REFINEMENT OF A FLIGHT DECK MOTION MONITORING SYSTEM THROUGH USER INTERFACE EVALUATION TRIALS

N. R. Bourgeois, R. G. Langlois, Dept. of Mechanical and Aerospace Eng., Carleton University, Ottawa, Canada

ABSTRACT

Shipboard launch and recovery of maritime helicopters is difficult and dangerous, particularly in elevated sea conditions. Typically, during the aircraft hover and landing phases, a Landing Signals Officers (LSO), among other responsibilities, monitors ship motions from a position close to the flight deck and communicates the state of deck quiescence to the pilot. A Flight Deck Motion Display (FDMD) system has been developed for use by navies to improve the safety and efficiency of helicopter/ship operations by displaying critical motion parameters to the LSO in an ergonomic fashion. This paper presents the results of a user evaluation that took place in May 2008 with the cooperation of Carleton University, General Dynamics Canada, and 12 Wing, Shearwater. The purpose of the evaluation was to gather feedback on the FDMD's unique method of displaying flight deck motion data and communicating flight deck quiescence to an operator, with the goal of refining the user interface of the FDMD so that it would be of maximum utility and accepted by actual operators. This paper provides an overview of the design and capabilities of the FDMD system, followed by a description of the evaluation setup and results of the evaluation trials. The paper concludes with a summary of modifications that were made to the FDMD due to the results of the evaluation, and a discussion of the overall implications of the evaluation.

KEY WORDS

flight deck motion display, real-time operator guidance, ship motion, dynamic interface analysis, shipboard helicopter operations, flight deck motion

1. INTRODUCTION

Shipboard launch and recovery of maritime helicopters is a safety critical task which requires an accurate assessment of ship motions. Analysis of actual Canadian flight operations has suggested that landing opportunities are discriminated by a combination of deck roll angle and flight deck vertical acceleration [1]. Typically, during the aircraft hover and landing phases, a Landing Signals Officer (LSO), among other responsibilities, monitors ship motions from a position close to the flight deck and communicates the state of deck quiescence to the pilot.

While human detection of orientation is relatively accurate, judgment of vertical acceleration is not. The issue is further complicated due to the fact that flight decks on most non-flight-dedicated military vessels are located at the stern, which causes the flight deck's vertical acceleration to be strongly influenced by both the vertical acceleration of the ship's centre of gravity and its pitch angular acceleration. Historically, the approach taken to allow vertical acceleration limits to be expressed as limits on pitch angle has been to impose a very narrow band on acceptable pitch angles. This results in not only a reduced motion envelope for operations, but can be misleading in cases where high flight deck vertical accelerations occur at low pitch angles.

Between May 2007 and August 2008 the Applied Dynamics Research Group at Carleton University developed a Flight Deck Motion Display (FDMD) system with a goal to increase operational safety and efficiency of helicopter operations in high sea states. This device delivers real-time ship motion information to a flight deck operator along with information on how those motions compare to predefined limits for specific flight deck operations. Specifically, it allows a flight deck operator to monitor flight deck pitch angle, roll angle, and vertical acceleration, or any other motion, and to a precision that is sufficient for supporting flight deck operations. A device such as the FDMD allows real-time motion limits to be specified that designate the maximum motions that can be tolerated when performing a specific activity. To an operator, this can mean the difference between generally knowing when ship motions are within limits and being able to clearly identify whether ship motions are within predefined limits at a particular moment in time.

In order to refine the user interface of the FDMD so that it will be of maximum utility and accepted by actual operators, an evaluation of the FDMD system was arranged to take place on Tuesday, May 27, 2008 in Shearwater, Nova Scotia. The evaluation was coordinated by researchers from Carleton University and General Dynamics Canada (Ottawa). Six current military Sea King pilots with LSO experience and two DND observers from 12 Wing, Shearwater took part in the evaluation.

The test subjects were exposed to a ship motion simulation of limited immersion and were instructed to use the FDMD to mark when they believed ship motions were within safe limits for a helicopter landing based on a predefined definition of quiescence. Each subject participated in a number of sessions with varying degrees of ship motion and several FDMD user interface configurations. In addition to the recording of quantitative results, after each session the subjects were asked a variety of survey questions in order to facilitate discussion of their experience.

