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**INCH-POUNDS**

**ADS-33E-PRF**

SUPERSEDING

ADS-33D-PRF

10 MAY 1996

**PERFORMANCE SPECIFICATION**

**HANDLING QUALITIES REQUIREMENTS**

**FOR MILITARY ROTORCRAFT**

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# **1. SCOPE**

## **1.1 Scope**

This specification contains the requirements for the flying and ground handling qualities of rotorcraft.

## **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 procuring activity. Additional or alternate special requirements may be specified by the procuring activity. For example, if the form of a requirement should not fit a particular vehicle configuration or control mechanization, the procuring activity may, at its discretion, agree to a modified requirement that will maintain an equivalent degree of acceptability.

## **2. APPLICABLE DOCUMENTS**

### **2.1 Government documents**

NA

### **2.2 Specifications, standards, and handbooks**

NA

### **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**

The procuring activity 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 procuring activity 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 steady wind and azimuth for rotor start and stop and for ground taxi.

The sea state for ship operations.

Applicability of ditching requirements.

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

The degree of divided attention operation.

#### **3.1.4 Multi-crew rotorcraft**

Unless otherwise stated, all requirements shall apply for the primary pilot station. The procuring activity 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**

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. The quantitative criteria in this specification 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 limits for all flying qualities parameters which taken together will ensure good handling qualities for all mission tasks. Thus the Predicted Levels of handling qualities could be in error. Similarly, the flight test maneuvers are not

sufficiently comprehensive to represent all mission maneuvers in all environments that a particular aircraft may be called upon to perform, nor is it practical to perform the designated maneuvers throughout the OFE for all loadings. Thus the Assigned Levels are not complete. Comparisons with both the quantitative criteria and the flight test maneuvers are necessary to maximize the likelihood of an accurate assessment of the Level of handling qualities. If there are conflicts between the Predicted and Assigned Levels, the quantitative criteria and the MTE results should 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.

#### **3.1.5.1 Predicted Levels of handling qualities**

Predicted Levels are obtained from comparisons with quantitative boundaries of flying qualities parameters. When establishing compliance, the rotorcraft's flying qualities parameters shall be determined and compared with the boundaries appropriate to the rotorcraft's operational requirements. A Level 1 rotorcraft must 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. The quantitative criteria are based on previous experiments and analyses, and hence result in predicted Levels of handling qualities.

#### **3.1.5.2 Assigned Levels of handling qualities**

Assigned Levels are obtained from test pilots performing the designated MTEs. A team of at least three pilots shall assign HQRs to the aircraft for each MTE. The average HQR determines the Level for each MTE and a Level 1 rotorcraft must be rated Level 1 for all of the MTEs designated as appropriate to the aircraft's operational requirements

### **3.1.6 Flight envelopes**

The Flight Envelopes shall be defined by the contractor.

#### **3.1.6.1 Operational Flight Envelopes (OFE)**

The Operational Flight Envelopes 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 procuring activity, as necessary to accomplish the operational missions. Any warnings or indications of limiting or dangerous flight conditions, required by 3.1.15.1, shall occur outside the OFEs.

#### **3.1.6.2 Service Flight Envelopes (SFE)**

The Service Flight Envelopes are 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 contractor shall define the configurations required for performance of the operational missions of 3.1.1.

### **3.1.8 Loadings**

The contractor shall determine the possible Loadings for the Configurations defined in 1.1.6.

### **3.1.9 Flight conditions**

The contractor shall define flight conditions where significant handling qualities effects or changes occur.

### **3.1.10 Settings**

The contractor shall define the Settings that are available to the pilot.

### **3.1.11 States**

The contractor shall determine the Settings and Failure States that correspond to failure probabilities allowed by Table II.

### **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.

### **3.1.13 Levels for Normal States**

The required Levels of flying qualities in the Operational and Service Flight Envelopes are specified in Table II.

#### **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 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 are to 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. The contractor shall:

- 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 III.

#### **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. The contractor and procuring agency shall mutually agree on which Failure States shall be treated as “Specific Failures.” The allowable Level of flying qualities for each Specific Failure will be specified by the procuring activity. Alternatively, the procuring activity 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 approved by the procuring activity.

#### **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. The contractor shall conduct tests to define the transients for comparison with the values in Table IV and the results shall be made available to the procuring activity. For rotorcraft without failure warning and cueing devices, the perturbations encountered shall not exceed the limits of Table IV.

#### **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. When approaching such limits, it shall be possible by clearly discernible means for the pilot to recognize the situation and take preventive action.

#### **3.1.15.1 Warning and indication of rotorcraft limits**

Warning and indication of approach to a rotorcraft limit shall be clear and unambiguous so that the pilot can avoid dangerous conditions. In Near-Earth Operations, the pilot shall be able to interpret warnings and avoid limiting and potentially dangerous conditions with eyes out of the cockpit.

#### **3.1.15.2 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**

There shall be 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. The distinction between residual motions and vibration shall be based on mutual agreement between the manufacturer and procuring activity.

## 3.2 Response-Types

The required Response-Types are specified as a function of the Mission-Task-Elements, and the Usable Cue Environments resulting from mission visual environments, including available vision aids and displays. These specified Response-Types are intended to be minimums, and an upgrade may be provided if superior or equivalent flying qualities can be demonstrated. If such an upgrade is selected, the detailed requirements in 3.3 and 3.4 pertaining to the upgraded Response-Type apply.

### 3.2.1 Determination of the Usable Cue Environment

The displays and vision aids provided to the pilot shall be assessed to determine their effectiveness for stabilization and control. 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 3.1.1. The Usable Cue Environment (UCE) is defined in Figure 3 using the visual cue ratings (VCRs) obtained from the Figure 2 scale during the flight assessments specified below. The VCRs shall be made by at least three pilots and the UCE shall be obtained by using the following procedure. 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 V to determine the required Response-Type.

#### 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 Limited and Moderate agility MTEs of 3.11, 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, 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

If the standard deviation of the individual visual cue ratings among the pilots is greater than 0.75, either additional pilots shall be employed, or the procuring activity shall assign a level of UCE.

### 3.2.2 Required Response-Types

The required Response-Types are specified for each axis of control for hover and low speed (Table V) and forward flight (Table VI). These specified 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 detailed 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 must meet the definition of a Vertical Rate Response-Type (3.2.10).

#### 3.2.2.2 Additional requirement for Turn Coordination

Turn Coordination (TC) 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 is 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 UCE

Table V and Table VI allow a reduction in Response-Type for Level 2 for some selected cases. If the dynamics of the particular Response-Type are Level 2 or 3 based on one or more of the requirements of 3.3, the combination of degraded Response-Type, dynamics, and UCE may result in flying qualities Levels that are worse than for any single degradation alone. Table VII defines the Levels corresponding to these combinations.

### 3.2.5 Rotorcraft guidance

For near-earth operations at night and in poor weather, 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 must 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 is 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. It shall be possible 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 able 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. It is required that these Response-Types meet their stated objectives (e.g., Airspeed Hold systems must hold airspeed) and the requirements of this specification, and shall not result in excessive excursions in rotorcraft attitudes.

### **3.2.13 Requirements for inputs to control actuator**

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) are waived for Levels 2 and 3. This is to allow the use of control input shaping to achieve the necessary command-response relationship for backup flight control systems.

### **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 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 ( $\omega_{BW}$ ) and phase delay ( $\tau_p$ ) parameters are obtained from frequency responses as defined in Figure 6. It is desirable to meet this criterion for both controller force and position inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing should 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 in aggressive maneuvers should 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 is 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 apply at all frequencies below the bandwidth frequency obtained in 3.3.2.1. Use of an Attitude Hold Response-Type constitutes 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 depends 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 VIII. 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.

### 3.3.5 Small-amplitude yaw attitude changes

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

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

#### 3.3.5.2 Mid-term response

The mid-term response characteristics apply at all frequencies below the bandwidth frequency obtained in 3.3.5.1. Use of a Heading Hold Response-Type constitutes 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 depends on the degree of pilot attention according to 3.1.3.

##### 3.3.5.2.1 Fully attended operation

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 operation

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 yaw rate response following a step lateral gust input,  $r_{pk}/V_g$ , shall not exceed the limits of Table IX.

The parameter  $r_{pk}$  is defined as the peak yaw rate within the first three seconds following the input.

Demonstration of compliance may be shown by analysis or simulation. The magnitude of the lateral gust input shall be varied 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.

### 3.3.8 Large-amplitude heading changes

The achievable yaw rate in hover shall be at least the values specified in Table VIII. The specified angular rates must 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.

### 3.3.9 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. In all cases pitch and roll excursions shall be limited by use of the pitch and roll controllers. 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 pitch due to roll (q/p) and roll due to pitch (p/q) coupling for Aggressive agility 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 ( $q/\delta_{lat}$ ) divided by roll-due-to-roll control input ( $p/\delta_{lat}$ ) averaged between the bandwidth (phase = -135 deg) and neutral-stability (phase = -180 deg) frequencies of the pitch-due-to-pitch control inputs ( $\theta/\delta_{lon}$ ). Similarly, average p/q is defined as the magnitude ( $p/\delta_{lon}$ ) divided by ( $q/\delta_{lon}$ ) between the roll-axis ( $\phi/\delta_{lat}$ ) 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 should 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 delay parameters defined by the following equivalent first-order vertical-rate-to-collective transfer function are given in Table X.

$$\frac{\dot{h}}{\delta_c} = \frac{K e^{-\tau_{heq} \cdot s}}{T_{heq} \cdot s + 1}$$

The equivalent system parameters are to 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  $\dot{h} \left( \dot{h}_{est} \right)$

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

where  $t$  is time (sec) and  $K$ ,  $1/T_{heq}$  and  $\tau_{heq}$  are the variables. (Note:  $\tau_{heq}$  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  $i$ th observed data point.

The goodness of fit of the estimated curve is 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, it shall be possible to produce the vertical rates specified in Table XI, 1.5 seconds after initiation of a rapid displacement of the collective control from trim. 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

When Position Hold is required, the rotorcraft shall be capable of automatically holding 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  $\pm 18$  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,  $T_{x_{eq}} (T_{y_{eq}})$ , no less than 2.5 seconds and no greater than 5 seconds. The

parameter  $T_{x_{eq}} (T_{y_{eq}})$  is defined in Figure 15a. For Level 1, the following requirements 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 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 inputs shall meet the limits specified in Figure 16. The bandwidth ( $\omega_{BW\theta}$ ) and phase delay ( $\tau_{p\theta}$ ) parameters are obtained from frequency responses as defined in Figure 6. It is desirable to meet this criterion for both controller force and position inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing should 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 in aggressive maneuvers should be performed to determine acceptability.

#### **3.4.1.2 Mid-term response to control inputs**

The mid-term response characteristics apply at all frequencies below the bandwidth frequency obtained in 3.4.1.1. Use of an Attitude Hold Response-Type constitutes 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 depends on the degree of pilot attention according to 3.1.3.

##### 3.4.1.2.1 Fully attended operation

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

##### 3.4.1.2.2 Divided attention operation

The limits of Figure 7 shall be met, except that the Level 1 damping 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 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 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 pilot's cockpit controller shall not lead the control force at any frequency below 5 rad/sec. For Level 1 the following requirements apply:

- a. For centerstick controllers, the local force gradient,  $F_s/n$ , 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  $F_s$  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, it shall be possible from trimmed, unaccelerated flight to 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 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 is 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 is 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 are given in Table XII. The equivalent system parameters are to be obtained using the time domain fitting method defined in Figure 13. The coefficient of determination,  $r^2$ , shall be greater than 0.97 and less than 1.03 for compliance with this requirement.

$$\frac{\dot{h}}{\delta_c} = \frac{K e^{-\tau_{heq} s}}{T_{heq} s + 1}$$

### 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<sup>2</sup>, 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

$\left| \Delta\theta_{\text{peak}} / \Delta n_{z_{\text{peak}}} \right|$  is no greater than 0.5 deg/ft/sec<sup>2</sup> in the up direction and 0.25 deg/ft/sec<sup>2</sup> 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,

a. It shall not require more than 15 percent of full (stop-to-stop) cockpit pitch controller travel or force to hold pitch attitude constant.

b. There shall be at least 5 percent of the total (stop-to-stop) pitch controller effectiveness remaining throughout the maneuver.

#### 3.4.5.2 Pitch due to roll and roll due to pitch coupling for Aggressive agility

The pitch due to roll (q/p) and roll due to pitch (p/q) coupling for Aggressive agility 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 ( $q/\delta_{\text{lat}}$ ) divided by roll-due-to-roll control input ( $p/\delta_{\text{lat}}$ ) averaged between the bandwidth (phase = -135 deg) and neutral-stability (phase = -180 deg) frequencies of the pitch-due-to-pitch control inputs ( $\theta/\delta_{\text{lon}}$ ). Similarly, average p/q is defined as the magnitude ( $p/\delta_{\text{lon}}$ ) divided by ( $q/\delta_{\text{lon}}$ ) between the roll-axis ( $\phi/\delta_{\text{lat}}$ ) 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 should 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 inputs shall meet the limits specified in Figure 17. The bandwidth ( $\omega_{\text{BW}_\phi}$ ) and phase delay ( $\tau_{p_\phi}$ ) parameters are obtained from frequency responses as defined in Figure 6. It is desirable to meet the requirement for both controller force and position inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing should 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 in aggressive maneuvers should be performed to determine acceptability.

