EIGHTEENTH EUROPEAN ROTORCRAFT FORUM

F - 01

PAPER No 135

USEABLE CUE ENVIRONMENT (UCE) AND ITS APPLICATION TO SIMULATOR TESTING

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SEPTEMBER 15-18, 1992

AVIGNON, FRANCE

ASSOCIATION AERONAUTIQUE ET ASTRONAUTIQUE DE FRANCE

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Abstract

The proposed updated helicopter specification, MIL-H-8501C, is contained in Aeronautical Design Standard - 33C (ADS-33C). ADS-33C presents new and significantly different test methodology. This paper describes the Useable Cue Environment (UCE) evaluation process. The UCE determination is the first step in determining vehicle compliance with ADS-33C. Tests have been conducted in the United States, Germany and in the UK. This paper is specific to simulators. New helicopters and developmental programs will involve considerable amounts of simulator engineering and development before a first flight. Future programs such as the European Active Control Technology program and the *RAH-66 Commanche* have and will involve extensive simulation. ADS-33C is the next Helicopter Handling Qualities Specification. An understanding of its new and novel testing techniques is required.

1. BACKGROUND

Night and poor weather operations are typical of future helicopter missions. The technology exists or will exist shortly to off-load the pilot in these demanding missions. As seen in Operation Granby/Desert Storm, helicopters operated in extreme conditions. In conditions like these, pilots require increased control and stabilization. Degraded visual cues can be compensated for by increased stabilization. A methodology to quantify this requirement is the UCE.

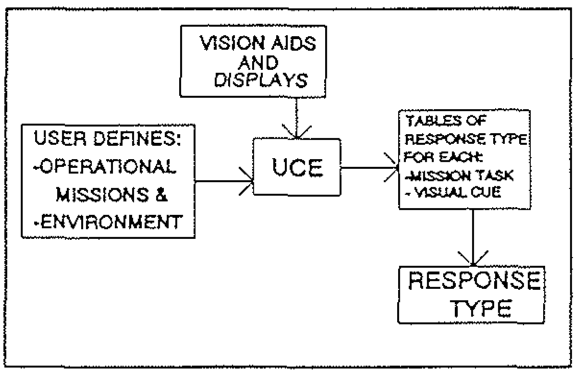
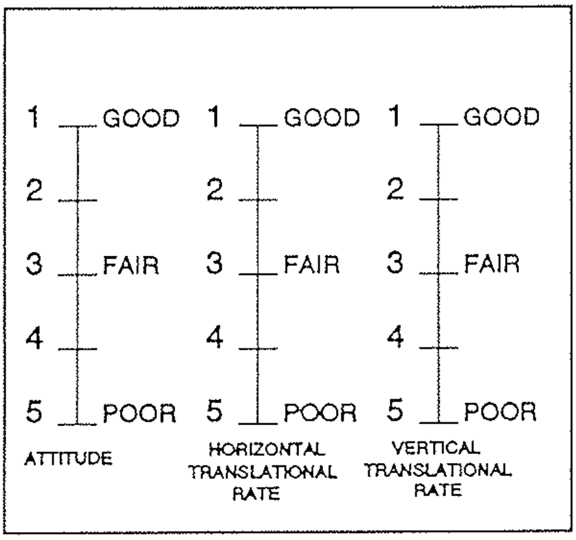


FIGURE 1. USEABLE CUE ENVIRONMENT

2. USEABLE CUE ENVIRONMENT

The UCE testing consists of two parts. The first part is the intended helicopter mission and its operational environment. Evaluation pilots should have a clear understanding of the mission (attack/scout/utility/cargo). Pilot experience in the mission is helpful but not required. The second is the pilot vision aids and displays. In theory the vision aids and display could be installed or mounted in a surrogate airframe or simulator (Figure 1).

