VISUAL LANDING AID EVALUATION USING SIMULATED DYNAMIC INTERFACE METHODS IN THE MANNED FLIGHT SIMULATOR (MFS)

BY

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ABSTRACT

Rotocraft/ship analytic testing were conducted using the NAVAIR Manned Flight Simulator to evaluate the effect of changes in a Landing Period Designator (LPD) display symbology on pilot workload while performing simulated Dynamic Interface shipboard mission scenarios. The simulated tests were flown by instructor pilots from the US Naval Test Pilot School (US and UK), the US Army, and from an operational US Navy Squadron. This paper briefly reviews some early Dynamic Interface program options, early ship lighting programs, the US Navy and Royal Navy helicopter ship test techniques, and also briefly discusses the LPD development. Tests were performed using a variety of ship motion and environment conditions that were repeated for the basic LPD, for the LPD with a display rate option, and for the LPD OFF. Qualitative pilot comments, including specific pilot effort ratings for each shipboard landing, and similar quantitative data were recorded. This paper presents an analysis of the test data and presents recommendations for future LPD applications to help support rotocraft/ship applications.

INTRODUCTION

It is important to develop options to reduce the cost and cycle time associated with the test and evaluation process, to enhance the productivity of flight test team members, and to improve the safety of flight operations especially in adverse environments. Flight testing is required in both land based and sea based environment with a variety of test aircraft and ships. Simulation is often listed as one option with the potential to help reduce the cost associated with flight testing[1]. The simulation of helicopter operations from naval vessels provides a unique set of challenges.

DYNAMIC INTERFACE

US Helicopter/ship operations have been ongoing since the mid 1940's[2]. The tempo of Navy helicopter/ship testing increased in the 1970's with the advent of the SH-2 Light Airborne Multi-Purpose System (LAMPS MK1) helicopter designed primarily for shipboard operations. During this time frame the term "Dynamic Interface or DI" was first coined at the US Naval Air Test Centre (NATC) and it involved the development of launch/recovery envelopes for a specific type helicopter operating in the at-sea environment of a specific class ship. The US Navy helicopter/ship focus in the 1980's was primarily on the SH-60B LAMPS MKIII helicopter. During this time period, the conventional DI flight testing was supplemented with a new analytic approach[3]. The DI analytic approach represents a difficult task due to the many problem variables, including aircraft type, ship class, ship airwake and motion, environmental conditions, and a large backlog of ship classes that required testing at that time[4][5]. It is also difficult to get adequate quantitative shipboard flight test data to validate analytical models. Night/low visibility and/or high ship motion conditions may increase the pilot workload during shipboard landings and also increase the difficulty in acquiring quantitative data due to safety concerns.

Ground and flight testing were used during the late 1960's and early 1970's to develop a standard visual landing aids (VLA) package to support night helicopter/ship operations on surface combatant ships. The standard VLA package helped the pilot identify the ship position and direction of movement, provided glide slope alignment for the approach, and flight deck lighting to help the pilot determine the aircraft position over the flight deck. The standard VLA package does not provide the pilot with flight deck energy information, which may be very important during periods of reduced visibility and/or increased ship motion. The current emphasis is on a new generation of ship VLA components with reduced radar signatures. The ongoing multi-national work to develop improved helicopter/ship analytic models, and the work on a new generation of ship VLA components should have a positive impact on integrating the total ship VLA cueing to support future pilot flight operations.

HELICOPTER-SHIP LAUNCH AND RECOVERY

United States Navy

The launch and recovery procedures for US Navy helicopters aboard "small decks" which include cruisers (CG), guided-missile destroyers (DDG), guided-missile frigates (FFG), and supply vessels differ from the large amphibious ships: landing helicopter assault (LHA) or landing helicopter dock (LHD), and aircraft carriers (CV) or (CVN). The procedures for launching and recovering various helicopter types aboard a ship can be differentiated on whether the helicopter handling system is present and used (rapid securing device or RSD) and whether the launch or recovery will occur in day visual meteorological conditions (VMC), night VMC, or in instrument meteorological conditions (IMC) with night vision device (NVD) launch and recoveries being a subset of VMC launch and recoveries. Ships containing helicopter recovery systems have three deck configurations for recovering a helicopter aboard a small deck are: clear deck, free deck; and recovery assist (RA).

A clear deck landing means the RSD is stowed and the helicopter will be landing without the use of the RSD or RA systems. A free deck landing means the RSD has been positioned in the landing area and the pilot will fly the helicopter to a position above the RSD and land the helicopter placing the RA probe into the RSD which will then be used to secure the helicopter to the deck of the ship (FIG.1). Lastly, to execute a RA landing, the pilot will fly to and establish a hover over the flight deck. From the aircraft the RA probe will be lowered to the flight deck via a messenger cable. Flight deck personnel will attach to the RA cable to the RA probe which will then be reeled back up to the aircraft and secured. Once the RA cable is secured to the aircraft, the ship will establish hover tension (850 to 2000 lbs) onto the RA system which stabilizes the aircraft over the RSD. When the pilot is ready to land, the ship will select maximum tension (4000 lbs) which hauls the aircraft down into the RSD, then the RSD clamps around the RA probe securing the aircraft to the flight deck.

FIG.1 – SH-60 AND RSD TRAP

The distinguishing characteristic between an approach flown to a small deck in day VMC, night VMC or an approach flown in instrument meteorological conditions (IMC) is how the aircraft arrives behind the ship. A day VMC approach (FIG.2) is commenced from at least 1.5 nm behind the ship at not less than 200 ft above ground level (AGL) at approximately 80 KIAS heading along the ship's base recovery course (BRC).

The pilot then flies toward the stern of the ship aligning his approach path with the ship's line up line meeting a series of altitude and range gates that terminates with the aircraft at one-quarter nm and 125 ft AGL astern the ship with a closure rate suitable for the given conditions. The closure rate (the difference between aircraft ground speed and the ship's speed of advance) will depend on several factors such as sea state, ship motion and visibility. During a night VMC approach, the pilot will fly or be vectored to a point at least 1.2 nm behind the ship at 400 ft AGL at 80 KIAS aligned with the ship's BRC (FIG.2).

The pilot will then fly to intercept the stabilized glideslope indicator (SGSI) green/amber interface and fly the green/amber interface to arrive behind the stern of the ship at a suitable closure rate (FIG.3). An IMC approach is flown much like a ground controlled approach (GCA) is flown at any suitably equipped airfield. A controller aboard the ship will guide the pilot to a point astern the ship by providing heading and altitude commands. Unlike an approach to an airfield, however, the pilot must remember to slow his rate of closure as the aircraft approaches the stern of the ship.

