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# Developing Modified ADS-33D Helicopter Maneuvers for the Shipboard Environment

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To the Graduate Council:

I am submitting herewith a thesis written by Philippe Catoire entitled "Developing Modified ADS-33D Helicopter Maneuvers for the Shipboard Environment." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Mr. Robert B. Richards, Major Professor

We have read this thesis and recommend its acceptance:

Dr. U. Peter Solies, Mr. Richard J. Ranaudo

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Dr. Anne Mayhew
Vice Provost and
Dean of Graduate Studies

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# DEVELOPING MODIFIED ADS-33D HELICOPTER MANEUVERS FOR THE SHIPBOARD ENVIRONMENT

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Philippe A. Catoire
May 2003

# ABSTRACT

The Office of the Secretary of Defense chartered the Joint Shipboard Helicopter Integration Process (JSHIP), Joint Test and Evaluation (JT&E) Program to improve Joint interoperability between U.S. Navy ships and U.S. Army/Air Force helicopters. One effort of the JSHIP JT&E Program was to improve the modeling and simulation tools and fidelity levels associated with conducting Joint shipboard helicopter operations, for both testing agencies and operational users. The UH-60A helicopter and the LHA class ship were identified as the highest priority helicopter-ship pair for operational forces and also allowed JSHIP to enhance models that currently existed. Enhancing the visual model of an LHA ship was a primary effort for the research and testing community in order to accurately replicate the shipboard visual cueing environment. Evaluating enhanced visual models in a research flight simulator in order to reduce actual shipboard flight testing or expand wind launch/recovery envelopes required the use of more aggressive and precise flight maneuvers than standard shipboard takeoffs and landings. The U.S. Army's Aeronautical Design Standard 33D (ADS-33D) contained flight test industry accepted maneuvers of sufficient aggressiveness and precision, but were not designed for, or intended to be flown from the deck of a ship at sea.

The methodology and procedure used to modify selected ADS-33D flight maneuvers so that they could safely be executed aboard an LHA class ship is presented in this thesis, along with the final maneuver descriptions, locations, and flight tolerances. The results of the shipboard test program and follow-on simulator assessment are not presented here, as they fall outside the scope of this thesis. However, conclusions from the at-sea flight tests relating to development of the modified ADS-33D were included. The flight test philosophy, methodology, and lessons learned while developing the modified ADS-33D maneuvers for the shipboard environment are the primary conclusions drawn.

# PREFACE

A large percentage of the data contained in this thesis was obtained during tests conducted by the Joint Shipboard Helicopter Integration Process (JSHIP), Joint Test and Evaluation (JT&E) Program. The research, results, conclusions, and recommendations presented are the opinion of the author and are not an official position of the United States Department of Defense, the Office of the Secretary of Defense, the United States Navy, the United States Army, or the JSHIP JT&E Program office.

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Chapter Page

# LIST OF FIGURES

# LIST OF ABBREVIATIONS AND SYMBOLS

| Abbreviation/symbol | Definition |
|---|---|
| ° | degree(s) |
| ADS-33D | Aeronautical Design Standard number 33D |
| ADS-33E | Aeronautical Design Standard number 33E |
| BIUG | Background Information and User's Guide |
| CG | Center of gravity |
| DAST | Dedicated At-Sea Test |
| DIPES | Deck Interface Pilot Effort Scale |
| DOF | Degree of freedom |
| DGPS | Differential Global Positioning System |
| DVE | Degraded visual environment |
| FLIR | Forward looking infrared |
| ft | foot, or feet |
| DGPS | Differential Global Positioning System |
| GVE | Good visual environment |
| HQR | Handling qualities rating |
| IRIG | Inter-Range Instrumentation Group |
| JSHIP | Joint Shipboard Helicopter Integration Process |
| JT&E | Joint Test and Evaluation |
| kph | kilometers per hour |
| lb | pound(s) |
| LCAC | Landing Craft Air Cushion |
| LHA | Landing Helicopter Assault (Amphibious Assault Ship) |
| LHD | Landing Helicopter Deck (Amphibious Assault Ship) |
| MAGTF | Marine Air Ground Task Force |
| MCS | Mine Countermeasure Support Ship |
| MTE | Mission Task Element (flight test maneuver) |
| M&S | Modeling and simulation |
| NAS | Naval Air Station |
| NASA | National Aeronautics and Space Administration |
| NATOPS | Naval Air Training and Operating Procedures Standardization |
| NOE | Nap of the Earth |
| NVG | Night Vision Goggle |
| OSD | Office of the Secretary of Defense |
| PCM | Pulse code modulation |
| RAM | Random access memory |
| sec | second(s) |
| TN | Technical Note |
| UCE | Usable Cue Environment |
| USS | United States Ship |
| VCR | Visual Cue Rating |
| VMS | Vertical Motion Simulator |

# CHAPTER I
# INTRODUCTION

## BACKGROUND

The use of modeling and simulation (M&S) to reduce the amount and associated costs of actual aircraft flight testing has been an accepted industry and government practice for many years. However, any M&S used to replace or supplement actual flight testing must initially be validated with some type of actual flight test data to verify the results of the simulation. Some of the most difficult M&S challenges in aviation are found when trying to replicate the aircraft handling qualities and pilot workload associated with a specific flight task. The more difficult and complex the flight task, the higher the pilot workload and the more difficult it is to model and simulate correctly, primarily due to the variable nature of human responses.

In 1998, the Joint Shipboard Helicopter Integration Process (JSHIP) Joint Test and Evaluation (JT&E) Program was chartered by the Office of the Secretary of Defense (OSD) to improve the interoperability and compatibility of joint helicopters (Army and Air Force) aboard Navy ships. These improvements were to come from hardware/ material changes, procedures and training improvements, and M&S enhancements for both the aircraft testing and operational user communities. A primary JSHIP M&S goal was to validate the concept of augmenting actual shipboard launch/recovery flight test data with man-in-the-loop simulator flight test data conducted in a research quality flight simulator. While eight different models were identified for the complete aircraft-ship interface, the visual display model was judged by the author and JSHIP test team to be one of the most critical. The visual model had to be sufficient to provide all needed visual cues to the pilot while operating 70 ft above the surface of the water with no other visual cues, and possibly no horizon, under day, night, and Night Vision Goggle (NVG) flight modes.

Determining the visual model fidelity level needed to conduct shipboard launch/ recovery envelope expansion testing in a simulator required more aggressive and precise flight maneuvers than simple shipboard approaches, landings and takeoffs. Normal shipboard landings and takeoffs are relatively benign in nature, but can become substantially more difficult under high wind and ship motion conditions. When the turbulence associated with landing near the ship superstructure under high wind conditions is also factored in, the pilot's flight control strategy for maneuvering the aircraft becomes much more aggressive in order to maintain position relative to the ship.

Using accepted flight test methodology and standardized flight maneuvers was important in order to gain acceptance from the flight test community. The U.S. Army's Aeronautical Design Standard 33D (ADS-33D) contains a series of mission task elements, or flight maneuvers, designed to evaluate aircraft handling qualities during aggressive and/or precise flight maneuvers. The ADS-33D flight maneuvers have specific tolerances, or deviations, that are used to define the aircraft flying qualities and pilot workload associated with each maneuver. The maneuver descriptions and tolerances also differentiate between flying in a good visual environment and a degraded visual environment to allow for conducting the same, or similar, maneuvers under different conditions. A good visual environment can be described as daytime, with good visual cues to determine aircraft velocity, attitude and altitude. The good visual environment may also be supplemented with reference markers to aid in conducting the maneuver. The degraded visual environment can be described as anything less than the good visual environment, which can range from daytime operations with poor visual cues (open ocean, desert, etc.) to night operations, with or without the use of additional visual cueing aids (NVG, FLIR, etc.). The ADS-33D flight maneuvers served as established and accepted flight test maneuvers and methodology from which modified shipboard maneuvers could be developed.

The development of the modified shipboard ADS-33D maneuvers was needed by the JSHIP JT&E program to establish a link between flying the aircraft in the real shipboard environment and flying a research grade flight simulator attempting to replicate the same environment. This paper deals with the actual development and modification of the ADS-33D maneuvers, but does not include results of the flight or simulator evolutions flown aboard the LHA class ship or in the NASA Ames Vertical Motion Simulator.

## OBJECTIVE

The primary objective in developing the modified ADS-33D maneuvers for the shipboard environment was to modify established and accepted flight test maneuvers and methodology in order to safely conduct them on the confined space of a U.S. Navy LHA class ship. In a much broader sense, the modified ADS-33D maneuvers were needed to characterize the shipboard visual environment and evaluate the same flight test maneuvers in both real life and the simulator environment.

## SHIP DESCRIPTION

The ship chosen for the test was a U.S. Navy Landing Helicopter Assault (LHA) class ship. A computer generated model of an LHA class ship is shown in Figure 1. LHA ships are a class of amphibious assault ships intended to accommodate and deploy elements of a Marine Air Ground Task Force (MAGTF). The LHA supports extensive helicopter operations from the flight deck, which is 820 ft long, 118 ft wide, and approximately 60 ft above the ship's waterline. The flight deck has 10 marked helicopter landing spots and can support day, night, or Night Vision Goggle (NVG) flight operations. A flight deck dimensional drawing and aviation facilities summary of LHA 2 (USS SAIPAN) is presented in Figure 2. LHA class ships are 834 ft long, 132 ft wide, have a 26 ft draft, and displace approximately 39,300 tons fully loaded. Two boilers provide steam to drive two geared turbine engines, producing nearly 70,000 shaft

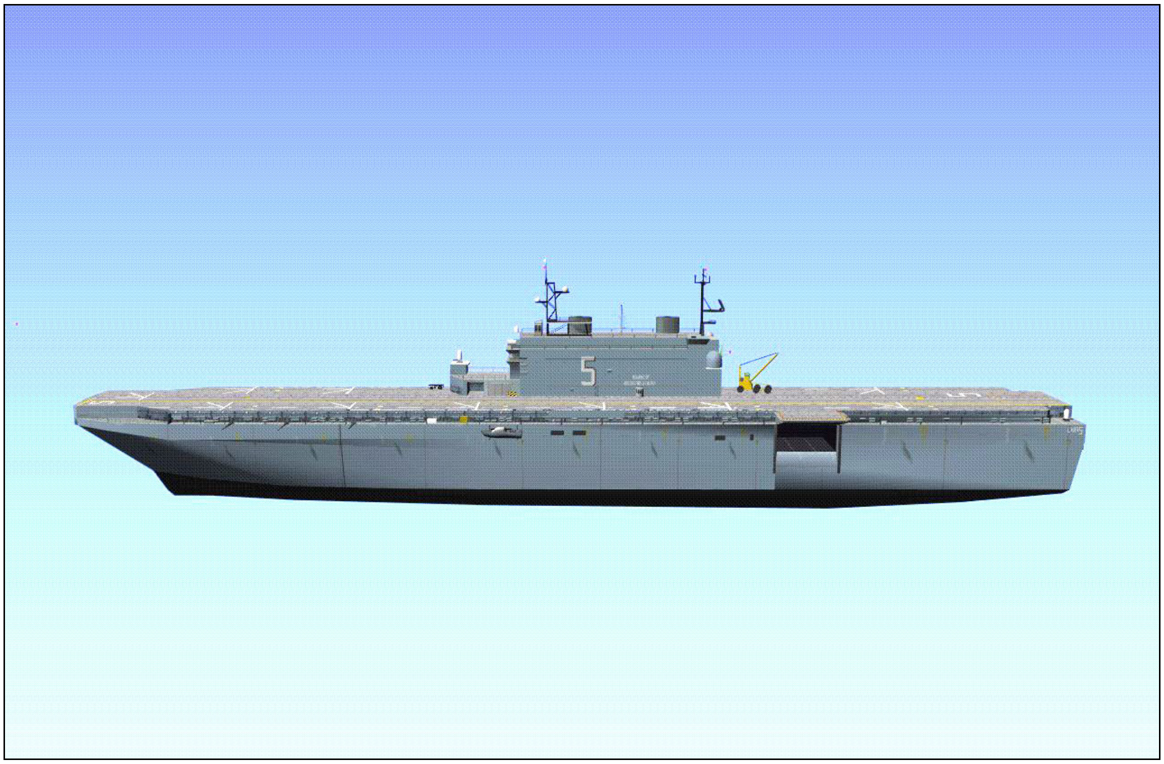
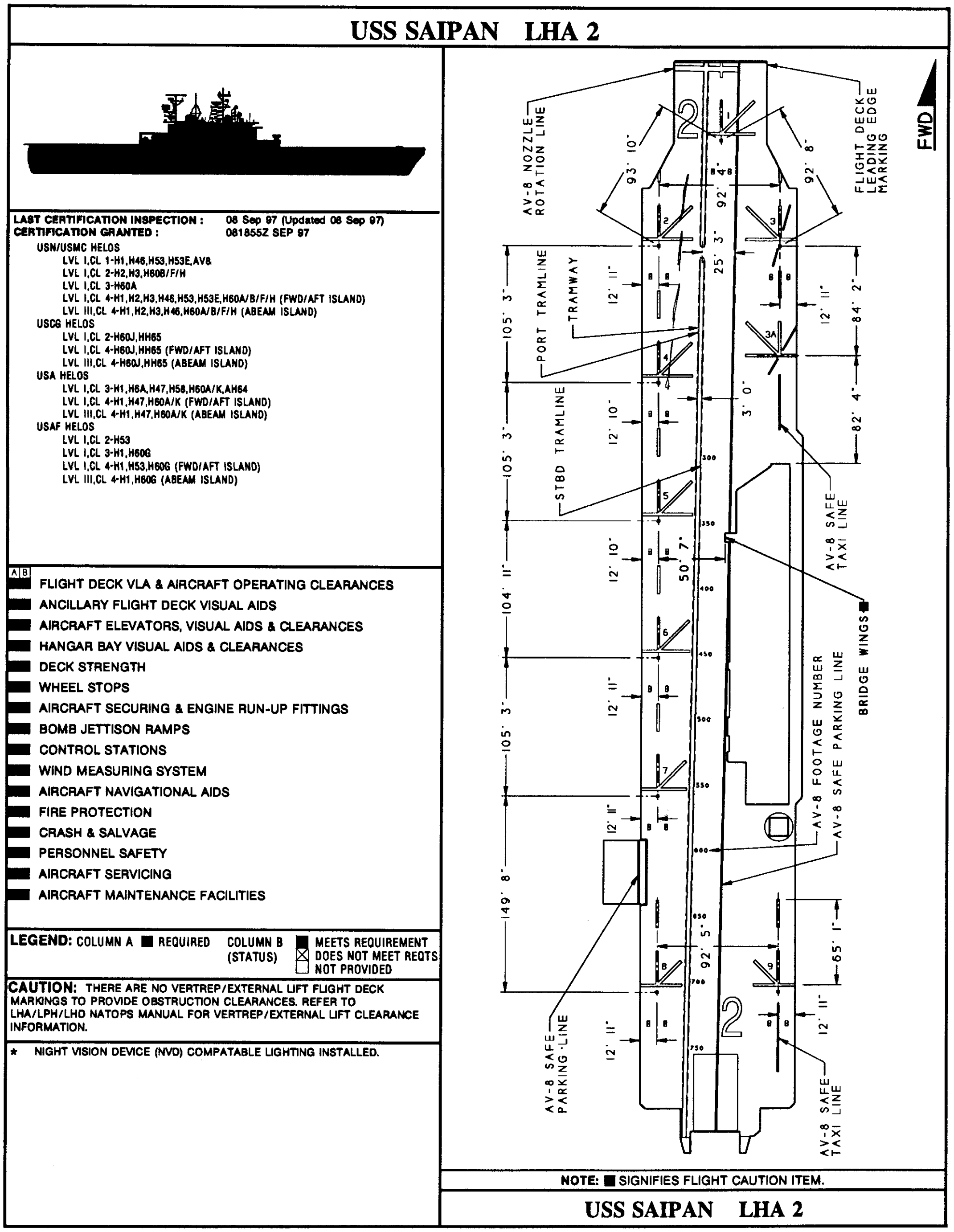


Figure 1. Computer Generated Model of an LHA Class Ship

Source: *Dedicated At-Sea Test 1A, Detailed Activity Test Plan* (2000).