The pilot's visual aids and displays are evaluated for their effectiveness in helping the pilot in aircraft stabilization and control. Visual Cue Ratings (VCR) (Figure 2) are used to determine the UCE (Figure 3). The UCE determination consists of the precision and moderately aggressive maneuvers located in Section 4 of Ref A. ADS-33C requires, before the actual UCE evaluation is conducted that the test vehicle possess Level 1 flying qualities. Additionally, it must have a rate-response type flight control system. A list of definitions that are ADS-33C specific are contained in Annex A.



DEFINITIONS OF CUES

X = PITCH or ROLL ATTITUDE and LATERAL/ LONGITUDINAL, or VERTICAL TRANSLATIONAL RATE.

GOOD X CUES: Can make aggressive and precise X corrections with confidence and precision is good.

FAIR X CUES: Can make limited X corrections with confidence and precision is only fair.

POOR X CUES: Only small and gentle corrections in X are possible, and consistent precision is not attainable.

FIGURE 2. VISUAL CUE RATING SCALE

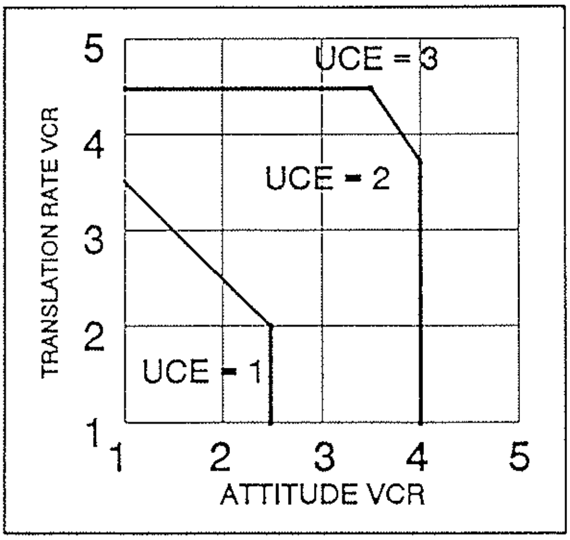


FIGURE 3. DEFINITION OF USABLE CUE ENVIRONMENT

Mission & Operational Environment

The first part of the UCE is the aircraft mission and operational environment. ADS-33C is not the source document for this information. It is the responsibility of the procuring agency to supply this.

The *RAH-56 Commanche* specification contained detailed mission profiles. A typical mission profile contained airspeed, time/distance at that airspeed, mission environment (MIDEAST/ EUROPEAN), and the aircraft configuration (ARMED RECON-NAISSANCE/ATTACK). Typical missions were available for review and discussion. The specification also detailed the environment. Winds, density altitude and ambient light levels were clearly stated.

For each airframe the US Army has Aircrew Training Manuals (ATM). These ATM detail the aircraft's mission by *Task, Condition and Standard*. The various ATMs were consulted, as a reference, for exact details of current US Army mission training standards. The ATMs coupled with the LHX specification provided an understanding of the missions.

Vision Aids & Displays

The second part of the UCE is the pilot vision aids and displays. This methodology is referred to as Visual Cue Rating. A VCR quantifies the pilot's perception of how aggressively and precisely a maneuver is flown. Pilots in very aggressive flying keep the aircraft 'state' dynamic all the time. Pilots know through outside cues ground speed, altitude, roll attitude and pitch attitude. He 'feels' through his body normal acceleration, turn quality and aircraft vibrations. He knows through viewing cockpit instruments: engine parameters, IAS, heading, etc. Pilots get 85 to 90 per cent of their information visually. With decreased visibility the pilot relies less on outside cues and more on body and cockpit information. In reduced visibility the pilot knows his body may trick him. Thus, the need to provide better visually acquired information.

3. VISUAL CUE RATING

The maneuvers found in paragraph 4 and Part 4 of reference 1 were flown to provide VCRs. ADS-33C separates a VCR into three parts: Attitude, Horizontal Translational Rate and Vertical Translational Rate. Experience from LHX and DRA Bedford show that the Attitude was easier to correlate if further subdivided. Thus Roll Attitude and Pitch Attitude were substituted. In Figure 2, the numerical ratings correspond to GOOD, FAIR and POOR. The terms Good, Fair and Poor were experi-mentally determined to posses a linear evaluation scaling. Half integer rating are allowed.

