Dynamic Interface Modelling and Simulation. Part 2: Developing Robust Fidelity Requirements for Maritime Rotorcraft Flight Simulators

Wajih A Memon*, Neale A Watson, Mark D White and Ieuan Owen
School of Engineering
University of Liverpool
Liverpool, UK.

Launch and recovery operations of helicopters to and from ships are often carried out in challenging at-sea conditions, such as a confined landing deck, irregular ship motion, sea spray and unsteady airflows over and around the ship's superstructure. Together, these elements form the Helicopter Ship Dynamic Interface (HSDI) environment, posing a high risk to the helicopter, ship and crew [1]. To determine the safe operability of helicopter to ships, a safety envelope known as Ship Helicopter Operating Limit (SHOL) is constructed, normally through First of Class Flight Trials (FOCFTs). This process can be time-consuming and expensive and new approaches to determine SHOLS are being developed.

Modelling and Simulation (M&S) of the HSDI environment is being used in flight simulators with the aim of making SHOL testing safer, quicker, and more cost-effective [2-4]. However, the reliability of this approach depends upon the determination of the fidelity requirements of the various M&S elements: motion and visual cueing, flight dynamics modelling and the integration of the ship airwake into the flight loop (Fig. 1). The development and assessment of high-fidelity airwakes and tools to support ship design and pre-SHOL testing is reported in a companion paper (Part 1 [5]). Attempts have been made to assess the fidelity of rotorcraft simulators to support SHOL testing e.g. the JSHIP programme [6]. The Flight Science and Technology research group at the University of Liverpool (UoL) have also examined the effect of motion, visual and airwake fidelity on overall simulation fidelity and task performance in simulated SHOL testing [7-9]. However, a standardized guideline to quantify and qualify the overall fidelity of research and engineering simulators is a challenge which is yet to be fully addressed. The research presented in this paper is part of a project at the UoL, funded by QinetiQ and Dstl, which has undertaken a structured examination of the M&S elements of the HSDI simulation environment to develop robust simulation fidelity criteria to support at-sea flight trials.

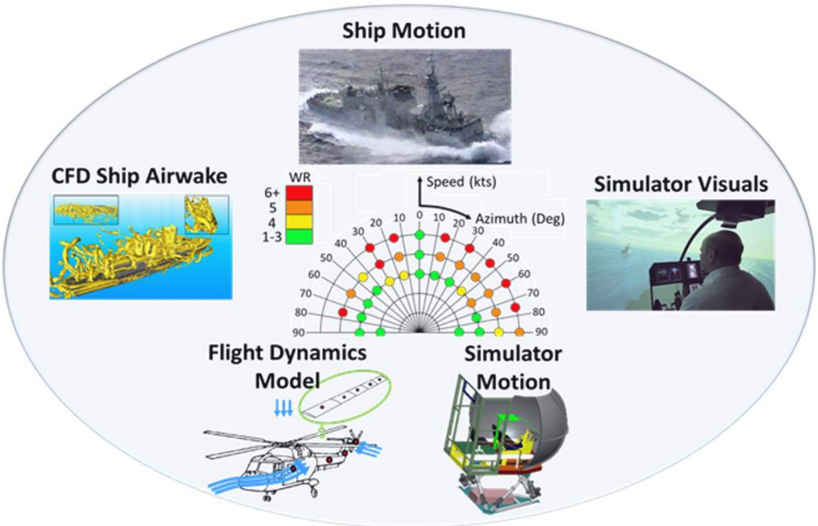

Fig. 1 HSDI modelling and simulation elements

The paper will report the results of the research that has been conducted in this project in three phases. In the first phase, objective assessment and optimisation of the vestibular motion cueing fidelity in maritime rotorcraft flight simulators was conducted using a novel approach, Vestibular Motion Perception Error (VMPE) [10, 11]. The technique was utilised to optimise the simulator motion drive laws for deck landing operations on two different naval ships: the Queen Elizabeth class aircraft carrier [10] and a single-spot destroyer [11]. This research was followed in the second phase by the assessment of the interaction and coherence between the simulator visual and vestibular motion cueing fidelity. This was examined in a dedicated piloted simulation flight trial assessment using a range of simulator vestibular motion settings operating in different visual cueing scenarios [12]. From these investigations, an 'Optimised' vestibular motion setting and a High Visual Cueing scenario combination of the simulator cueing system was designed, which resulted in improved task performance and reduced pilot workload. An example of the effect of visual cueing and simulator motion settings on a helicopter's trajectory during a deck landing task performed in the UoL's HELIFLIGHT-R full-motion simulator can be seen in Figure 2. Additional results will be presented in the proposed paper.

Finally, an assessment of the airwake integration with a helicopter flight dynamics model in the flight simulator was conducted to study the impact of the airwake fidelity on the helicopter dynamic response, and to optimise the flight dynamics airload computational model. A sensitivity analysis was carried out in which the number of airload computation points on the main rotor of a helicopter model representing a SH-60B Seahawk were examined, the results of which will be detailed in the full paper. This was achieved using the in-house M&S tools: a virtual software-based airwake dynamometer called Virtual AirDyn (VAD) [13], a pilot-model based predictive simulation tool (SIMSHOL) and a Piloted Flight Simulator Trial, described in more detail in a companion paper [5].