**USS SAIPAN LHA 2**

**LAST CERTIFICATION INSPECTION :** 08 Sep 97 (Updated 08 Sep 97)
**CERTIFICATION GRANTED :** 081855Z SEP 97

- USN/USMC HELOS
  - LVL I,CL 1-H1,H46,H53,H53E,AV8
  - LVL I,CL 2-H2,H3,H60B/F/H
  - LVL I,CL 3-H60A
  - LVL I,CL 4-H1,H2,H3,H46,H53,H53E,H60A/B/F/H (FWD/AFT ISLAND)
  - LVL III,CL 4-H1,H2,H3,H46,H60A/B/F/H (ABEAM ISLAND)
- USCG HELOS
  - LVL I,CL 2-H60J,HH65
  - LVL I,CL 4-H60J,HH65 (FWD/AFT ISLAND)
  - LVL III,CL 4-H60J,HH65 (ABEAM ISLAND)
- USA HELOS
  - LVL I,CL 3-H1,H6A,H47,H58,H60A/K,AH64
  - LVL I,CL 4-H1,H47,H60A/K (FWD/AFT ISLAND)
  - LVL III,CL 4-H1,H47,H60A/K (ABEAM ISLAND)
- USAF HELOS
  - LVL I,CL 2-H53
  - LVL I,CL 3-H1,H60G
  - LVL I,CL 4-H1,H53,H60G (FWD/AFT ISLAND)
  - LVL III,CL 4-H1,H60G (ABEAM ISLAND)

| A | B | |
|---|---|---|
| ■ | ■ | FLIGHT DECK VLA & AIRCRAFT OPERATING CLEARANCES |
| ■ | ■ | ANCILLARY FLIGHT DECK VISUAL AIDS |
| ■ | ■ | AIRCRAFT ELEVATORS, VISUAL AIDS & CLEARANCES |
| ■ | ■ | HANGAR BAY VISUAL AIDS & CLEARANCES |
| ■ | ■ | DECK STRENGTH |
| ■ | ■ | WHEEL STOPS |
| ■ | ■ | AIRCRAFT SECURING & ENGINE RUN-UP FITTINGS |
| ■ | ■ | BOMB JETTISON RAMPS |
| ■ | ■ | CONTROL STATIONS |
| ■ | ■ | WIND MEASURING SYSTEM |
| ■ | ■ | AIRCRAFT NAVIGATIONAL AIDS |
| ■ | ■ | FIRE PROTECTION |
| ■ | ■ | CRASH & SALVAGE |
| ■ | ■ | PERSONNEL SAFETY |
| ■ | ■ | AIRCRAFT SERVICING |
| ■ | ■ | AIRCRAFT MAINTENANCE FACILITIES |

**LEGEND:** COLUMN A ■ REQUIRED COLUMN B (STATUS) ■ MEETS REQUIREMENT ☒ DOES NOT MEET REQTS ☐ NOT PROVIDED

**CAUTION:** THERE ARE NO VERTREP/EXTERNAL LIFT FLIGHT DECK MARKINGS TO PROVIDE OBSTRUCTION CLEARANCES. REFER TO LHA/LPH/LHD NATOPS MANUAL FOR VERTREP/EXTERNAL LIFT CLEARANCE INFORMATION.

* NIGHT VISION DEVICE (NVD) COMPATABLE LIGHTING INSTALLED.

NOTE: ■ SIGNIFIES FLIGHT CAUTION ITEM.

**USS SAIPAN LHA 2**

Figure 2. LHA 2 (USS SAIPAN) Flight Deck Markings

Source: *Shipboard Aviation Facilities Resume* (1999).

horsepower, which propel the ship via twin screws to speeds in excess of 20 knots. Bilge keels provide passive control of ship motion. The ship also has a large below-decks aircraft hangar, two aircraft elevators, several below-decks vehicle storage areas, berthing for over 1,700 troops, extensive medical facilities, and a floodable well deck for small boats or large Landing Craft Air Cushion (LCAC) hovercraft.[1] A more complete description of LHA class ships can be found in the LHA/LHD NATOPS manual.

## AIRCRAFT DESCRIPTION

The aircraft chosen for the test was the UH-60A Black Hawk helicopter, pictured in Figure 3. The UH-60A is a two pilot, twin engine, utility helicopter manufactured by Sikorsky Aircraft, a division of United Technologies. The UH-60A is the initial production design and was in production until 1989. The aircraft's primary missions are troop transport and combat support, aeromedical evacuation, repositioning of reserves, and command and control. It is designed to carry a crew of three, plus 11 combat-equipped troops, at a maximum gross weight of 22,000 lb. The power plant consists of two General Electric T700-GE-700 turboshaft engines, operating in parallel, with a maximum installed rating (standard day, sea level) of 1,560 shaft horsepower each. The engines drive a four-bladed, fully articulated main rotor (53.7 ft diameter) and a 20° canted tail rotor (11 ft diameter). The flight controls are hydraulically boosted, supplemented by an automatic flight control system to enhance the aircraft static and dynamic stability characteristics. The landing gear is non-retractable, consisting of two main gear assemblies and a tail wheel assembly.[2] A more detailed description of the test aircraft can be found in the operator's manual. The actual aircraft used for both the ADS-33D shipboard maneuver development and the actual at-sea flight tests was a specially instrumented JUH-60A (Army serial number 88-26015) from the U.S. Army Aviation Technical Test Center. A description of the aircraft instrumentation system is presented in the Appendix.

## SIMULATOR DESCRIPTION

The research flight simulator used for the evaluation was the Vertical Motion Simulator (VMS), located at the NASA Ames Flight Research Center in Moffett Field, CA. The VMS is a six degree of freedom (DOF) motion based simulator that provides near real time, high fidelity cueing for the evaluation pilot. The simulator cueing systems included: visual scene presentations, sustained dynamic forces, high frequency vibrations, aircraft state information, flight control positioning and force feel, and simulated aircraft and environmental audio. The most impressive feature of the VMS is the motion system, which was designed to duplicate the sustained force cueing associated with dynamic aircraft maneuvers. The VMS is the world's largest motion based simulator, but cannot

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[1] Dedicated At-Sea Test 1, Detailed Test Activity Plan (1999) p. 3-2.

[2] Ibid, p. 3-1.

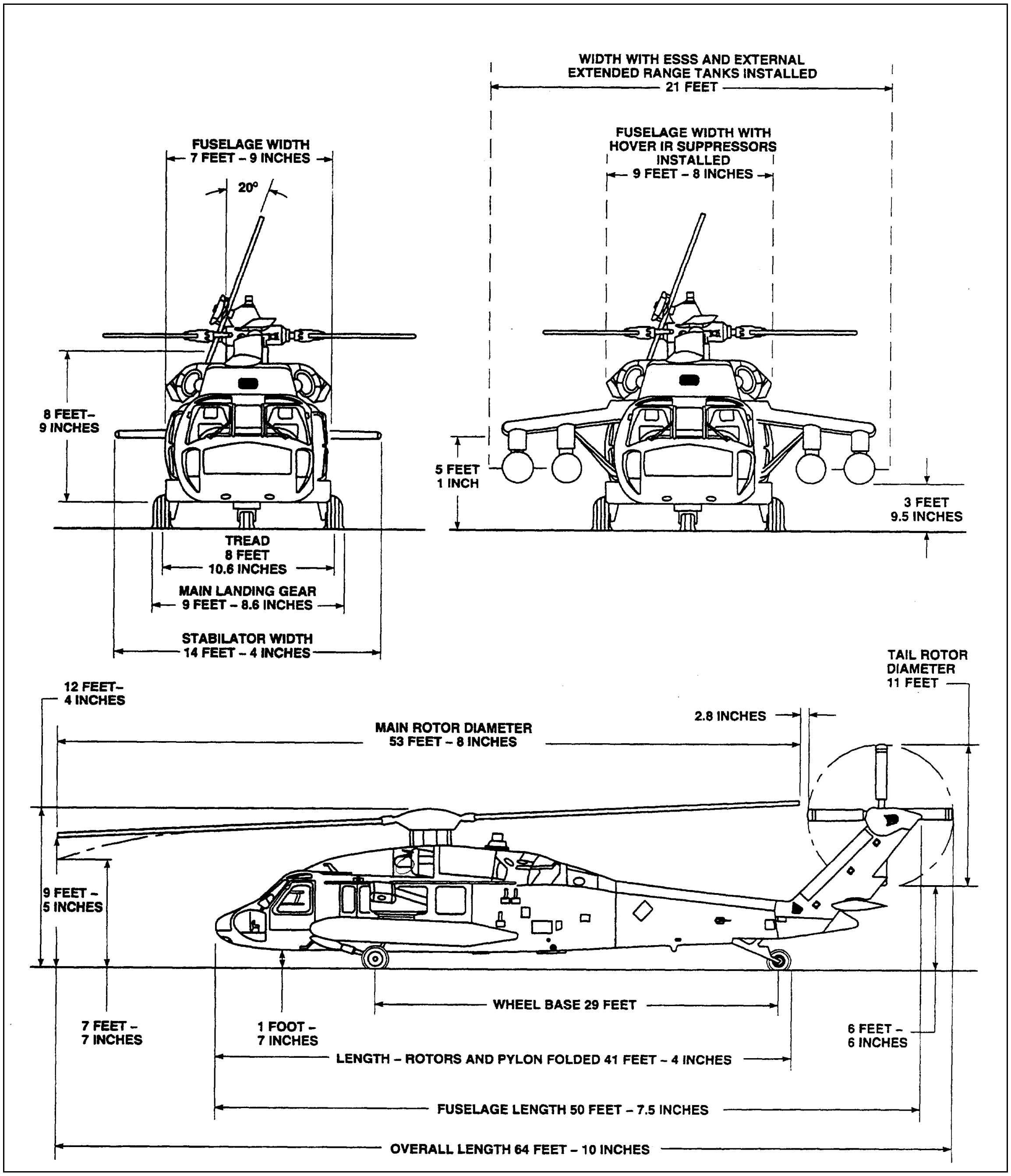

Figure 3. UH-60A Blackhawk Helicopter Three View Drawing

Source: *Operator's Manual for UH-60A, UH-60L and EH-60A Helicopters* (1996).

sustain large motion cueing in one direction for long periods of time due to translational limits (linear and angular) of the system. The six DOF motion system allows the VMS cab to translate vertically, laterally, and longitudinally along with pitch, roll, and yaw – all occurring simultaneously.[3] Table 1 presents the VMS nominal motion limits. Figure 4 shows a close-up of the VMS cab and lateral track, while Figure 5 shows a time lapse photo of the VMS in motion.

Table 1. VMS Nominal Motion Limits

| **Axis** | **Displacement** | **Velocity** | **Acceleration** |
|---|---|---|---|
| Vertical | ± 30 ft | 16 ft/sec | 24 ft/sec$^2$ |
| Lateral | ± 20 ft | 8 ft/sec | 16 ft/sec$^2$ |
| Longitudinal | ± 4 ft | 4 ft/sec | 10 ft/sec$^2$ |
| Pitch | ± 18° | 40°/sec | 115°/sec$^2$ |
| Roll | ± 18° | 40°/sec | 115°/sec$^2$ |
| Yaw | ± 24° | 40°/sec | 115°/sec$^2$ |

Source: *Baseline Test and Evaluation Report for the DIMSS of the NASA Ames VMS* (1999).

Figure 4. NASA Ames Vertical Motion Simulator Cab and Track

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[3] Baseline Test & Evaluation Report for the DIMSS of the NASA Ames VMS (1999) p. 1.

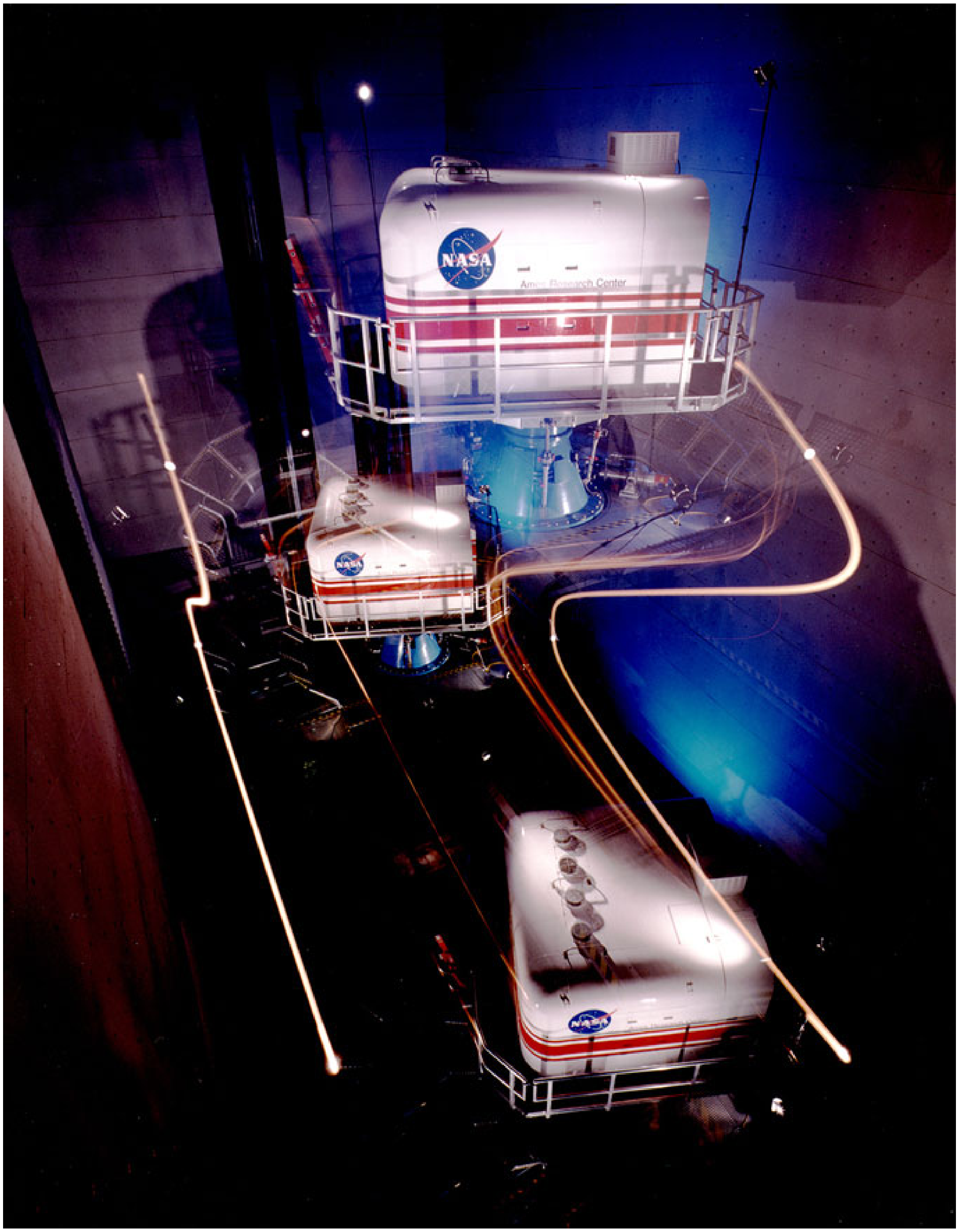

Figure 5. NASA Ames Vertical Motion Simulator Time Lapse Photo

Source: NASA Ames Flight Research Center.