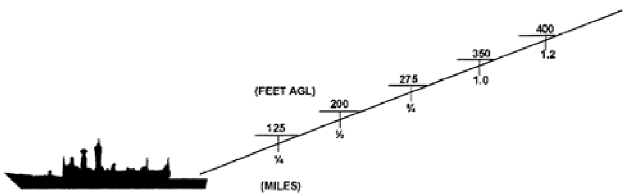


FIG.2 – SMALL DECK NORMAL NIGHT APPROACH PROFILE

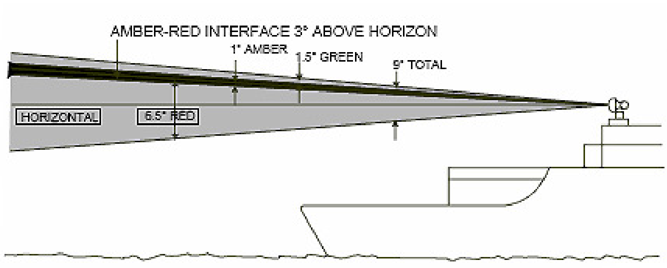


FIG.3 – STABILIZED GLIDESLOPE INDICATOR BEAM

Regardless of how the aircraft arrives at the stern of the ship, the final phase of the approach to land on the flight deck is flown purely using visual cues. There is no prescribed method for flying the last phase of the approach to land on the flight deck. From experience, if there is little deck motion, the rate of closure can be arrested as the aircraft arrives over the aft end of the flight deck at approximately 20 ft above the deck. The pilot will then establish a slow creep to position the aircraft over the intended landing point decreasing his altitude appropriate for the method of recovery (clear deck, free deck or RA). In higher sea states that generally equate to a lot of deck motion, experience has shown the best method for approaching the flight deck is for the pilot to establish a hover (zero closure rate to the ship) behind the stern of the ship and observe the deck motion. What the pilot is looking for is to qualitatively determine when the ship flight deck is in the quiescent period. The pilot should plan to make his landing when the ship flight deck is in a quiescent period. Accurately determining when the ship flight deck is in the quiescent period is difficult requiring a lot of experience and a little luck. The landing period designator (LPD) can assist the pilot in determining the energy state of the flight deck and hence the quiescent period.

Launching from a small deck is much simpler. All launches are flown using the same method and only differ as to whether the aircraft is in the RSD or free of the RSD prior to launch. If the aircraft is in the RSD, the landing safety officer (LSO) will release the aircraft from the RSD prior to the aircraft lifting to a hover. As the pilot lifts the aircraft to a hover, he will slowly back the aircraft away from the hangar increasing his hover altitude to approximately 20 ft above the flight deck. Once clear of the hangar face and with a clear departure corridor, he will pedal turn the aircraft into the wind and depart into wind. The aircraft will be flown to 200 ft AGL and 60 KIAS prior to making any turns.

Royal Navy into Wind Port Approach

The Royal Navy conducts two distinct flight profiles for approach and landing to a vessel under way; forward facing (from both port and starboard) and into-wind. As the into-wind approach has many similarities to the standard USN flight profile, this paragraph will concentrate on the forward facing profile, in particular port approach.

The aim of the forward facing port approach is to fly a constant angle approach to a point slightly behind and above the flight deck (FIG.4). Particularly at night, the profile is commenced from a 'gate' position _ nm astern the vessel on the Red-165 (Port side 165° from ships head) at 125 ft and 60 kts groundspeed (min 40 KIAS to max 80 KIAS).

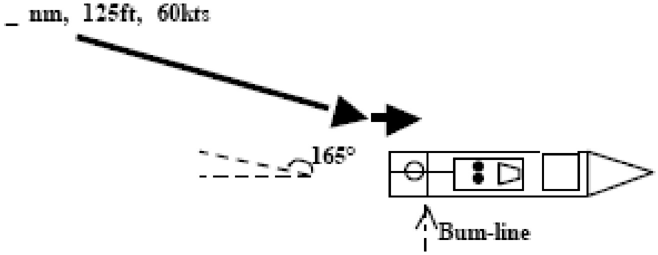


FIG.4 – PORT APPROACH FORWARD FACING LANDING

From the gate position a controlled approach is conducted with a progressive descent and deceleration to arrive at a point slightly behind and above the flight deck in a slow hover taxi; at night the approach angle is supplemented by a 3° Glide Path Indicator. The aircraft is then taxied forward the last 10 yards, on the same heading as the ship's heading, while ensuring there is approximately one rotor span lateral clearance between the rotor disc and the flight deck. The aircraft is thus brought to the hover with the pilot sitting abeam the bum-line, one rotor span laterally and 10-15 ft vertically displaced from the flight deck (FIG.5). The bum-line is used as a reference to prevent any fore and aft drift with respect to the flight deck. Once in the hover, and if possible during the whole approach, the deck motion is assessed to try and determine the frequency and severity of motion. This allows the pilot the opportunity of predicting a suitable quiescent period for landing. If a suitable quiescent period can not be forecast, the ships course and speed may be altered to provide more favourable flight operation conditions.

FIG.5 – IMPRESSION OF A MERLIN ON T45 DESTROYER

Once it is assessed that a quiescent period is approaching the aircraft is then moved laterally along the bum-line until in a hover over the centre of the flight deck at 10-15 ft. The aircraft is then descended vertically, with no drift, aiming for a firm, but not heavy, landing.

LANDING PERIOD DESIGNATOR (LPD)

The LPD is an electro-optical device that senses ship acceleration and rate motion energy, and presents this energy in terms of a visual landing aid graphical format that pilots can use to help determine when the ship motion is approaching a quiescent or low ship energy condition conductive to a safe landing. It is composed of a motion reference unit (MRU), a computer containing a standard operating system, the energy index algorithm and ship-motion processing programs, and an external and internal light indicator (FIG.6).

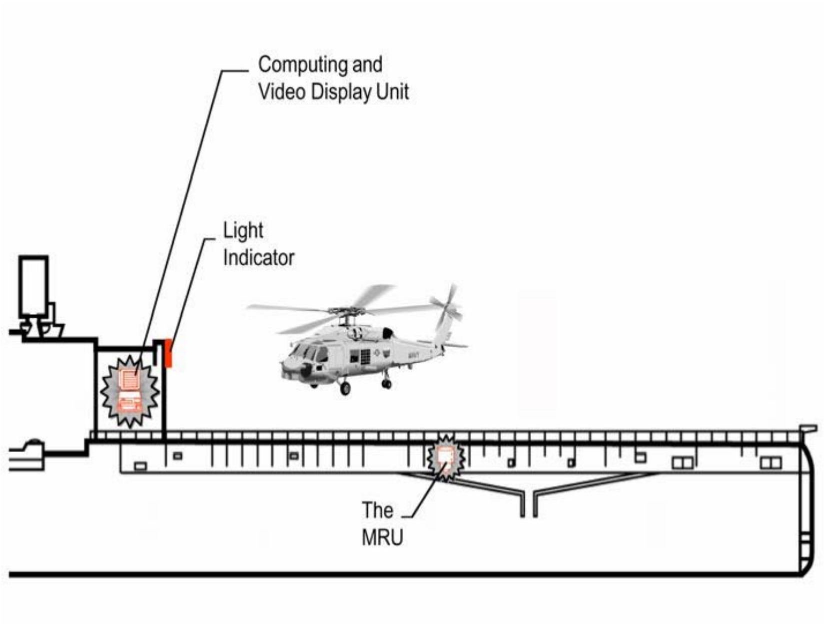


FIG.6 – LPD COMPONENT ARRANGEMENT

The external light indicator communicates the status of the deck while providing the same information to (internal light system or peanut lights) the operator on the ship. The monitor displays an echo of the light system, along with gauges indicating ship's roll, pitch, vertical and lateral information, ship's list and trim along with a 10 minute graphed history of ship's motion and the energy index. If required, shipborne staff may access all the degrees of the freedom, their rates and accelerations in real-time. Tabular information includes deck energy distribution by second along with rise-time data.