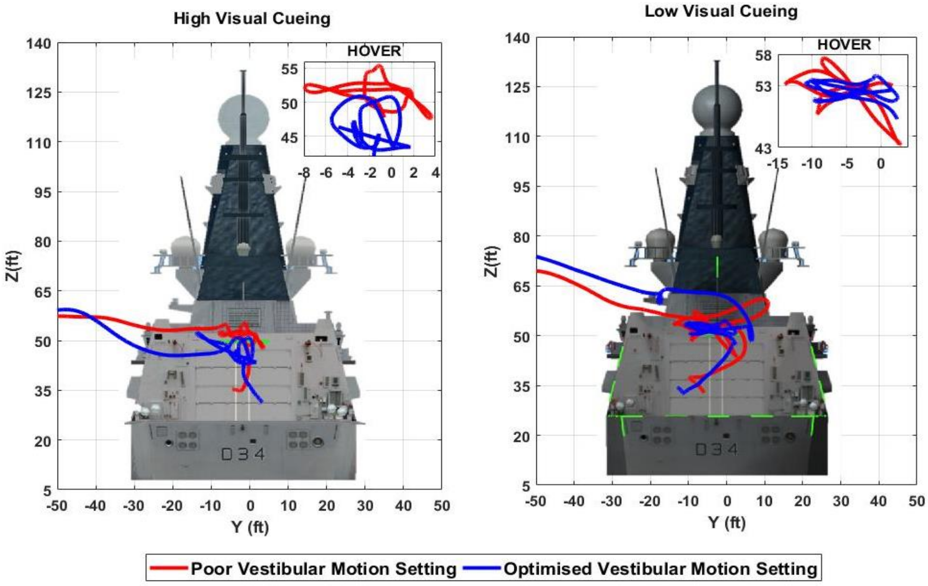

Fig. 2 HELIFLIGHT-R simulated flight trial deck landing trajectory comparison for "*Poor*" and "*Optimised*" simulator vestibular motion setting operating in "*High*" and "*Low*" visual cueing scenarios

The paper will detail and summarise the subjective and objective results gathered during the three research phases, with key results from five piloted simulation flight trial experiments, which were conducted in HELIFLIGHT-R full-motion simulator by former Royal Navy test pilots. The progress in determining simulation fidelity specifications and a new metric defining the M&S fidelity requirements for high-fidelity simulated HSDI operations in maritime rotorcraft simulators will also be presented in the paper.

References

1. Lumsden, B., Wilkinson, C. H. and Padfield, G. D. "Challenges at the Helicopter-Ship Dynamic Interface," 24th European Rotorcraft Forum, France, Sep. 1998.
2. Advani, S. and Wilkinson, C. "Dynamic Interface Modelling and Simulation - A Unique Challenge," Royal Aeronautical Society Conference on Helicopter Flight Simulation, London, Nov. 2001.
3. Roscoe, M. F. and Wilkinson, C. H. "DIMSS - JSHIP's M&S Process for Ship helicopter Testing and Training," AIAA Modeling and Simulation Technologies Conference and Exhibit, California, Aug. 2002.
4. Val, J. and Healey, V. "Simulating the Helicopter-Ship Interface as an Alternative to Current Methods of Determining the Safe Operating Envelopes," NAVAIR: Air Vehicle Division, 1986.
5. Watson, N. A., Memon, W. A., White, M. D. and Owen, I. "Dynamic Interface Modelling and Simulation. Part 1: Preparation and Analysis for High-Fidelity Helicopter-Ship Flight Simulations," 8th Asian/Australian Rotorcraft Forum, Ankara, Turkey, Oct.-Nov. 30-2, 2019. (Abstract submitted)
6. Roscoe, M. F. and Wilkinson, C. H. "DIMSS - JSHIP's M&S Process for Ship helicopter Testing and Training," AIAA Modelling and Simulation Technologies Conference and Exhibit Proceedings, California, Aug. 2002.
7. Hodge, S. J., Forrest, J. S., Padfield, G. D. and Owen, I. "Simulating the Environment at the Helicopter-Ship Dynamic Interface: Research, Development and Application," *The Aeronautical Journal*, Vol. 116, (1185), Nov. 2012, pp. 1155-1184.
8. Owen, I., White, M. D., Padfield, G. D. and Hodge, S. "A Virtual Engineering Approach to the Ship-Helicopter Dynamic Interface; A Decade of Modelling and Simulation Research at the University of Liverpool," *The Aeronautical Journal,* Vol. 49, (1246), Dec. 2017, pp. 1833-1857.
9. Wang, Y., White, M. D., Owen, I., Hodge, S., and Barakos, G., "Effects of Visual and Motion Cues in Flight Simulation of Ship-Borne Helicopter Operations," *CEAS Aeronautical Journal*, Vol. 4, Dec. 2013, pp. 385-396.
10. Memon, W. A., White, M. D., Owen, I. and Robinson, S. "Preliminary Progress in Establishing Motion Fidelity Requirements for Maritime Rotorcraft Flight Simulators," 74th American Helicopter Society Forum, USA, May 2018.
11. Memon, W. A., Owen, I. and White, M. D. "Motion Fidelity Requirements for Helicopter-Ship Operations in Maritime Rotorcraft Flight Simulators," *Journal of Aircraft*. (Accepted for Publication).
12. Memon, W. A., White, M. D. and Owen, I. "Visual-Vestibular Motion Cueing Assessment in Maritime Rotorcraft Flight Simulators," 45th European Rotorcraft Forum, Poland, Sep. 17-20, 2019.
13. Kääriä, C. H., Forrest, J. S. and Owen, I. "The virtual AirDyn: A simulation technique for evaluating the aerodynamic impact of ship superstructures on helicopter operations," The Aeronautical Journal, 2013, 117, (1198), pp 1233-1248