Any oscillatory modes following a pulse controller input shall meet the requirements of Figure 23.

#### 3.4.6.2 Moderate amplitude attitude changes (attitude quickness)

The ratio of peak roll rate to change in bank angle,  $p_{\text{pk}}/\Delta\phi_{\text{pk}}$ , 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 XIII. 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 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 used are defined in Figure 19.

##### 3.4.7.1 Bank angle oscillations

The value of the parameter  $\phi_{OSC}/\phi_{AV}$  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,  $\phi_{AV}$  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 ( $\omega_{BW_\psi}$ ) and phase delay ( $\tau_{p_\psi}$ ) parameters are obtained from frequency responses as defined in Figure 6. It is desirable to meet this criterion for both controller force and position inputs. If the bandwidth for force inputs falls outside the specified limits, flight testing should 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  $\beta_L$
- Level 2: the lesser of 8 degrees or  $1/2 \beta_L$
- Level 3: the lesser of 4 degrees or  $1/4 \beta_L$

where  $\beta_L$  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, it shall be possible 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 XVII. 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,  $\omega_n$ , and damping ratio,  $\zeta$ , of the lateral-directional oscillations following a yaw control doublet, shall meet the minimums specified on Figure 23. 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 are expressed in terms of characteristics in 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 apply. Between sideslip angles of  $\pm 15$  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, left lateral control deflection and force shall be required in left sideslips and right control deflection and force shall be required in right sideslips. For Levels 1 and 2, the variation of lateral control deflection and force with sideslip angle shall be essentially linear.

##### 3.4.10.3.1 Positive effective dihedral limit

For Level 1, positive effective dihedral (right roll control for right sideslip and left roll control for left sideslip) shall never be so great that more than 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 is required. This requirement shall be met for Level 1, and relaxed according to 3.2.13 for Levels 2 and 3.

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

NA

## **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 requirements for breakout force are given in Table XIV and Table XV. Table XIV applies for hover and low speed whereas the values in Table XV apply 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 XVI 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 should preferably have zero force gradient unless an autothrottle function 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 XVII.

### **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. Compliance with this requirement shall be in actual flight, and shall include at least the MTEs required by 3.1.1, and transitions between cruise and hover.

### **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 be compatible with the required Level of flying qualities.

### **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, lightly damped, high frequency oscillations that cease when the pilot releases the controller are not permitted.

## **3.7 Specific failures**

The requirements relating to specific system failures 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**

The transient response of the rotorcraft shall not result in an unrecoverable flight condition with the controls held fixed for 3 seconds following the engine failure. In addition, 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 jettisoning external loads.
- d. 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.

### **3.7.4 Failures of Externally Slung Loads**

## **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, it shall not be 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 to view the required annunciation.

### **3.8.2 Control forces during transfer**

With the rotorcraft initially trimmed at a fixed operating point, the peak pitch, roll, yaw, and collective control forces required to suppress the transient rotorcraft motions resulting from the transfer and maintain the desired heading, attitude, altitude, rate of climb or descent, or speed without use of the trimmer control, shall not exceed one-third of the appropriate limit control force in Table XVII. For blending, this applies 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:  $2 \text{ sec} < t_{\text{blend}} < 10 \text{ sec}$

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

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.

### **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**

If required by the procuring activity, the following characteristics shall be provided either as part of the rotorcraft design or in supplementary kit form.

#### **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**

Techniques and procedures (i.e., recommended pitch 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 in up to Sea State 6 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. A sea anchor, or similar device, shall not be used in demonstrating compliance; however, it may be used to assist in deployment of life rafts. The flotation time and trim attitude characteristics shall be investigated throughout the range of Sea States from 0 to 6 and shall be satisfactory in waves having height/length ratios typical of these Sea States.

### **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) up to Sea State 3, and if possible up to Sea State 6.

## **3.10 Requirements for externally slung loads**

### **3.10.1 Short term dynamic response to control**

#### **3.10.1.1 Pitch**

#### **3.10.1.2 Roll**

#### **3.10.1.3 Yaw**

#### **3.10.1.4 Collective**

### **3.10.2 Effective load damping**

### **3.10.3 Flight control system stability (gain and phase margins)**

*The contractor shall perform frequency response tests to show adequate gain and phase margin with AFCS ON, under the most critical loading.*

### **3.10.4 Rotor-load coupling (vertical bounce)**

### **3.10.5 Load release**

#### **3.10.5.1 Single hook**

Normal release/ Failures

#### **3.10.5.2 Multi hook**

##### **3.10.5.2.1 Single load**

Normal release/ Failures

##### **3.10.5.2.2 Multiple loads**

Normal release/ Failures

### 3.11 Flight test maneuvers

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. All NOE maneuvers shall be conducted in calm winds unless otherwise specified. 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. 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 procuring activity. 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 procuring activity. 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

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enhance the visual cues in the DVE, the changes shall be defined and submitted to the procuring activity 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 depending on the sling length. 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 is to 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 helicopter. 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
<b>DESIRED PERFORMANCE</b>						
• 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*
<b>ADEQUATE PERFORMANCE</b>						
• 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 aircraft when the pilot’s eye is at the hover point.

**d. Performance standards.**

**Performance – Landing**

	GVE	DVE
<p><b>DESIRED PERFORMANCE</b></p> <ul style="list-style-type: none"> <li>• Accomplish a gentle landing with a smooth continuous descent, with no objectionable oscillations</li> <li>• Once altitude is below 10 ft, complete the landing within X seconds</li> <li>• Touch down within <math>\pm X</math> ft longitudinally of the designated reference point</li> <li>• Touch down within <math>\pm X</math> ft laterally of the designated reference point</li> <li>• Attain a rotorcraft heading at touchdown that is aligned with the reference heading within <math>\pm X</math> deg:</li> <li>• 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.</li> </ul>	<p>✓</p> <p>10 sec</p> <p>1 ft</p> <p>0.5 ft</p> <p>5 deg</p> <p>✓</p>	<p>NA</p> <p>10 sec</p> <p>1 ft</p> <p>0.5 ft</p> <p>5 deg</p> <p>NA</p>
<p><b>ADEQUATE PERFORMANCE</b></p> <ul style="list-style-type: none"> <li>• Touch down and remain within <math>\pm X</math> ft of the designated landing point</li> <li>• Attain a rotorcraft heading at touchdown that is aligned with the reference heading within <math>\pm X</math> deg:</li> </ul>	<p>3 ft</p> <p>10 deg</p>	<p>3 ft</p> <p>10 deg</p>

**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
<b>DESIRED PERFORMANCE</b>		
• 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 $\pm X$ 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 limitations such as mast loads shall remain within the OFE	✓	✓
<b>ADEQUATE PERFORMANCE</b>		
• 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 $\pm X$ 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 limitations such as mast loads 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, perform the maneuver with a moderate wind from the most critical azimuth. If a critical azimuth 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 (0, Figure 25) with the rotorcraft located at the center of the pirouette circle. An alternate suggestion is to use the precision hover course with two extra markers placed in the 6 o'clock position relative to the aircraft. The maneuver begins with the aircraft lined up on these extra markers and the hover target and board located at the aircraft's 6 o'clock position.

**d. Performance standards.**

**Performance – Hovering Turn**

	Scout/Attack		Cargo/Utility	
	GVE	DVE	GVE	DVE
<b>DESIRED PERFORMANCE</b>				
• Maintain the longitudinal and lateral position within $\pm X$ ft of a point on the ground	3 ft	6 ft	3 ft	6 ft
• Maintain altitude within $\pm X$ ft:	3 ft	3 ft	3 ft	3 ft
• Stabilize the final rotorcraft heading at 180 deg from the initial heading within $\pm X$ 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
<b>ADEQUATE PERFORMANCE</b>				
• Maintain the longitudinal and lateral position within $\pm X$ ft of a point on the ground	6 ft	12 ft	6 ft	12 ft
• Maintain altitude within $\pm X$ ft:	6 ft	6 ft	6 ft	6 ft
• Stabilize the final rotorcraft heading at 180 deg from the initial heading within $\pm X$ 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 helicopter. 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, perform the maneuver in moderate and calm winds.

**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
<b>DESIRED PERFORMANCE</b>		
• Maintain a selected reference point on the rotorcraft within $\pm X$ ft of the circumference of the circle.	10 ft	10 ft
• Maintain altitude within $\pm X$ ft:	3 ft	4 ft
• Maintain heading so that the nose of the rotorcraft points at the center of the circle within $\pm X$ 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
<b>ADEQUATE PERFORMANCE</b>		
• Maintain a selected reference point on the rotorcraft within $\pm X$ ft of the circumference of the circle.	15 ft	15 ft
• Maintain altitude within $\pm X$ ft:	10 ft	10 ft
• Maintain heading so that the nose of the rotorcraft points at the center of the circle within $\pm X$ 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 helicopter this maneuver is to simulate a rapid unmask/remask maneuver, with an aiming task at the unmask. For a utility or cargo helicopter, 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 while referencing a second hover board and target, 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 height. The maneuver is to be completed in calm or moderate winds.

**c. Description of test course.** The test course shall consist of markings on the ground that clearly define desired and adequate performance. The suggested course shown in Figure 26 is considered adequate for the evaluation. It may also be useful to add objects to assist the pilot with longitudinal and lateral cueing, such as an extended row of cones along a 45 degree angle.

**Performance standards.**

**Performance – Vertical Maneuver**

	Scout/Attack		Cargo/Utility		Externally Slung Load	
	GVE	DVE	GVE	DVE	GVE	DVE
<b>DESIRED PERFORMANCE</b>						
• 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
<b>ADEQUATE PERFORMANCE</b>						
• 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 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 28.

**d. Performance standards.**

**Performance –Depart/Abort**

	<b>Cargo/Utility</b>		<b>Externally Slung Load</b>	
	<b>GVE</b>	<b>DVE</b>	<b>GVE</b>	<b>DVE</b>
<b>DESIRED PERFORMANCE</b>				
• 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
<b>ADEQUATE PERFORMANCE</b>				
• 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

**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 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 aircraft 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 27.

**d. Performance standards.**

**Performance – Lateral Reposition**

	Cargo/Utility		Externally Slung Load	
	GVE	DVE	GVE	DVE
<b>DESIRED PERFORMANCE</b>				
• Maintain longitudinal track within $\pm X$ ft	10 ft	10 ft	10 ft	10 ft
• Maintain altitude within $\pm X$ ft:	10 ft	10 ft	10 ft	10 ft
• Maintain heading within $\pm X$ deg:	10 deg	10 deg	10 deg	10 deg
• Time to complete maneuver:	18 sec	20 sec	25 sec	25 sec
<b>ADEQUATE PERFORMANCE</b>				
• Maintain longitudinal track within $\pm X$ ft:	20 ft	20 ft	20 ft	20 ft
• Maintain altitude within $\pm X$ ft:	15 ft	15 ft	15 ft	15 ft
• Maintain heading within $\pm X$ 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 aggressive forward flight maneuvering.
- Check for objectionable interaxis coupling during 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. 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 29. 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 29).

**d. Performance standards.**

**Performance – Slalom**

	GVE	DVE
<b>DESIRED PERFORMANCE</b> <ul style="list-style-type: none"> <li>• Maintain an airspeed of at least X knots throughout the course</li> <li>• Accomplish maneuver below reference altitude of X ft:</li> </ul>	60  Lesser of twice rotor diameter or 100 ft	30  100 ft
<b>ADEQUATE PERFORMANCE</b> <ul style="list-style-type: none"> <li>• Maintain an airspeed of at least X knots throughout the course</li> <li>• Accomplish maneuver below reference altitude of X ft:</li> </ul>	40  100 ft	15  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 27.

**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 $\pm X$ ft of a reference point on the ground.	8 ft	12 ft
• Maintain altitude after remask and during displacement within X ft:	$\pm 10$ ft	+10 and -15 ft
• Maintain lateral ground track within $\pm X$ ft:	10 ft	15 ft
• Maintain heading within $\pm X$ 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 highly aggressive maneuvering, i.e., near the 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 28.