The focus of the evaluation was on the design and layout of the user interface and not on the potential performance improvements achievable using such a system. Accomplishing the latter would require a fully immersive environment that would at a minimum include visual, motion, and auditory cues, and a complexity beyond the time and equipment constraints of the arranged evaluation.

This paper introduces flight deck quiescence monitoring and presents the basic real-time operation capabilities of the FDMD. The format and procedure of the user interface evaluation is given, and the quantitative and qualitative results of the evaluation are discussed. The paper concludes with a summary of modifications made to the FDMD as a result of the evaluation feedback.

1.1. HELICOPTER OPERATIONS

In shipboard helicopter landings, standard operational procedures are followed. In Canada, these involve the use of trafficator lights for visual communication between the deck crew and the pilot, a hauldown system to aid helicopter fine positioning during landing, and a securing device to stabilize the helicopter once it is on deck. The primary steps of Canadian landing procedures are outlined below [2].

Hauldown landings are used during moderate to high sea states and are much more demanding than landings in calm conditions. It is for this type of landing that the FDMD's use is targeted. In general, the following steps are followed:

1. When the helicopter receives clearance it approaches the flight deck and enters a high hover of 15 to 17 feet above the deck.

2. The helicopter positions itself to the side of the Rapid Securing Device (RSD) and lowers a messenger cable. As soon as it is safely possible, flight deck personnel ground the messenger cable and attach a hauldown cable.

3. The hauldown cable retracts to apply a constant tension, but does not prevent the distance between the helicopter and ship deck from changing.

4. The helicopter descends to a lower hover of approximately 5 feet and the pilot notifies the deck crew when ready to land.

5. The LSO gives instructions for the helicopter to position itself over the RSD, and when the deck is steady, advises the helicopter to land.

6. Once the helicopter is on deck, the hauldown cable tension is increased and the helicopter is mechanically secured to the ship by the RSD and helicopter securing probe(s). Flight deck personnel may install additional securing restraints to the aircraft at this point.

In the procedure outlined above, the LSO must wait until the deck is steady or 'quiescent' before advising the helicopter to land. If it appears that it will be some time before a quiescent period occurs, the helicopter may return to high hover or in some cases be waved off and the landing process repeated. The FDMD is designed to aid the LSO in making this decision.

1.2. DEFINITION OF QUIESCENCE

A quiescent period is defined as a time when all monitored motion parameters are within limits for performing a specific activity. Two rules for changing quiescence status are defined in [1] and [3]. (1) The state is not quiescent when at least one limit is exceeded, and (2) in order to change state from non-quiescent to quiescent, each motion which has exceeded its limit must experience a subsequent motion peak below its limit. This means that quiescence calculations much take data history into account as they are constantly updated.

This definition has been incorporated into the FDMD software that computes quiescent status. Three discrete states are used to define quiescent status.

- Red - the flight deck motion is out of limits.
- Yellow - the flight deck motion is within limits but close to a limit.
- Green - the flight deck motion is well within limits.

Quiescent status is calculated separately for each motion parameter and then the results are combined, with yellow taking precedence over green and red taking precedence over both green and yellow.

2. FDMD OPERATION

The origins of the concept of the FDMD in Canada began with a design specification written by Colwell in 2004 [3], which he states was the direct consequence of the experience gained by Defence Research and Development Canada (DRDC) in supporting Canadian frigate helicopter/ship flight deck certification trials. This document introduces the basic operation and design of a quiescent period indicator, for quickly identifying whether ship motions are within limits for a particular operation. In 2006 the Canadian Department of National Defence (DND) released a document titled "Flight Deck Motion Display Requirements Specification" [4] which outlines the draft design requirements for a flight deck motion monitoring system. This document acted as a guideline for the design of the FDMD as it provides details on the hardware arrangement, hardware ruggedness specifications, software operating modes, and software capabilities of an FDMD system.

The goal of the FDMD's primary operating mode is to allow an operator, in once glance, to determine the current state of the ship, the amplitude of key motion parameters relative to established limits, and whether ship motions in general are increasing or decreasing. It does this without predicting future ship motions, as such a device would have unattainable requirements for accuracy given current ship motion prediction capability.