# CHAPTER II
# METHODOLOGY

## EVALUATING AIRCRAFT HANDLING QUALITIES

Aircraft handling qualities are normally evaluated by test pilots specifically trained for such tasks. For many years, the NASA Cooper-Harper Handling Qualities Rating (HQR) scale published and described in NASA Technical Note D-5153 has been the standard for assessing aircraft characteristics and the pilot workload required to perform the task. The HQR scale is presented in Figure 6 and has ten ratings, from HQR 1 (excellent/highly desirable aircraft characteristics, pilot compensation not a factor for desired performance), to HQR 10 (aircraft characteristics exhibit major deficiencies, aircraft control will be lost during some portion of required operations)[4].

The process of evaluating aircraft handling qualities begins with development of a specific task or flight maneuver, then assigning desired and adequate performance tolerances in each area. For example, the maneuver may be to maintain a stationary hover over a fixed spot on the ground, while the performance tolerances may include: height control, fore/aft and lateral drift control, heading control, and possibly a minimum time to maintain the specified tolerances. Both desired and adequate performance tolerances are set based on the aircraft type and mission expected to be performed. Therefore, the same maneuver can have very different desired/adequate performance tolerances when looking at different aircraft and missions. Pilot workload is also a major influence on the HQR for a specific maneuver. The workload definitions are by no means specific (minimal, moderate, considerable, etc.), but have been proven in numerous studies and flight test programs as adequate descriptors for pilot workload. The final HQR is a combination of meeting performance tolerances (desired, adequate, or not meeting adequate) and the pilot workload associated with that tolerance. Maneuvers are normally flown several times to allow the pilot sufficient opportunity to achieve the best performance, which normally also results in the highest workload for the maneuver. For example, if a specific maneuver was flown to adequate tolerance, but pilot workload was only minimal, the maneuver should be re-flown until either desired performance is met or increased pilot workload cannot achieve desired performance.

ADS-33D further categorizes the HQR scale by defining “Levels” of flying qualities. There are three defined “Levels” of flying qualities: Level 1, Level 2, and Level 3. Each “Level” contains a grouping of HQR scale ratings. Level 1 contains HQR’s 1-3, Level 2 contains HQR’s 4-6, and Level 3 contains HQR’s 7 and 8. HQR’s 9 and 10 are not assigned to a “Level” of flying qualities, as these ratings indicate major aircraft deficiencies that will result in the loss of aircraft control.[5] Figure 6 shows the different “Levels” as they relate to the HQR scale.

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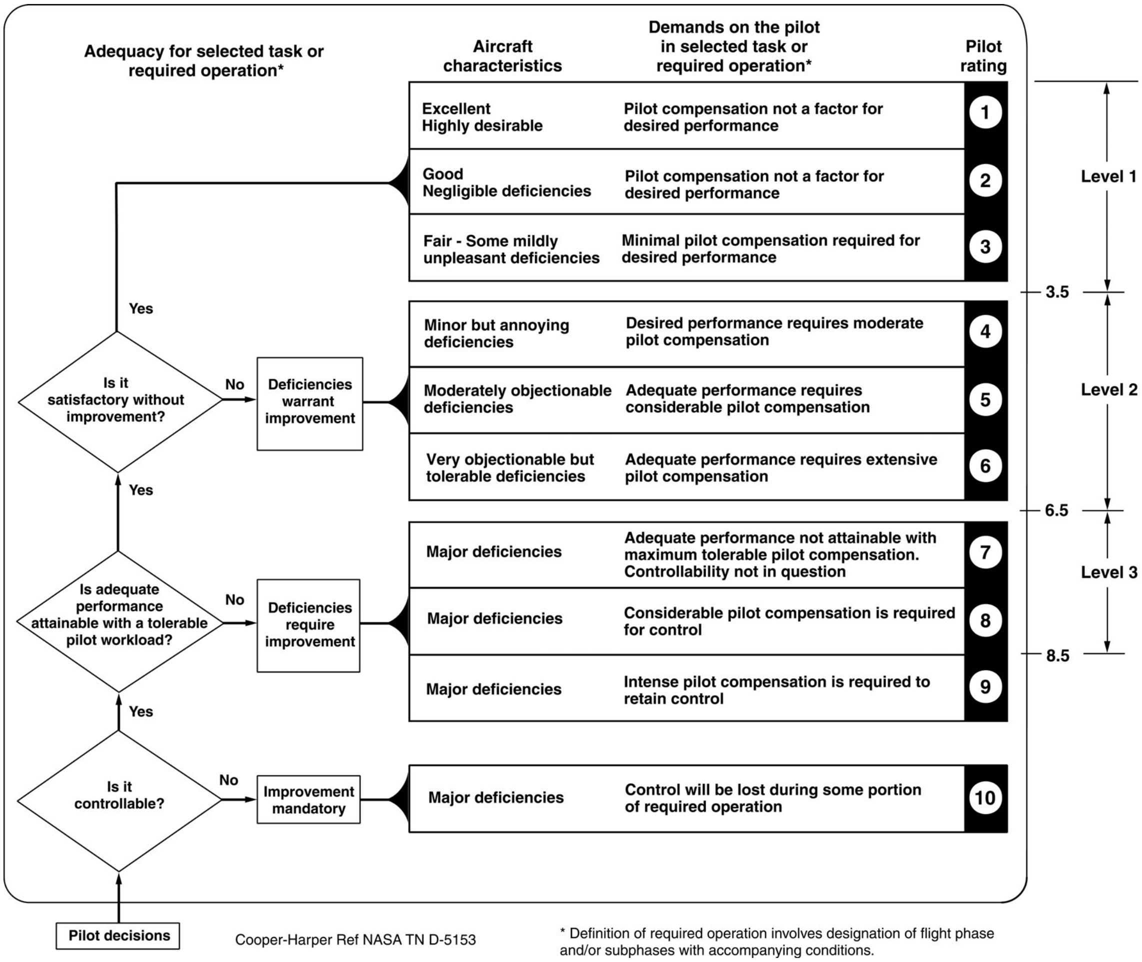
[4] Cooper, G. E. and Harper, R. P. (1969) p. 8-14.

[5] <u>Handling Qualities Requirements for Military Rotorcraft</u>. ADS-33D-PRF (1996) p. 3.



Cooper-Harper Ref NASA TN D-5153

* Definition of required operation involves designation of flight phase and/or subphases with accompanying conditions.

Figure 6. Cooper-Harper Handling Qualities Rating (HQR) Scale

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

## EVALUATING SHIPBOARD LANDINGS AND TAKEOFFS

Historically, assigning HQR's to shipboard landings and takeoffs has been very difficult to accomplish because the large variations in shipboard environmental conditions and different flight deck markings and dimensions (even among ships in the same class) make determining valid desired and adequate tolerances impractical. For most large deck ships, landing within ± 5-7 ft of the intended point and within ± 5-10° of the intended heading are acceptable – but this is not always true. The same criteria cannot be applied to smaller deck ships with more confined landing areas, or even to specific landing spots aboard large deck ships. The pilot could end up having to define separate adequate and desired tolerances for each spot on every ship. This method would be virtually impossible to implement and does not lend itself to comparing the relative difficulty of landings or takeoffs among various spots on the same ship, or between ship classes. The primary areas of interest for shipboard landings and takeoffs are pilot workload and if the evolution can be conducted safely by the typical operational pilot. The Deck Interface Pilot Effort Scale (DIPES), shown in Figure 7, was developed for launch/recovery envelope expansion testing that evaluates overall pilot workload and has the test pilot subjectively rate if the typical operational pilot could safely conduct the maneuver.

## USABLE CUE ENVIRONMENT AND VISUAL CUE RATINGS

ADS-33D contains methodology and procedures for determining the Usable Cue Environment (UCE) that the aircraft is to operate in. For actual ADS-33D UCE determination, a Level 1 flying qualities aircraft (when operated in a very good visual cueing environment) is required.[6] Six different specified mission task elements, or maneuvers, are then flown over set courses with pre-defined desired and adequate tolerances. In addition to assigning an HQR for each maneuver, three different Visual Cue Ratings (VCR) are assigned for each maneuver: attitude (aircraft), horizontal translation rate (fore/aft and lateral), and vertical translation rate. Each VCR is rated on the same scale from 1-5 (Good-Poor), with definitions provided for Good (VCR 1) cues, Fair (VCR 3) cues, and Poor (VCR 5) cues.[7] Figure 8 shows the VCR scale and associated definition of cues.

Determining the actual Usable Cue Environment requires plotting the VCR's onto the UCE Environment graph shown in Figure 9. The translational rate VCR is the average of the horizontal and vertical translation rate VCR's.[8] The Good Visual Environment (GVE) is defined as UCE = 1, while the Degraded Visual Environment (DVE) is defined as UCE > 1. ADS-33D uses UCE level to define required aircraft response types throughout the helicopter's flight envelope.

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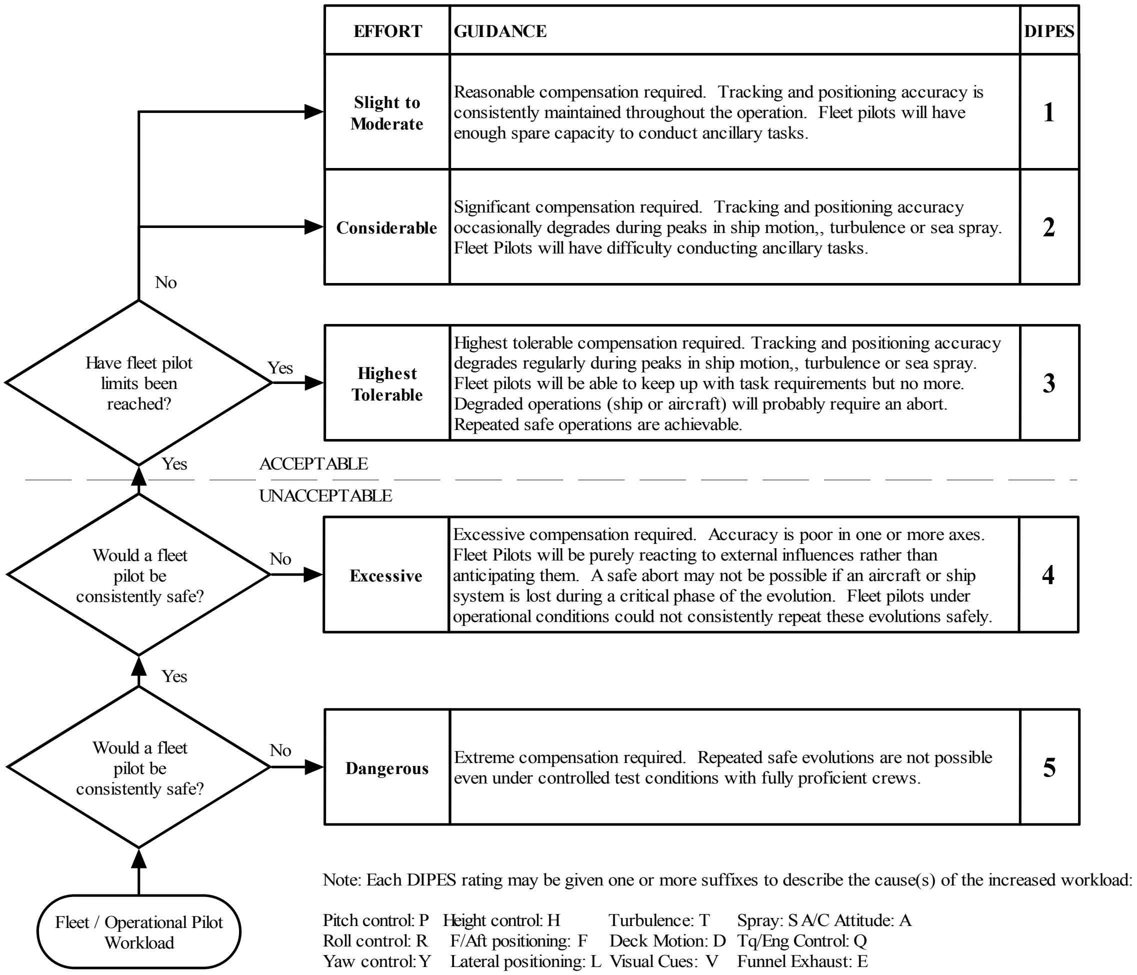
[6] Ibid. p. 12.

[7] Ibid. p. 13.

[8] Ibid.



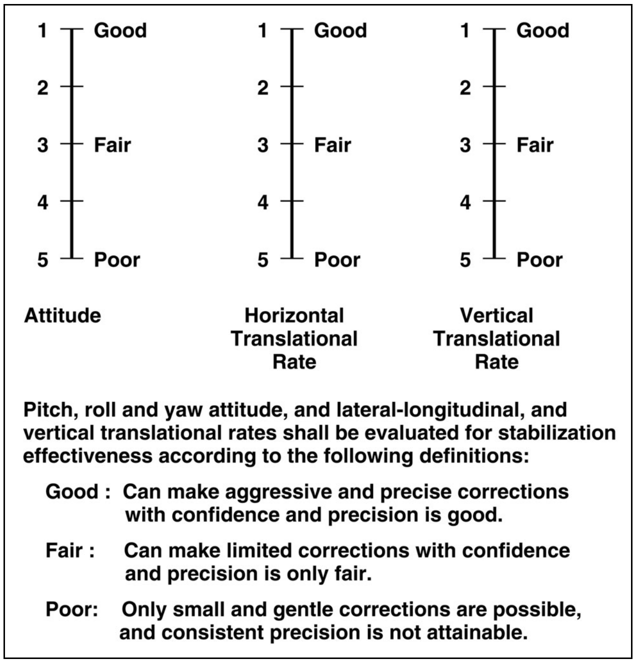
| EFFORT | GUIDANCE | DIPES |
|---|---|---|
| **Slight to Moderate** | Reasonable compensation required. Tracking and positioning accuracy is consistently maintained throughout the operation. Fleet pilots will have enough spare capacity to conduct ancillary tasks. | **1** |
| **Considerable** | Significant compensation required. Tracking and positioning accuracy occasionally degrades during peaks in ship motion,, turbulence or sea spray. Fleet Pilots will have difficulty conducting ancillary tasks. | **2** |
| **Highest Tolerable** | Highest tolerable compensation required. Tracking and positioning accuracy degrades regularly during peaks in ship motion,, turbulence or sea spray. Fleet pilots will be able to keep up with task requirements but no more. Degraded operations (ship or aircraft) will probably require an abort. Repeated safe operations are achievable. | **3** |
| **Excessive** | Excessive compensation required. Accuracy is poor in one or more axes. Fleet Pilots will be purely reacting to external influences rather than anticipating them. A safe abort may not be possible if an aircraft or ship system is lost during a critical phase of the evolution. Fleet pilots under operational conditions could not consistently repeat these evolutions safely. | **4** |
| **Dangerous** | Extreme compensation required. Repeated safe evolutions are not possible even under controlled test conditions with fully proficient crews. | **5** |

Note: Each DIPES rating may be given one or more suffixes to describe the cause(s) of the increased workload:

Pitch control: P Height control: H Turbulence: T Spray: S A/C Attitude: A
Roll control: R F/Aft positioning: F Deck Motion: D Tq/Eng Control: Q
Yaw control: Y Lateral positioning: L Visual Cues: V Funnel Exhaust: E

Figure 7. Deck Interface Pilot Effort Scale (DIPES)

Source: *Dedicated At-Sea Test 1 (DAST 1), Detailed Activity Test Plan (DTAP)* (1999).