Precision and aggressiveness were chosen as the metrics. To picture aggressiveness and precision think of "hummingbird-like" agility. In poor visual cue environments, pilots tend to be very gentle (non-aggressive) on the controls to avoid losing control. Hence, precision is sacrificed. Large or gross amplitude flight maneuvers are not within the context of this definition. If the only way to attain a desired precise hover is to sneak-up to it, then the VCR would necessarily reflect the inability to be aggressive.

When evaluating a maneuver, subdivide the VCR:

1) ATTITUDE. The ability to aggressively and precisely control pitch and roll attitude. Opinion is divided on the issue of the attitude VCR rating. The LHX (*RAH-56 Commanche*) evaluation chose to further divide the attitude VCR into pitch and roll. Attitude VCR methodology was used. The question for the pilot is: How precise and aggressive are you in pitch? The rating is returned in words: Good, Fair, or Poor. Or some pilots prefer a numerical 0-5 point rating. Half ratings i.e., 1.5 are allowed. The same methodology for roll attitude precision and aggression apply.

2) HORIZONTAL TRANSLATION RATE. The ability to aggressively and precisely control the aircraft's translational velocity. Another way of looking at this is the ability to be speed stable throughout the range of airspeeds and maneuvers required. An example of this would be the ability to maintain 60 knots throughout the Lateral Jinking Task. The intent of ADS-33C was to drive the helicopter flight control system to an augmentation level that gives the pilots speed stability during dynamic lateral maneuvering.

3) VERTICAL TRANSLATION RATE. The Vertical Translation Rate is the ability to aggressively and precisely maneuver the aircraft in the heave axis. To understand Vertical Translation Rate, relate the task to a real mission. From a stable hover, vertically climb to acquire and engage an enemy with a weapon system. Another example is a quick-stop maneuver. It is hard sometimes to differentiate pure heave from pitch-up or pitch-down in a maneuver. As an example, the pilot is rapidly decelerating the aircraft to arrive at a desired position. The

aircraft "balloons" and gains altitude. Is the problem in heave or the result of an over-aggressive pitch maneuver?

From Ref B. & C. are guidelines for assigning VCRs:

- Base ratings on <u>ability</u> to be precise and aggressive.

- Use precision hover and landing tasks as a primary measure of precision.

- Use Quickhop and Sidestep tasks as primary measure of aggressiveness.

- Consider your <u>ability to stabilize quickly</u> at the end of the Quickhop and Sidestep maneuvers.

- Consider the amount of <u>concentration</u> required to acquire and maintain a stable hover.

- Do not try to separate aircraft dynamics and visual environment.

- Do not try to extrapolate simulator to real world; <u>*Rate What You See*</u>.

Each flight maneuver was practiced three times. Then the pilot flew the maneuver a maximum of three time for a VCR. Each maneuver had tolerances.

<u>Hover</u>

Desired Performance (From ADS-33C)

- Maintain horizontal position within three feet of a reference point.

- Maintain altitude within +/- 2 feet.

- Maintain heading within +/- 5 degrees.

Adequate Performance (From LHX Evaluation)

- Maintain horizontal position within 5 feet of a reference point.

- Maintain altitude within +/- 5 feet.

- Maintain heading within +/- 10 degrees.

All parameters were monitored by the engineer on strip charts for compliance. After the maneuver is flown, the engineer prompts the pilot for a rating. If the pilot gives a VCR of 1 yet did not meet the *Desired Performance Standards*, he can either lower the rating or re-fly the maneuver. Rationale being, that if the pilot thinks he met the criteria and failed then the cues are insufficient. The Pitch/Roll Attitude VCR is cross-plotted to the Vertical/Horizontal Translational Rate VCR to get an UCE rating (Figure 3). The UCE corresponds to the Level of flying qualities i.e., UCE 2 = Level 2 Handling Qualities.