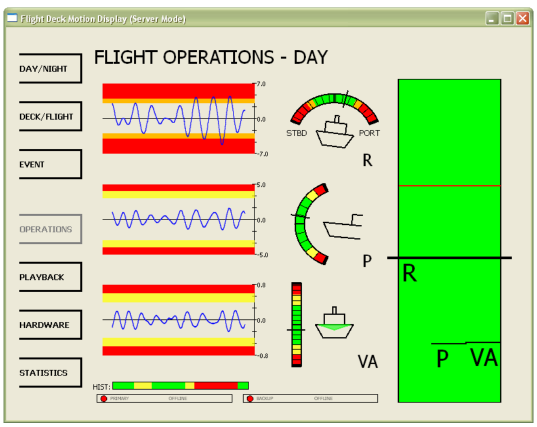

Figure 1. Screenshot of FDMD operations user interface.

The FDMD has a number of operating modes, with one specific user interface used for real-time monitoring of ship motions. A screenshot of the user interface for this operating mode is shown in Figure 1. For each monitored ship motion parameter, the operations user interface displays a two minute time history with motion limits information, an indicator that displays the current value of each motion on a dial, and a quiescent status indicator. The instantaneous indicators use the same limits as the data history. The pitch and roll instantaneous indicators display a ship animation which moves with the ship's motions. Since the pitch indicator spreads 10 degrees of indicator over 120 degrees of screen space, the motion of the pitch ship animation is scaled down in order to avoid cases where it appears that the ship is sinking at high pitch amplitudes. Since vertical acceleration cannot be directly related to a displacement of the ship, a coloured arrow is instead drawn over the image of a ship, and changes heights and colours to match the magnitude and quiescence status of vertical acceleration. Quiescence status histories for each parameter are also calculated. In Figure 1, these three histories are combined into a single bar at the bottom of the screen in order to reduce screen clutter. The quiescent status indicators for all motions are combined into a single user interface element, the vertical bar on the right side of the screen, which changes colour based on the combined quiescent status of the motions.

During the user interface evaluations, the quiescent status indicator, or quiescent period indicator (QPI), used three distinct states to convey overall quiescence status information. The three states are shown in Figure 2. The heights of the quiescent period indicator's horizontal bars represent the magnitude of the last peak experienced by each motion parameter, relative to their defined limit. The red horizontal line that is two-thirds the maximum height of the vertical bar represents the point where the motions will exceed their limits, even though those limits are all numerically different. Bar heights respresenting peak motion magnitudes are displayed because if only instantaneous values are used to calculate bar heights, there are cases where the bar is red while ship motions are passing through zero and that can convey the wrong message to an operator.

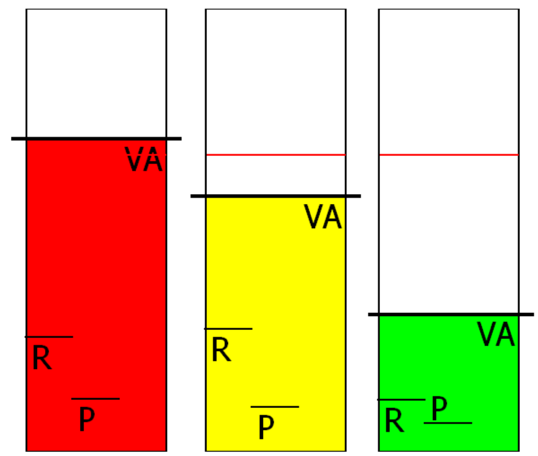

Figure 2. Three possible colour states of the QPI.

A carefully considered and deliberate decision in implementing the operations user interface was to make all critical information available to the user on a single screen. While this necessitates a relatively busy display, LSOs are proficient at scanning a portion of available instrumentation to extract information of interest. The current version of the display avoids redundant information and places vital information where it can be identified and extracted with a fleeting glance.

The FDMD prototype system also includes the following capabilities.

- The system can receive data from multiple sources and forward data to additional computer terminals in order to provide a backup in case of failure, ensure data consistency, and provide data to multiple operators as needed.
- Continuous data for 6 dof flight deck motion, as measured by a high-quality inertial sensor, is recorded to disk and can be readily reviewed by an operator.
- Multiple, and reconfigurable motion limits can be toggled to allow the FDMD to be used in ship operations

with a variety of motion limits. As a minimum, this could include deck and flight operations, during day and night.