SIMULATORS TO SUPPORT DI TESTING

Launch and recovery envelopes are typically developed by at-sea experimentation which focuses on describing the dynamic boundary area over the deck (wind-over-the-deck speed and direction). To achieve the identification of an envelope, days of sea testing may be required which are vulnerable to the random nature of the elements. Flight simulators provide a unique controlled environment and in the future may be used to help estimate suitable relative wind envelopes to support flight testing. Ship motion models may provide basic information for a laboratory to compute deck motion limits for ships with conventional hull shapes. Factors affecting an air vehicle on a moving platform are primarily ship motion; wind-over-the-deck; ship airwake turbulence; and deck conditions (e.g.: wet, dry, oily, obstructed). Deck handling limitations can be defined as the point at which an aircraft/ship incident occurs. Incident means an occurrence of aircraft turnover, pitchback or on-deck slide at any point from touch-down to hangar stowage and back to launch. Deck handling studies determine turnover limits, sliding freedom, tiedown forces, traversing factors, and pitch back limitations. Motion of an aircraft on the flight deck is calculated in terms of ship motion as a function of the aircraft model. The aircraft model is considered an extension of the ship. The model is defined by its landing gear footprint; deck location and orientation; aircraft weight and inertias, centre of gravity, lateral drag area and centre of pressure. The aircraft experiences ship transferred forces and moments that create rectilinear and angular accelerations on the air vehicle. The accelerations can be numerically integrated to determine the position and attitude of the helicopter relative to the ship as function of time, for various ship motions[6]. In essence, the aircraft is displaced as the sum of all forces to which it is exposed. A wind force is added to the ship motion induced forces.

To house the dynamic interface programs, existing flight simulators are used (RNAS Culdrose in the UK and in the NAVAIR Manned Flight Simulator (MFS) in the US) with external federate models. These are introduced to provide ship and environment functionality such as real time representation of ship motion and the air wake flow field.

For those supporting the development of simulated dynamic interface, a key objective is to provide a system capable of conducting operational envelope estimates during ship development and prior to sea trials. It is envisioned that a cost-effective combination of simulation and first-of-class flight trials at sea will maximize the operating envelope for the various new ship platforms from which a manned helicopter or UAV is intended to operate. Real-life flight trials are expensive operations and are also limited by the prevailing weather conditions available for the duration of the test period.

SIMULATED DI WITH LPD VLA

One of the key factors related to increased operational capability in landing helicopters onboard ship, is the ability to repeatedly launch and recover safely from a ship moving in response to the seaway. Currently, the procedure for landing manned aircraft requires the aircraft to be piloted to a position of hovering over the moving deck. When the LSO, perceives that the ship is suitably quiescent, he/she will advise the aircraft pilot that deck motion is within acceptable limits. This procedure is empirical in nature with aid of inclinometers used to record average ship motion conditions. The deck limits of a helicopter may be increased if it can be confidently landed only when the deck is quiescent irrespective of the seaway. The flight deck officer and staff will still need to position the aircraft over the RSD trap, but computational methods are now proposed to resolve the difficult assessment of the quiescent point.

In designing a deck operation envelope the test team will give the ship a set of relative wind directions and speeds, which it deems suitable for safe repeatable landings. In addition the test team will provide a simple limit of ship motion, e.g. ±2° Pitch and ±3° Roll, within which the landing should occur. As yet no heave limits are given with a deck-operating envelope. Remaining within the combined pitch and roll limits, and the limitations of heave such that the aircraft undercarriage limits are not exceeded, is usually dealt with by the pilot attempting to land the helicopter only during a quiescent period.

One of the main difficulties associated with teaching a new Naval Aviator to conduct helicopter flight deck operations is teaching the skill associated with predicting the approach of a quiescent period when the vessel is in a high sea state environment. The lesson is even harder to appreciate under the reduced visual reference cuing associated with night landings. This skill is generally learned through experience over a protracted period of time. Even when experienced, a pilot will always err to the side of caution, unless other more demanding circumstances prevail.

The information provided by the LPD has many benefits in providing the pilot with important cues associated with deck motion, in particular heave. These cues complement the Relative Wind envelope and the information provided from a gyro stabilized horizon bar.

The LPD provides a clue to the ship's 'energy index' and thus the potential for the deck to go to an out-of-limits condition (Red LPD indication). Safe landings can be made in any LPD indication except Red or the 'Wake-Off' indication. The information provided is dependent on the LPD indication;

- GREEN (Very Safe Deck) – the ship is at a low energy state and will thus require considerable energy to be transferred from the sea state to place the flight deck out of limits. The momentum change required will take a minimum period to occur (rise time) for each helicopter type combined with each class of vessel;

- GREEN-AMBER (Safe Deck) – the ship is at a higher energy state and has a much lower safe rise-time available. The LPD then becomes an additional aid in judging the potential quiescent period. If the indication is Green-Amber with only occasional Amber the flight deck should remain safe over protracted periods during the landing;

- AMBER (Caution Deck) – the ship is operating at the upper end of the safe deck motion limit. The peanut light arc (eyebrow) associated with the Amber indication gives trend information of the energy index in this condition and thus the tendency of the deck motion to either an in-limit or out-of-limit condition. Again, the LPD becomes an additional aid in judging the potential quiescent period;

- RED (Unsafe Deck) – the deck motion is such that one of the degrees of freedom has exceeded acceptable aircraft limits for a safe recovery. An occasional 'flash' of Red on a particular flying course could be considered acceptable; dependent on the other associated LPD indications. However, protracted period of Red will indicate that a new flying course is required. This indication will be of particular benefit to the Ship's bridge team in establishing a good flying course in very poor sea state conditions.

TEST OBJECTIVES

The NAVAIR Manned Flight Simulator testing program was designed to investigate the effects on Ship Helicopter Operating Limits for the DDG Destroyer and SH-60 helicopter using the Landing Period Designator under a variety of conditions and to assess emerging landing aid technologies for effectiveness and application. The simulated flight test has 3 (three) essential global objectives: assess the capabilities of the Landing Period Designator to support or conduct deck limit trials; demonstrate simulator utility as a platform to test aircraft-ship interface issues; and evaluate recovery safety improvements offered by LPD.