**d. Performance standards.**

**Performance – Acceleration-Deceleration**

	GVE	DVE
<b>DESIRED PERFORMANCE</b>		
<ul style="list-style-type: none"> <li>• 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.</li> </ul>	1.5 sec	NA
<ul style="list-style-type: none"> <li>• Achieve a nose-down pitch attitude during the acceleration of at least X deg below the hover attitude:</li> </ul>	NA	12 deg
<ul style="list-style-type: none"> <li>• Maintain altitude below X ft:</li> </ul>	50 ft	50 ft
<ul style="list-style-type: none"> <li>• Maintain lateral track within <math>\pm X</math> ft:</li> </ul>	10 ft	10 ft
<ul style="list-style-type: none"> <li>• Maintain heading within <math>\pm X</math> deg:</li> </ul>	10 deg	10 deg
<ul style="list-style-type: none"> <li>• Decrease power to less than 5% within X seconds to initiate deceleration.</li> </ul>	3 sec	NA
<ul style="list-style-type: none"> <li>• Significant increases in power are not allowed until just before the final stabilized hover.</li> </ul>	✓	✓
<ul style="list-style-type: none"> <li>• 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.</li> </ul>	30 deg	15 deg
<ul style="list-style-type: none"> <li>• Longitudinal tolerance on the final hover point is plus zero, minus a distance equal to X % of the overall helicopter length.</li> </ul>	50 %	50 %
<ul style="list-style-type: none"> <li>• Rotor RPM shall remain within the limits of X without undue pilot compensation</li> </ul>	OFE	OFE
<b>ADEQUATE PERFORMANCE</b>		
<ul style="list-style-type: none"> <li>• 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.</li> </ul>	3 sec	NA
<ul style="list-style-type: none"> <li>• Achieve a nose-down pitch attitude during the acceleration of at least X deg below the hover attitude.</li> </ul>	NA	7 deg
<ul style="list-style-type: none"> <li>• Maintain altitude below X ft:</li> </ul>	70 ft	70 ft
<ul style="list-style-type: none"> <li>• Maintain lateral track within <math>\pm X</math> ft:</li> </ul>	20 ft	20 ft
<ul style="list-style-type: none"> <li>• Maintain heading within <math>\pm X</math> ft:</li> </ul>	20 deg	20 deg
<ul style="list-style-type: none"> <li>• Decrease power to less than 30% of maximum within X seconds to initiate deceleration.</li> </ul>	5 sec	NA
<ul style="list-style-type: none"> <li>• Significant increases in power are not allowed until just before the final stabilized hover.</li> </ul>	✓	✓
<ul style="list-style-type: none"> <li>• Achieve a nose-up pitch attitude during the deceleration of at least X deg above the hover attitude.</li> </ul>	10 deg	10 deg
<ul style="list-style-type: none"> <li>• Longitudinal tolerance on the final hover point is minus a distance equal to X % of the overall helicopter length.</li> </ul>	100 %	100 %
<ul style="list-style-type: none"> <li>• Rotor RPM shall remain within the limits of the:</li> </ul>	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. The maneuver may be performed in calm winds, or in a headwind of less than 10 knots.

**c. Description of test course.** The test course consists of any reference line on the ground that is readily visible to the pilot. This may consist of a solid line or series of markers, such as Figure 27, or any other method deemed acceptable by the testing activity.

#### d. Performance standards.

#### Performance - Sidestep

	GVE	DVE
<b>DESIRED PERFORMANCE</b>		
• 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 $\pm X$ ft of the ground reference line:	10 ft	10 ft
• Maintain altitude within $\pm X$ ft at a selected altitude below 30 ft:	10 ft	10 ft
• Maintain heading within $\pm X$ deg:	10 deg	10 deg
• Achieve a stabilized hover within X seconds after reaching the hover point:	5 sec	10 sec
<b>ADEQUATE PERFORMANCE</b>		
• 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 $\pm X$ ft of the ground reference line:	15 ft	15 ft
• Maintain altitude within $\pm X$ ft at a selected altitude below 30 ft:	15 ft	15 ft
• Maintain heading within $\pm X$ 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 highly 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  $V_H$  or 120 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)	Less than 10%
	3 sec	5 sec
• Achieve either X% of maximum continuous power (or X% of the transient limit) within Y sec of initiating the acceleration.	95%	80%
	2 sec	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 $\pm X$ deg:	5 deg	10 deg
• Maintain altitude below X ft:	200 ft	200 ft
• Maintain altitude within $\pm X$ 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 highly aggressive maneuvering in all axes.
- Check for undesirable coupling between pitch, roll, and yaw during highly 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 $\pm X$ 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 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 incremental load factor within X % of the target normal acceleration:	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, in a moderate wind from the most critical azimuth. If a critical azimuth has not been defined, the turn shall be completed with the wind blowing directly from the rear of the rotorcraft. 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 $\pm X$ ft of a reference point on the ground.	6 ft	12 ft
• Maintain altitude within $\pm X$ 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 $\pm X$ 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 aircraft. 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 aircraft. The maneuver is initiated from level unaccelerated flight, with both aircraft at an airspeed equal to  $(V_H - 20 \text{ knots})$  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
<ul style="list-style-type: none"> <li>• Interaxis coupling shall not be:</li> <li>• Maintain the missile launch constraints for X sec:</li> <li>• Acquire the target with no tendency for pitch overshoots</li> <li>• 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.</li> <li>• Maintain power within <math>\pm 10\%</math> of maximum continuous. If +10% exceeds a limit, do not exceed that limit.</li> </ul>	Undesirable	Objectionable
	7 sec	4 sec
	✓	✓
	✓	NA
	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 $\pm X$ ft:	12.5 ft	25 ft
• Maintain localizer within $\pm X$ ft:	50 ft	75 ft
• Maintain airspeed within $\pm X$ 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 aircraft 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 $\pm X$ knots:	5 knots	10 knots
• Prior to glideslope intercept, maintain altitude within $\pm X$ 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 $\pm X$ ft:	100 ft	200 ft
• Maintain target airspeeds within $\pm X$ 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 $\pm X$ ft:	100 ft	200 ft
• Trim hands-off at target airspeed within $\pm X$ knots:	3 knots	5 knots
• Change from one trim airspeed to another within X minutes:	1 minute	2 minutes
• Maintain heading within $\pm X$ deg:	5 deg	10 deg

## 4. VERIFICATION

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 procuring activity, Table XVIII and Table XIX shall be observed. Table XVIII indicates the appropriate milestones for analysis, simulation and flight test. Table XIX indicates the range of Rotorcraft Status and Flight Conditions from which specific combinations must be selected to demonstrate compliance with this specification. Guidance regarding the complexity and scope of these demonstrations follows.

**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 helicopter.

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.

**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 procuring activity. The simulation shall include a validated representation of all controls and displays that will be available to the pilot for control of the helicopter. Rotorcraft Status to be tested will 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 will 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 should be repeated in the piloted simulator environment. Any discrepancies between the piloted simulator results and the off-line math model results should 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 aircraft 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 should 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-of-the-window visual scene response should not cause a change from the aircraft'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.

**c. 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 will develop a test plan to adequately demonstrate the full-mission capability and define limiting conditions. The test plan will be subject to approval by the procuring activity.

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 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 configuration corresponding to  $Pf > 10^{-5}$ ).

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.

## **5. PACKAGING**

## 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 specification establishes the performance requirements for flying and ground handling qualities of military rotorcraft.

### 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 procuring activity, 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
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
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 <sub>H</sub>	- 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 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.

### **6.2.8 Mission-Task-Element (MTE)**

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

### **6.2.9 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.

### **6.2.10 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.

### **6.2.11 Rotorcraft Status**

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

### **6.2.12 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.

### **6.2.13 Speed ranges**

#### **6.2.13.1 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.

#### **6.2.13.2 Hover**

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

#### **6.2.13.3 Low speed**

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

#### **6.2.13.4 Forward flight**

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

### **6.2.14 Stabilized hover**

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

### **6.2.15 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.

### **6.2.16 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.

### **6.2.17 Winds**

#### **6.2.17.1 Calm winds**

Winds with a steady component of less than 5 knots.

#### **6.2.17.2 Light Winds**

Winds with a steady component of between 10 and 15 knots

#### **6.2.17.3 Moderate winds**

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

### **6.3 Changes from Previous Issues**

This document has been rearranged to comply with the structure defined in the “spec-on-specs,” 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: 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; 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).

The following paragraphs briefly review the specific changes that involve more than minor editorial clarifications.

#### **6.3.1 Operational Missions (3.1.1)**

This paragraph requires the procuring activity 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 by the user and procuring activity for a specific application are collected in this paragraph, plus 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 form the basis for tailoring this generic specification for use in a specific procurement.

#### **6.3.4 Levels of Handling Qualities (3.1.5)**

No change 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 rotorcraft 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 Rotorcraft failures (3.1.14.1)**

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

#### **6.3.7 Required response types (3.2.2)**

The table has been modified to explicitly relate the MTE to response type. Reference to generic mission tasks that are not MTEs has been deleted.

#### **6.3.8 Character of Attitude Hold and Heading Hold response-types (3.2.7)**

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

#### **6.3.9 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.

#### **6.3.10 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.

#### **6.3.11 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.

#### **6.3.12 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 agility levels. This excludes the Limited and Moderate agility levels and is consistent with the research simulations on which the criteria were based.

### **6.3.13 Pitch due to roll and roll due to pitch coupling for Aggressive agility (3.3.9.2)**

The requirement has been changed to eliminate the time domain criteria and replace them with the frequency response criteria developed as described in Ref. 1. Ref. 2 found these criteria to be more discriminating and provided consistent results for hover and forward flight.

### **6.3.14 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.

### **6.3.15 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.

### **6.3.16 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.”

### **6.3.17 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.

### **6.3.18 Pitch control power (3.4.2)**

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

### **6.3.19 Flight path control (3.4.3)**

This is a new form of requirement for flight path control. The original requirement in ADS-33C was identical to the hover and low speed requirement. This was found to be unrealistic since pitch attitude has a large effect on flight path at high speeds. As a result, for ADS-33D-PRF, the requirement was modified to a strictly qualitative statement that flight path response to collective or longitudinal cyclic shall not be objectionable.

### **6.3.20 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.

### **6.3.21 Pitch due to roll and roll due to pitch coupling for Aggressive agility (3.4.5.2)**

The reference to specific MTEs and operational mission tasks has been deleted from the text.

The requirement has been changed to eliminate the time domain criteria and replace them with the frequency response criteria developed as described in Ref. 1. Ref. 2 found these criteria to be more discriminating and provided consistent results for hover and forward flight.

### **6.3.22 Turn coordination (3.4.7.2)**

There is no change to the requirement, but figure 7(3.4) 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.

### **6.3.23 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.

### **6.3.24 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.

### **6.3.25 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.

### **6.3.26 Trimming characteristics (3.6.6)**

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

### **6.3.27 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.”

### **6.3.28 Flight test maneuvers (3.11)**

The preamble to this section has been modified slightly to introduce the new arrangement for defining the MTEs. Also, any 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.

### **6.3.29 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 helicopters, and to remove the possible hazard of such a structure blowing around.

### **6.3.30 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.

### **6.3.31 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.

### **6.3.32 Acceleration and deceleration (3.11.11)**

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

### **6.3.33 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.

### **6.3.34 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  $V_H$ .

### **6.3.35 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.

### **6.3.36 Pull-up/pushover (3.11.15)**

Based on the recommendation in Ref. 3, the target speed was defined as 120 kt or  $V_H$ , the requirement for sustained load factor was deleted, and the termination was to level flight, not the original airspeed.

### **6.3.37 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.

### **6.3.38 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.

### **6.3.39 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.

### **6.3.40 Verification (4.)**

This is a completely new section provided in accordance with the standard on specifications. It provides guidance on 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.

### **6.3.41 References**

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-REQUIRED AGILITY	ROTORCRAFT CATEGORY				EXTERNALLY SLUNG LOAD
		ATTACK	SCOUT	UTILITY	CARGO	
<b>Tasks in GVE</b>						
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	✓	✓			
<b>Tasks in DVE</b>						
Hover	L	✓	✓	✓	✓	✓
Hovering Turn	L	✓	✓	✓	✓	✓
Landing	L	✓	✓	✓	✓	
Pirouette	L	✓	✓	✓	✓	✓
Vertical Maneuver	L	✓	✓	✓	✓	✓
Acceleration and Deceleration	L	✓	✓	✓		
Depart/Abort	L			✓	✓	✓
Sidestep	L	✓	✓	✓		
Lateral Reposition	L			✓	✓	✓
Slalom	L	✓	✓	✓		
<b>Tasks in IMC</b>						
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 Normal States**

	OPERATIONAL FLIGHT ENVELOPE	SERVICE FLIGHT ENVELOPE
Minimum Handling Qualities	Level 1	Level 2

**Table III. Levels for Rotorcraft Failure States**

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

**Table IV. 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 V. Required Response-Types for hover and low speed, near earth**

	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.	<b>RATE</b>	<b>RATE</b>	<b>ACAH</b>	<b>RATE + RCDH</b>	<b>TRC+RCDH + RCHH+PH</b>	<b>ACAH</b>
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 remark			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 VI. Required Response-Types for forward flight**

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 VII. Levels for combinations of degraded Response-Type, dynamics, and UCE**

UCE	LEVEL FOR RESPONSE-TYPE (Table V)	LEVEL FOR DYNAMICS (3.3)	OVERALL LEVEL
2	1	2	2
2	2	1	2
2	2	2	3
3	1	2	2
3	2	1	2
3	2	2	3

**Table VIII. 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 Target Acquisition and Track Turn to Target	±30	±50	±60	±13	±50	±22	±30	±60	+20 -30	±30

**Table IX. Maximum allowable yaw rate response to lateral gusts – hover and low speed**

MISSION-TASK-ELEMENT	$r_{pk}/V_g \left( \frac{\text{deg/sec}}{\text{ft/sec}} \right)$	
	LEVEL 1	LEVEL 2
All MTEs	0.30	1.0

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

LEVEL	$T_{heq}$ (sec)	$\tau_{heq}$ (sec)
1	5.0	0.20
2	$\infty$	0.30

**Table XI. Vertical axis control power – hover and low speed**

LEVEL	ACHIEVABLE VERTICAL RATE IN 1.5 SECONDS -- ft/min
1	160
2	55
3	40

**Table XII. Maximum values for flight path response to collective controller (backside) – forward flight**

LEVEL	$T_{heq}$ (sec)	$\tau_{heq}$ (sec)
1	5.0	0.20
2	10.0	0.30

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

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

**Table XIV. 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 XV. Allowable breakout forces, pounds – forward flight**