- Different motion limits for entering and exiting quiescence can be specified.
- Sensor data can be transformed to the helicopter hauldown point and data from multiple sensors can be compared in order to detect sensor faults in the system during operation.

Further details on the design and development of the FDMD system are described in [5].

3. EVALUATION CONFIGURATION

The user interface evaluations were scheduled to take place over a period of eight hours with four hours dedicated to the individual evaluation sessions. Evaluation overview documents were distributed and an overall introduction and orientation presentation was given.

Two sets of evaluation equipment were used. Each consisted of a digital projector, a dual-core laptop, a portable computer with touch-key or touch-screen input, and a network switch or router. The laptop was used to run a ship motion simulation and generate a 3D image of the ship's motion for the digital projector. The laptop also transmitted simulated ship motion sensor data over the network connection to the portable computer running the FDMD software. A diagram of the hardware configuration is shown in Figure 3.

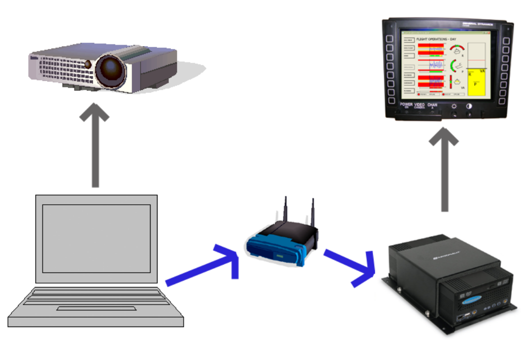

Figure 3. Evaluation hardware layout with digital projector, laptop, router, and portable computer.

The realistic time-varying simulated ship motion was generated based on ship response characteristics computed using the SHIPMO7 hydrodynamics code [6].

4. EVALUATION PROCEDURE

User interface evaluations were divided into four different sessions, each with a different user interface configuration provided on the FDMD display. Each session consisted of a primary and a secondary task for the subject to complete.

The primary task was to monitor a 3D view of a helicopter on board a ship, with the point of view located as if the subject were standing in the LSO compartment which is often located forward and to the starboard of the designated landing area (DLA). The helicopter 3D model periodically changed colour from gray to black. Each colour change to black lasted one second. The subject was instructed to indicate verbally whenever a colour change occurred. The purpose of the primary task was to, in a simplified way, simulate a situation where the LSO would focus on the flight deck task rather than on the FDMD, as is the case at sea.

The secondary task was to monitor the FDMD and to press the event marker key whenever the state of the flight deck quiescence first satisfied the applicable quiescence definition. Each session provided a short amount of time for observing the ship motions before landing periods were marked. The 3rd and 4th sessions also included an extra event marking period at a higher sea state.

A description of each session is summarized in Table 1. A photograph of an evaluation session from a subject's point of view is shown in Figure 4.

Table 1. Evaluation session descriptions.

Session	Description	Sea State (SS)
1	Instantaneous value indicators only	Upper SS5
2	Instantaneous value indicators and data history	Upper SS5
3(a)	Instantaneous value indicators, data history, and two-state quiescent period indicator	Upper SS5
3(b)		Upper SS6
4(a)	Instantaneous value indicators, data history, and three-state quiescent period indicator	Upper SS5
4(b)		Upper SS6

5. QUANTITATIVE RESULTS

The results of the quiescent period event marking were analyzed in three ways: (1) to check how many times the subjects pressed the event marker when the ship was not in a quiescent period; (2) to compare how many quiescent periods were marked to the total number of quiescent periods that were presented; and (3) to compare how many quiescent periods having a minimum four second duration were marked to the total number of quiescent periods exceeding four seconds duration. A duration of four seconds was chosen because it

Figure 4. Evaluation setup from a subject's point of view.

is generally believed that four seconds is sufficient time for a takeoff or a recovery from low hover to occur.