The indicator for success was the pilot's ability to safely and repeatedly recover the aircraft in the range of desired conditions, such that the RSD could be engaged. Pilot flight runs were consistent with current flight patterns. Flight runs were programmed for day and night and under progressively difficult deck conditions. In addition to the objectives indicated earlier, particular attention was made to recovery times and envelope limits.

Primary Testing Objectives and Conditions:

- Indicator of success was the pilot's ability to safely and repeatedly recover to the deck;
- Day and night and under progressively difficult deck conditions;
- Programmed deck NATOPS/Ship Helicopter Operational Limit (SHOL) by aircraft;
- Standard Circuit: First Circuit LPD OFF. There after: LPD ON, LPD OFF first day then night, same order. The pilot rated workload using the Deck Interface Pilot Effort Scale (DIPES) plus comments on the overall task cueing.

The LPD hangar light is attached to the upper starboard side of the hangar (FIG.7). It is in plain view over the flight deck and in full view from hover. From this location on the starboard side of the ship, the indicator is visible during either stern approach (USA) or the port-approach (UK) and hover. If the SH-60 is simulated in its positive pitch up attitude, the indicator light visual might be at the limit of the field of view.

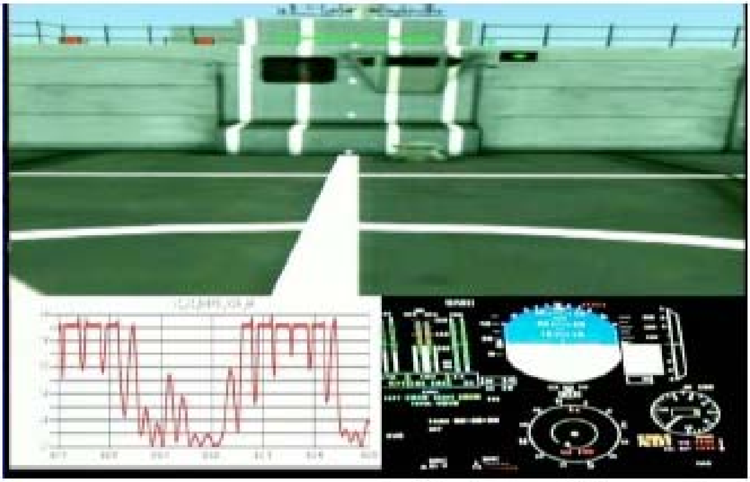
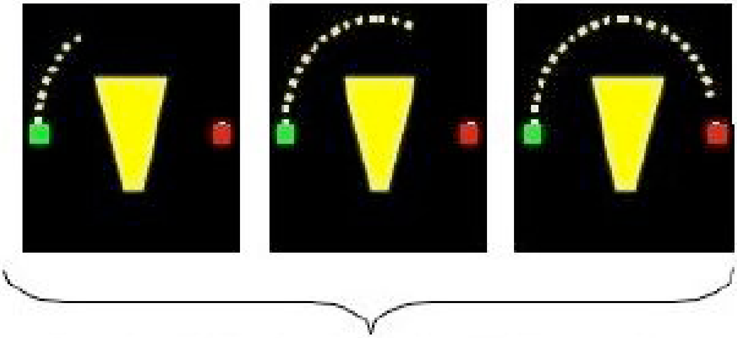


FIG.7 – USN MFS DESTROYER WITH LPD DISPLAY

The LPD calculates the Energy Index and broadcasts it over the simulator visualization system. Depending on the value of the Energy Index, the appropriate symbol is illuminated on the LPD indicator visual box. (FIG.8) displays the light on the actual ship.

FIG.8 – THE LIGHT INDICATOR ON DDG 88

In the initial configuration, the symbology is reduced to green, amber and red. In the amber region, peanut lights are illuminated as the energy index rises or falls giving the impression of the direction the energy in the deck is going (FIG.9).



Arc shows energy index level within the amber zone, allowing trending to be seen toward green or red.

FIG.9 – LIGHT RATES SYMBOLOGY

TEST RESULTS

There were four test pilots involved in the simulated dynamic interface test over the course of the exercise. Pilots hailed from VX-1 squadron, a US Navy Test

Pilot School (USNTPS) instructor, the Royal Navy exchange test pilot instructor at USNTPS, and a pilot from the US Army Joint Operations. A total of 133 flights runs were conducted in conditions, which varied in relative wave direction and wave height. Winds were kept between 10 to 30 knots vectored in the direction of the relative wave angles (winds are computed as a constant force). Ship's speed was maintained at 10 knots. At the end of the test program, some additional testing was conducted at 20 knots. The visibility was either day or night with several scenarios computed during rain or snowstorms. In addition, LPD light configurations included the standard symbology along with the rate system for both day and night.

Simulation flights focused on a planned test matrix. The matrix contained a number of environmental variables including ship's speed, relative wave angle, significant wave height and period. In addition, three VLA states, LPD ON, OFF and rates, were listed. Almost all aspects of the flight and ship characteristics were cross-referenced; it was relatively easy to develop parametric trends and cause and effect principles during the course of the test. Three flight runs (A-C) are discussed below. The three primary study graphics for flight A are presented in (FIG's 10-12).

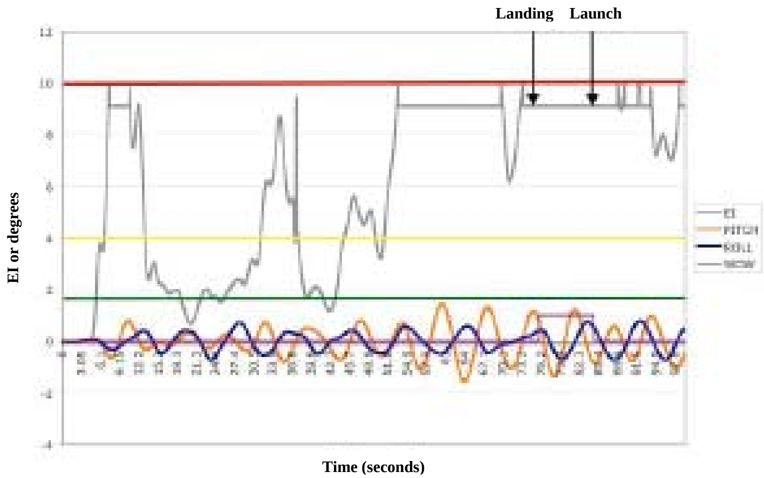


FIG.10 – FLIGHT A (DAY) WITH LAUNCH AND RECOVERY

(FIG.10) displays the ship's roll and pitch time history along with the corresponding energy index trace during flight run A. The ship's velocity is 10 knots, the relative wave angle is 15° and the significant wave height is 9 feet. The visual landing aid configuration had the LPD OFF trace during day hours. Both the recovery and launch occurred from an amber or caution deck. The corresponding translation traces showed similar displacements at launch. Oleo compression (FIG.11) appeared normal with the tail wheel touching the deck first. The engine torque was measured well within proscribed limits throughout the run (FIG.12). The relatively low pilot workload ratings recorded during a measured high sea state 4 condition may be attributed to the exceptional experience of the test pilots.