**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 8. Visual Cue Rating (VCR) Scale

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

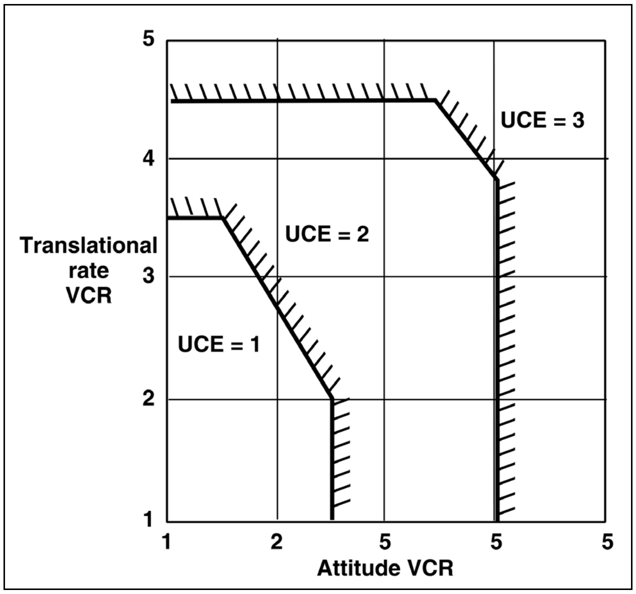


Figure 9. Definition of Usable Cue Environments

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

## SPECIFIC METHODOLOGY USED

The purpose of conducting the flight test program was to match the visual cueing environment and pilot workload in the research flight simulator to that of actual shipboard flight-testing. Therefore, the overarching methodology used by the author and test team was to match the Visual Cue Ratings (VCR) and Handling Qualities Ratings (HQR) for each maneuver. The author used the Cooper-Harper HQR scale exclusively to evaluate aircraft handling qualities and pilot workload/compensation. The author determined that the DIPES scale was not specific enough to evaluate aircraft handling qualities or the visual cueing environment.

ADS-33D UCE methodology was used, but was modified since the actual shipboard UCE was never determined, nor was it desired. First, the intent was not to define the actual shipboard UCE - only to match the shipboard visual cueing environment with the simulator visual cueing environment. Second, the author did not use a Level 1 flying qualities aircraft (required by ADS-33D) and modified both the maneuver descriptions and performance tolerances in order to perform the shipboard maneuvers. Therefore, the overarching methodology used by the author and test team was to match the Visual Cue Ratings (VCR) and Handling Qualities Ratings (HQR) for each maneuver. ADS-33D also calls for the use of markers and cones to represent the course to be flown and desired/adequate performance tolerances. This was not done for two reasons. First, it would have been impractical, if not impossible for some maneuvers, to place the markers and cones on the surface of the flight deck due to extremely limited space constraints. Second, and most important, replicating the visual environment of the ship was the primary goal, so the addition of markings and cones on the ship flight deck could adversely affect the VCR's for both the ship and the simulator. To the greatest extent possible, existing ship flight deck markings were used for all maneuvers. Some additional markings were required for the Pirouette maneuver, which were made with chalk and will be discussed in the next chapter during modification of the maneuver.

## MANEUVER SELECTION

ADS-33D specifies six maneuvers to be flown when conducting UCE determination testing. The six specified maneuvers are: Hover, Landing, Pirouette, Bob-Up and Bob-Down, Acceleration and Deceleration, and Sidestep. The Hover, Landing and Pirouette maneuvers are considered precision tasks, while the Bob-Up and Bob-Down, Acceleration and Deceleration, and Sidestep are considered aggressive tasks.[9] Since night operations are considered a degraded visual cueing environment, the task descriptions and performance parameters for each maneuver in the degraded visual cueing environment formed the basis for the NVG maneuvers. A description of each initial maneuver, including associated desired and adequate performance tolerances, is included next in this chapter.

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[9] Ibid. p. 12.

## MANEUVER DESCRIPTIONS

The following maneuver description for each maneuver formed the initial point of departure for developing the unique shipboard maneuver descriptions, and desired/adequate tolerances. Where applicable, the initial NVG performance tolerances are also presented. These descriptions and tolerances are taken from the ADS-33D Performance Specification. The description of the test course has been omitted from each maneuver, as they had no bearing on the development of the modified maneuvers and were not used for the flight test development. Since the author and test team determined that all maneuvers would be performed in winds less than five knots (see Chapter III), all references to specific wind conditions have also been omitted.

### Hover Maneuver

The hover maneuver has two basic objectives:

- Check the ability to transition from translating flight to a stabilized hover with precision and a reasonable amount of aggressiveness.
- Check the ability to maintain a precise position, heading, and altitude.

Description of the maneuver. Initiate the maneuver at a ground speed of between 6-10 knots, at an altitude less than 20 ft, with the nose of the aircraft oriented in the direction of the final hover, and the target hover point oriented approximately 45° relative to the aircraft heading. 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 Figure 10 for a top view of the ADS-33D Hover maneuver.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- 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 creep up to the final position. Attain a stabilized hover within 3 (8) sec (NVG: within 10 (20) sec) of the initiation of the deceleration.
- Maintain a stabilized hover for at least 30 sec.
- Maintain the longitudinal and lateral position within ± 3 ft (± 6 ft) [NVG: position within ± 3 ft (± 8 ft)] of a point on the ground and altitude within ± 2 ft (± 4 ft).
- Maintain heading within ± 5° (± 10°).
- There shall be no objectionable oscillations in any axis either during the stabilized hover, or the transition to a hover. This parameter applies only to desired performance.

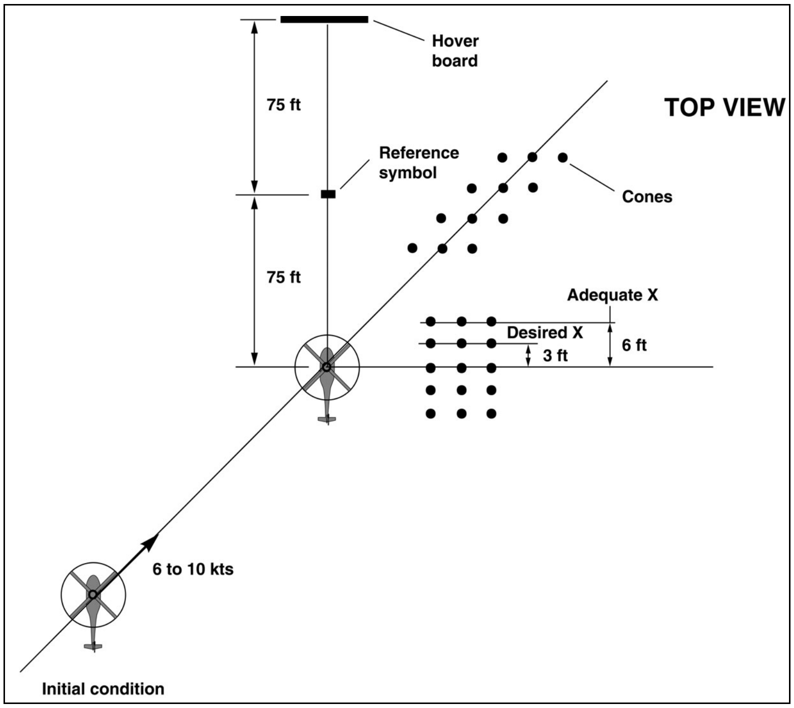


Figure 10. ADS-33D Hover Maneuver Course

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

Landing Maneuver

The Landing maneuver has two basic objectives:

- Check the ability to precisely control the rotorcraft position during the final descent to a precision landing point.
- Check the pilot-vehicle dynamics when the pilot is forced into a tight compensatory tracking behavior.

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

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Accomplish the landing with a smooth continuous descent, with no objectionable oscillations. This parameter applies only to desired performance.

- Once altitude is below 10 ft, complete the landing within 10 sec (NVG: within 15 sec). This parameter applies only to desired performance.
- Touch down laterally within ± 0.5 ft (± 1.5 ft) [NVG: laterally within ± 3 ft - desired and adequate performance tolerance] and longitudinally within ± 1 ft (± 3 ft) [NVG: longitudinally within ± 6 ft - desired and adequate performance tolerance] of a designated reference point.
- Align rotorcraft touchdown heading within ± 5° (± 10°) [NVG: ± 10° (± 15°)] of the reference heading.
- The 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 ground. This parameter applies only to desired performance.

Pirouette Maneuver

The Pirouette maneuver has one basic objective:

- Check the ability to accomplish precision control the rotorcraft simultaneously in the pitch, roll, yaw, and heave axes.

Description of the 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 an altitude of approximately 10 ft. Accomplish a lateral translation around the circle, keeping the nose of the rotorcraft pointed at the center of the circle and the circumference of the circle under a selected point on the helicopter. Terminate the maneuver with a stabilized hover over the starting point. Perform the maneuver in both directions. See Figure 11 for a pictorial view of the ADS-33D Pirouette maneuver.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Maintain a selected reference point on the rotorcraft within ± 10 ft (± 15 ft) of the circumference of the circle.
- Maintain altitude within ± 3 ft (± 10 ft) [NVG: within ± 4 ft (± 10 ft)].
- Maintain heading so that the nose of the rotorcraft points at the center of the circle within ± 10° (± 15°).
- Complete the circle and arrive back over the starting point within 45 sec (60 sec) [NVG: within 60 sec (75 sec)]. Maintain essentially constant lateral groundspeed throughout the maneuver.
- Achieve a stabilized hover over the starting point ± 10 ft (± 15 ft) within 5 sec (10 sec) [NVG: within 10 sec (20 sec)].

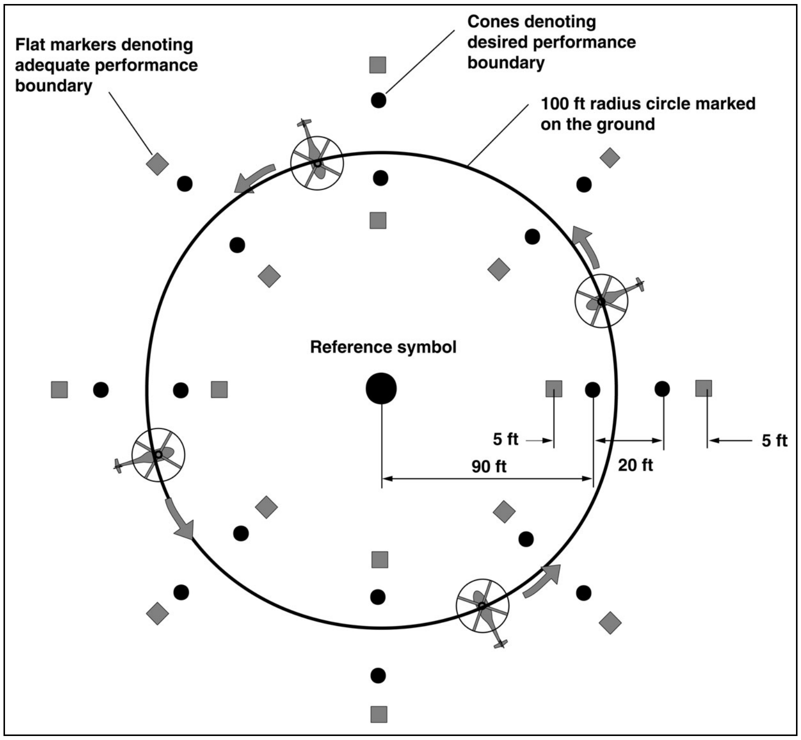


Figure 11. ADS-33D Pirouette Maneuver Course

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

## Bob-Up and Bob-Down Maneuver

The Bob-up and Bob-down maneuver has four basic objectives:

- Check for adequate heave damping (i.e., the ability to precisely start and stop a vertical rate).
- Check for adequate vertical control power.
- Check the characteristics of the heave axis controller.
- Check for undesirable coupling between the collective and the pitch, yaw, and roll axes.

Description of the maneuver. From a stabilized hover at 10 ft, bob-up to a defined reference altitude between 40 and 50 ft. The defined reference altitude, and associated outside cues, shall be established by the evaluation pilot prior to initiating the maneuver. Stabilize at the reference altitude for at least 2 sec, simulating an attack with fixed guns. Bob-down to re-establish the 10 ft stabilized hover. See Figure 12 for a pictorial view of the ADS-33D Bob-up and Bob-down maneuver.

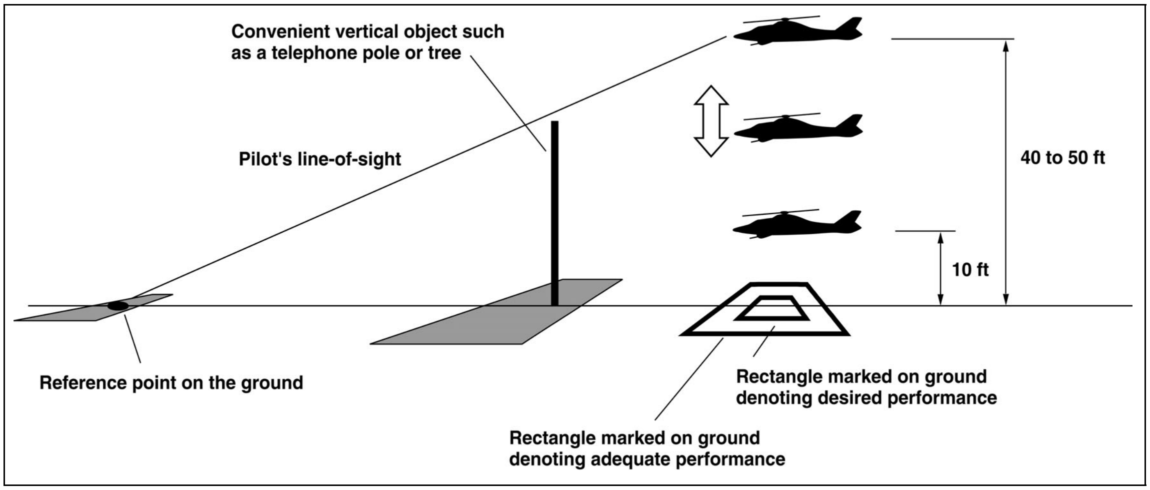


Figure 12. ADS-33D Bob-Up and Bob-Down Maneuver Course

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Complete the maneuver within 10 sec (15 sec) [NVG: 20 sec (30 sec)].
- Maintain the longitudinal and lateral position of the rotorcraft within ± 6 ft (± 10 ft) [NVG: within ± 10 ft (± 20 ft)] of a reference point on the ground.
- Maintain heading within ± 3° (± 6°).
- Capture and maintain the final stabilized hover altitude within ± 3 ft (± 6 ft).

Acceleration and Deceleration Maneuver

The Acceleration and Deceleration maneuver has five basic objectives:

- Check the pitch axis and heave axis handling qualities during aggressive maneuvering.
- Check for undesirable coupling between the longitudinal and lateral-directional axes during aggressive maneuvering in the longitudinal axis.
- 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.

Description of the maneuver (day). From a stabilized hover, rapidly increase power to approximately maximum, and maintain altitude constant with pitch attitude. 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 pitch attitude should occur just before reaching the final stabilized hover.

Description of the maneuver (degraded visual environment (DVE) - NVG). From a stabilized hover, accelerate to a groundspeed of at least 50 knots, then immediately decelerate to a hover over a defined point. The maximum nose-down attitude should occur immediately after initiating the maneuver, and the peak nose-up pitch attitude should occur just before reaching the final stabilized hover. See Figure 13 for a pictorial view of the ADS-33D Acceleration and Deceleration maneuver.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day. Some tolerances for this maneuver specify using aircraft length, or portions of aircraft length. These have been replaced with values corresponding to a UH-60A helicopter (approximately 50 ft).

