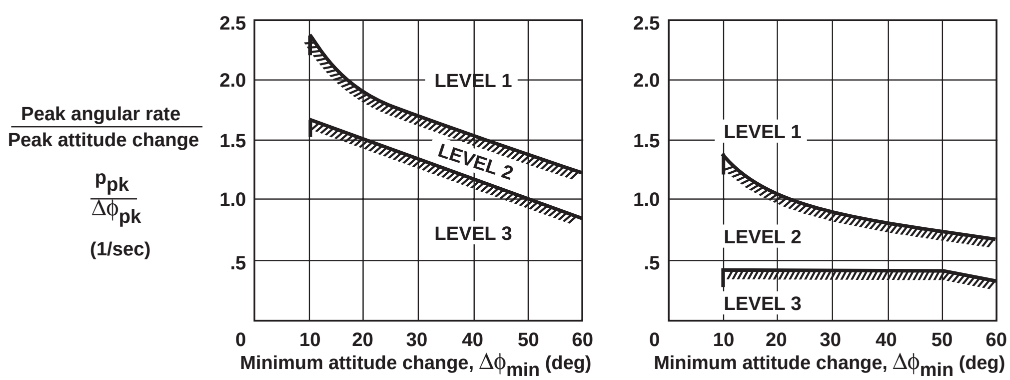


a) Target Acquisition and Tracking

b) All Other MTEs - VMC and Fully Attended Operations

c) All Other MTEs - IMC and/or Divided Attention Operations

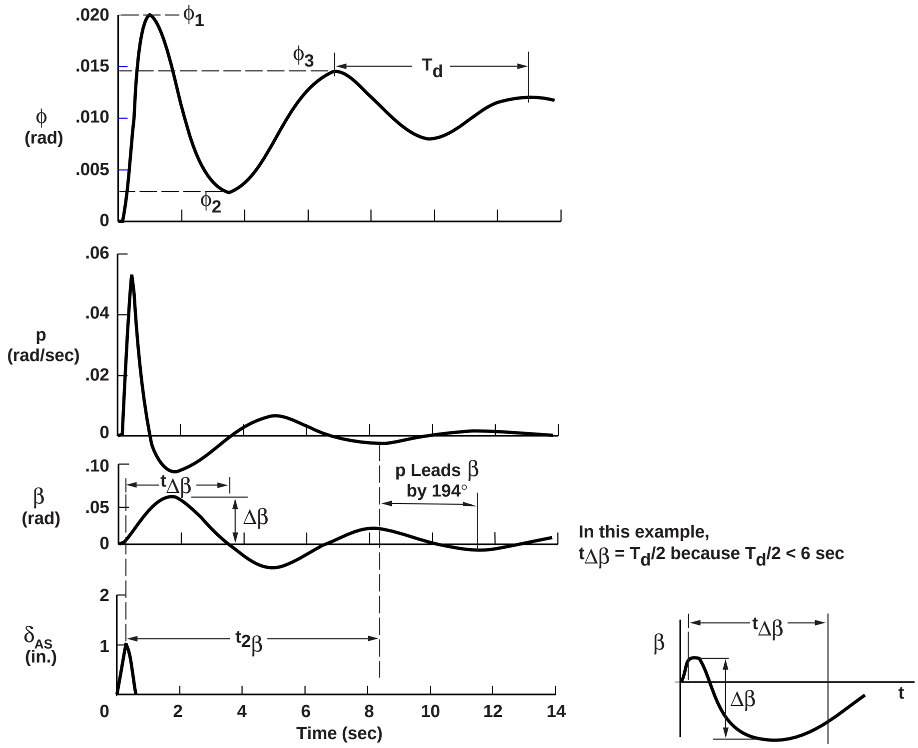
Figure 17. Requirements for small-amplitude roll attitude changes – forward flight



a) Target Acquisition and Tracking

b) All Other MTEs

Figure 18. Requirements for moderate-amplitude roll attitude changes – forward flight



Example to illustrate definition of $\Delta\beta$ in a response with sideslip reversal at $t < t_{\Delta\beta}$

$$T_d = \frac{2\pi}{\omega_n \sqrt{1-\zeta^2}}$$

ζ, ω_n from paragraph 3.4.9.1

$$\frac{\phi_{osc}}{\phi_{av}} = \frac{\phi_1 + \phi_3 - 2\phi_2}{\phi_1 + \phi_3 + 2\phi_2} \quad (\zeta \le 0.2) \qquad = \frac{\phi_1 - \phi_2}{\phi_1 + \phi_2} \quad (\zeta > 0.2)$$

ϕ, β, δ_{AS} change in roll attitude, sideslip, and lateral control position from trim.