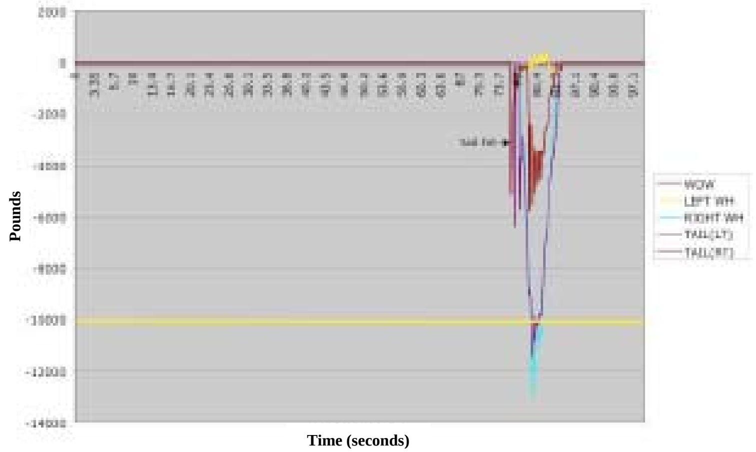


FIG.11 – FORCE ON WHEELS (-Z = POSITIVE FORCE)

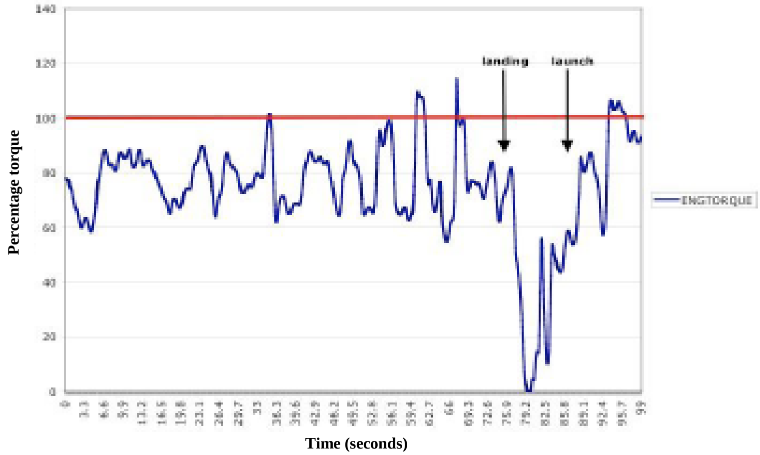


FIG.12 – FLIGHT A ENGINE TORQUE

In flight B, the significant wave height measured 12 feet with LPD light OFF. All other parameters were held constant. (FIG's 13-15) displays the related recordings.

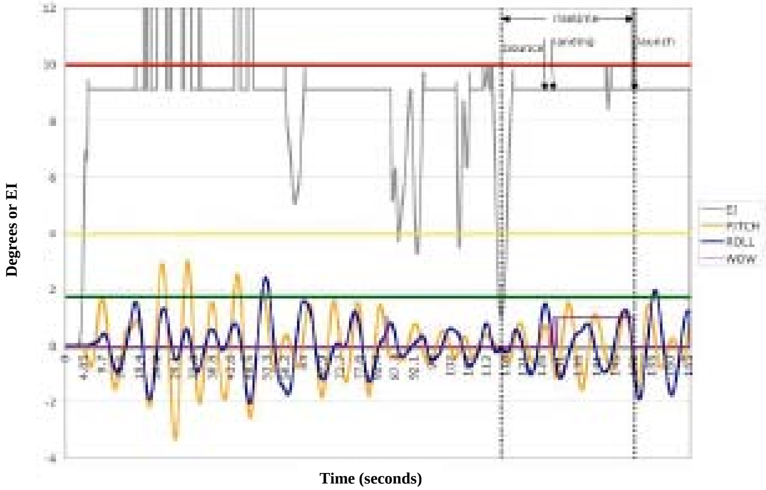


FIG.13 – FLIGHT RUN B (DAY) WITH EVENTS

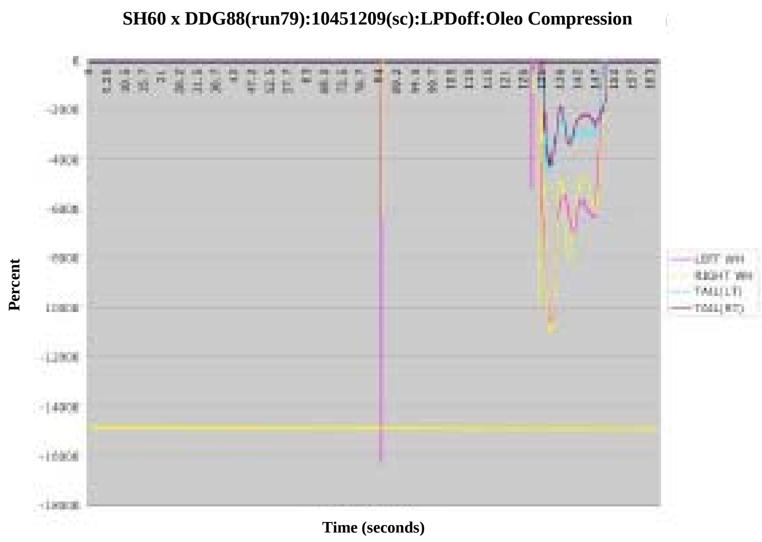


FIG.14 – FLIGHT B (DAY) OLEO COMPRESSION

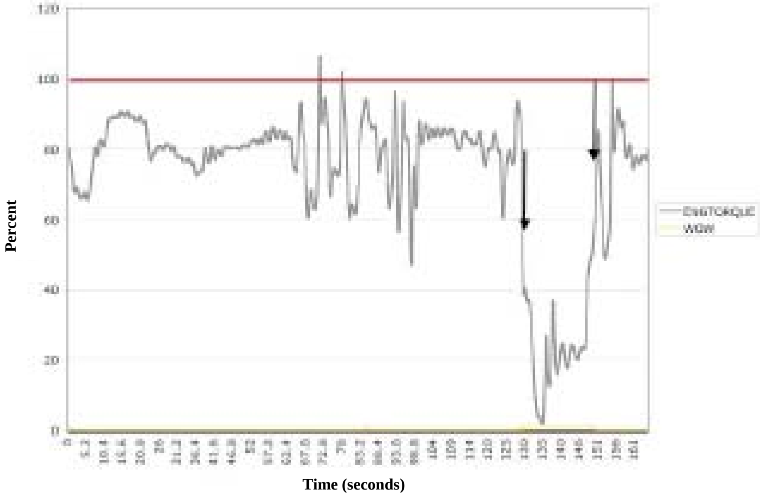


FIG.15 – FLIGHT RUN B (DAY) ENGINE TORQUE

(FIG.13) displays the motion, energy index (visual was OFF) and launch and recovery traces. The recovery occurred after a bounce to a high amber deck. The launch was from a deck defined by NATOPS as out-of-limits. The corresponding oleo compression (FIG.14) shows a heavy bounce then left main wheel first strike on deck landing with light encountered forces. The engine torque (FIG.15) shows lower overall engine activity. This contrasts with flight C which contained the same environmental conditions as B but had the LPD light ON with rate feature.