5.1. DATA MINING PROCEDURES

A limitation of real-time motion parameter monitoring is that it is difficult to determine a priori how long a quiescent period will last. A fully immersive environment of motion, visuals, and sounds would be needed to accurately convey all of the cues that LSOs normally process during helicopter-ship operations. In the case of this evaluation, a ship visualization was provided that did allow some of the subjects to only use the FDMD to confirm their own visual identification of quiescent periods. Other subjects only paid close attention to the FDMD and pressed the event marker every time it indicated green status.

A software algorithm was written that identified the following characteristics of each trial:

- start and end times of each quiescent period;
- duration in seconds of each quiescent period and whether it was greater than four seconds;
- whether the event marker was pressed within each quiescent period;
- location of the two minute mark in each recording;
- number of quiescent periods marked;
- number of four-second quiescent periods marked;
- total number of quiescent periods; and
- total number of four-second quiescent periods.

5.2. MISPLACED EVENT MARKERS

As expected, the subjects became more proficient at marking helicopter colour changes as the evaluation proceeded, and this was reflected in the results. A misplaced event marker event signified a case where a subject identified a quiescent period when the FDMD did not. In the first session the subjects misplaced approximately twenty percent of their markers, and less than five percent in subsequent trials. In the trials simulating upper sea state six, for which ship motion was most severe, no markers were misplaced.

5.3. QUIESCENT PERIOD MARKING

The number of quiescent periods marked in each trial was compared to the total number of quiescent periods and to the total number that were at least four seconds in duration. Overall there were very few cases where quiescent periods that were not four seconds in length were marked. The results are displayed in Figures 5 and 6. Note that on the graphs, the order of trials 3b and 4a have been switched so that the sea state six trials are both on the right side of the graph (trials 3b and 4b).

The clearest trend in the results is observed in Figure 6 where one can see that as more information was provided to the subjects, the accuracy in marking four-second quiescent periods increased.

The results show different trends for the high and low sea state sessions. In the lower sea state sessions, the observed proficiency of the subjects increases as they are given additional information, but the opposite trend is observed at the higher sea state. It is interesting to note that the addition of the yellow quiescent state did not affect the number of quiescent periods marked but did increase the number marked that were at least four seconds in duration.

In the higher sea state, it is shown that the subjects became more cautious with marking quiescent periods when the yellow state was added. This is consistent with the fact that some of the quiescent periods in the higher sea state were only displayed as a yellow state regardless of their length due to the ship motions not fulfilling the requirements necessary to achieve a green quiescent state.

6. QUALITATIVE FEEDBACK

After each quiescent period marking session the subjects were encouraged to provide feedback on their experience and were asked to complete survey questions, through conversation with the trial coordinator, to facilitate the process.

6.1. SESSION 1

The first evaluation session only provided the subjects with instantaneous indicators. A sample of the user interface is

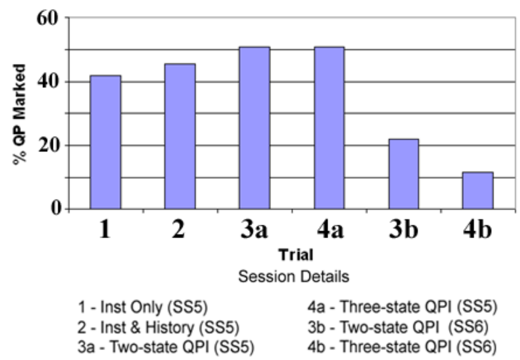

Figure 5. Average percentage of quiescent periods marked for each trial.

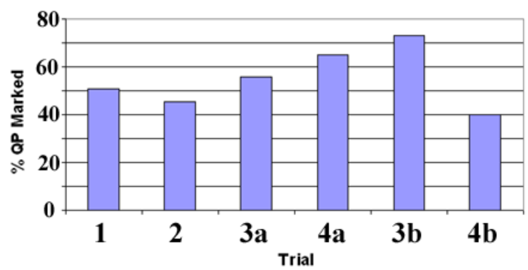

Figure 6. Average percentage of four-second quiescent periods marked for each trial.

shown in Figure 7.