$\Delta\beta$ the maximum change in sideslip following an abrupt roll control pulse command within time $t_{\Delta\beta}$

$t_{\Delta\beta}$ the lesser of 6 sec or $T_d/2$.

$t_{n\beta}$ time for the lateral-directional oscillations in the sideslip response to reach the n^{th} local maximum for a right command.

ψ_β phase angle expressed as a lag for a cosine representation of the lateral-directional oscillation in sideslip, where:

$$\psi_\beta = -360\, t_{n\beta} / T_d + (n - 1)\, 360 \quad \text{(degrees)}$$ with n as in $t_{n\beta}$ above

$|\phi/\beta|_d$ at any instant, the ratio of amplitudes of the bank angle and sideslip angle envelopes in the lateral-directional oscillatory mode.

Figure 19. Roll-sideslip coupling parameters

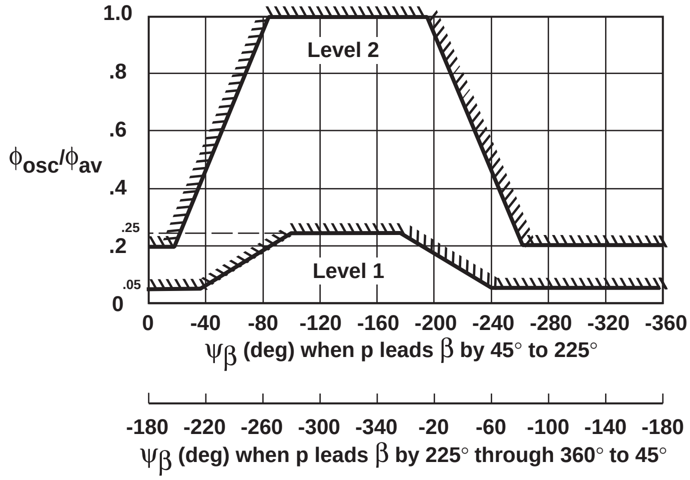


Figure 20. Bank angle oscillation limitations

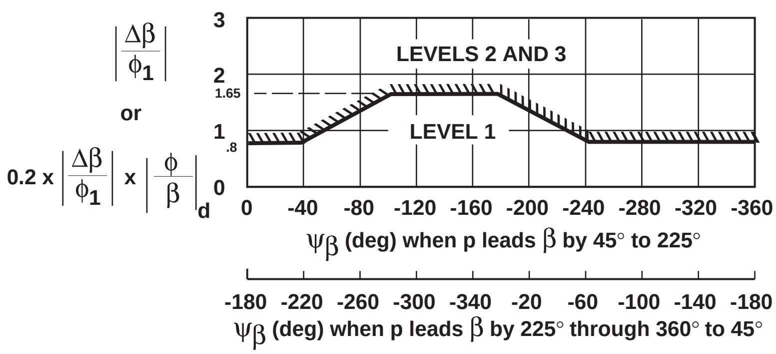


Figure 21. Sideslip excursion limitations

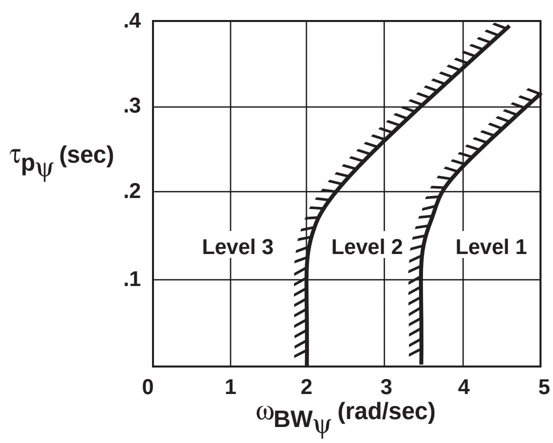


Figure 22. Requirement for small-amplitude yaw response for Target Acquisition and Tracking – forward flight