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

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

**Table XVI. 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 XVII. 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 XVIII. Requirements/verification cross-reference matrix**

PARAGRAPH NO.	REQUIREMENT	CRITICALITY	SEC 4 VERIFICATION	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 Pitch 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							
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	A	A	F
3.7.1	Failures of the Flight Control System			A	A	S	S	T
3.7.2	Engine Failures			A	A	S	S	T
3.7.3	Loss of Engine and/or Electrical Power					A	S	T
3.8	Transfer Between Response-Types				A	A	S	F
3.9.1	Rotor Start/Stop				A	A	A	F
3.9.2	Parked Position					A	A	F
3.9.3	Wheeled Rotorcraft Ground Requirements					A	A	F
3.9.4	Ditching Characteristics				A	A	A	T
3.10	Requirements for Externally Slung Loads							
3.11	Flight Test Maneuvers					S	S	F

Requirement Criticality (Assigned by User):

- N - Non Critical
- C - Critical

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 XIX. Rotorcraft status and flight conditions for verification**

HQ LEVEL REQD	ROTORCRAFT STATUS				FLIGHT CONDITIONS	REQTS TO BE SATISFIED		
	CONFIGURATIONS	LOADINGS	SETTINGS	STATES		FQ CRITERIA	APPLICABLE MTE	
1	As required by the operational missions	Possible range for applicable Configs	Primary SCAS	Normal for GVE and Pf $>2.5 \times 10^{-3}$	GVE OFE	All for rotorcraft category	All for mission	
			Primary or Augmented SCAS	Normal for DVE and Pf $>2.5 \times 10^{-3}$	DVE OFE			
2			Secondary SCAS	Normal and Pf $>2.5 \times 10^{-5}$	GVE OFE			
3					DVE OFE			
2			Primary SCAS	Normal	GVE SFE			NA
			Primary or Augmented SCAS	Normal	DVE SFE			
3			Backup	Pf $>2.5 \times 10^{-7}$	GVE	NOE Egress		
Control-lable					DVE		NA	Up-&-away egress

Pf = Probability of encountering a failure per flight hour.

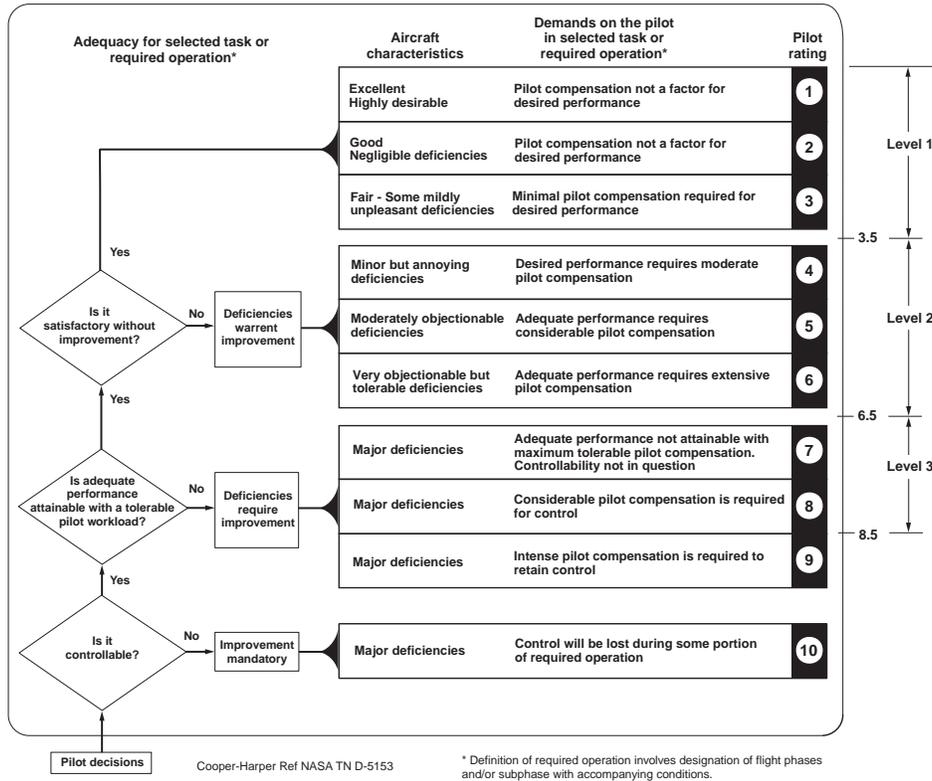
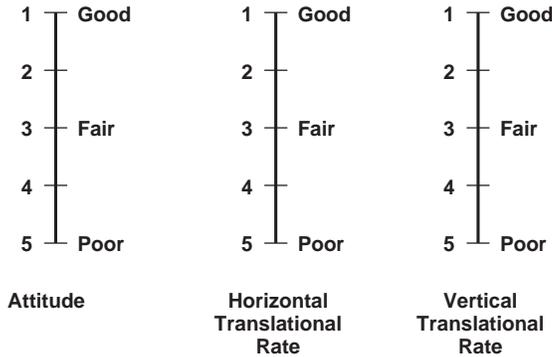


Figure 1. Definition of handling qualities Levels



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

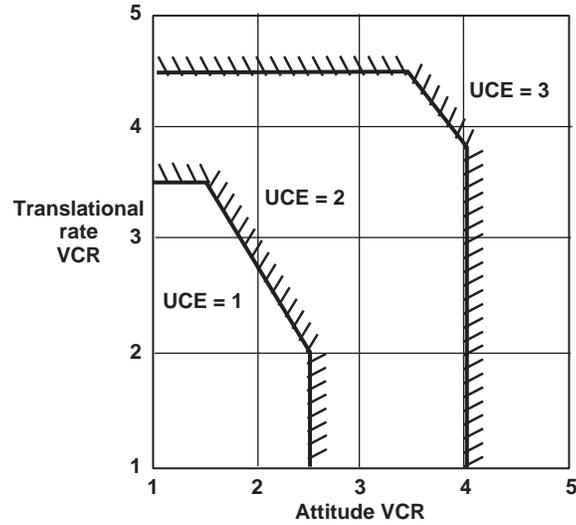


Figure 3. Usable Cue Environments for Visual Cue Ratings

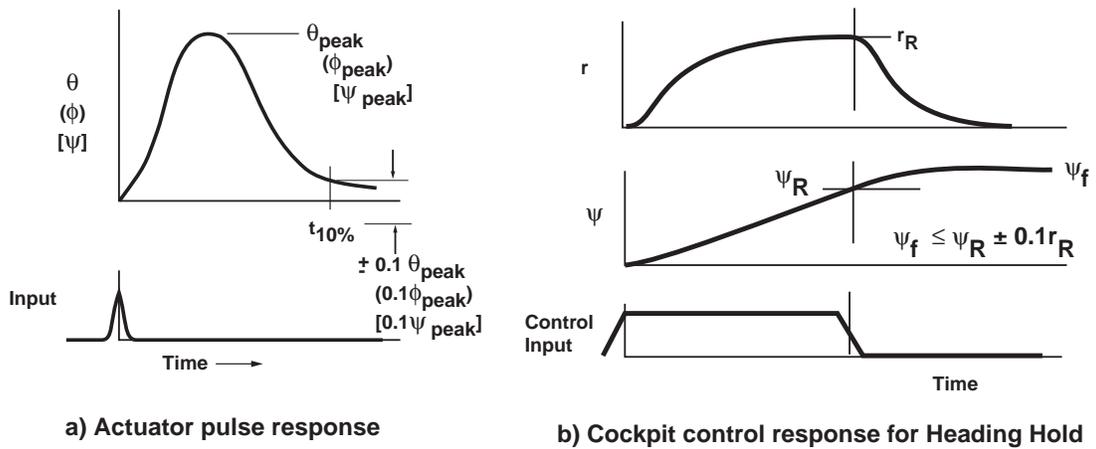
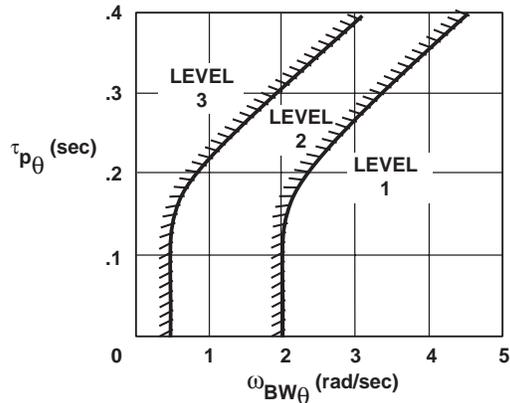
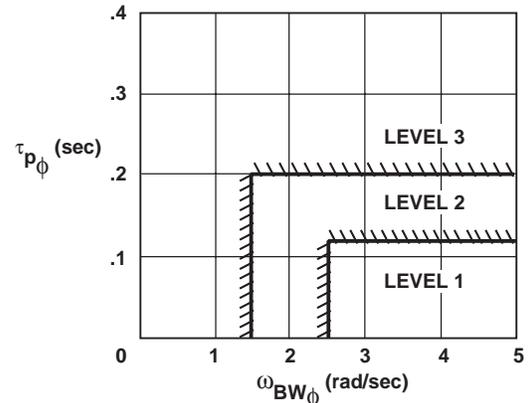


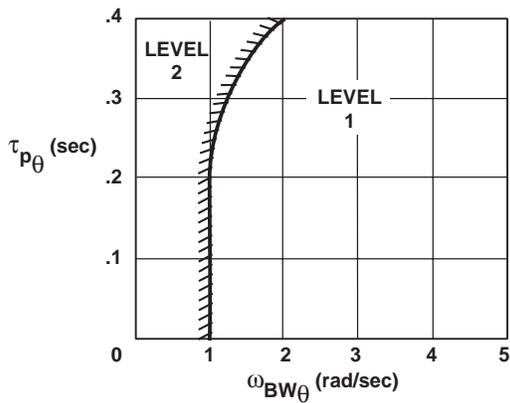
Figure 4. Responses for Attitude Hold and Heading Hold Response Types



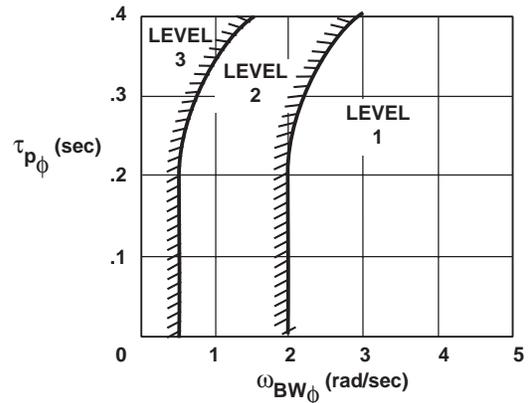
a) Target Acquisition and Tracking (pitch)



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)

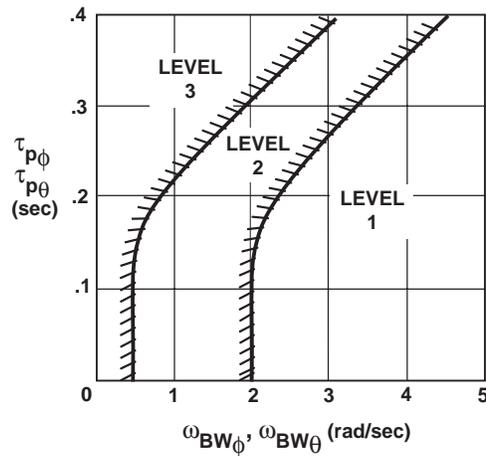


Figure 5. Requirements for small-amplitude pitch (roll) attitude changes – hover and low speed