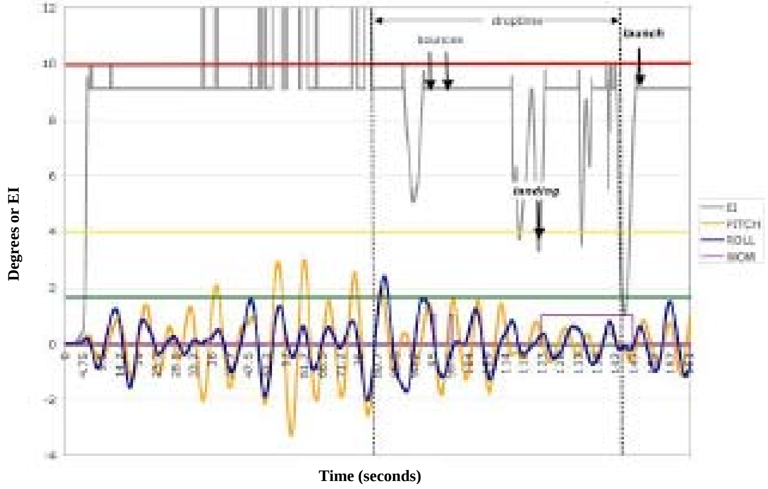


FIG.16 – FLIGHT RUN C (DAY) WITH LAUNCH AND RECOVERY POINTS

In flight run C, the significant wave height measured 09 feet with LPD light ON. All other parameters were held constant. (FIG's 16-18) displays the related recordings.

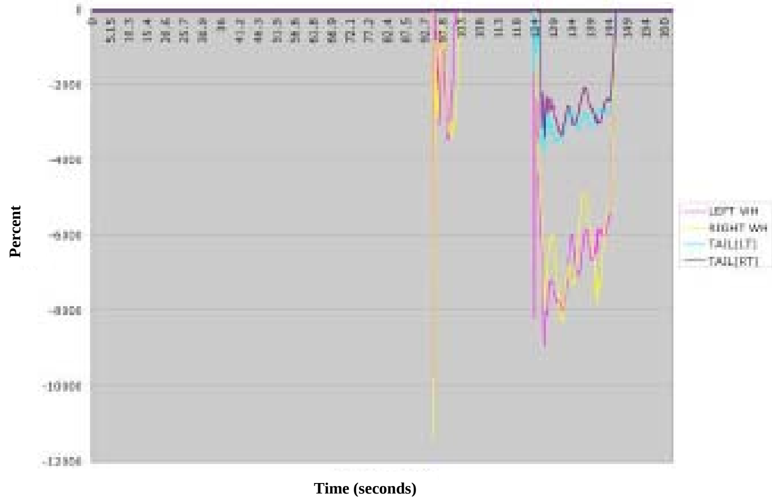


FIG.17 – FLIGHT RUN C (DAY) OLEO COMPRESSION

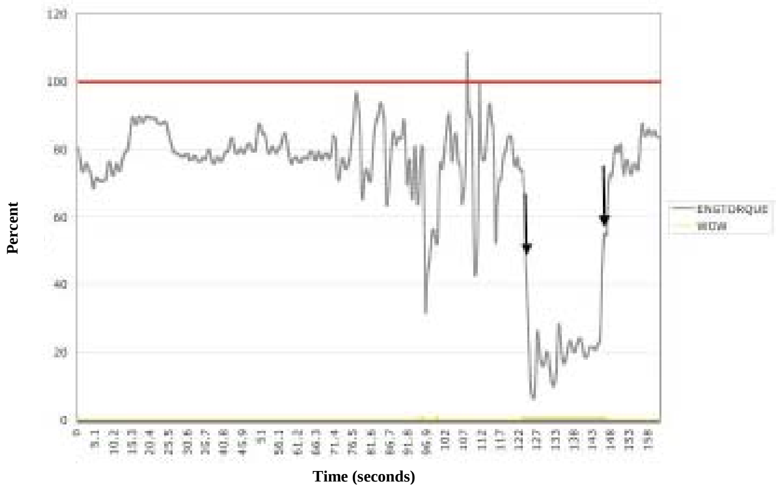


FIG.18 – FLIGHT RUN C (DAY) ENGINE TORQUE

(FIG.16) displays the last day file evaluated and contains motion, energy index (visual rate was ON) and launch and recovery traces. The recovery occurred from a green-amber deck. The launch was from a high amber deck. The corresponding oleo compression (FIG.17) shows a heavy 3-point deck strike followed by normal deck landing. The engine torque (FIG.18) shows slightly lower engine activity.

DECK RECOVERY

The LPD was applied as a visual landing aid and operated as a federate. The Manned Flight Simulator was modified to implement a federated operation allowing individual simulation components to be replaced with a minimum of change to the other components. Among the issues analyzed, was the fundamental question as to whether or not the LPD could be used to improve launch and recovery activities. The answer to that question would manifest itself in the recorded data and would be supported by pilot commentary and observations.

As mentioned earlier, one of the key factors related to increased operational capability in landing helicopters onboard ship, is the ability to repeatedly launch and recover safely from a ship moving in response to the seaway. The successful repetition of the same event raises the overall confidence in conducting the launch and recovery evolution. One of the objectives in using the LPD is to recover on a quiescent or near quiescent deck, regardless of the condition of the seaway. The primary objective is to assess operational improvement as a function of environmental conditions, with and without LPD. The metric of success is the choice of recovery with LPD on quiescent or near quiescent deck which equates to a minimum of ship displacement. The data for this metric is recorded and displayed.

(FIG.19) displays the average distribution, by percentage, of LPD status during launch and recovery events. The distribution represents the combined results of the participating pilots. The current test used uncommon ship motion files with a modified test matrix including a third LPD configuration or state (rate deck indicator). There were no red deck events recorded while LPD was ON. LPD-OFF configuration, however, did contain out-of-limit recordings. The night time events with LPD-ON appear approximately the same between test periods. One of the apparent rate indicator results is the perceptible pilot encouragement to safely use all three available deck energy states. This coupled with the specific deck motion files has resulted in a higher amber deck distribution solution.