- Complete the maneuver over the reference point at the end of the course. The longitudinal tolerance on the final hover position is +0 to –25 ft (+0 to –50ft), with positive being forward.
- Maintain altitude below 50 ft (70 ft).
- Maintain lateral track within ± 10 ft (± 20 ft).
- Maintain heading within ± 10° (± 20°).
- Within 1.5 sec (3 sec) from initiating the maneuver, achieve at least 95% of maximum continuous power or 95% of maximum transient power that can be sustained for the duration of the acceleration, whichever is greater. If 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 the operational flight envelope for Nap of the Earth (NOE) flying. This performance parameter applies to day flight operations only.
- Decrease power to full down collective (less than 30% of maximum) within 3 sec (5 sec) to initiate deceleration. Significant increases in power are not allowed until just before the final hover. This performance parameter applies to day flight operations only.
- Achieve a nose-up pitch attitude during the deceleration of at least 30° (10°) above the hover attitude. This performance parameter applies to day flight operations only.
- Achieve pitch attitude changes from the hover attitude of at least 12° (7°) nose-down for the acceleration and at least 15° (10°) nose-up for the deceleration. Significant increases in power are not allowed until just before the final hover. This performance parameter applies to NVG flight operations only.
- Rotor RPM shall remain within the limits of the operational (service) flight envelope without undue pilot compensation.

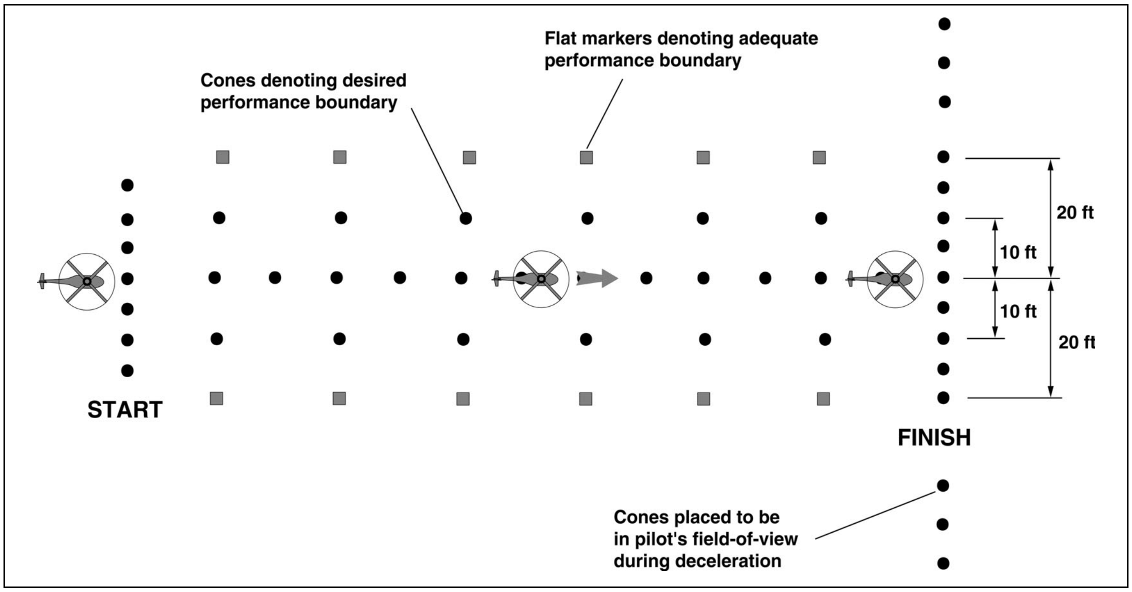


Figure 13. ADS-33D Acceleration and Deceleration Maneuver Course

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

Sidestep Maneuver

The Sidestep maneuver has three basic objectives:

- Check the lateral-directional handling qualities during aggressive maneuvering.
- Check for objectionable inter-axis coupling.
- Check the ability to coordinate bank angle and collective to hold constant altitude.

Description of the maneuver (day). From a stabilized hover with the longitudinal axis of the rotorcraft oriented 90° to a reference line marked on the ground, initiate a rapid and aggressive lateral translation, with a bank angle of at least 25°, holding altitude constant with power. When the rotorcraft has achieved a lateral velocity within 5 knots of its maximum allowable lateral airspeed, or 45 knots, whichever is less, immediately initiate an aggressive deceleration to hover at a constant altitude. The peak bank angle during deceleration should be at least 30°, and should occur just before the rotorcraft comes to a stop. Establish and maintain a stabilized hover for 5 sec. Immediately repeat the maneuver in the opposite direction.

Description of the maneuver (degraded visual environment - NVG). From a stabilized hover with the longitudinal axis of the rotorcraft oriented 90° to a reference line marked on the ground, initiate a lateral translation, holding altitude constant with power.

When the rotorcraft has achieved a lateral velocity of at least 17 knots, immediately initiate a deceleration to hover at a 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 sec. Immediately repeat the maneuver in the opposite direction. See Figure 14 for a pictorial view of the ADS-33D Sidestep maneuver.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Maintain the selected reference point on the rotorcraft within ± 10 ft (± 15 ft) of the ground reference line.
- Maintain altitude within ± 10 ft (± 15 ft) at a selected altitude below 30 ft.
- Maintain heading within ± 10° (± 15°).
- Achieve at least 25° of bank angle within 1.5 sec (3 sec) of initiating the maneuver. This performance parameter applies to day flight operations only.
- Achieve at least 30° of bank angle within 1.5 sec (3 sec) of initiating the deceleration. This performance parameter applies to day flight operations only.
- Achieve at least 20° (10°) of bank angle during the acceleration and deceleration. This performance parameter applies to NVG flight operations only.
- Achieve a stabilized hover within 5 sec (10 sec) [NVG: within 10 sec (20 sec)] after reaching the hover point.

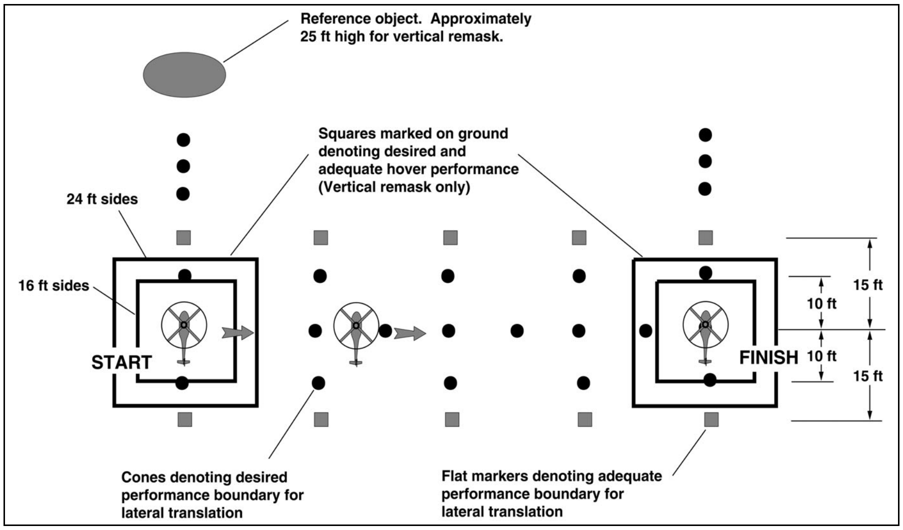


Figure 14. ADS-33D Sidestep Maneuver Course

Source: *Handling Qualities Requirements for Military Rotorcraft.* ADS-33E-PRF (2000).

## ADJUSTING PERFORMANCE PARAMETERS FOR HQR

As mentioned earlier in this chapter about UCE and VCR methodology, the goal was not to determine the actual shipboard UCE or evaluate the handling qualities of the UH-60 while conducting the ADS-33D maneuvers aboard ship. Instead, the purpose was to match simulator shipboard flight test maneuver VCR and HQR data to that actually obtained during at-sea flight tests. Both desired and adequate performance parameters were adjusted while developing the maneuvers during land-based testing, so that the average HQR obtained by several of the test pilots was in the HQR 3-4 range. The HQR 3-4 range was selected by the author for several reasons. First, HQR 4 is the limit for achieving desired performance. Second, pilot workload increases from HQR 3 are usually very easy for test pilots to determine, since the workload definitions for each HQR are clearly defined: HQR 3 (minimal), HQR 4 (moderate), HQR 5 (considerable), HQR 6 (extensive), and so on. Third, the HQR 3-4 range is the dividing line between Level 1 and Level 2 handling qualities. If performance parameters were too difficult, or too easy to attain, it would be very difficult to distinguish between a higher HQR or VCR due to poor visual cueing, or simply poorly developed flight maneuvers. This methodology was used first during the day, and then applied independently again for the NVG maneuver modifications.

## SIMULATOR CONSTRAINTS

While the VMS was an excellent research-grade flight simulator, there were space constraints inside the flight cab itself. With the UH-60 helicopter configuration (side by side seating), there was only room for one pilot inside the simulator flight cab. This caused additional modifications to the ADS-33D flight maneuvers. The author and test team determined that the right seat pilot’s station would be the evaluation position for all maneuvers. The UH-60 aircraft also had poor cross-cockpit field of view, making it very difficult, if not impossible, to conduct maneuvers or maintain references on the left side of the aircraft. As a safety precaution and to ensure that sufficient visual cues were present to conduct the maneuvers, only right lateral translations and maneuvers would be performed.

## MEASURING SHIPBOARD POSITION DEVIATIONS

All ADS-33D maneuvers have recommended courses that should be set up to aid the pilot in not only performing the flight maneuver, but also to assess if desired or adequate performance was attained. As discussed earlier, this method was not used by the author or test team as the cones and markings would be impractical on the flight deck of the ship and could adversely affect the VCR’s for both the ship and the simulator. Instead, existing ship markings were used to the greatest extent possible. Ship markings were augmented with chalk markings when needed. Due to the accuracy of ship markings (they are certified with engineering drawings), it was possible for the author and flight crew to determine position deviations relatively easily without many additional markings. Altitude deviations were judged by the pilots using both the radar altimeter and visual cueing next to the ship island superstructure.

Determining position and altitude accuracy from the cockpit to within 3-5 ft, at an altitude of up to 50 ft and traveling at approximately 25-30 knots, without the aid of additional markings and on a moving ship under day and NVG conditions, was not something the author or flight crew could be certain of. To allow post-flight determination of position accuracy for desired or adequate performance, two extremely accurate differential Global Positioning System (DGPS) receivers were used for the test. Both DGPS receivers were identical, with one receiver placed on the ship and the other placed on the aircraft. The aircraft DGPS lever arms were calculated from the DGPS antenna on the aircraft to the reference point on the helicopter. The author placed the helicopter reference point longitudinally at the pilot's seats (approximately fuselage station 227) and laterally centered on the aircraft (butt line 0.0). The shipboard DGPS antenna location was surveyed and the x, y, z coordinate differences for each needed reference point on the ship's flight deck were determined.

In order to get accurate DGPS information, a dedicated DGPS ground station is required to be placed at a surveyed, non-moving, location to provide accurate error correction information to the secondary DGPS receiver. This was not possible aboard a ship at sea, but an alternate technique was devised, since the absolute position of the ship and aircraft were unimportant, only the relative position differences were needed. The shipboard DGPS receiver will still act as the DGPS ground station, providing error correction information for the helicopter DGPS receiver. Data processing after the flight took the shipboard DGPS signal, position corrected for the test location of interest, and calculated the x, y, and z position differences from the aircraft. This method of using DGPS allowed aircraft position to be determined within approximately 6-8 in., although not in real time.

# CHAPTER III
# DEVELOPING THE MODIFIED ADS-33D MANEUVERS

## SHIPBOARD MANEUVER LOCATION

### Maneuvering Limitations

The limited maneuvering space on the flight deck of an LHA class ship required several of the ADS-33D maneuvers to be significantly modified in order to remain over the ship and provide sufficient clearance between the ship and aircraft to safely conduct the maneuver. The Hover, Landing, and Bob-Up and Bob-Down maneuvers did not require significant changes to the basic maneuver description or execution. The Pirouette maneuver required significant changes in order to accomplish the maneuver while remaining over the flight deck. The ADS-33D Pirouette maneuver calls for completing a 100 ft radius circle with the aircraft, which was not possible on a 132 ft wide flight deck. Additionally, the author and test team determined that there was insufficient clearance between the helicopter tail rotor and various ship structures to safely conduct a complete circle on the flight deck. Similarly, both the Sidestep and Acceleration and Deceleration maneuvers required significant modification, in both speed and aggression, to execute on the LHA flight deck. The specific modifications are discussed later in this chapter for each maneuver.

### Visual Cueing Limitations

In addition to modifying the tolerances and conditions on some of the six maneuvers, the author was concerned about the location aboard the ship that each maneuver would be flown from. Different locations on the LHA class ship provide significantly different visual cueing, depending upon the maneuver being performed and the specific VCR affected (attitude, horizontal translation rate, or vertical translation rate). In general, areas to the rear of the ship gave the greatest of visual cueing, though not necessarily the best for each VCR. The area at the aft portion of the ship superstructure, or island, gave the best vertical cueing, while forward of the island afforded the worst vertical cueing. The most forward 150 ft of the ship presented the worst vertical cueing, since there were no vertical structures at all and the front edge of the ship dropped off abruptly to the water, approximately 70 ft below. The author, in conjunction with the test team, determined that each maneuver would need to be conducted two times to account for the different visual cueing environments on the ship. The specific locations for each maneuver and the rationale are discussed later in this chapter.

### Relative Wind and Turbulence Effects

Wind considerations also had to be factored into the maneuver locations. While the normal winds encountered at sea are relatively uniform in direction and speed at any given time, those same winds can generate significant turbulence, vorticity, and up/down drafts when traveling over and around the ship structures. The abundance of sharp 90° corners located on the ship's flight deck and island superstructure, coupled with the ability to change the relative wind by steering the ship on a different heading, meant that ratings from the different maneuver locations could be impacted by the wind, as well as by a different visual cueing environment. To further isolate wind effects from the pilot ratings (HRQ and VCR), the author and test team determined that the maneuvers would only be conducted in calm winds (less than five knots) from any direction.