**Phase delay:**

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

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

**Caution:**

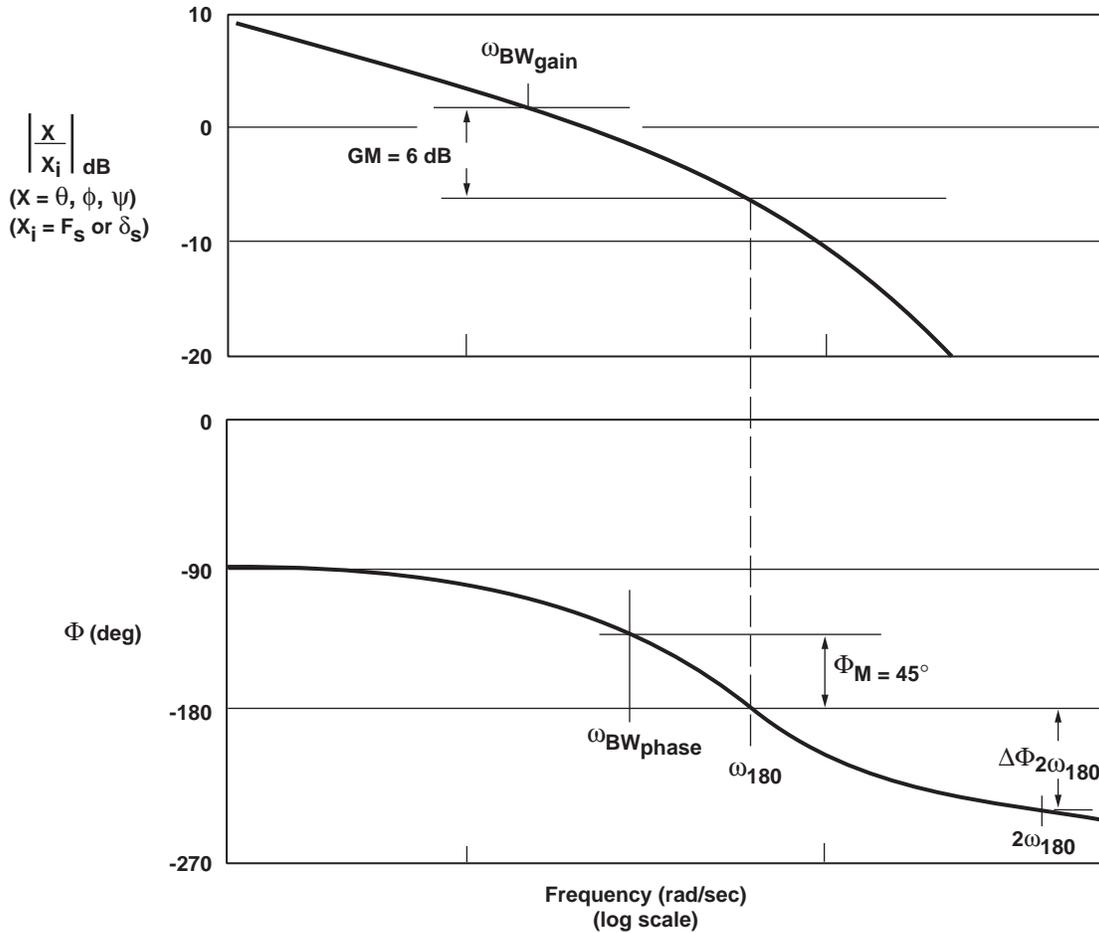
For ACAH, if  $\omega_{BW_{gain}} < \omega_{BW_{phase}}$ , or if  $\omega_{BW_{gain}}$  is indeterminate, the rotorcraft may be PIO prone for super-precision tasks or aggressive pilot technique.

**Rate response-types:**

$\omega_{BW}$  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**

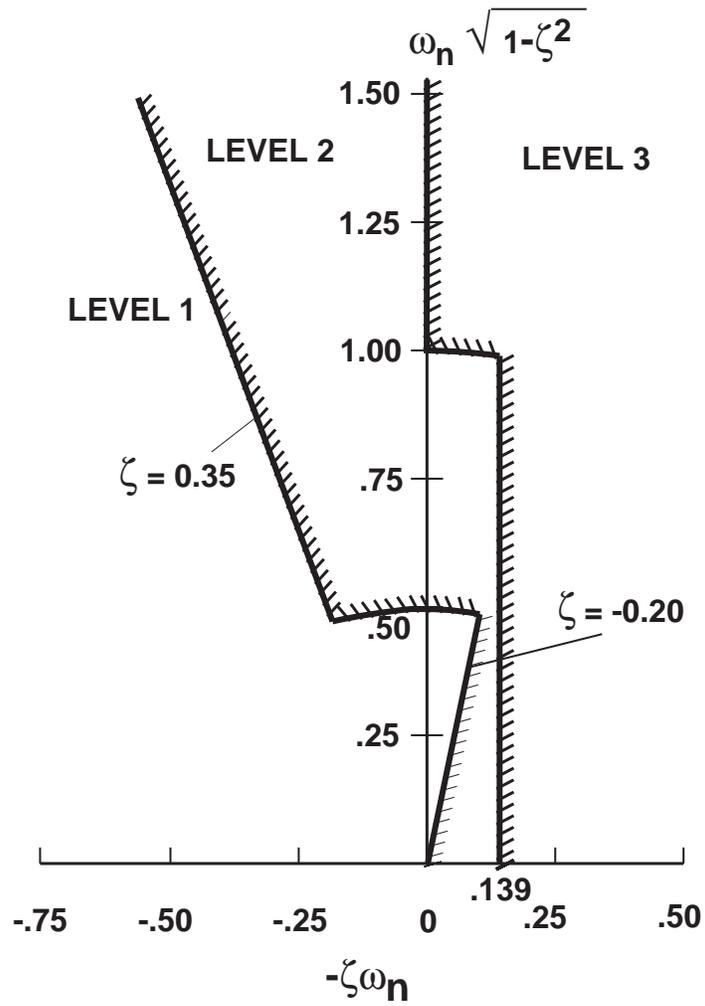
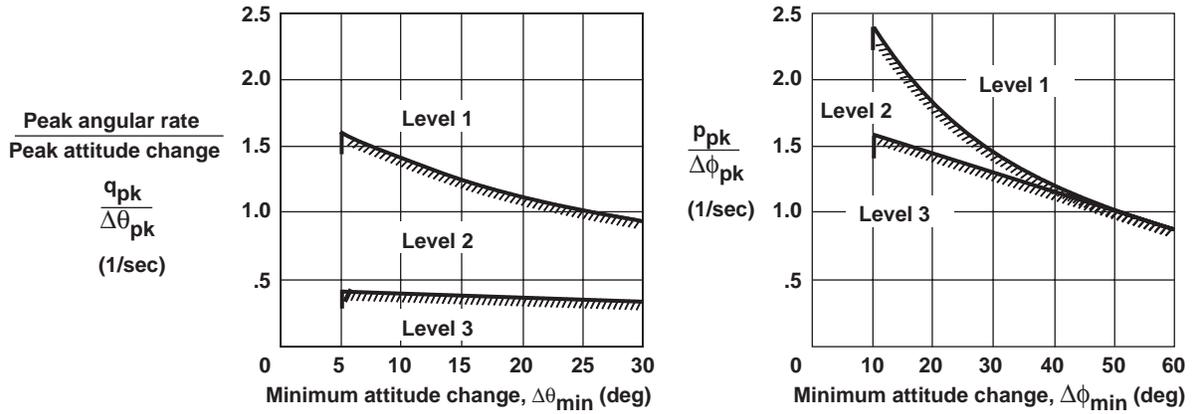
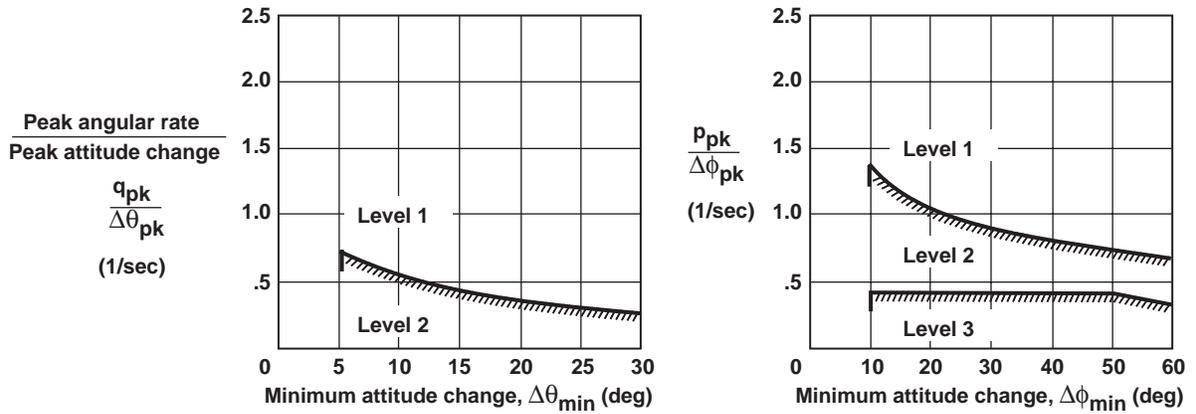


Figure 7. Limits on pitch (roll) oscillations – hover and low speed



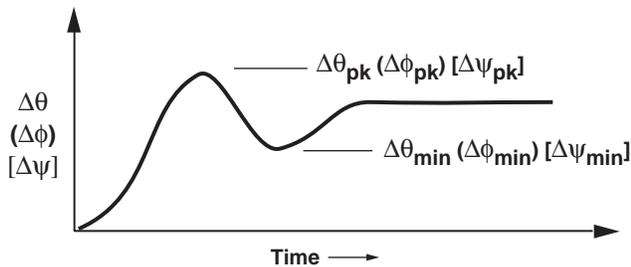
a) Target Acquisition and Tracking (pitch)

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**

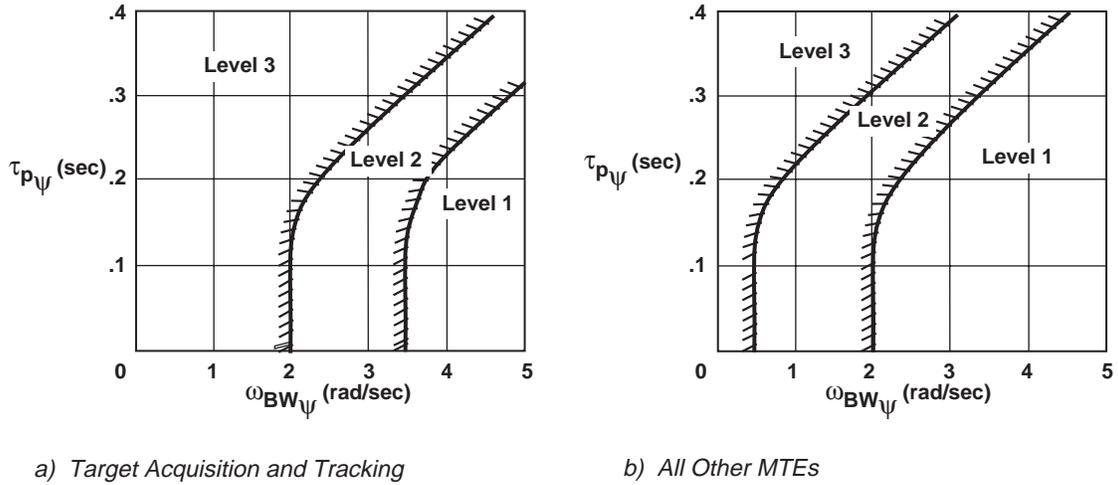


Figure 9. Requirements for small-amplitude heading changes – hover and low speed

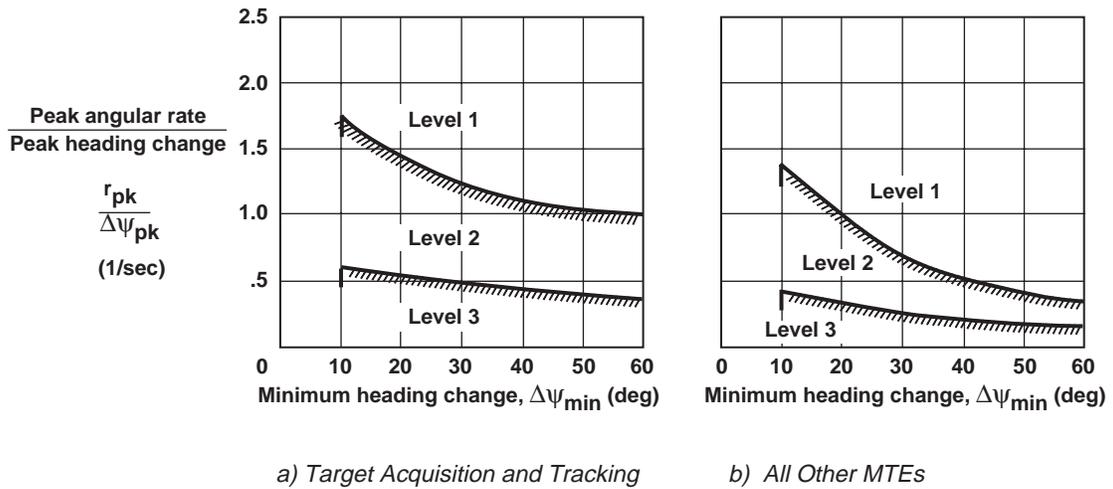
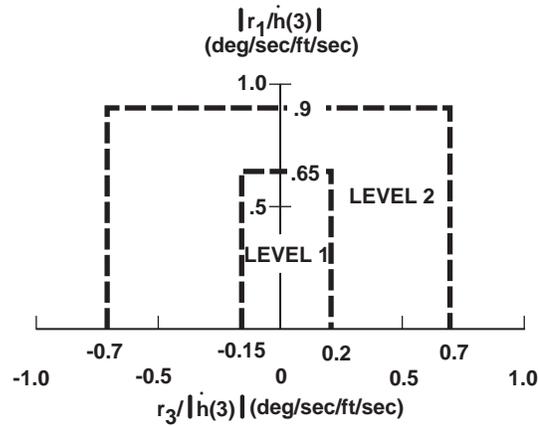


Figure 10. Requirements for moderate-amplitude heading changes – hover and low speed