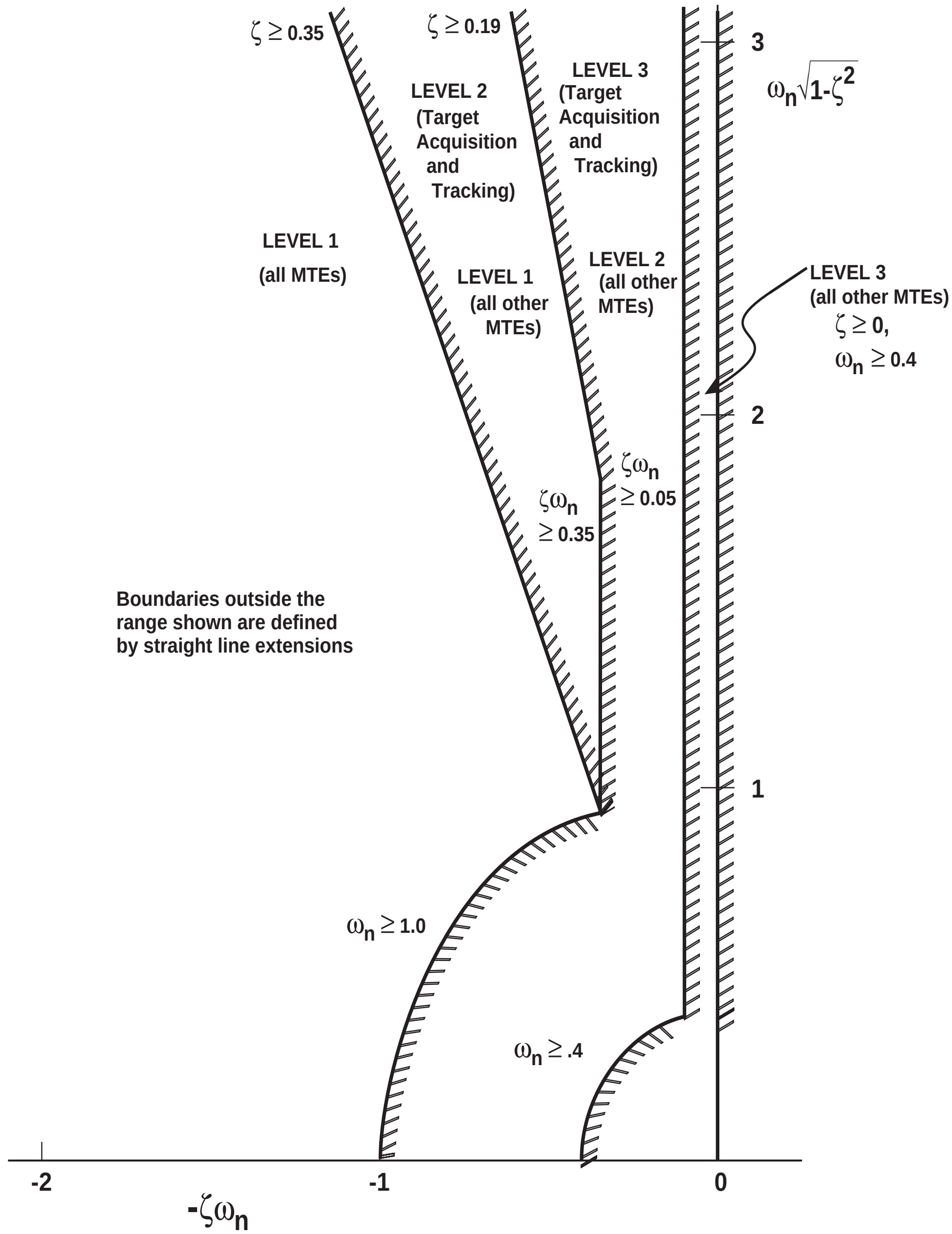


Figure 23. Lateral-directional oscillatory requirements

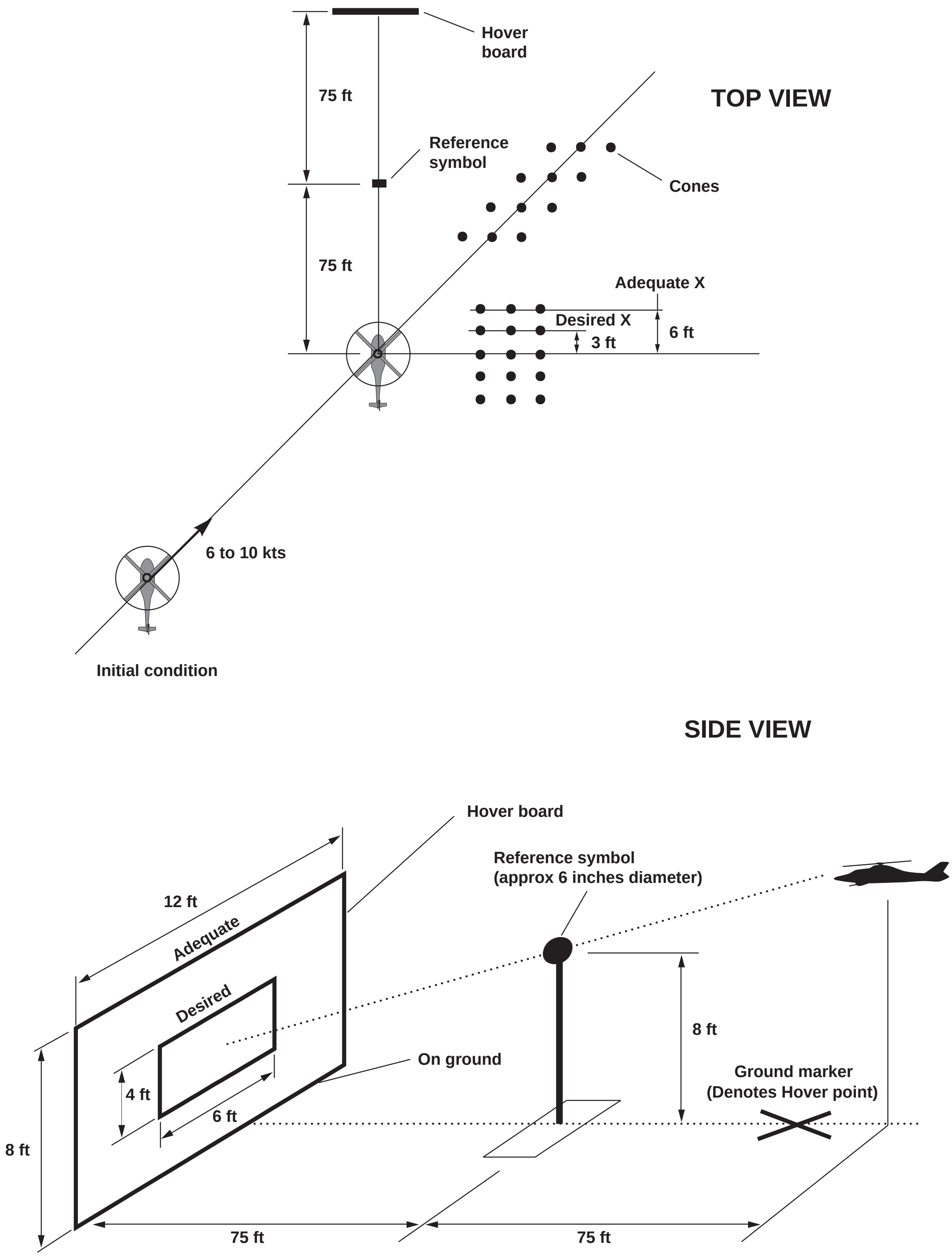