### Initial Location Determination

The Hover, Landing, and Bob-Up and Bob-Down maneuvers are all referenced over single stationary spot during the evaluation (the Hover maneuver terminates over a single stationary spot). The Hover and Bob-Up and Bob-Down maneuvers also depend on a significant amount of vertical cueing for altitude determination and maintenance; particularly during the climb and descent portions of the Bob-Up and Bob-Down maneuver. The author and test team determined that the aircraft landing spots and other flight deck markings should give sufficient position cueing to conduct the maneuvers, with performance tolerances adjusted as needed. The LHA class ship flight deck markings are shown in Figure 2, while the individual landing spot markings are presented in Figure 15. In order to evaluate the cueing influence of the ship superstructure, or

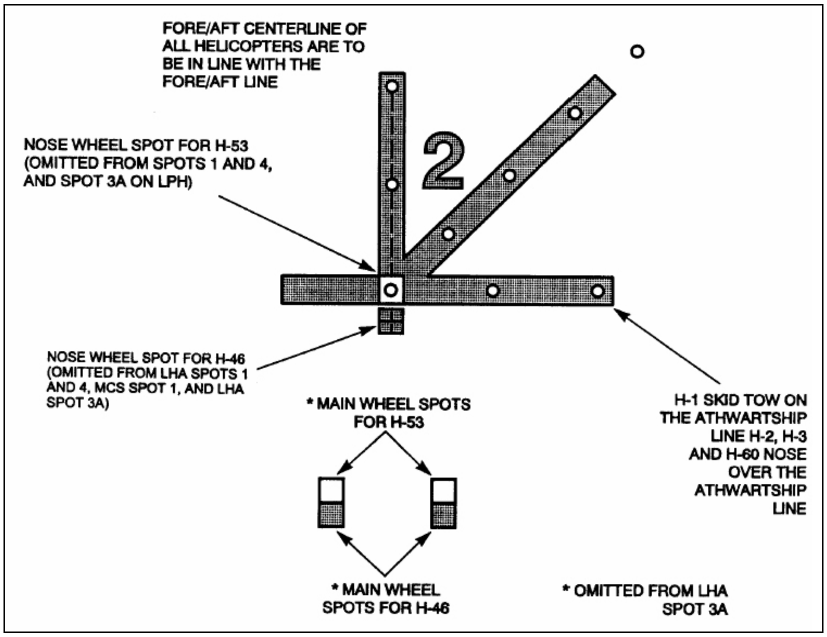


Figure 15. LHA Landing Spot Markings

Source: *LHA/LHD/MCS NATOPS* (1998).

island, the author and test team selected landing spots 2 and 7 to perform the Hover, Landing, and Bob-Up and Bob-Down maneuvers. Spot 2 is the farthest forward landing spot on the left (port) side of the ship, providing minimal fore-aft, lateral, and vertical cueing. Although landing spot 1 is located farther forward on the ship, it was not selected because visual reference with any part of the ship was difficult above approximately 15 ft, providing insufficient cueing to adequately perform the maneuvers. Spot 3 was not selected because it would require a left lateral translation by the pilot in the right seat of the helicopter, which was ruled out as a safety concern in earlier discussions. Spot 7's proximity to the ship superstructure provided good vertical and fore-aft cueing, as well as good lateral cueing along the length of the flight deck.

The Pirouette maneuver had to be conducted completely forward or aft of the ship superstructure. Forward of the superstructure, spots 2 and 3 were located directly opposite each other, near the bow of the ship. Aft of the superstructure, spots 8 and 9 were also located directly opposite each other, near the stern of the ship. As previously discussed, insufficient clearance existed between the helicopter tail rotor and the ship superstructure, or other equipment, to conduct a complete circle; a half-circle Pirouette maneuver was used instead. The ship's crash crane aft of the superstructure (denoted by the square in a circle aft of the island in Figure 2 and visually represented in Figure 1) and flight deck ground support equipment (tow tractors, fire-fighting gear, etc.) in the vicinity of spot 3A were the primary ship obstacles preventing completion of a full circle Pirouette maneuver. Since only right lateral translations would be conducted, the Pirouette would be flown from spot 8 to spot 9, and from spot 3 to spot 2.

The Acceleration and Deceleration maneuver described in ADS-33D required a much longer course than possible on the ship. Accelerating to 50 knots and then decelerating back to a hover requires approximately 1,000 ft in the UH-60 helicopter, significantly more than the 834 ft length of the LHA flight deck. The author and test team also wanted to evaluate the visual cueing differences associated with conducting the aggressive deceleration both next to the ship superstructure and at the front of the ship. Conducting the deceleration next to the superstructure would provide improved vertical and fore-aft cueing over the front of the ship. This required conducting the maneuver two times. One iteration of the maneuver would be performed from landing spot 8 to spot 5, while the second iteration would occur from landing spot 6 to spot 2.

The Sidestep maneuver described in ADS-33D also required a longer course than practical on the ship. The Sidestep would only be conducted to the right, to preclude left lateral translations. As with the Acceleration and Deceleration maneuver, the author and test team also wanted to evaluate the visual cueing differences associated with conducting the lateral translation and aggressive lateral deceleration both in front of the ship superstructure and clear of the superstructure at the stern of the ship. Conducting the lateral deceleration next to the superstructure would provide improved vertical and lateral cueing over the back of the ship. This required conducting the maneuver two times. One Sidestep maneuver would be performed from landing spot 2 to spot 6, while the second Sidestep would occur from landing spot 5 to spot 8.

## LAND BASED MANEUVER DEVELOPMENT

While the author and test team had made significant progress in modifying the maneuvers in preparation for the at-sea test period, a method of further defining the descriptions and tolerances was needed before shipboard testing could commence. Additionally, all test pilots would need to practice each maneuver until proficient, using the shipboard markings found on the flight deck as the visual cueing references. Fortunately for the author and test team, a dimensionally correct LHA flight deck had been painted on runway 02/20 at Naval Air Station (NAS) Patuxent River, MD by the V-22 test team for previous testing. The painted LHA flight deck had all the correct flight deck markings and included a painted outline of the ship superstructure, shown in Figure 16. A close-up of an approach to spot 7 on the painted LHA flight deck is shown in Figure 17. All maneuvers were flown and modified using the painted LHA flight deck at NAS Patuxent River by the author and another test pilot until both were satisfied that the maneuvers could be flown safely aboard ship and that the tolerances and description had been modified sufficiently to meet the test objectives. Maneuvers were flown and modified for both day and NVG conditions. Once land-based maneuver development was completed by the author, all participating test pilots were required to practice each maneuver, from both locations, day and NVG, prior to flying them aboard ship.

Figure 16. LHA Painted Flight Deck at NAS Patuxent River, MD

Figure 17. LHA Painted Flight Deck, Close-Up of Landing Spot 7

## MODIFIED ADS-33D MANEUVERS

Each modified ADS-33D maneuver is described, along with the rationale and methodology for the modifications. Changes are presented in Italics, with rationale for the changes at the end of each paragraph. The NVG maneuver descriptions and performance tolerances are also presented when they differ from day descriptions and performance tolerances. As stated earlier, all maneuvers were intended to be performed in winds less than five knots, to eliminate any adverse turbulence associated with the ship flight deck and superstructure. The objectives for each maneuver were not changed, so they will not be presented again here.

### Hover Maneuver

The Hover maneuver was selected by the author and test team to be performed at two locations, landing spot 2 and spot 7, as shown in Figure 18. The final hover target and primary reference markings used during the maneuver were the landing spot markings, also known as the “crow’s feet”, and shown in Figure 15. The basic maneuver description was not changed, but information specific to the shipboard environment was added.

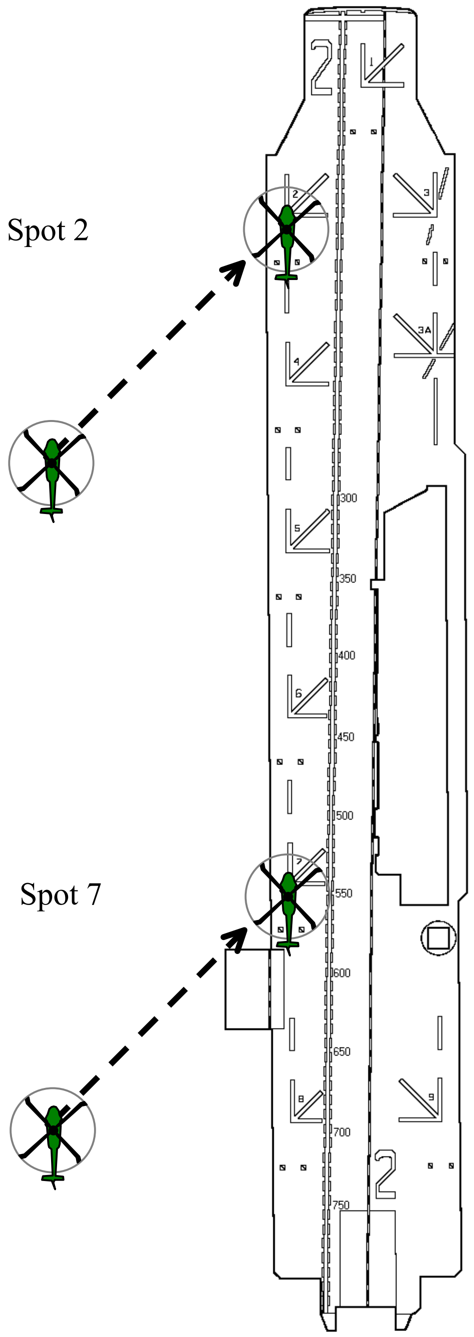


Figure 18. Modified Shipboard Hover Maneuver

Description of the modified Hover maneuver. Initiate the maneuver at a ground speed of between 6-10 knots *(11-18 kph)*, at an altitude less than 20 ft, with the nose of the aircraft aligned with the *ship's longitudinal axis*, and *the aircraft aligned with the 45° line-up line of the landing spot marking*. The target hover point is a repeatable, ground referenced point from which rotorcraft deviations are measured. *Maintain alignment with the 45° line-up line of the landing spot marking until arriving over the landing spot.* See Figure 18 for a top view of the modified ADS-33D Hover maneuver. These subtle changes from the original description were made only to facilitate conducting the maneuver aboard ship.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- 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 creep up to the final position. Attain a stabilized hover within *5* (8) sec (NVG: within *8 (15)* sec) of the initiation of the deceleration. The time to attain a stabilized hover during the day was changed to 5 sec (from 3 sec) to reduce the aggressiveness of the deceleration and keep the average HQR rating in the HQR 3-4 range. The NVG tolerances were shortened to 8 and 15 sec (from 10 and 20 sec), for desired and adequate performance, because the maneuver was too easy with the initial tolerances, resulting in several HQR 2 ratings from the author when performed on the LHA painted deck during land-based testing.
- Maintain a stabilized hover for at least 30 sec.
- Maintain the longitudinal and lateral position within ± 3 ft (± 6 ft) [NVG: position within ± 3 ft (± 8 ft)] of a point on the ground and altitude within ± 2 ft (± 4 ft).
- Maintain heading within ± 5° (± 10°).
- There shall be no objectionable oscillations in any axis either during the stabilized hover, or the transition to a hover. This parameter applies only to desired performance.

## Landing Maneuver

The Landing maneuver was selected by the author and test team to be performed at two locations, landing spot 2 and spot 7, as shown in Figure 19. The primary reference markings used during the maneuver were again the landing spot markings, shown in Figure 15. The maneuver description was not changed.

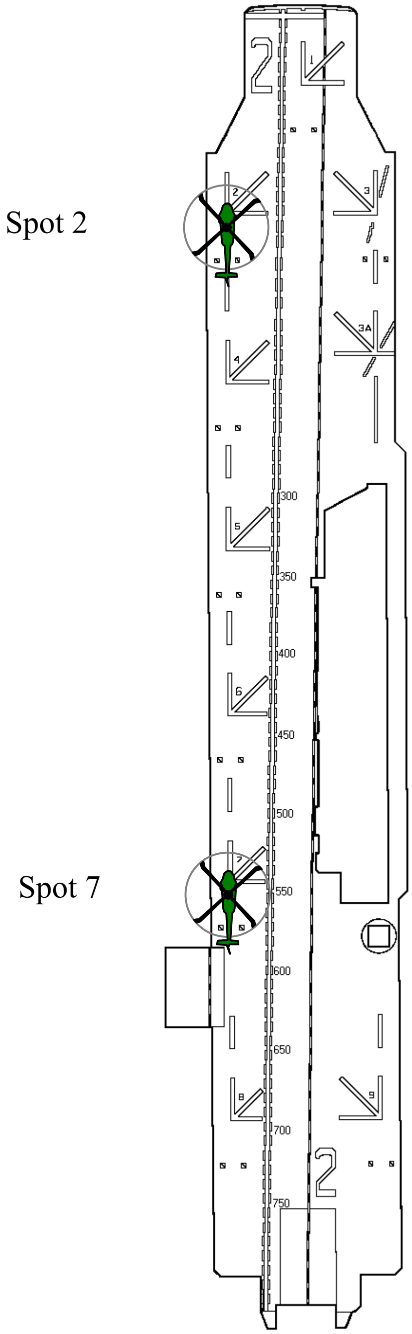


Figure 19.  Modified Shipboard Landing & Bob-Up and Bob-Down Maneuver

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

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Accomplish the landing with a smooth continuous descent, with no objectionable oscillations. This parameter applies only to desired performance.
- Once altitude is below 10 ft, complete the landing within 10 sec (NVG: within *10 sec*). This parameter applies only to desired performance. The NVG time tolerance was reduced to 10 sec (from 15 sec) after multiple test runs on the land-based LHA painted deck resulted in average ratings of HQR 3 for times of 7-9 sec. The author felt that additional time was not needed and might result in lower HQR ratings. It was also desirable to have the day and NVG tolerances the same, whenever possible.
- Touch down laterally within *± 1 ft (± 2 ft)* [NVG: laterally within *± 2 ft* (± 3 ft)] and longitudinally within ± 1 ft (± 3 ft) [NVG: longitudinally within *± 3 ft* (± 6 ft)] of a designated reference point. The day lateral tolerances were increased to 1 ft (2 ft) (from 0.5 ft and 1.5 ft) due to the width of the spot markings. The longitudinal, lateral and 45° line-up lines were all 1 ft wide, making it very difficult to detect 0.5 ft differences from the cockpit. The NVG desired lateral tolerance was decreased to 2 ft (from 3 ft), as the author and another test pilot were able to consistently land within 2 ft laterally and stay within the HQR 3-4 range. Day longitudinal tolerances were not changed, but NVG desired longitudinal tolerance was decreased to 3 ft (from 6 ft), again because the author felt that 6 ft was too easy and would result in lower HQR and VCR ratings.
- Align rotorcraft touchdown heading within ± 5° (± 10°) [NVG: *± 8°* (± 15°)] of the reference heading. Only the NVG desired performance tolerance was adjusted – it was decreased to 8° (from 10°). The author and two other test pilots had very little difficulty in attaining the correct touchdown heading within 7-8° and determined that the larger 10° tolerance might caused reduced pilot workload and decrease ratings below the HQR 3-4 range.
- The 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 ground. This parameter applies only to desired performance.

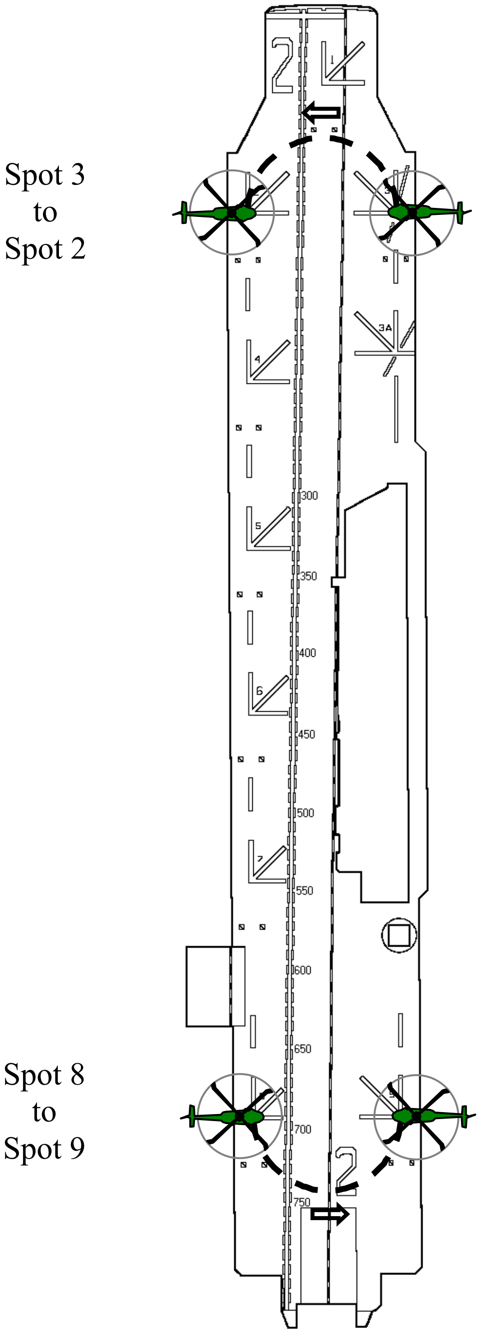
Pirouette Maneuver

The Pirouette maneuver was selected by the author and test team to be performed at two locations, from spot 3 to spot 2 and from spot 8 to spot 9, as shown in Figure 20. The start and stop points were directly over the landing spots, with the helicopter nose oriented inboard. In order to fly the half-circle arc and determine if desired or adequate performance was achieved, the author used three different chalk markings to trace the flight path. A primary chalk line, made with thick white chalk, was the desired path that the evaluation pilot would keep under the aircraft reference point throughout the maneuver. Two secondary chalk lines, denoting desired performance limits, were drawn with a radius ± 5 ft of the primary reference line, but made thinner and with darker chalk. No other chalk lines were drawn to show adequate performance limits, but a 1 ft chalk circle was drawn at the center of the half-circle as a heading reference point for the test pilots.