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**

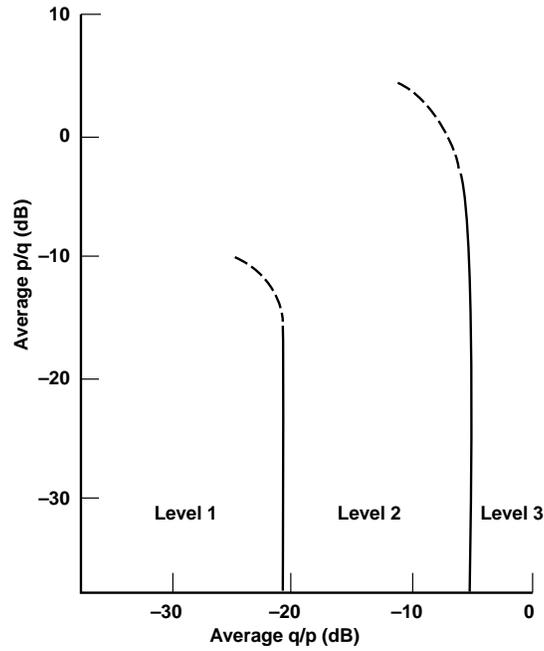


Figure 12. Requirements for pitch due to roll and roll due to pitch coupling for Aggressive agility

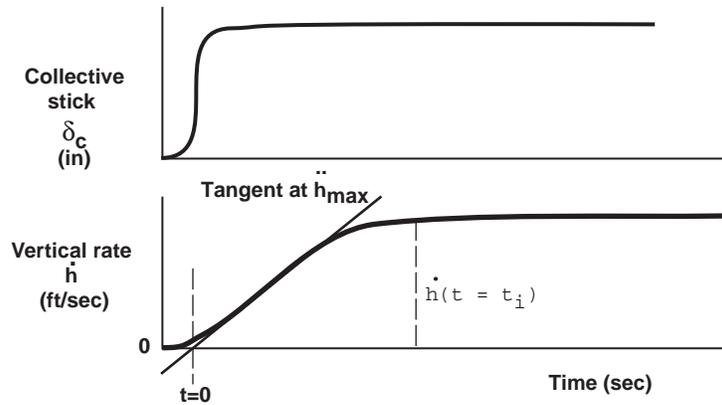
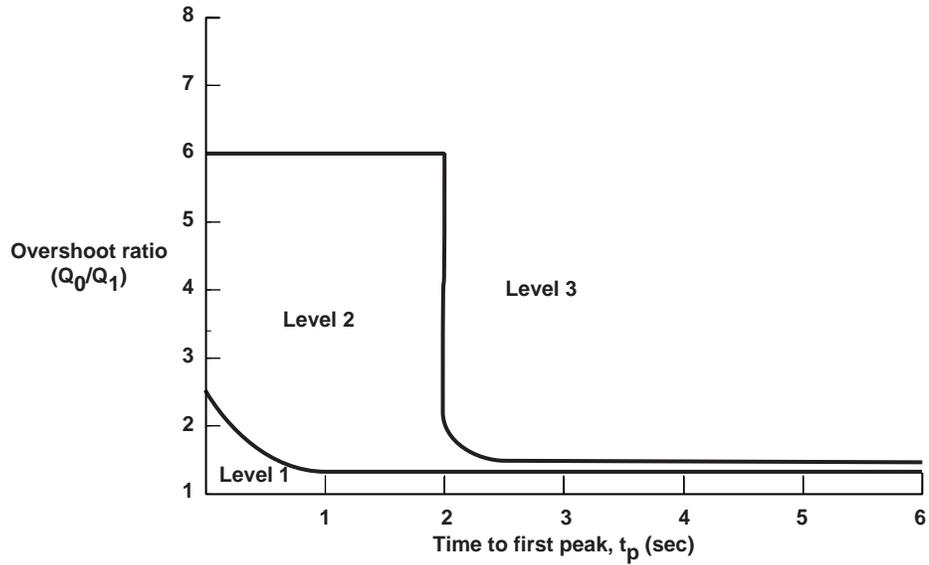
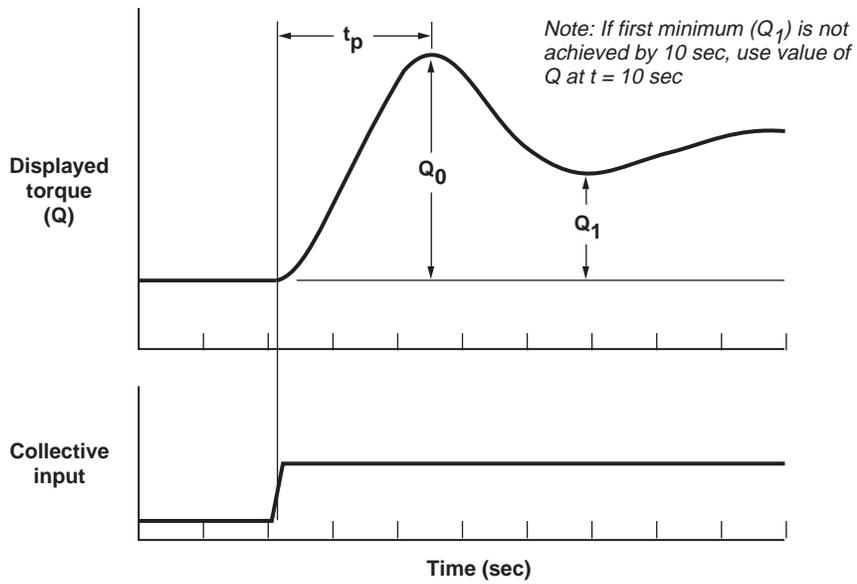


Figure 13. Procedure for obtaining equivalent time domain parameters for the height response to collective controller

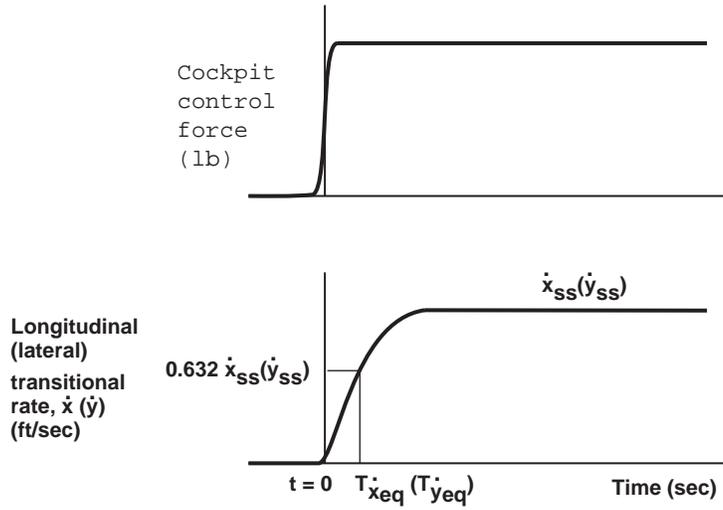


a) Requirement on dynamics of displayed torque based on step collective change

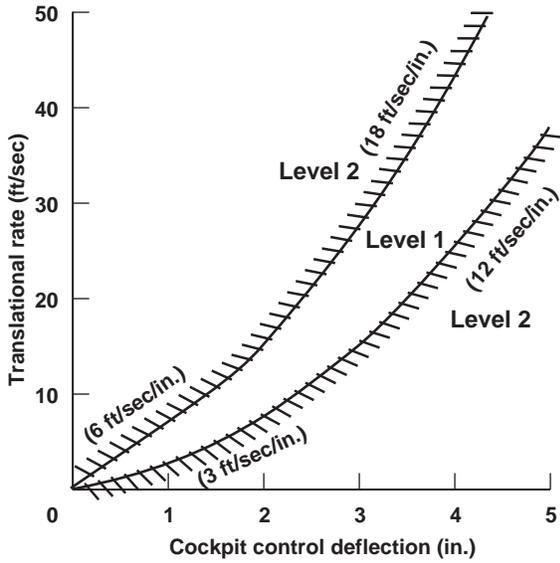


b) Definition of  $Q_0/Q_1$  and  $t_p$  for displayed torque requirement

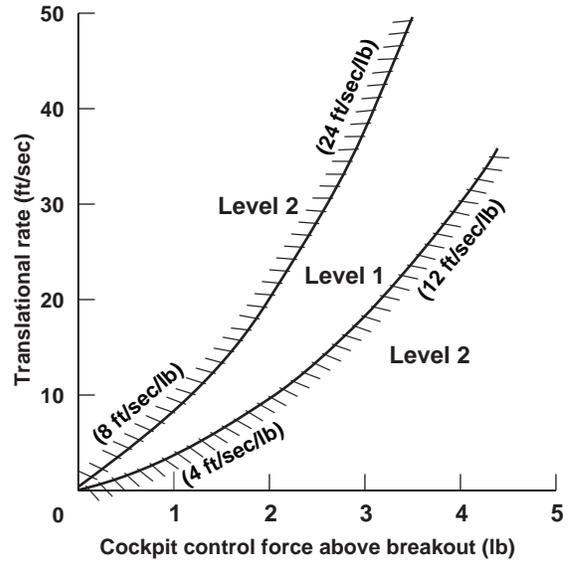
**Figure 14. Displayed torque response requirement**



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**

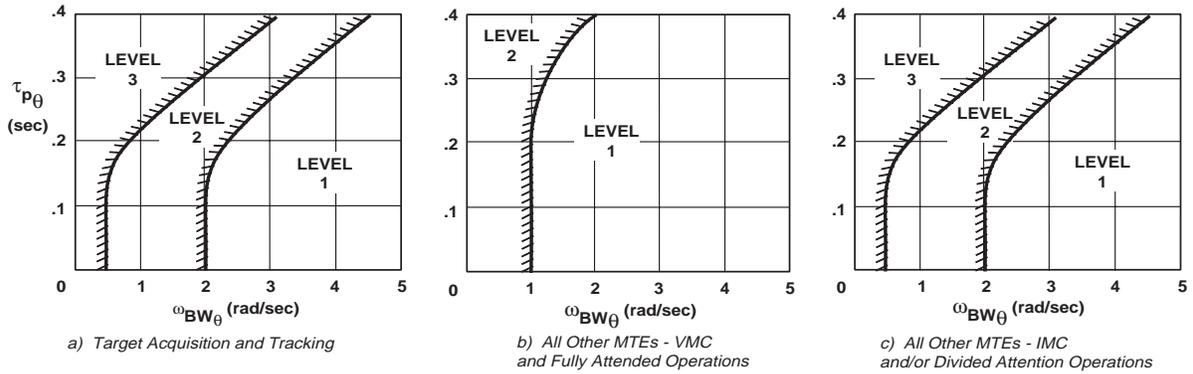


Figure 16. Requirements for small-amplitude pitch attitude changes – forward flight

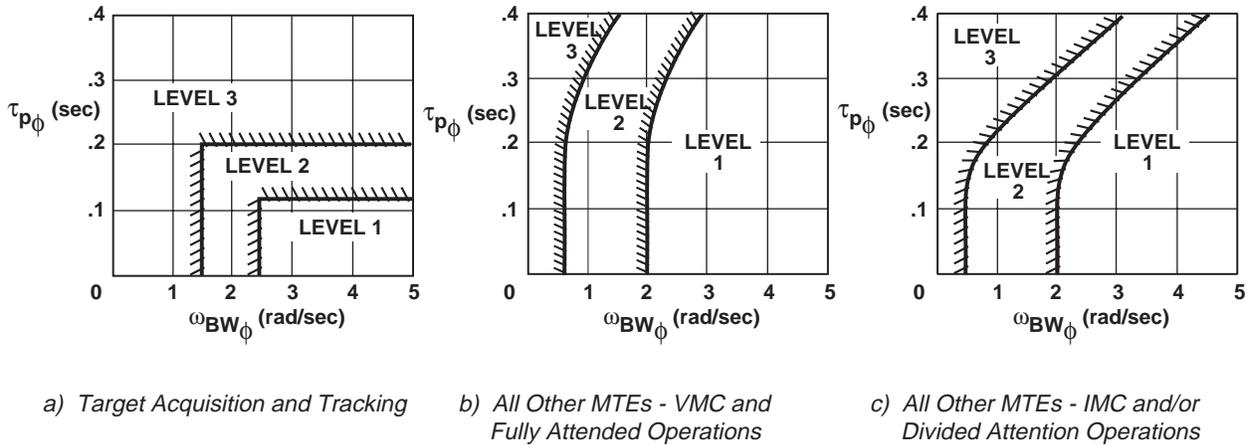


Figure 17. Requirements for small-amplitude roll attitude changes – forward flight

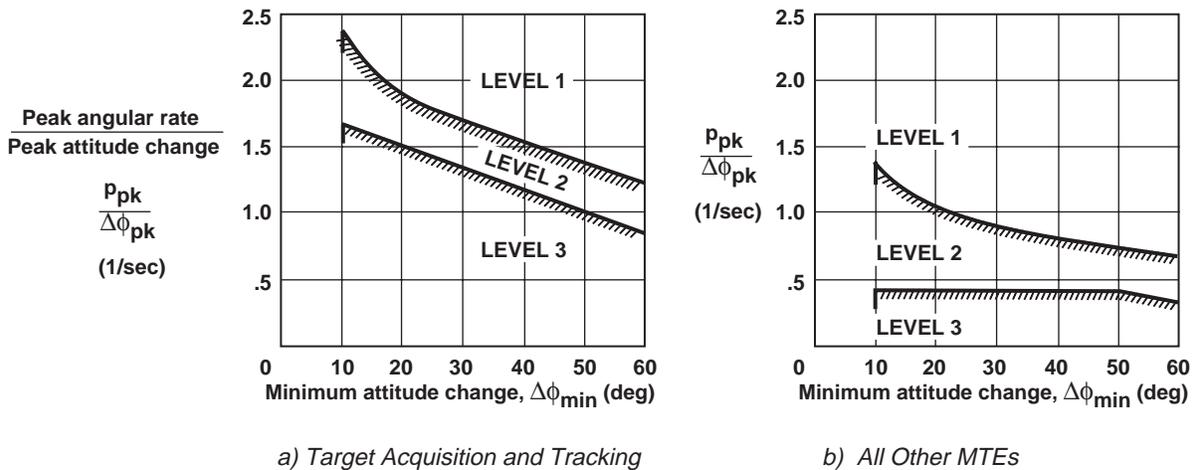


Figure 18. Requirements for moderate-amplitude roll attitude changes – forward flight