Required Response Type for Hover & Low Speed

Once the UCE numerical rating is established the required level of flight control augmentation/stabilization is determined. Using Table 1 for the Precision Hover maneuver a UCE of 2 requires that the minimum response-type be:

Attitude Command Attitude Hold
Rate Command with Heading Hold
<u>*Rate Command Height Hold*</u>
ACAH + ACHH + RCHH

	UCE = 1		UCE = 2		UCE = 3	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Vertical takeoff and transition to forward flight - clear of earth.	Rate	Rate	Rate	Rate	Rate	Rate
Precision Hover. Slung Load Pick-up and delivery. Slung Load carrying. Shipboard landing including RAST recovery. Verticle takeoff and transition to near-earth flight. Hover-taxi / NOE traveling. Rapid Slalom	Rate	Rate	ACAH[1] + RCDH[2] + RCHH[3]	Rate + RCDH	TRC[4] + RCDH + RCHH + PH[5]	ACAH+ RCDH + RCHH

[1]ACAH => Attitude Command Attitude Hold Response-Type
[2]RCDH => Rate-Command with Heading (Direction) Hold Response-Type
[3]RCHH => Vertical Rate-Command with Altitude (Height) Hold Response-Type
[4]TRC => Translational-Rate-Command Response-Type
[5]PH => Translational-Rate-Command Response-Type

TABLE 1. REQUIRED RESPONSE-TYPE FOR HOVER AND LOW SPEED - NEAR EARTH (Extracted from ADS-33C Table 1(3.2))

4. FLIGHT TASKS

Flight tasks are designed to combine the aircraft mission elements into well defined manageable pieces. A task normally contains too many elements to be able to give a good Cooper-Harper Handling Qualities Rating (HQR). The admonishment here that if you have not read the Cooper-Harper technical note, then you should. Their application is rigorous.

A maneuvers commentary is provided below. The exact technique is not the important element. A flight test rule: *all data must be repeatable*. Hence, the fundamental is that pilots decide how to fly the maneuver. Pilots do not always fly what the engineers and researchers intend, leaving them frustrated. The flight tasks from ADS-33C and the US Army's LHX Design Specification were to gross in their intent. The LHX evaluation team spent several hours confering with the authors of ADS-33C/LHX specifications. The result was "how to" fly the maneuvers. The details spelled out below are those of the author's LHX experience and work done on the Large Motion Simulator at Defense Research Agency, Bedford U.K. These maneuvers are those of the DRA and test results are in another paper presented here.

SIDESTEP TASK. This task involves the aircraft roll, heave and yaw axis. There are numerous maneuvers in this task. Included are a stable hover and starting a right roll to begin the aircraft translation. Upon reaching the desired bank angle, maintain the right bank angle until the roll-reversal to arrest the translation. As the aircraft velocity approaches zero, achieve a stable and accurate hover in front of the sighting markers. Five maneuvers are described in this one task.

- STABLE HOVER X 2
- INITIATE ROLL TO THE RIGHT
- RIGHT TRANSLATION
- ROLL REVERSAL

HURDLES TASK. This task involves the aircraft pitch and heave axis. Initially, from level un-accelerated flight a change in aircraft attitude is required. Either by a cyclic climb or a pure collective step input climb the aircraft to clear the bottom of the "Vertle" opening. The arrestment of the pitch-up or reduction of the vertical heave must insure that the aircraft does not balloon over the "Vertle". Next, there is a pitch-over or collective reduction to begin the loss of altitude. During the descent there is a stable aircraft state and then there is arresting the rate-of-descent. Then a stable low airspeed forward flight state before repeating the maneuver. At least three maneuvers are described.

- CLIMB
- DESCENT
- LEVEL UN-ACCELERATED LOW AIRSPEED FLIGHT

LATERAL JINKING TASK. This task has three variations. First is the task accomplished at a constant velocity. Then the maneuver is repeated accelerating throughout the task. The final variant is to enter the task gaming area at 60 knots and constantly decelerate while performing the task. The task is started by the aircraft passing through the center set of pylons then quickly rolling to the left. The desired angle-of-bank is an aggression parameter. Then, align and pass through a double set of pylons. After passing through the left pylons the aircraft upon exiting the pylons must bank right to align and pass through the center-line double set of pylons. Upon exiting the center-line pylons the aircraft is banked left to align and pass through another double set of pylons and exit the task area. There are three maneuvers with three variations described.