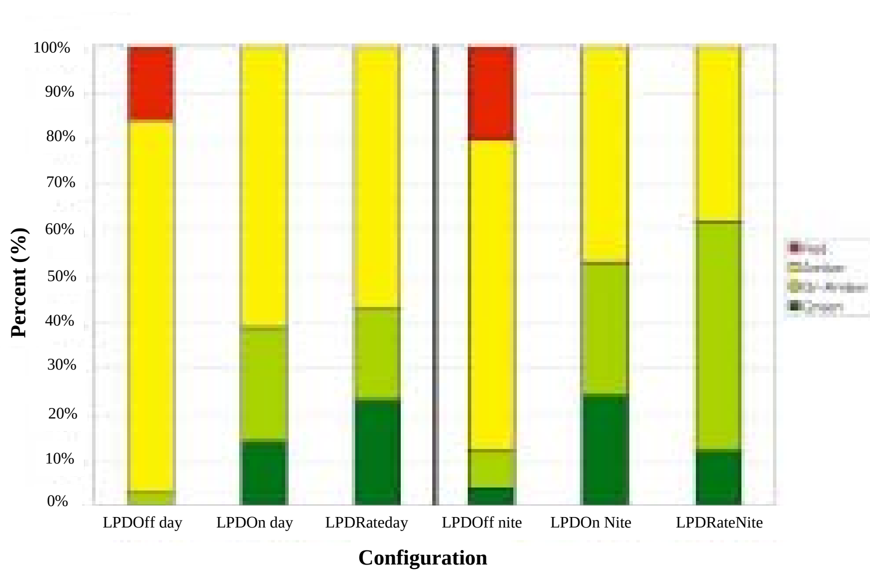


FIG.19 – DISTRIBUTION OF LPD STATUS DURING LAUNCH AND RECOVERY EVENTS

(FIG.20) displays the deck conditions at launch and recovery. The chart is divided into day and night runs. The charts are divided into with and without LPD (and LPD rates). Referring to the day, launch and recovery attempts with LPD are between 15 – 25% from quiescent deck. A little over 20% of the deck evolutions occurred while the deck was green-amber (or safe). Well over 50% of the launch and recoveries occurred on an Amber deck. There were **no red (out-of-limit deck)** LPD-ON/rate launch and recoveries. Compare this with the launch and recoveries without LPD. No events occurred in quiescent. Green-amber rose to 5% while 80% of the events occurred in Amber conditions. Almost 15% of the launch and recoveries occurred while the deck was out-of-limit or red.

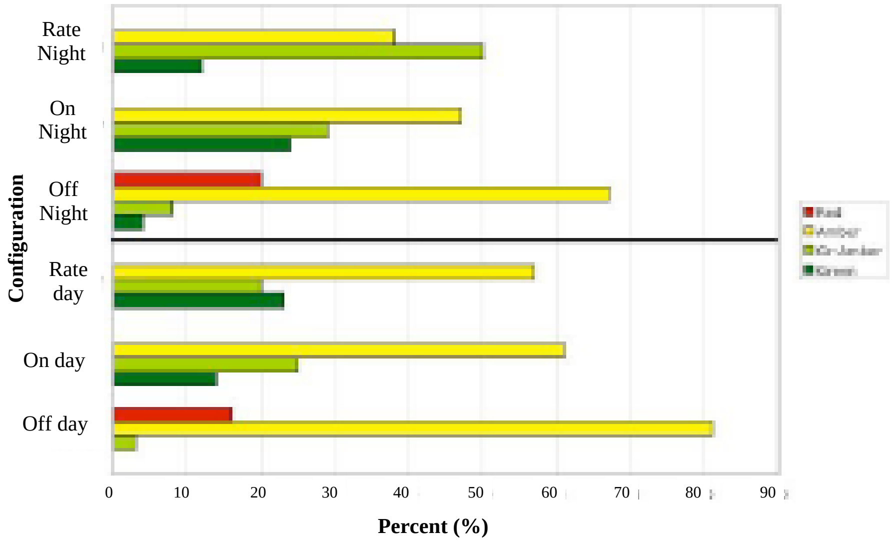


FIG.20 – PERCENT DISTRIBUTION BY ENERGY STATE

Still referring to (FIG.20), night launch and recovery attempts with LPD indicated 25% rate of successfully choosing a quiescent (or green) deck. A little over 20% of the deck evolutions occurred while the deck was green-amber (or safe). About 40% of the events occurred from an amber deck. Here again, **there were no events to or from a red deck**. In the present series of tests with the LPD OFF, a little over 5% occurred while the deck was green, under 10% in green-amber and about 65% had been recorded amber. Red deck accounted for 20% of the launch and recovery attempts. Comparing the rate indicator with the LPD traditional light, there doesn't appear to be large difference in the day results while the night results appear to record slightly lower energy levels using the rate indicator.

Another key factor related to increased operational capability in landing helicopters onboard ship, is the ability to repeatedly launch and recover safely from a ship moving in response to the seaway. One of the objectives in using the LPD is to rapidly but safely recover to a quiescent or near quiescent deck, regardless of the condition of the seaway.

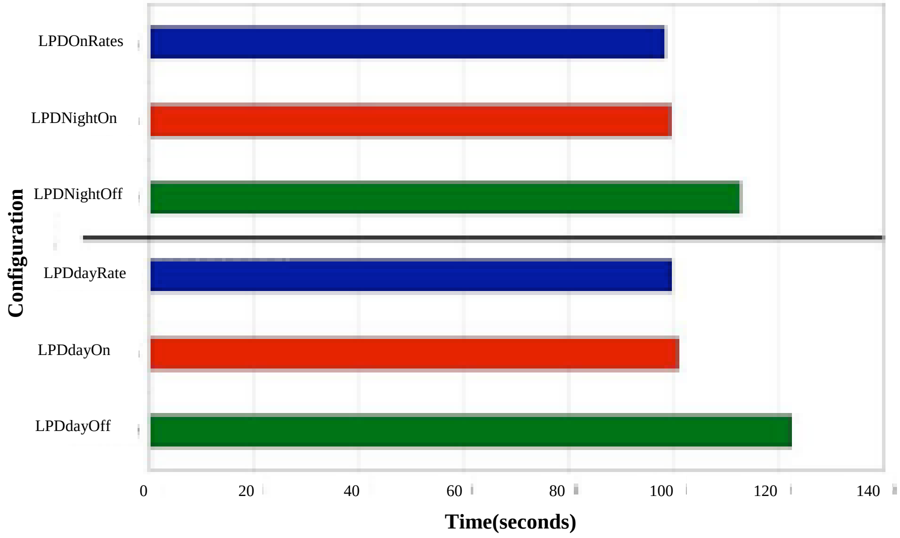


FIG.21 – BOARDING TIMES TO THE DECK

(FIG.21) is divided into Day and Night operations, with and without LPD/rates. The test began from a simulator unfreeze point. Referring to the Day portion of the graphic, with LPD OFF, it took longer to manoeuvre the aircraft and for the pilot to achieve a landing solution than with the LPD ON. There does not appear to be a significant impact on the boarding times when comparing LPD ON with LPD rates. Referring to the night portion of the graphic, with LPD OFF, the same tendencies are demonstrated. The improved recovery times are attributed to improved confidence on the part of the pilots making the landing decision. The quicker recovery time of night evolutions to day evolutions is attributed to the availability of fewer cues for the pilot to achieve a landing solution. The deck status conditions were also recorded and studied during the simulated DI. (FIG.22) displays the average deck status for the test.