Figure 24. Suggested course for hover maneuver

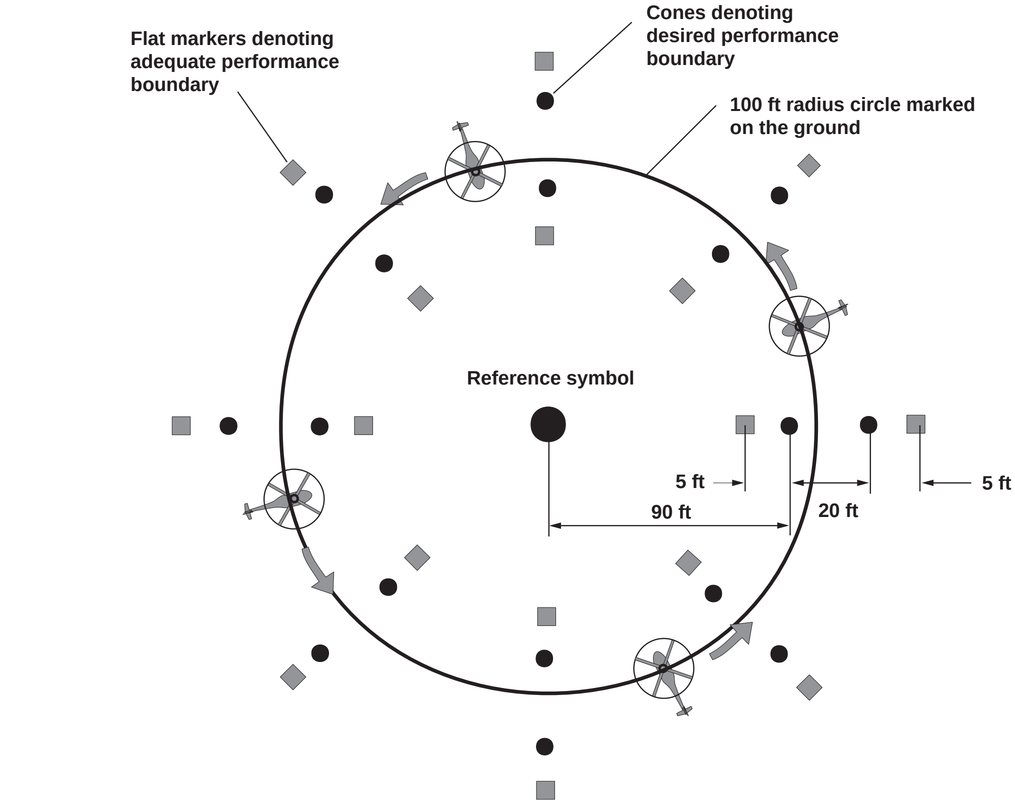


Figure 25. Suggested course for pirouette maneuver