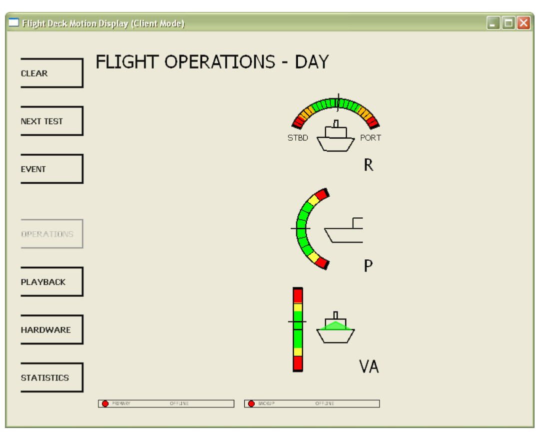

Figure 7. FDMD operations user interface with only instantaneous indicators displayed.

The survey results revealed that subjects were clear on what motions were being measured but found it slightly difficult to evaluate the approximate magnitudes of ship motions using the scales provided. Generally, the subjects spent most of their time monitoring the ship motion using the 3D display and only checked the FDMD when the ship's motions were visually identifiable as being within limits. Some additional user comments included the following.

- The green areas of the scale are too small. One possible solution is to use a nonlinear scale to make the green areas larger.
- Since vertical acceleration is often the deciding factor, its placement should be optimal.
- The current LSO indicator shows combined pitch and roll so that an operator only has to look in one place. Doing the same thing for roll/vertical acceleration could be helpful.

6.2. SESSION 2

The second evaluation session provided the subjects with instantaneous indicators and a two-minute motion data history for each monitored parameter. A sample of the user interface is shown in Figure 8.

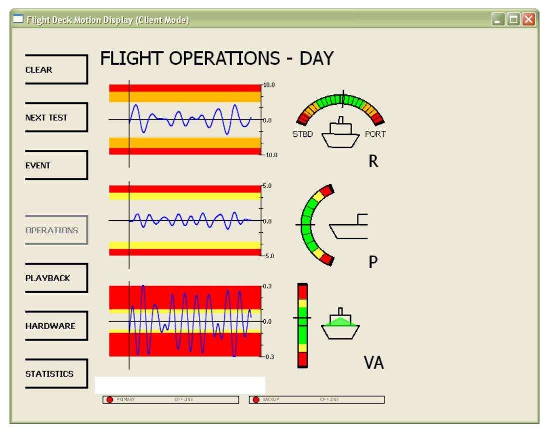

Figure 8. FDMD operations user interface with instantaneous indicators and data history.

The survey results revealed a neutral opinion on the usefulness of the additional data histories. The subjects generally did not find that they either aided or interrupted their quiescent period marking task, although some did agree that a longer monitored time period could be useful. The general consensus in this session was that the subjects would only find the data history useful if they were in a situation where they would have time to interpret the graphs. Some additional user comments included the following.

- A time history length of 5/10/15 minutes could be useful for flight planning and dealing with operations in rougher seas.
- Time history could be useful for training or subsequent analysis.
- Vertical acceleration history was used to estimate when the next quiescent period would occur in some cases.

6.3. SESSION 3

The third evaluation session introduced the quiescent period indicator (QPI) to the operators, using a two-state QPI capable of alternating between red and green statuses. An image of the user interface is shown in Figure 9.

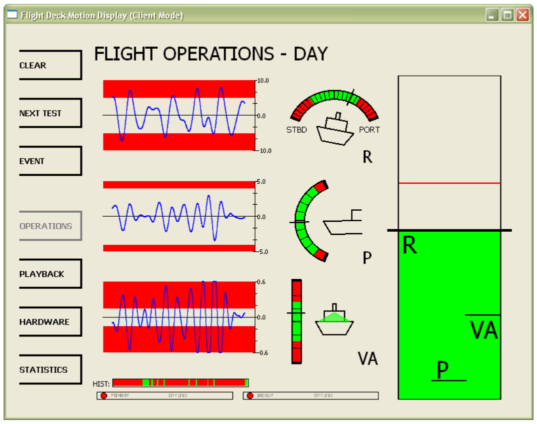

Figure 9. FDMD operations user interface with all elements and QPI configured for red and green states.

The general consensus among all of the subjects was that with the addition of the QPI, the remaining user interface elements became considerably less useful. It was thought that the QPI would be very useful as something that could be monitored in peripheral vision while focusing most attention on the helicopter in a low hover situation. Some additional user comments included the following.