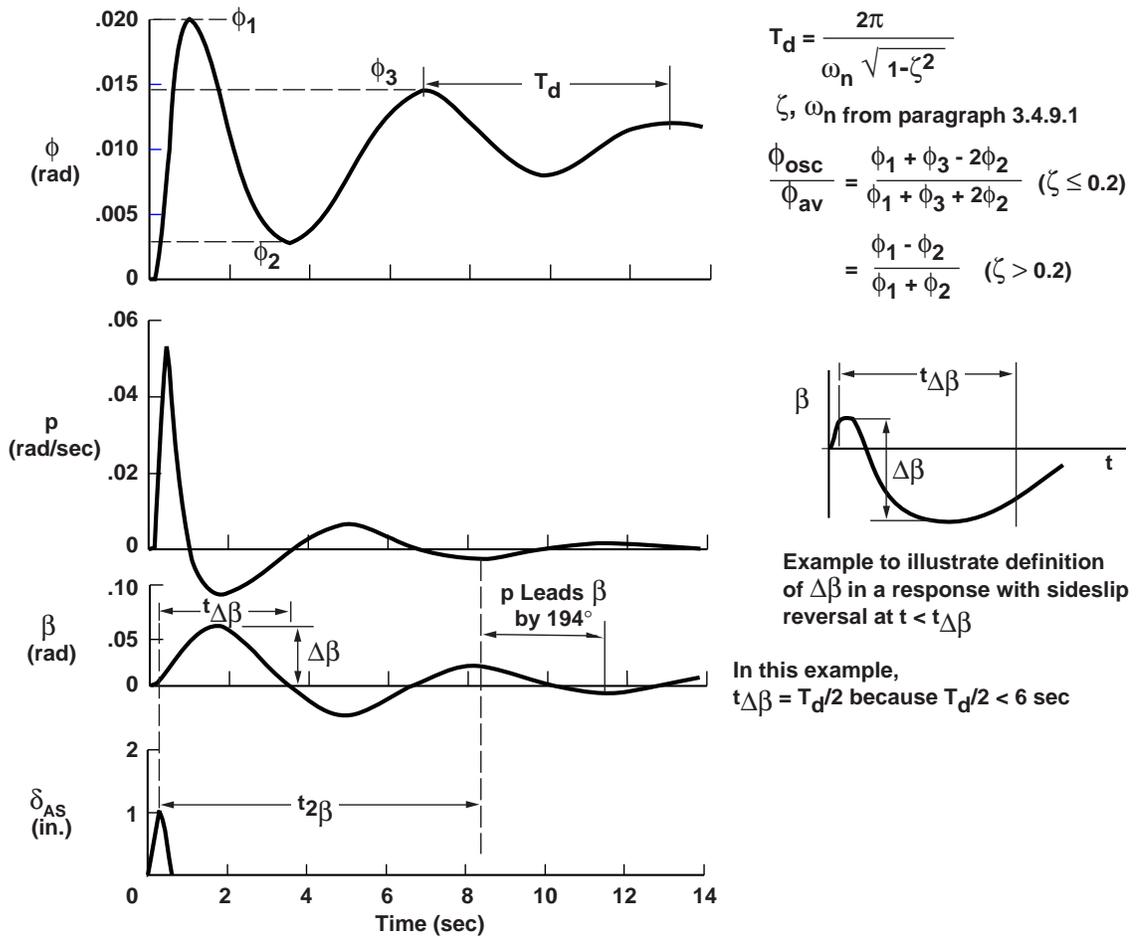


Figure 19. Roll-sideslip coupling parameters

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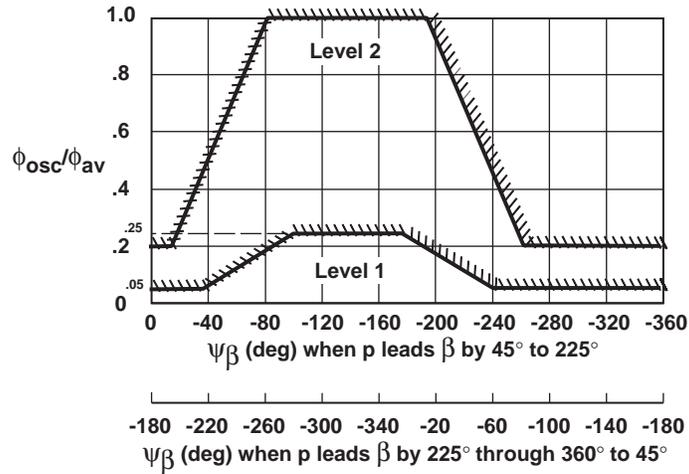


Figure 20. Bank angle oscillations

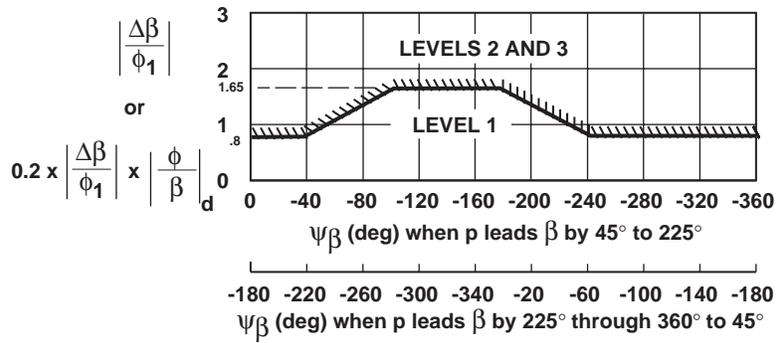


Figure 21. Sideslip excursion limitations

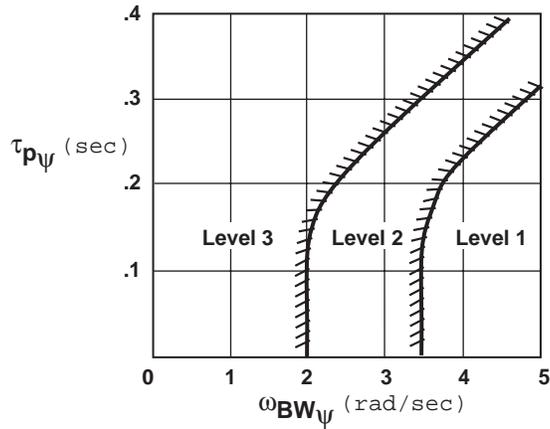


Figure 22. Requirement for small-amplitude yaw response for Aggressive agility – forward flight