- LEVEL UN-ACCELERATED FLIGHT
- LEFT ROLL (Uncoordinated)
- RIGHT ROLL (Uncoordinated)

HURDLES HOPPING. Begin the maneuver from level un-accelerated flight by passing under a hurdle and then starting a climb to pass through the notch of a standard "Vertle". The climb can be either cyclic only, collective (heave) only or a combination of the two. The aircraft is then pitched over to fly under another hurdle. This encompasses three tasks: the pitch over or collective reduction, rate-of-descent arrestment at the bottom and the level flight phase as the aircraft passes under the bar. Finally, the pilot has to sight a vertical pitch bar and 'track' a 10m level flight path. Upon exiting the 'fly-under-hurdle' the aircraft jumps the next hurdle and reassumes the 10m level flight path. A single jump encompass four maneuvers. Initially, the aircraft must climb to the required altitude without ballooning. A rate-of-descent established then the rate-of-descent arrested and level flight established. Once the aircraft has passed under the final hurdle the task is complete. There are variations of at least three maneuvers.

- LEVEL UN-ACCELERATED FLIGHT
- CLIMBS
- DESCENTS

QUICKHOP TASK. The maneuver starts by attaining a stable hover on the center-line within the vertical parameters. The aircraft is aggressively accelerated along the center-line maintaining the desired altitude and heading. The aircraft acceleration is stopped to attain a level un-accelerated flight condition while maintaining desired heading. The aircraft then has to decelerate aggressively to arrive at the desired final position while maintaining desired altitude, heading, no drift or residual oscillations. There are at least five maneuvers in this task.

- STABLE HOVER
- AGGRESSIVE ACCELERATION
- LEVEL UN-ACCELERATED FLIGHT
- AGGRESSIVE DECELERATION
- PRECISION STABLE HOVER

It is critical that all pilots and flight test engineers understand the technique the pilots use in each maneuver. It is important that detailed briefings and debriefings be held. This insures all test participants agree and are aware of the pilot techniques used to fly the task.

The pilot is also responsible for knowing the make-up of the gaming area. The visual scene is normally full of information and cues. Various color schemes, pitch bars, route aids and markers will normally aid in task performance. A common pitfall is the computer generated imagery interpretation. Designers have been looking at that same scene detail since it was first conceived on their drafting tables months before the pilot first views it. Pilots should ask where and why the color changes occur. What is their relation to the task i.e., is the color band at the desired hover height? Sometimes scene detail is so overwhelming that it can, in some cases, detract from a maneuver.

5. SIMULATORS

Flight Control System. In any evaluation the pilots must have a clear understanding of the flight control system. A technique for understanding a flight control system architecture is shown below.

Review all the available WRITTEN material on the flight control system before it is explained. This should be broken down by axis first. As shown below, a simple block diagram shows the pitch axis. The change from Rate Command Attitude Hold to Rate Command/Airspeed Hold happens at 15 knots without any blending. Additionally at 135 knots there is a bob-weight to provide artificial feel.

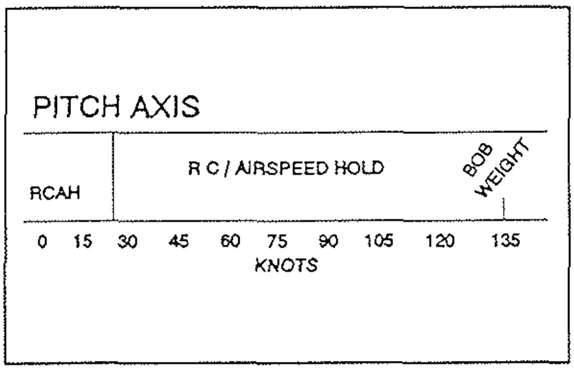


FIGURE 4. PITCH AXIS

A simple block diagram shows the yaw axis. The change from Rate Command to Rate Command/Turn Coordination is blended between 30 and 45 knots.