- The QPI was useful for confirming the visual identification of a quiescent period.
- The inner details of the QPI were rarely used.
- Since green intuitively means 'go', and may not mean 'go' with the QPI, that colour is somewhat inappropriate.
- Data history could be more useful if provided as numerical values (for example previous peak values or average time between quiescent periods).
- Putting previous peaks on the QPI could be useful information for avoiding very short quiescent periods.
- When the green bar is really small it occasionally leaves peripheral vision.
- Short green periods can be misleading, especially in higher sea states.
- There were times when the QPI showed an unintuitive status because of the value of vertical acceleration.

Of special interest are the last three points, which give some insight into the implications of using a device like the FDMD in ship operations and for possible improvements that can be made to the FDMD. The confirmation that vertical acceleration did not always behave as expected was reassuring, as that was an expected observation.

6.4. SESSION 4

The final evaluation session added a third, yellow quiescent state to the QPI. A screenshot of the user interface is shown in Figure 10.

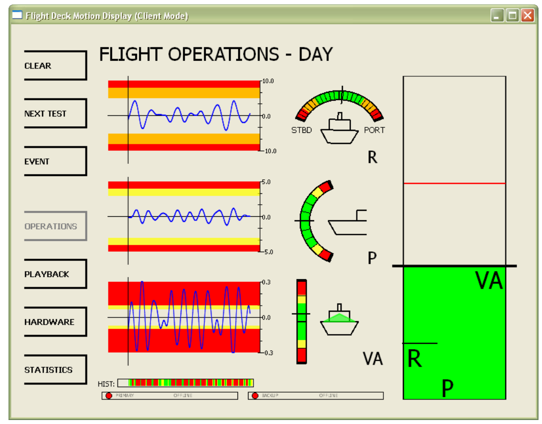

Figure 10. FDMD operations user interface with all elements and three-state QPI.

The yellow quiescent state replaces a portion of the green motion range. It is defined as a time when it is safe to land, but when the deck is close to the limits of quiescence. In general, there was limited positive feedback about the addition of the yellow state. Some additional comments included the following.

- There was too much information and it was easier to just concentrate on the QPI being red or not red.
- Yellow is difficult to differentiate from green in peripheral vision.
- It is better for yellow to either mean approaching or leaving danger.
- Waiting through a yellow for a possible green could be too time costly in real operations.

6.5. GENERAL DISCUSSION

After all of the evaluation sessions had been completed, a general discussion was held with all of the event's participants. The discussion included the following comments.

- The FDMD could have the potential to reduce radio chatter by providing sea condition information in multiple locations.
- Displaying the last peak experienced would be useful in addition to, or instead of the time history. This type of information could be useful for relaying to the ship bridge and helicopter.

- Additional information on the FDMD screen would be useful, such as true/relative wind speed and heading, and RADHAZ information (extremely high power electromagnetic radiation generated by a ship's radars).

- One of the disadvantages of using flight planning to identify preferred flight operation headings is that often the ship only turns into the wind for a quick launch or recovery and then returns to its original course. Overall flight planning would be more useful on the bridge. Comprehensive history and motion minimum/maximum data would be valuable in the LSO compartment.

7. FDMD MODIFICATIONS

One of the major lessons learned during the evaluation was that a device such as the FDMD is best suited to being used only as a confirmation tool in daytime helicopter operations, visible only in an LSO's peripheral vision during the crucial moments of helicopter recovery. In such a case, an LSO would only use an FDMD to confirm their visual and physical identification of potential quiescent periods.

Following the evaluation, two major changes were made to the FDMD's operation.

1. The quiescent period indicator was adjusted so that the entire bar is stationary and changes colour while the individual magnitude-indicating bars continue to move. This resulted in it being more compatible with use in peripheral vision.

2. The yellow quiescence status was removed from the quiescent period indicator because at a single instant in time it did not provide useful information. Yellow limits were not removed from the data history or instantaneous value user interface elements.

Samples of the refined quiescent period indicator are shown in Figure 11. Refinements on the presentation of the individual instantaneous value indicators was also considered but not carried out. There is some uncertainty as to which parameters should be shown in the final version as there is rarely a case where a pitch limit is exceeded when a vertical acceleration limit is not. Individual operational communities may also have specific requirements for the way in which roll/pitch/vertical acceleration data is presented.