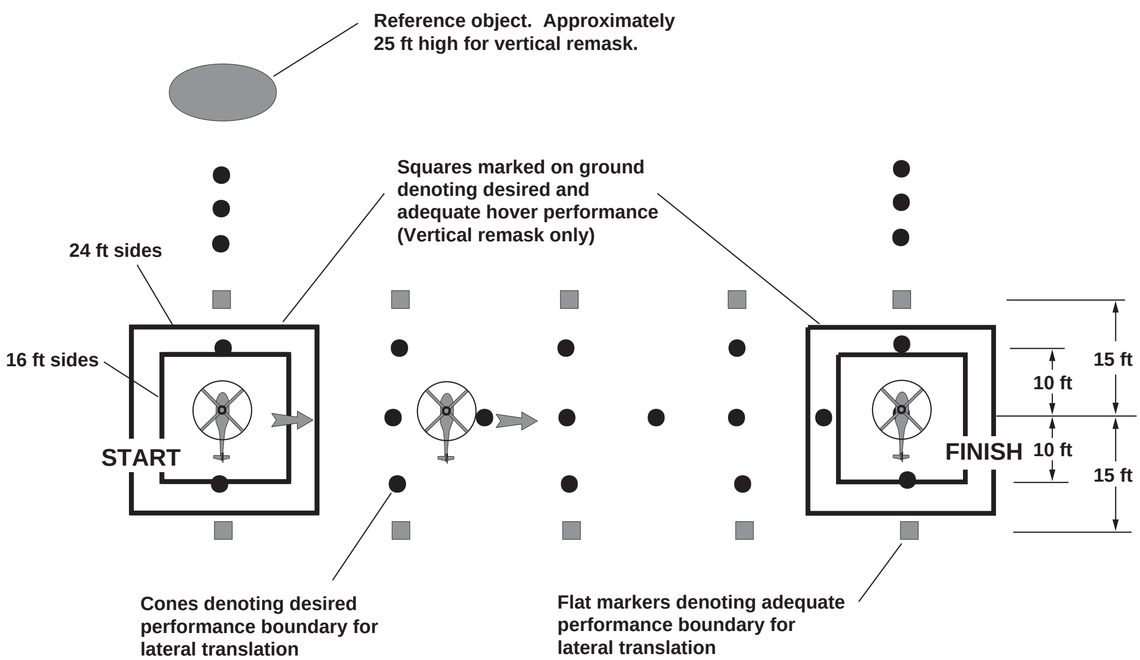


Figure 26. Suggested course for sidestep and vertical remask maneuvers

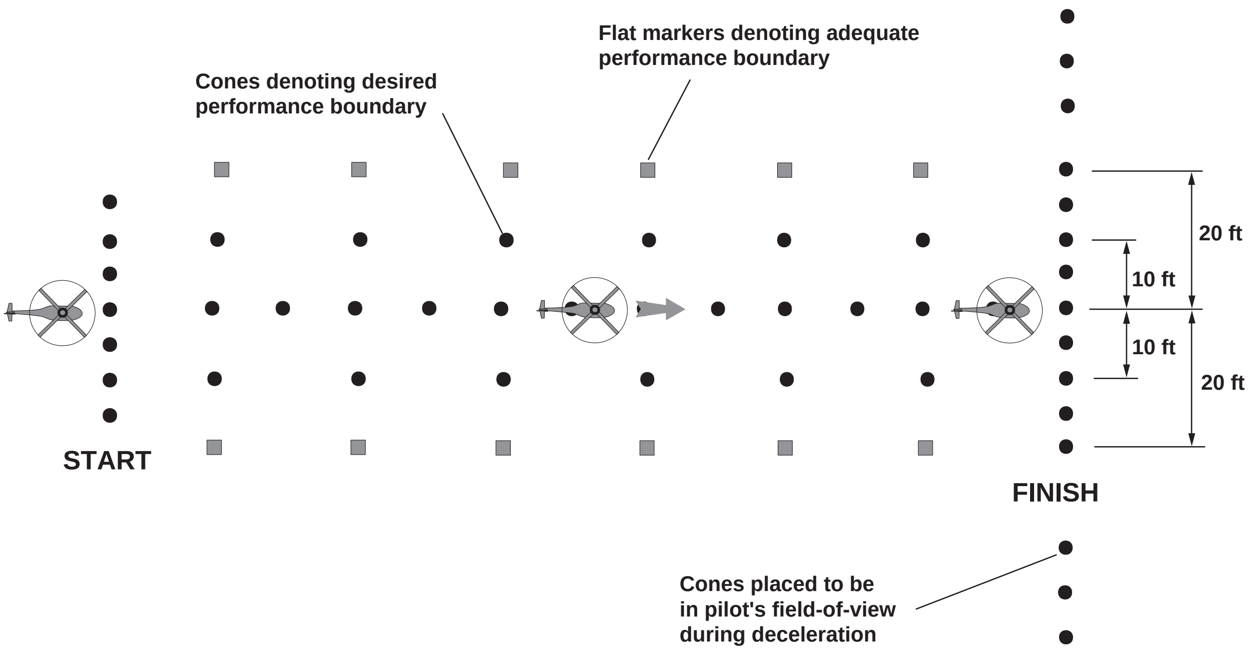