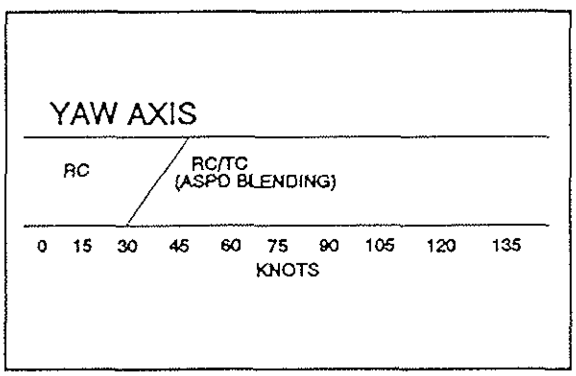


FIGURE 5. YAW AXIS

Several other pieces of information are required to understand a simulator's flight control system. Some characteristics or equipment are emulated. An evaluation could be biased without a full understanding of these systems.

The next step to is have the flight control systems designer describe the flight control system. Again, an axis by axis methodology is often helpful. Insure that any mechanization is clearly described. As an example, if a button or switch is pressed to change or activate a mode. Find out: 1) does the switch have to be held till there a Head-Up-Display (HUD) or other indication of the mode switch or, 2) does it just take a momentary activation. Mode switching is the most confusing portion of any flight control system. Be clear about each mode change and where it occurs.

Each pilot should develop their own flight card for a step by step evaluation of each flight control mode. The card matrix should cover each axis. It may help to divide the low airspeed range and forward flight. Pay special attention to switching modes. Accelerate and decelerate through airspeeds where mode change blending starts and finishes. Make power changes at the airspeed switching points.

Radar Altimeters. An aircraft's radar altitude is 'normal' to the aircraft's "z" axis. In a simulator the radar altitude is always normal to the center-of-gravity (Figure 4). Hence, a radar altitude signal used in a height hold is unrealistically perfect. In a hover or NOE, a pilot would never use a height hold feature in aggressive (beyond 10-15 deg) pitch and roll maneuvers. However, in a simulator a height hold feature works perfectly.

Sidearm Controller. A Sidearm Controller is a force device that produces a corresponding voltage. The variables include the pivot axis, the x/y orientation, and tactile buttons/ witches used to change configurations. Review the manufacturers

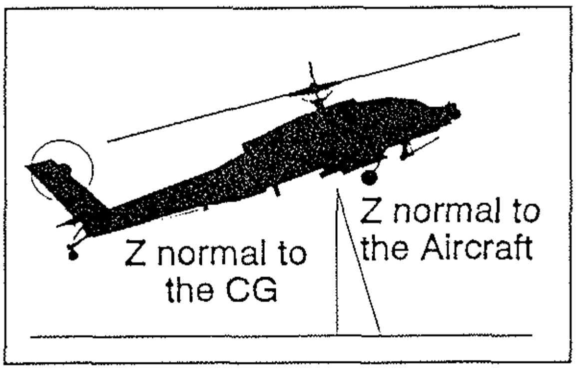


FIGURE 6. RADALT ORIENTATION

force versus displacement graph, to have an idea of control harmony, breakout and the force gradient. As an example, a high breakout force could contribute to the inability to make fine or precise control inputs. *Consequently, causing* a pilot induced oscillation (PIO).

The x/y or pitch versus roll axis orientation in most sidearm controllers is adjustable. The situation to be aware of is that everyone has a different ergonomic orientation. Small variations are not bad, but if a pilot is consistently contaminating the off-axis, bad data and frustration is the result.

The mechanization of tactile buttons and switches is another critical parameter. Flight controls designers often mechanize small fine controls inputs by the use of vernier or speed "beep" trims.These systems present various challenges. *The pilot must be aware of* pitch/ roll translation rates (knots, m/sec). Additionally, the simulator's sidearm controller augmentation disengagement switches should emulate the aircraft.