Description of the modified Pirouette maneuver. Initiate the maneuver from a stabilized 10 ft hover *over spot 3/8,* with the helicopter oriented at the center reference marker. Accomplish a lateral translation around the *46¼ ft radius semi-*circle, keeping the nose of the rotorcraft pointed at the center of the circle, and the circumference of the semi-circle under a selected point on the helicopter. Terminate the maneuver with a stabilized hover over *spot 2/9, 180° from the starting point*. The Pirouette maneuver required significant modification to safely accomplish aboard an LHA class ship flight deck. Primarily, as discussed earlier, safety constraints due to tail rotor clearances with the ship superstructure prevented completing a full circle. This required many other modifications to the original tolerances, discussed below. Figure 20 depicts the modified shipboard ADS-33D Pirouette maneuver.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Maintain a selected reference point on the rotorcraft within *± 5 ft (± 8 ft)* of the circumference of the circle. It was necessary to decrease the tolerance from 10 ft (15 ft) to make sure that the aircraft remained over the ship flight deck throughout the maneuver, as the start/stop reference points were only 13 ft from the edge of the flight deck. Practice maneuvers on the LHA painted flight deck by the author also showed that unless the desired reference lines were moved to the ± 5 ft, it was very difficult to complete the maneuver and stop over the final reference point.
- Maintain altitude within *± 2 ft (± 4 ft)* [NVG: within *± 3 ft (± 5 ft)*]. The large altitude deviations allowed by ADS-33D ± 3 ft (± 10 ft) [NVG: within ± 4 ft (± 10 ft)] were unacceptable as even starting points for the UH-60A at a 10 ft



Spot 3
to
Spot 2

Spot 8
to
Spot 9

Figure 20. Modified Shipboard Pirouette Maneuver

hover. At a stationary hover, the UH-60A pitch attitude is approximately 4-6° nose-up, resulting in the tail wheel being approximately 6-7 ft from the ground. The nose-up attitude of the aircraft increases during decelerations, reducing the tail wheel to ground clearance even further. A higher hover altitude (12-15 ft) was tried by the author, but resulted in increased drift in all axes and decreased pilot field of view during the deceleration over the final reference point. The adequate tolerances were deemed to be the maximum deviations to conduct the maneuver and still maintain a margin of safety between the tail wheel and the flight deck.

- Maintain heading so that the nose of the rotorcraft points at the center of the circle within ± 10° (± 15°).
- Complete the *180° transition* and arrive over the *ending* point within *15 sec (20 sec)*. Maintain essentially constant lateral groundspeed throughout the maneuver. The initial time criteria of 45 sec (60 sec) [NVG: within 60 sec (75 sec)] to complete a full 100 ft radius circle had to be significantly modified for the transition around the 46¼ ft radius semi-circle. Multiple practice runs over the painted LHA flight deck by the author and other test pilots were required to establish appropriate desired/adequate time tolerances.
- Achieve a stabilized hover over the *ending* point *± 5 ft (± 8 ft)* within 5 sec (10 sec) [NVG: within *5 sec (10 sec)*]. The original position criteria of ± 10 ft (± 15 ft) had to be decreased to keep the aircraft over the flight deck throughout the maneuver. The original NVG time criteria of 10 sec (20 sec) was lowered to be the same as the day criteria, as the author and other test pilots had no trouble meeting the lower time requirements on the LHA painted deck and did not want to decrease the pilot workload and cause lower HQRs.

### Bob-Up and Bob-Down Maneuver

The Bob-up and Bob-down maneuver was selected by the author and test team to be performed at two locations, landing spot 2 and spot 7, as shown in Figure 19. The primary reference markings used during the maneuver were the landing spot markings, longitudinal lines running the length of the flight deck, and the landing spot markings of adjacent landing spots. Vertical cueing was virtually non-existent at spot 2, but was very good at spot 7, located directly next to the aft portion of the ship superstructure. The basic maneuver description was not changed.

Description of the modified Bob-up and Bob-down maneuver. From a stabilized hover at 10 ft, bob-up to a reference altitude of approximately 50 ft. The defined reference altitude, and associated outside cues, shall be established by the evaluation pilot prior to initiating the maneuver. Stabilize at the reference altitude for at least 2 sec. Bob-down to re-establish the 10 ft stabilized hover. The Bob-up and Bob-down maneuver depicted in Figure 12 (without the use of a hover board or additional position markings) will be completed over spot 2 and spot 7, as shown in Figure 19.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Complete the maneuver within *15 sec (25 sec).* The original day time tolerance of 10 sec (15 sec) was not sufficient to safely execute the maneuver with the UH-60A and resulted in excessive descent rates during the bob-down. Multiple practice runs on the LHA painted deck confirmed that the maneuver could be safely conducted within 15 sec for both day and NVG conditions.
- Maintain the longitudinal and lateral position of the rotorcraft within *± 10 ft (± 15 ft)* of a reference point on the ground. The original position tolerances were ± 6 ft (± 10 ft) [NVG: within ± 10 ft (± 20 ft)], which was too restrictive during the day because the pilot was unable to judge position better than approximately ± 10 ft at the top of the bob-up. The author and other test pilots were also able to maintain position ± 10 ft (± 15 ft) for NVG conditions.
- Maintain heading within ± 3° (± 6°).
- Capture and maintain the final stabilized hover altitude within ± 3 ft (± 6 ft).

<u>Acceleration and Deceleration Maneuver</u>

The Acceleration and Deceleration maneuver was selected by the author and test team to be performed at two locations, from landing spot 6 to spot 2 and from spot 8 to spot 5, as shown in Figure 21. Primary lateral reference markings used during the maneuver were the longitudinal line-up lines. The lateral line-up line at spot 2/5 was used as the target stopping point. The maneuver had to be changed in order to complete the maneuver on the flight deck, with the aggressiveness level reduced accordingly. The degraded visual environment maneuver description and tolerances are very close to the final version used.

Description of the modified Acceleration and Deceleration maneuver. From a stabilized hover over spot 6/8, maintain a continuous acceleration until initiating the deceleration to a hover over the final spot. The maximum nose-down attitude should occur immediately after initiating the maneuver, and the peak nose-up pitch attitude should occur just before reaching the final stabilized hover.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Complete the maneuver over spot 2/5. The longitudinal tolerance on the final hover position is +0 to –25 ft (+0 to –50ft), with positive being forward.

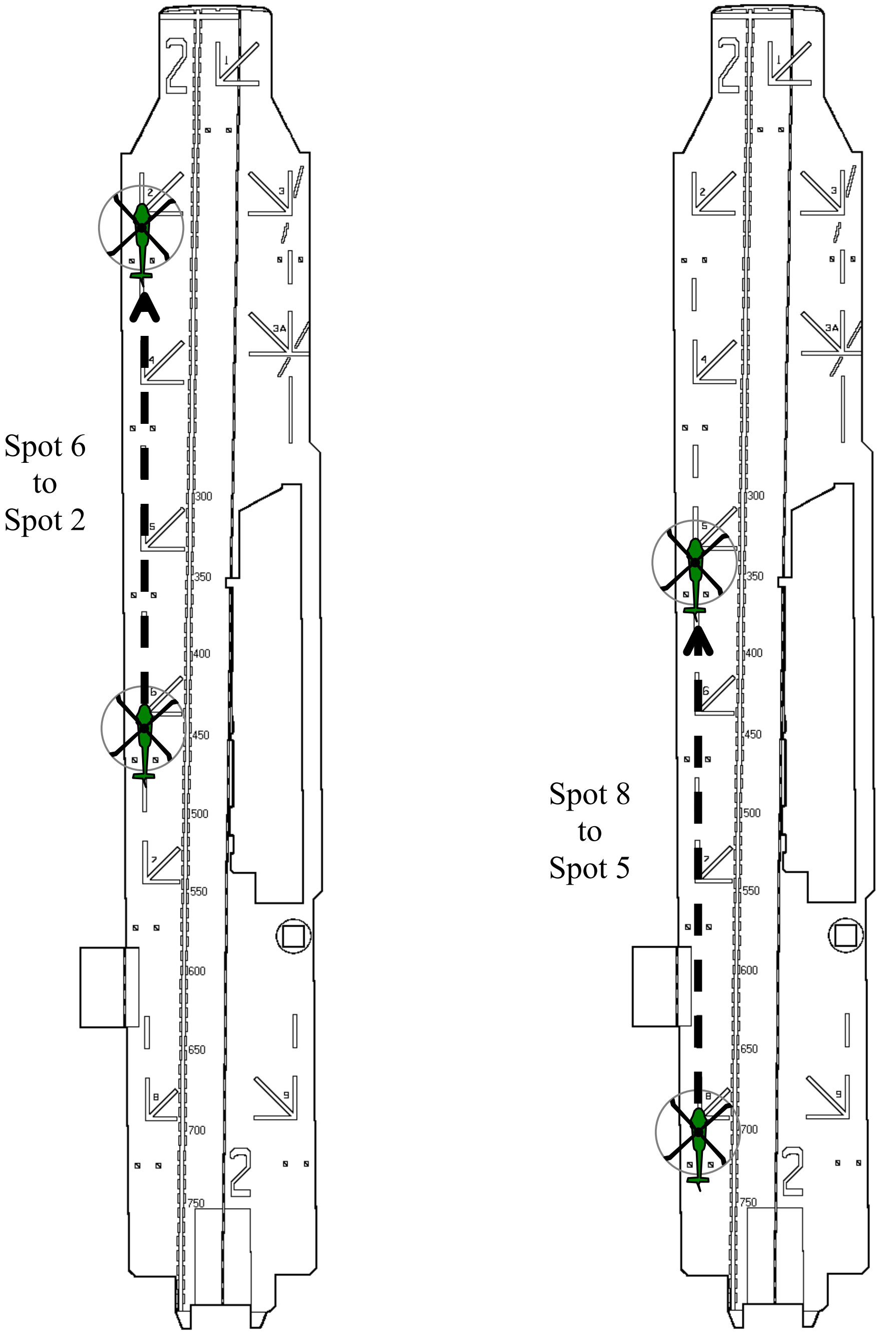


Figure 21. Modified Shipboard Acceleration and Deceleration Maneuver

- Maintain altitude below *40 ft (60 ft)*. The original altitude tolerances were decreased by 10 ft for both desired and adequate performance to adjust for the reduced aggressiveness of the maneuver.
- Maintain lateral track within ± 10 ft (*± 15 ft*). Adequate lateral track tolerance was reduced from the original ± 20 ft to ± 15 ft to ensure sufficient clearance between the rotor blades and the ship superstructure.
- Maintain heading within ± 10° (*± 15°*). Adequate heading tolerance was reduced from 20° to adjust for the reduced aggressiveness of the maneuver.
- Achieve pitch attitude changes from the hover attitude of at least 12° (7°) nose-down for the acceleration and at least 15° (10°) nose-up for the deceleration. Significant increases in power are not allowed until just before the final hover.

### Sidestep Maneuver

The Sidestep maneuver was selected by the author and test team to be performed at two locations, from landing spot 2 to spot 6 and from spot 5 to spot 8, as shown in Figure 22. Primary reference markings used during the maneuver were the ship's longitudinal line-up lines. The lateral line-up line at spot 6/8 was used as the target stopping point, although no specific tolerance was applied to final hover position. The maneuver had to be changed in order to complete the maneuver on the flight deck, with the aggressiveness level reduced accordingly. The degraded visual environment maneuver description and tolerances are very close to the final version used.

Description of the modified Sidestep maneuver. From a stabilized 35 ft hover over spot 2/5 with the nose oriented 90° to the ship's longitudinal line-up line (pointing towards the ship superstructure), initiate a right lateral translation, holding altitude constant with power. When the rotorcraft has achieved a lateral velocity of at least 17 knots, immediately initiate a deceleration to hover at a constant altitude. The peak bank angle during deceleration should occur just before the rotorcraft comes to a stop.

Performance parameters. Desired performance is presented first, followed by adequate performance in parenthesis. Unless specified, the performance parameter applies to both desired and adequate performance. NVG performance parameters are presented when they differ from day.

- Maintain the selected reference point on the rotorcraft within ± 10 ft (± 15 ft) of the ground reference line.
- Maintain altitude within ± 10 ft (*± 20 ft*). The altitude selected to begin the maneuver was selected to be 35 ft, as this was the lowest altitude the author felt could be used to provide sufficient clearance between the main rotor blades and the flight deck. Adequate tolerance was increase by 5 ft to adjust for the increased starting altitude.

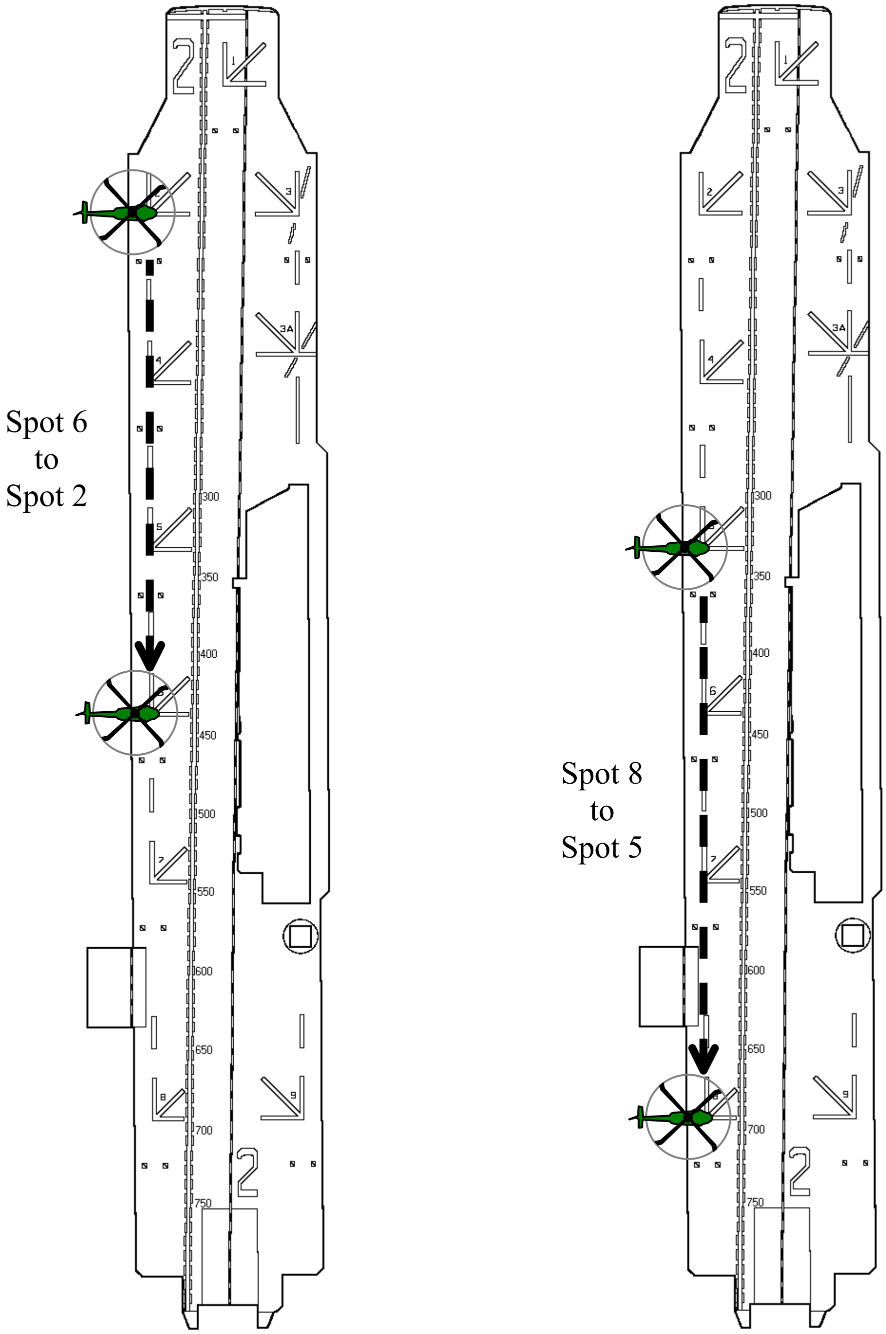


Figure 22. Modified Shipboard Sidestep Maneuver

- Maintain heading within ± 10° (*± 20°*). The adequate performance tolerance was increased from ± 15° as a result of practice maneuvers over the LHA painted deck.
- Achieve at least 20° (10°) of bank angle during the acceleration and deceleration.