Figure 27. Suggested course for acceleration-deceleration maneuver

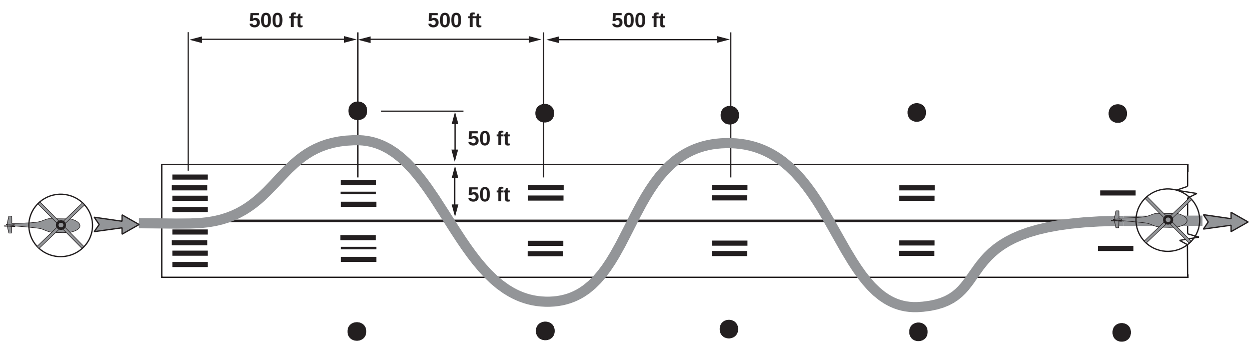


Figure 28. Suggested course for slalom maneuver