Pilots, as the gain of a task goes up, have been know to accidentally disengage ASE, SAS, CAC, etc. Inadvertent augmentation disengage-ment is important to an evalua-tion.

Speeds. Helicopter velocity computation methodology is important. Changes in the flight control system that are speed dependent can leave the pilot confused when switching occurs. Here is why. Often the airspeed switch depends *on ground* speed. The simulator software computes the ground speed based on the resolved values of longitudinal velocity "x" *and* lateral velocity "y". The x velocity, which is displayed on the HUD, may show a velocity less than 15 knots. However, the actual "x" (longitudinal) velocity, which activates the flight control mode switch, is greater than 15 knots. The airspeed dependent switch is activated and the pilot is unaware. This is common in lowspeed and/or uncoordinated flight.

Another situation that can frustrate a pilot is yawing the aircraft while flying in excess of the mode switching airspeed. The aircraft velocity, *based on the* resolved x and y values, falls below the flight control mode switch threshold when the aircraft is yawed. The flight control mode will change without the pilot realizing his airspeed has dropped. This can be particularly true when the HUD has a velocity vector display. The velocity vector is "immune" to sideslip and normally continues to show the original ground track.

Field-of-View (FOV). There are two problems with simulator FOV. First is the lack of lateral FOV while trying to accomplish lateral tracking tasks. Pilots try to use sideslip to "sneak" a look. Secondly, the pilot has no lateral *reference for ground rush cues.* This is particularly important for acceleration and deceleration maneuvers. The best comparison to the lack of cues would be to try these aggressive and precise maneuvers with night vision goggles and not look out to the side. Pilots would refuse to fly if lateral cues were not present.

Visual Aids. Visual aids encompass a wide variety of devices. They include Head-Up Displays (HUD), cockpit displays and the computer generated imagery (CGI). HUD symbology normally displays a large amount of information including: *Airspeed, Altitude* (radar/barometric), *Vertical Speed Indicator, Heading, Pitch/ Roll Attitude, Lateral Velocity* (turn quality), some indication of flight control mode (i.e., speed hold, heading hold, etc.). Pilots require a complete description of the HUD symbology and any de-clutter modes.

6. SIMULATOR DAY USEABLE CUE ENVIRONMENT (SIMDUCE)

The SIMDUCE is an amalgamation of the UCE evaluation as *described in* ADS-33C *and* its application to a simulator. SIMDUCE was invented by the US Army Aeroflightdynamics Labratory. The application of SIMDUCE was to determine the simulator's UCE. In the LHX Demonstration-Validation (DEM-VAL) Handling Qualities Evaluation, the competing teams had different simulators. The SIMDUCE was used to baseline the simulators and their UCE. During LHX DEM-VAL no allowances were made for the simulators.

7. FLIGHT TEST DOCUMENTATION

The maneuver methodology is critical to insure repeatability. The flight test engineer must insure the pilot is keenly aware of maneuver para-meters. During LHX, the flight test engineers took the extreme step of having real-time data strip charts of the parameters. Prior to the evaluation *Desired* and *Adequate* parameters were established. Flight test engineer should read the man-euver and the *Desired Performance* numbers to the pilots. There is general disagreement in the flight test community whether such scruti-ny of the test pilot performance is required. It is. Pilots are good at judging lots of things, but their own performance in a limited visual environment is not one of them.

If a pilot fails to meet the *Desired Performance* criteria, the problem is not the pilot it is the flight vehicle. The VCR must reflect that the pilot was unable to aggressively and precisely maintain the vehicle with the *Desired Performance* criteria. The simulator with its limited FOV is particularly prone to this false sense of "goodness".

During the work-ups to the LHX Handling Qualities Evaluation, evaluation engineer and pilots had a dedicated effort (one week) at the Crew Station Simulation Research Facility at NASA, Ames. With two evaluation teams, identical test methodology was required. We were sensitive that contractors wanted identical evaluations for the competing designs.