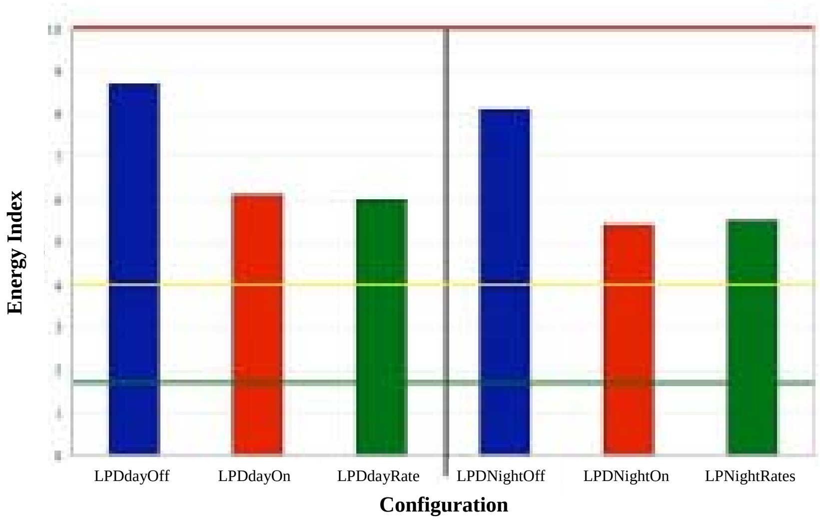


FIG.22 – OVERALL DECK STATUS ON MFS TEST

From the graphic the average deck energy condition measured lower for launch and recovery events with LPD than without. There does not seem to be any impact on the deck status condition when comparing the LPD rate with the LPD traditional light indicator. Part of the significance might be lost in averaging the data.

TEST SUMMARY

The key to a safe and successful landing of a helicopter aboard a small deck ship often hinges on the ability of the pilot to determine when the flight deck is in a quiescent period. Even in daylight VMC conditions, the task of accurately determining the quiescent period is difficult. To determine the quiescent period, the pilot must hold a stable hover (zero rate of closure) behind the stern of the ship which may have significant roll, pitch, heave, and sway motion with accompanied turbulence due to the ship's superstructure while simultaneously observing the ship's motion and the wave action in front of the ship. If the pilot assesses the quiescent period incorrectly, he may attempt to land the aircraft when the ship's motion is building possibly placing the ship's motion out of limits. In a poor visual cue environment at night or IMC conditions or when the aircraft is in close to the superstructure of the ship, the pilot loses the visual cues necessary for him to determine the ship's motion and hence the quiescent period. Although the LSO or the helicopter control officer (HCO) can provide the pilot with the recent observed pitch and roll motion of the ship, that information is time late and is most likely the maximum pitch and roll they observed during the time they were looking at the ship's inclinometers.

This report assesses aircraft and deck availability improvements by using the Energy Index to signal the top of recovery. Energy Index quiescent recovery opportunities may be used in the future to support operations presented outside of current operating limits. A brief synopsis of the theory and calculation of the ship motion simulation and Energy Index programs, were discussed. The study conducted in real-time space, analyzed the interface of the SH-60 and DDG-88. Permitting a certain level of aircraft incident risk, it may be generally stated that SH-60 x DDG-88 deck clearance for the briefly unsecured SH-60 , while lightly restricted ahead and unusually unrestricted in a beam sea should not limit SH-60 availability or impact directly on the performance of the air vehicle under normal operating conditions. Air vehicle and deck availability may be enhanced beyond the indicated envelope when the operator uses the energy index to signal the top of recovery. As developed in the report, green deck points are identified even in the worst of sea conditions. The periods may be rapid, but owing to the rise time, the deck is constrained to pass from green to red by a latency period. This approach to deck limits is based on dynamic factors rather than static. It should be apparent that the envelopes calculated above are combination specific and dependent on the mathematical definitions programmed. If any dynamic or static parameters are modified, the envelope limitations may be modified, as well. Dynamic issues continue to be present throughout this period. The deck needs to be sufficiently stable for some time after recovery. Once their rotor is stopped, the deck crew would use the LPD as a deck monitor. The limits would be those at which a person would stumble owing to boundary layer conditions. This is particularly important if the crew is refuelling, rearming or traversing the aircraft.

While the report focus was on air vehicle final approach and recovery, deck issues significant to air vehicles after recovery include chock and chain, aircraft on deck manipulation, handling and service.

In the development of this study, an overview of the ship motion and dynamic interface simulations and modelling has been described with the emphasis on undercarriage encountered forces and air vehicle response stability. Validation of the results is a priority because of the potential problems affecting ship-helicopter operating deck limit to be programme for air vehicle automatic recovery. Beyond the basic problem of data verification and validation, the analytic procedure demonstrated above is sound and could be used to cross-correlate between proposed aircraft-ship deck motion limits and the vehicle expected physical responses.

In general, during simulator operations, the LPD was a useful addition to the available cues of the deck motion of the ship. In lower sea states it was a comprehensive aid in the timing of the decision to land. The LPD will reduce the time to land, as it is easier to decide on the quiescent period with the LPD-ON. This will reduce the landing cycle and thus the time the ship is restricted in its ability to manoeuvre.

Also, in high sea states it will reduce the risk to the aircraft from landing on an overly-high energy deck and also allow the ship's command to set a suitable course for the prevailing conditions, prior to the attempt to land. Although it will not replace pilot experience in the landing cycle it will considerably enhance it.

CONCLUSION

The key to a safe and successful landing of a helicopter aboard a small deck ship often hinges on the ability of the pilot to determine when the flight deck is in a quiescent period.

In general, during simulator operations, the LPD was a useful addition to the available cues of the deck motion of the ship. Air vehicle and deck availability may be enhanced beyond the indicated envelope when the operator uses the energy index to signal the top of recovery. As developed in the report, green deck points are identified even in the worst of sea conditions. The periods may be rapid, but owing to the rise time, the deck is constrained to pass from green to red by a latency period. This approach to deck limits is based on dynamic factors rather than static. The deck needs to be sufficiently stable for some time after recovery. Once the rotor is stopped, the deck crew would use the LPD as a deck monitor. The limits would be those at which a person would stumble owing to boundary layer conditions. This is particularly important if the crew is refuelling, rearming or traversing the aircraft.

While the report focus was on air vehicle final approach and recovery, deck issues significant to air vehicles after recovery include chock and chain, aircraft on deck manipulation, handling and service. Also of great interest are the LPD application to other shipboard communities or interoperability.

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