# CHAPTER IV
# SUMMARY AND CONCLUSIONS

## SUMMARY

The development of modified ADS-33D maneuvers for the shipboard helicopter environment provided a method to compare the UH-60A helicopter handling qualities and the real shipboard visual cueing environment to the simulated aircraft and visual environment of the Vertical Motion Simulator. The modified ADS-33D maneuvers also allowed accepted flight test maneuvers and methodology to be used in support of validating simulator visual models. Two successful at-sea flight test periods were conducted using the modified ADS-33D maneuvers. The author participated in both tests as an evaluation pilot and as a safety pilot while other Experimental Test Pilots flew the maneuvers. Due to time constraints and aircraft maintenance, the author was the only Test Pilot to conduct the modified ADS-33D maneuvers under NVG conditions. All flight evolutions were safely executed, with no adverse comments from the pilots or ship personnel about either the safety of the maneuvers, or the proficiency of the aircrew.

## CONCLUSIONS

The shipboard environment presented several significant challenges, not usually encountered with land based testing during the modification of the ADS-33D maneuvers. The first obstacle to overcome was the size limitation associated with completing the maneuvers within a 820 ft long, 118 ft wide flight deck that is approximately 60 ft above the surface of the ocean. Selecting appropriate locations on the ship for the modified ADS-33D maneuvers was critical to obtaining accurate visual shipboard cueing data and correlating it in the simulator. That was why two different locations were chosen for each maneuver – one with the best visual cueing possible, the other with the worst cueing that still provided enough detail to safely execute the maneuver. The shipboard maneuvers were flown as close to a zero wind state as possible to remove any effects of wind or turbulence. The purpose was to develop maneuvers to evaluate the shipboard visual environment for comparison to a simulator visual environment – not to evaluate the aircraft handling qualities. The modified maneuver descriptions and tolerances were adjusted to place the average pilot rating in the HRQ 3-4 range, so that the maneuvers were not too hard or too easy to complete. Most of the changes made to the maneuver tolerances were relaxed, but some were made more restrictive due to the cueing available. This was done to customize the maneuver for the specific shipboard markings available for that maneuver and normalize the pilot HQRs, ensuring that both large and small variations in the maneuvers and cueing environment could be seen.

While initial maneuver modifications were completed prior to flying the practice maneuvers, the painted LHA flight deck was invaluable to finely tune the maneuver descriptions and tolerances. Without the land-based opportunity to develop and practice the maneuvers, the author and test team would have lost a significant amount of test time aboard ship simply refining the maneuvers and tolerances, instead of performing them. Land based development and practice allowed the major problems to be worked out prior to the at sea test periods. No changes were necessary to the actual ADS-33D test maneuvers flown at-sea after completing development on the land based LHA painted deck. Practicing new test procedures and maneuvers is vital, not only for the sake of safety, but also to conduct efficient flight testing at sea. By the time JSHIP conducted the first at-sea test period, all test pilots had practiced the maneuvers within the confines of the LHA painted flight deck and were proficient to conduct the maneuvers in both day and NVG conditions.

Conducting precision flight test maneuvers that have tolerances of ± 1 ft or ± 3° required sensitive aircraft instrumentation to back up the aircrew's assessment. Location determination to this accuracy on a moving ship at sea required the novel approach of using two identical DGPS receivers, one on the ship and one in the aircraft, to compute the precise position of the aircraft relative to the reference point or flight path. Additionally, the sensitive instrumentation package allowed complete post-flight data analysis to quantitatively evaluate and compare aircraft states (attitude, rate, acceleration) and flight control movement (displacement, frequency, control reversal and margins) during actual shipboard flight maneuvers with those observed in the NASA Ames VMS.

Safety was paramount throughout the maneuver development process. The author and test team determined that a complete pirouette maneuver would be unsafe due to the limited flight deck space, close proximity of the tail rotor to the ship superstructure, and inability of the crew to monitor tail rotor clearance. Safety also played a key role in restricting all flight maneuvers to the left, primarily due to poor cross-cockpit field of view.

Developing new flight test maneuvers, procedures, or methodology is not an easy process that gains quick acceptance from the flight test community. Sound reasoning and engineering judgement are rarely sufficient – real data from actual flight test is almost always required. However, just because it hasn't been done before, doesn't mean the methodology is wrong or won't be accepted. Thinking outside the box is what advances the state of the art in all fields!

# BIBLIOGRAPHY

# BIBLIOGRAPHY

Cooper, G.E. and Harper, R.P. *The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities.* NASA Technical Note D-5153. Moffett Field, California: Ames Research Center and Cornell Aeronautical Laboratory, 1969.

Hoh, R.H., Mitchell, D.G., Aponso, B.L., Key, D.L., and Blanken, C.L. *Background Information and User's Guide for Handling Qualities Requirements for Military Rotorcraft*. USAAVSCOM Technical Report 89-A-008. Moffett Field, California: United States Army Aviation Systems Command, Aeroflightdynamics Directorate, 1989.

*Baseline Test and Evaluation Report for the Dynamic Interface Modeling and Simulation System (DIMSS) of the NASA Ames Research Facility Vertical Motion Simulator (VMS).* Patuxent River, Maryland: Joint Shipboard Helicopter Integration Process, Joint Test and Evaluation, 1999.

*Dedicated At-Sea Test 1 (DAST 1), Detailed Activity Test Plan (DTAP).* Patuxent River, Maryland: Joint Shipboard Helicopter Integration Process, Joint Test and Evaluation, 1999.

*Dedicated At-Sea Test #1 Final Report, UH-60A & CH-47D Aboard the USS SAIPAN (LHA 2).* Patuxent River, Maryland: Joint Shipboard Helicopter Integration Process, Joint Test & Evaluation, 2000.

*Dedicated At-Sea Test 1A (DAST 1A), Detailed Activity Test Plan (DTAP).* Patuxent River, Maryland: Joint Shipboard Helicopter Integration Process, Joint Test and Evaluation, 2000.

*Dedicated At-Sea Test 1A Final Report, UH-60A Aboard the USS PELELIU (LHA 5).* Patuxent River, Maryland: Joint Shipboard Helicopter Integration Process, Joint Test & Evaluation, 2001.

*Guide to the Preparation of Theses and Dissertations.* Ninth Edition. Knoxville, Tennessee: The University of Tennessee, 2001.

*Handling Qualities Requirements for Military Rotorcraft.* Aeronautical Design Standard, Performance Specification, ADS-33D-PRF. St. Louis, Missouri: United States Army Aviation and Troop Command, 1996.

*Handling Qualities Requirements for Military Rotorcraft.* Aeronautical Design Standard, Performance Specification, ADS-33E-PRF. Huntsville, Alabama: United States Army Aviation and Missile Command, 2000.

*LHA/LHD/MCS NATOPS.* NAVAIR 00-80T-106. Patuxent River, Maryland: Naval Air Systems Command, 1998

*Operator's Manual for UH-60A, UH-60L and EH-60A Helicopters.* TM-1-1520-237-10. U.S. Army, 1996.

*Shipboard Aviation Facilities Resume.* NAEC-ENG 7576, Revision AS. Lakehurst, New Jersey: Naval Aircraft Engineering Center, 1999.

*Webster's Encyclopedic Unabridged Dictionary of the English Language.* New York, New York: Gramercy Books, 1989.

# APPENDIX

## JUH-60A (S/N 88-26015) INSTRUMENTATION DESCRIPTION

This instrumentation description was taken from the Dedicated At-Sea Test 1A Final Report (2001).

An externally mounted calibrated instrumentation boom was installed on the right forward underside of the aircraft (Figure A-1) and extended 98 inches forward of the nose. The boom incorporated an angle-of-attack sensor, angle-of-sideslip sensor, and a swiveling Pitot-static tube. An airborne data acquisition system was installed on the test aircraft (Figure A-2) and maintained by the U.S. Army Aviation Technical Test Center. Additionally, 4,340 lb of ballast was installed in the main cabin area (Figure A-2 and Figure A-3).

The system utilized pulse code modulation (PCM) encoding. The PCM system recorded the aircraft flight parameters (aircraft rates, aircraft attitudes, and engine parameters). Three small cameras were installed on the bottom of the aircraft (Figure A-4) to record the main and tail landing gear reactions to landing aboard a ship. Cockpit communications were recorded as well. Instrumentation and required special equipment already installed on the test aircraft are presented in the following lists.

### COCKPIT PANEL (In Addition to Standard Ship Instrumentation)

Altitude (boom)
Altitude (ship)
Airspeed, sensitive analog display (boom)
Airspeed, sensitive analog display (ship)
Angle-of-sideslip (boom)
Control positions
    Longitudinal cyclic
    Lateral cyclic
    Directional
    Collective
Event switch

### ENGINEER PANEL

Engine Fuel Flow (both engines)
Engine Fuel Used (both engines)
Total air temperature
Main rotor speed (sensitive, digital)
Time code display
Record number
Event switch
Instrumentation controls

### GPS PARAMETERS (RECORDED ON FLASH-RAM CARD)

X, Y, Z position of aircraft (Earth centered, Earth fixed)
VX,VY,VZ velocity of aircraft
GPS Time

## PCM PARAMETERS (RECORDED ON MAGNETIC TAPE)

IRIG B time code
Record number
Event switch
Altitude - boom
Airspeed - boom
Altitude - ship
Airspeed - ship
Angle-of-attack - boom
Angle-of-sideslip - boom
Main rotor speed
Main rotor speed (digital)
Engine fuel flow (both engines)
Engine total fuel used (both engines)
Fuel temperature (both engines)
Engine torque (both engines)
Turbine gas temperature (both engines)
Engine power turbine speed (both engines)
Engine gas producer speed (both engines)
Radar altimeter
Stabilator incidence angle
Control positions
    Longitudinal cyclic
    Lateral cyclic
    Directional
    Collective
Stability Augmentation System actuators
    Longitudinal
    Lateral
    Directional
Primary servo positions
    Lateral
    Forward
    Aft
Angular attitudes
    Pitch
    Roll
    Yaw
Angular rates
    Pitch
    Roll
    Yaw
Total air temperature
Linear accelerations
    CG normal
    CG lateral
    CG longitudinal

Figure A-1.  Airspeed Boom

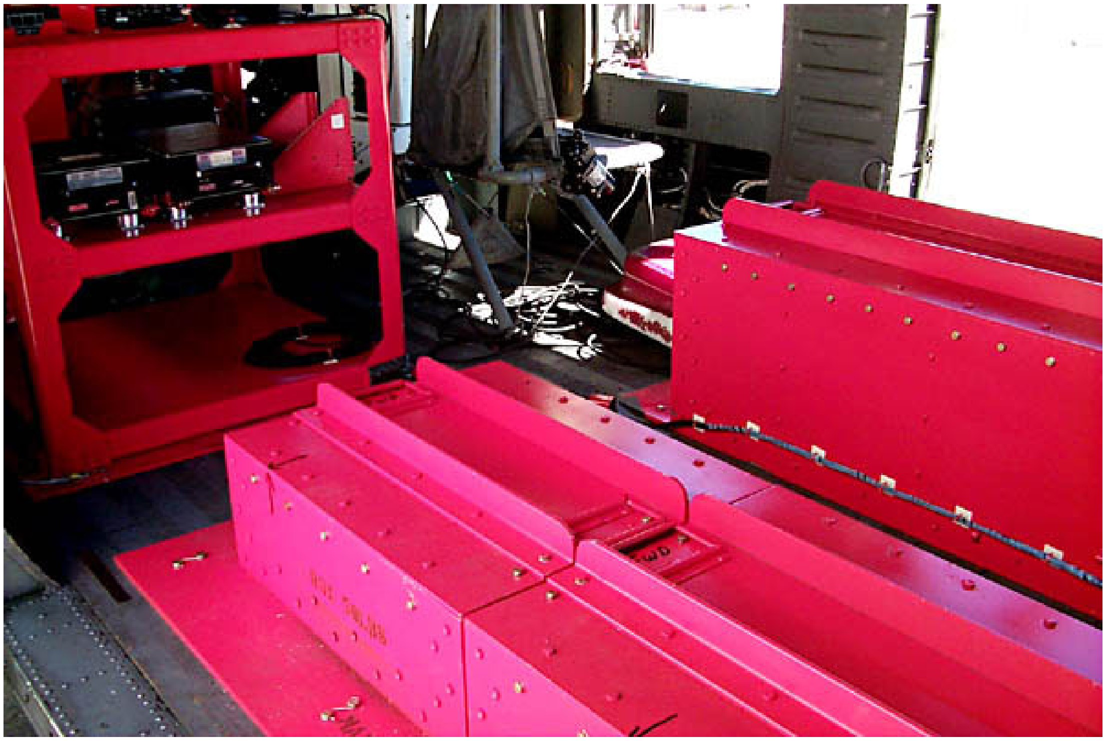


Figure A-2.  Instrumentation Rack and Ballast Boxes

Figure A-3.  Main Cabin Ballast Boxes

Figure A-4.  Main Landing Gear Camera Position (same both sides)

# VITA

Philippe A. Catoire was born in Toronto, Canada on October 3, 1964. He attended public school in Evanston, Illinois, graduating from Evanston Township High School in June, 1982. He received a Bachelor of Science degree in Engineering Technology from Austin Peay State University of Clarksville, Tennessee in 1993. In August, 1985, Mr. Catoire enlisted in the United States Army as part of the Warrant Officer Flight Training Program. He was appointed a Warrant Officer and Army Aviator in November, 1986, at Fort Rucker, Alabama. He graduated as part of Class 107 from the United States Naval Test Pilot School in June, 1995, returning to Fort Rucker, Alabama as an Experimental Test Pilot for the United States Army Aviation Technical Test Center. Mr. Catoire is currently stationed at Naval Air Station Patuxent River, Maryland in the Joint Shipboard Helicopter Integration Process, Joint Test and Evaluation Program Office.

Mr. Catoire is a Master Army Aviator with over 3,500 flight hours in over 50 different aircraft. He has conducted numerous systems and flight test programs on the OH-58D and UH-60 helicopters.