8. CONCLUSIONS

In order to improve operational safety and efficiency in helicopter/ship operations, a complete prototype Flight Deck Motion Display has been developed. This device provides real-time accurate motion information to a flight deck operator. A user interface evaluation was held in the spring of 2008 in order to gather feedback on the FDMD's method of displaying information so that the device could be refined and ultimately would provide valuable information to operators.

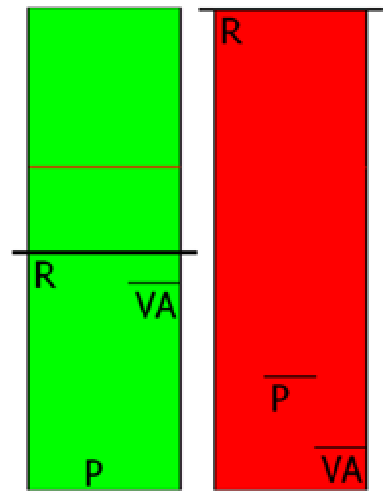

Figure 11. Refined QPI green and red statuses which always display a full bar of colour.

By far the most useful piece of information gathered from the evaluation is the insight into what role an FDMD system may be able to fulfill in current helicopter-ship operations. The most practical way the FDMD was used, was as a tool for confirming an LSO's determination of ship quiescence, when visible in the LSO's s peripheral vision. There is also the potential for improved communication of flight deck quiescence status to other parts of the ship, such as FlyCo, the bridge, or flight planning areas. Additionally, the FDMD's data recording capabilities could make it a useful tool for post operation analysis and incident investigation.

In the common situation where landings must be completed in very short quiescent periods, the ability of the FDMD to identify the onset of quiescence quickly and accurately can offer significant benefits in the challenging and critical task of shipboard helicopter recovery.

9. ACKNOWLEDGEMENT

The Flight Deck Motion Display project was supported jointly by General Dynamic Canada, Ontario Centres of Excellence, and Carleton University. All parties would like to thank 12 Wing, Shearwater for helping make the FDMD user interface evaluation a success.

REFERENCES

[1] J.L. Colwell. Real time ship motion criteria for maritime helicopter operations. In *ICAS Congress*, Toronto, Canada, 2002.

[2] Joint Maritime Command 1 Canadian Air Division. Shipborne helicopter operating procedures (SHOPS). Technical Report C-12-124-A00/MB-002, Jan. 2003.

[3] J.L. Colwell. Flight deck motion system FDMS: Operating concepts and system description. Technical Report DRDC-TM-2004-003, DRDC Atlantic, Jan. 2004.

[4] Canadian Department of National Defence. Flight deck motion display requirements specification. Accessed Sept. 2008.

[5] N. Bourgeois and R. Langlois. Design and implementation of a flight deck motion monitoring system. In *Proceedings of the Canadian Society for Mechanical Engineering Forum*, Ottawa, Canada, 2008.

[6] K. A. McTaggart. *SHIPMO07: An updated strip theory program for predicting ship motions and sea loads in waves*. Defence Research Establishment Atlantic, Dartmouth, Nova Scotia, Canada, March 1996. DREA Technical Memorandum 96/243.

BIOGRAPHY AND CONTACT INFORMATION

Nick Bourgeois received bachelor's and master's degrees in Aersopace Engineering from Carleton University in Ottawa in 2006, and 2008 respectively. He is currently self-employed as a software developer, working under a contract with the National Research Council.

Nick Bourgeois can be contacted at aeronick@gmail.com

Dr. Rob Langlois received an engineering diploma from St. Francis Xavier University in 1987 and bachelor's, master's, and doctorate degrees in mechanical engineering from Queen's University at Kingston in 1990, 1991, and 1996 respectively. From 1996 to 2001 he was Senior Dynamicist and subsequently Manager of Dynamic Analysis at Indal Technologies Inc. (now Curtiss Wright Flow Control Company – Indal Technologies). In 2001 he joined the Department of Mechanical and Aerospace Engineering at Carleton University where he teaches courses in applied dynamics and conducts research focussed on shipboard dynamic systems.

Rob Langlois can be reached at rlangloi@mae.carleton.ca