Our Flight Test Rules of Engagement:

1) The pilot and the whole flight test team held a detailed briefing. Items covered included weather, aircraft configuration, gross weight, center of gravity limits, flight limits, safety and finally the flight test card.

2) The flight card was briefed by the engineer running the test at the console. A discussion of each maneuver insured that pilot comments centered on "performance" parameters. Additionally, this reduced confusion over when the pilot was expected to call-out various points ("Stable-Hover", "On-Heading", etc.).

3) All flight test maneuvers to include pilots ratings and comments were recorded on videotape. This helped in data reduction and good written daily flight reports. Pilots were not allowed to fly the next sortie until a written daily flight report was complete for the prior flight. Since all recording devices were time-coded all flight-data could be reviewed at a later time with data, videotape and pilot comments all synchronized.

4) The HQR rating for a maneuver had to reflect the actual desired or required performance. Meaning that if the pilot gave the maneuver a HQR of 1-4 and the *Desired Performance* not attained, the maneuver was reflown. Consequently, maneuvers where pilot performance did not improve became Level 2 with the appropriate HQR. The same was true for *Adequate Performance* criteria and HQRs 5-7. If the pilot was unable to meet the *Adequate Performance* criteria the HQR would have to fall in the 8-10. The VCR and HQR data for the LHX pilots, with one exception, was +/- 1 number thus validating the methodology. This method was not at all popular within the contractor community. Initially, the contractors thought the approach to rigorous. Test team consensus was the words *Adequate* and *Desired* as defined in both ADS-33C and the Cooper-Harper Scale were synonymous. Therefore, data correlation was required.

8. CONCLUSIONS

The UCE is a method to determine the minimum response-type for a helicopter flight control system. The methodology is transferable to the UCE determination of a simulator. The evaluation methodology must be rigorous.

However, final results have two parts. First, the known simulator deficiencies. Second, the evaluation results. Engineers will determine the final results. Test Pilots are a team member in this process. Additionally, the Test Pilots must be well versed in ADS-33C. ADS-33C is here to stay. The future for Test Pilots and future aircraft controls architecture will rest within the principals of ADS-33C.

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B. Blanken, C. L., Hart, D. C., and Hoh, R. C., "Helicopter Control Response types for Hover and Low-Speed Near-Earth Task in Degraded Visual Conditions," 47th Annual Forum of the American Helicopter Society, Phoenix, Arizona, May 1991.

C. Hoh, R. C., "Pilot Briefing Notes, UCE Simulation on NASA Ames VMS", 12 August 1989.

Annex A.

The following definitions are from ADS-33C:

(2.1) Mission-Task-Element (MTE). An element of a mission treated as a handling qualities task. In ADS-33C all proposed missions are subdivided into Mission-Task-Elements.

(2.2) Response-Types. 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.).

(2.3) Near-Earth Operation. Flying operations sufficiently close to the ground, fixed objects on the ground, or near water so that flying is primarily accomplished with reference to outside objects.

(2.5) Extent of Divided Attention Operation. Some requirements are based on the time a pilot spends on tasks other than flying the rotorcraft.

(2.5.1) Fully Attended Operation. The pilot flying the rotorcraft can devote full attention to attitude and flight path control. Requirements for divided attention are minimal.

(2.5.2) Divided Attention Operation. The pilot flying the rotorcraft must perform non-control-related side-tasks for a moderate period of time.

(2.6) Speed Ranges. In the following definitions, ground speed means the speed with respect to a hover reference which may itself be moving, such as for shipboard operations.

(2.6.1) Hover. Hovering flight is defined as all operations occurring at ground speeds less than 15 knots (7.7 m/s).

(2.6.2) Low Speed. Low-speed flight is defined as all operations occurring at ground speeds between 15 and 45 knots (7.7 and 23 m/s).

(2.6.3) Forward Flight. Forward flight is defined as all operations with a ground speed greater than 45 knots (23 m/s).