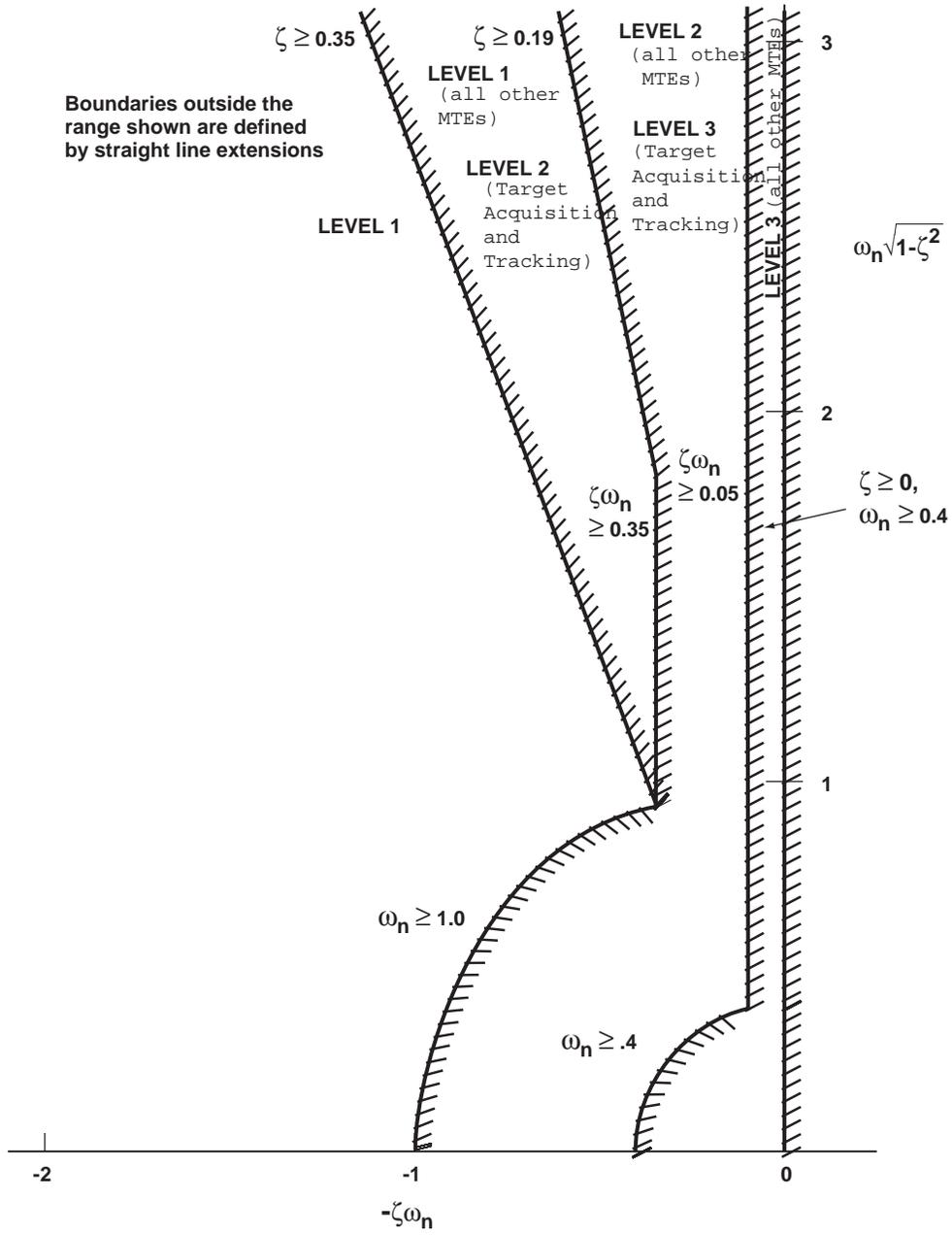


Figure 23. Lateral-directional oscillatory requirements

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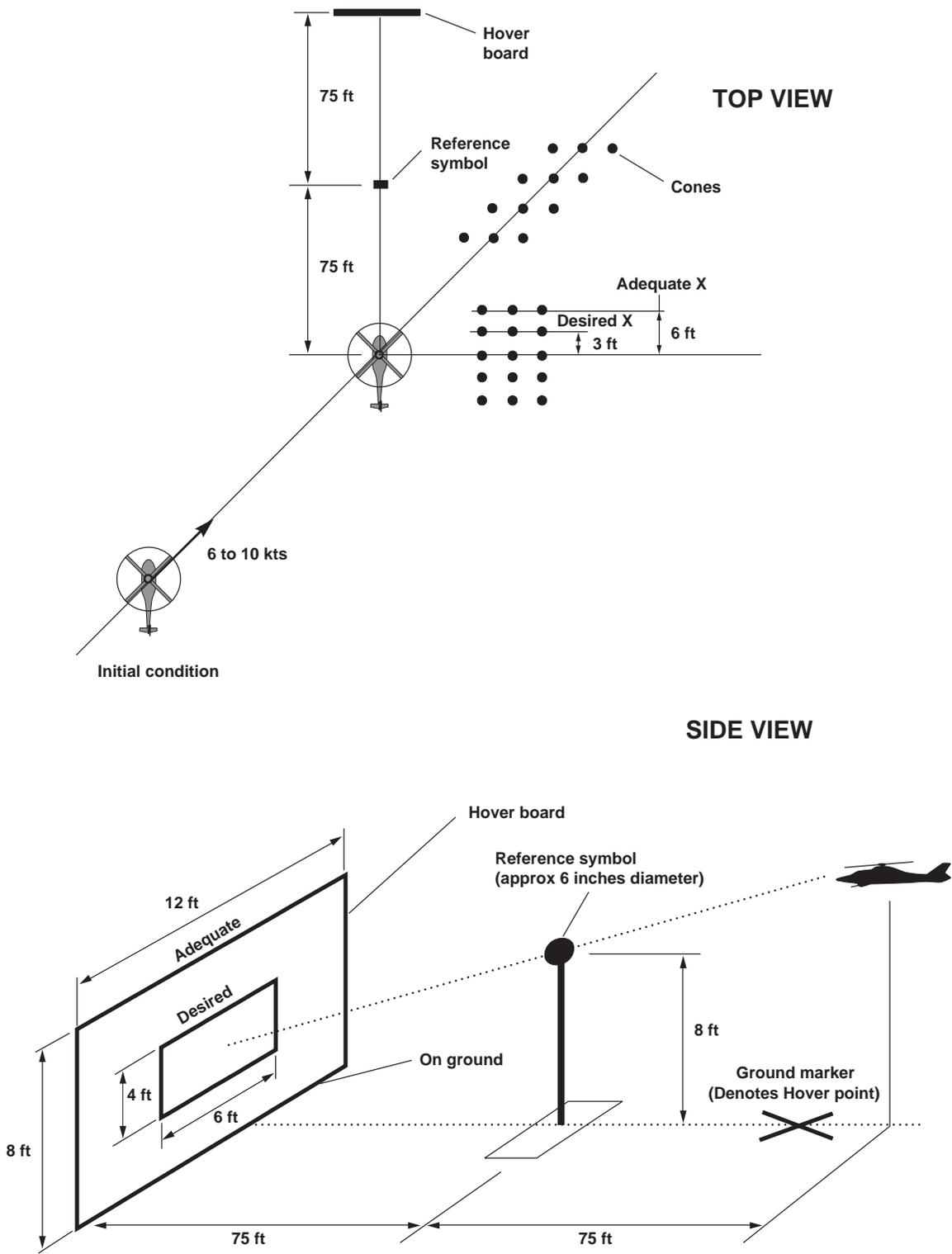
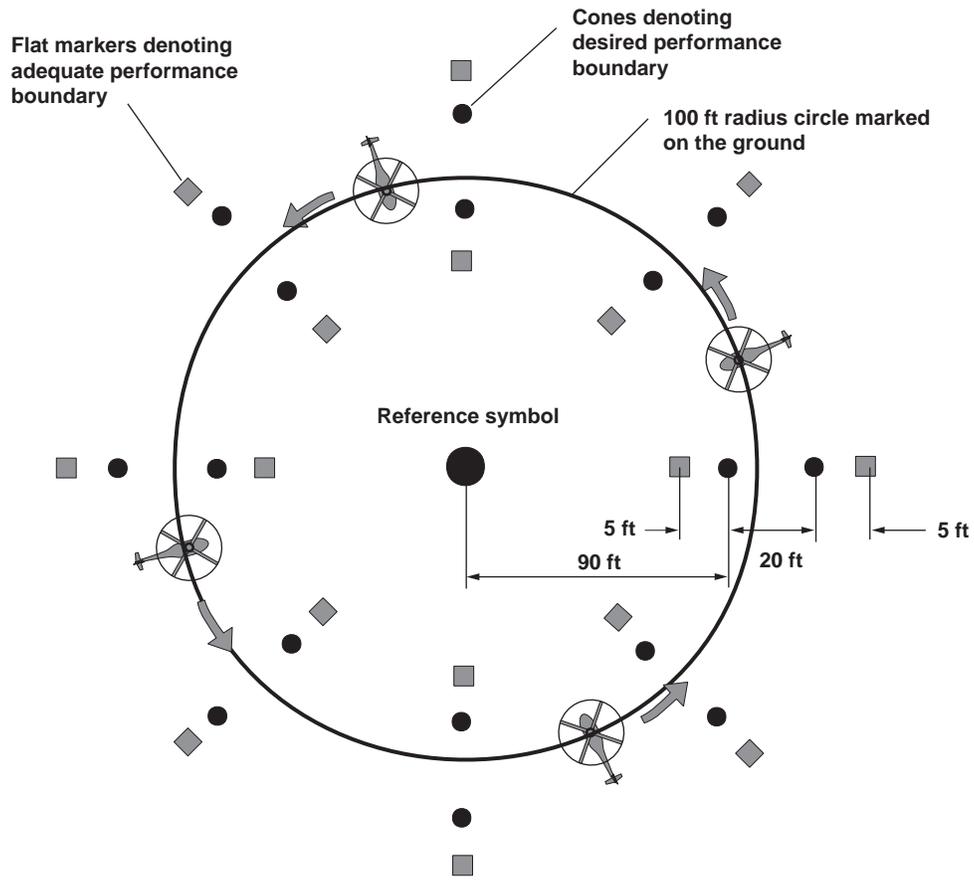
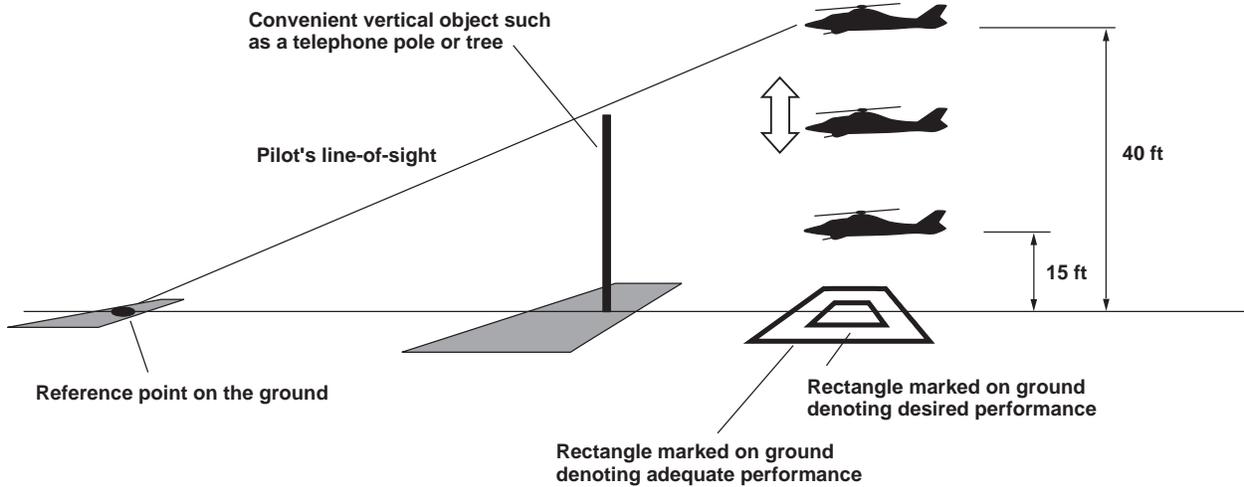


Figure 24. Suggested course for hover maneuver



**Figure 25. Suggested course for pirouette maneuver**



**Figure 26. Suggested course for vertical maneuver**

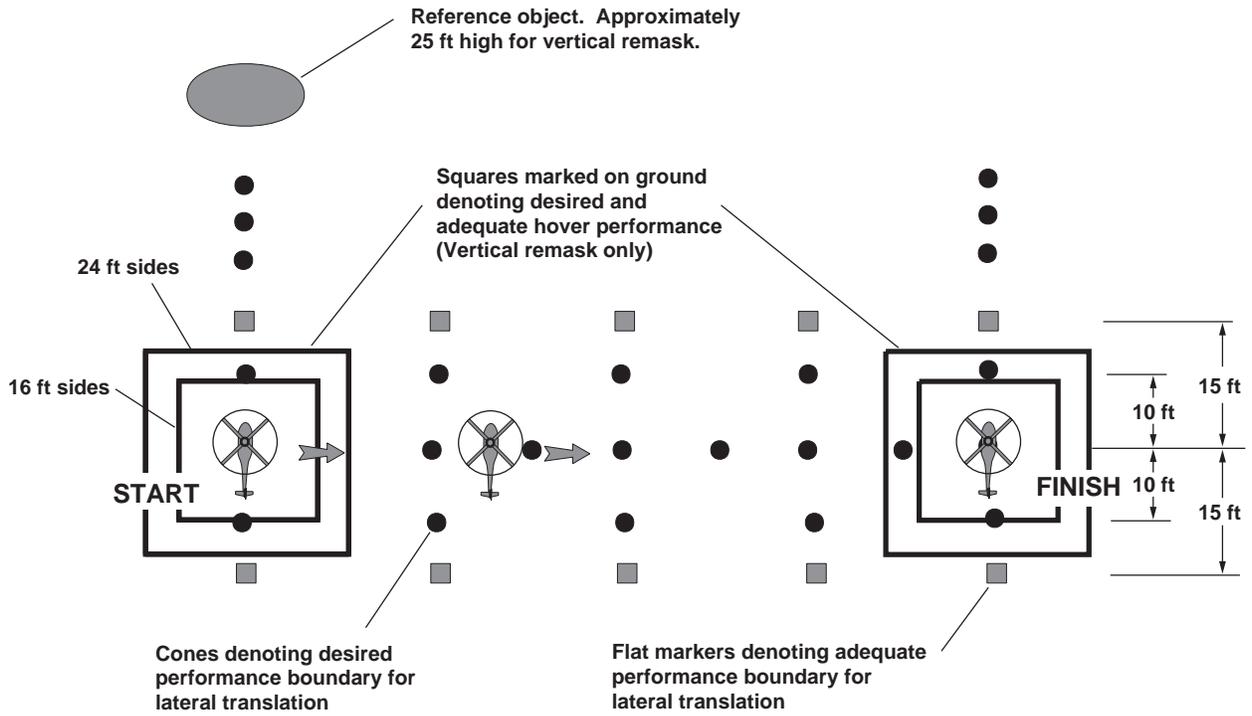


Figure 27. Suggested course for sidestep and vertical remark maneuvers

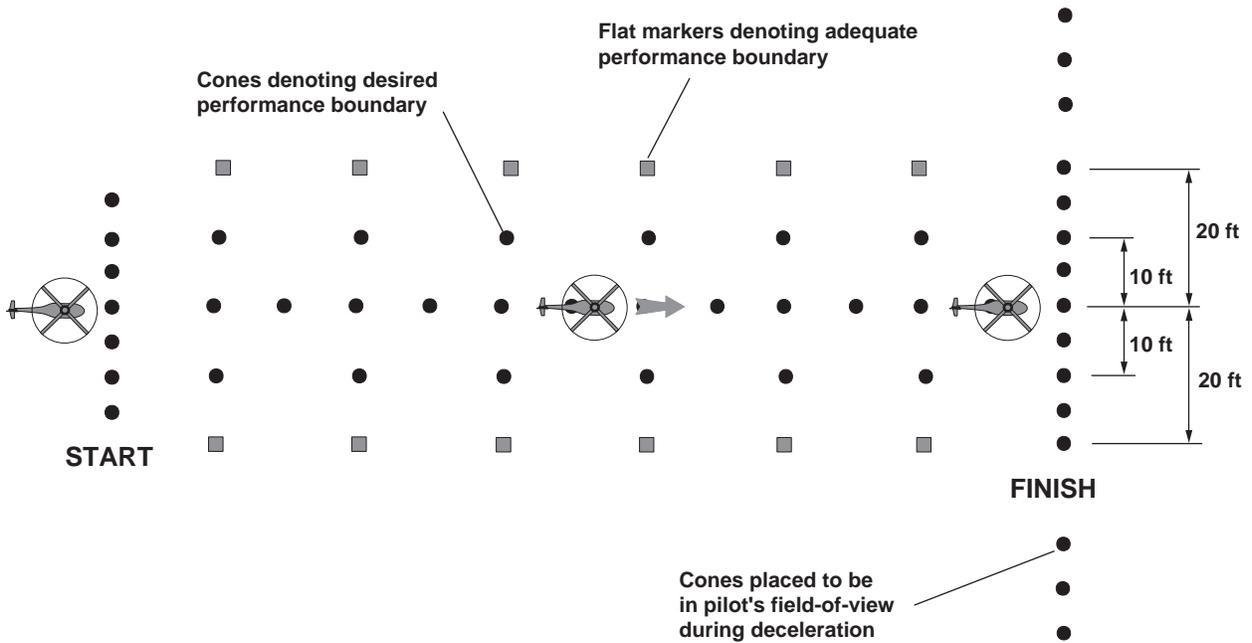
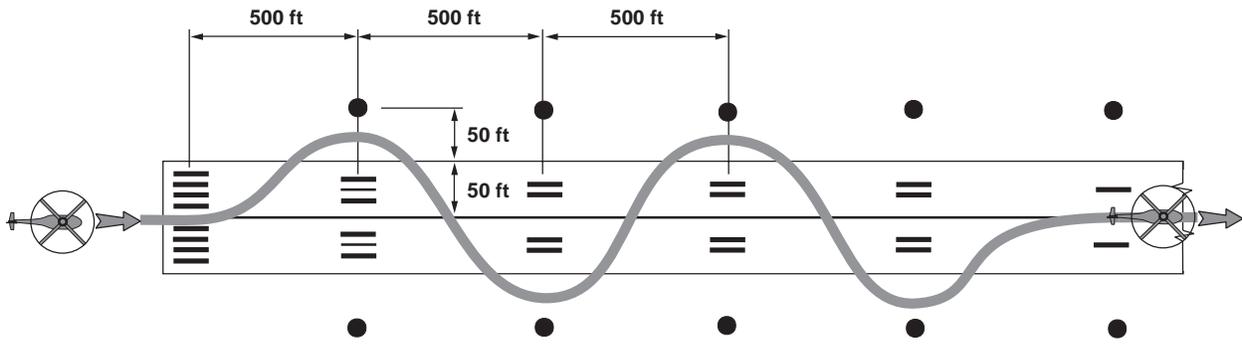


Figure 28. Suggested course for acceleration-deceleration maneuver

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**Figure 29. Suggested course for slalom maneuver**