Innovative Aircraft/Ship Visual Landing Aid (VLA) Test Tool

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Abstract—Stottler Henke has developed VERTICAL (VLA Experimental Resource for Testing Innovative Configurations And Lightings) for the US Navy. This test and design tool is being used to support vertical takeoff and landing/rotorcraft ship Visual Landing Aids (VLA) test and design at the test team members' work area. This effort has been accomplished by utilizing MS Flight Simulator, FSUIPC, C++, and OpenFlight. This paper describes the productized version, whose prototype was originally described in an IEEE Aerospace 2005 paper. [1 2]

VLAs provide the necessary support to the landing of aircraft on ships. For existing ship classes with fixed lighting systems, the ability to differentially adjust the intensity of drop lights, glide slope indicators, flood lights, and deck status lighting provides focus on different pilot cues during shipboard landing in a wide variety of meteorological conditions. Color is used to provide focus on different approach and landing cues in varying meteorological conditions. The drive to develop VLAs is to ultimately allow for a wider envelope of operations for aircraft from ships. That is, it is desired to be able to safely operate VTOL aircraft in higher sea states and lower visibility conditions than are allowed today.

To improve decision-making in this complex domain in an affordable manner, design and testing in simulated situations are critical. VERTICAL provides this solution by providing a test and design tool on a PC. It allows testers to fly shipboard approaches in specific aircraft (e.g., MH-60S, MH-60R, CH-53, Harrier, V-22) onto and off the deck of a specific ship class, both in existence and in development (e.g., LHD, DDG, DD(X), LCS), with a realistic view of day and night operations and under a variety of weather conditions, all the while providing an easy method of adjusting ship VLA components and environment lighting. VERTICAL combines an interactive graphical user interface with various aircrafts and custom built ships, controlled and rendered by Microsoft Flight Simulator 2004. By utilizing Microsoft's off-the-shelf simulator package, we are able to provide extremely detailed three-dimensional graphics (with accurate physics) that replicate visual scene properties relevant for the simulation of low-altitude flights at low cost, and with significantly reduced development time compared to custom tools.

Users are presented with a fully navigable three-dimensional environment provided by MS Flight Simulator containing the ship being targeted for VLA design. The environment may include other aircraft either flying or on the ship. Essentially, the environment is able to replicate whatever needs to be simulated for realistic meteorological or environmental conditions. MS Flight Simulator communicates with the rest of VERTICAL via an External System Interface (ESI) written in a product called FSUIPC. The lights on the ship can be controlled via the VLA modification GUI. The VLA Modification GUI, developed as a separate C++ application, provides an intuitive interface for modifying the VLA components. For final verification and NVG analysis of the ship model, configured as desired, can be exported as an OpenFlight model and used in full-flight simulators.

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1. INTRODUCTION

Visual Landing Aids (VLAs) provide the necessary support to the landing of aircraft on ships (Figure 1). For existing ship classes with fixed lighting systems, the ability to differentially adjust the intensity of drop lights, glide slope indicators, flood lights, and deck status lighting provides focus on different pilot cues during shipboard landing in a wide variety of meteorological conditions [1]. The use of color, and the quality of color (chromaticity) [2], is also used to provide focus on different approach and landing cues in varying meteorological conditions. The drive is to allow for a wider envelope of operations for aircraft from ships. That is, it is desired to be able to safely operate VTOL aircraft in higher sea states and lower visibility conditions than are allowed today.

[1] 0-7803-9546-8/06/$20.00© 2006 IEEE
[2] IEEEAC paper #1266, Version 8, Updated Jan. 03, 2006

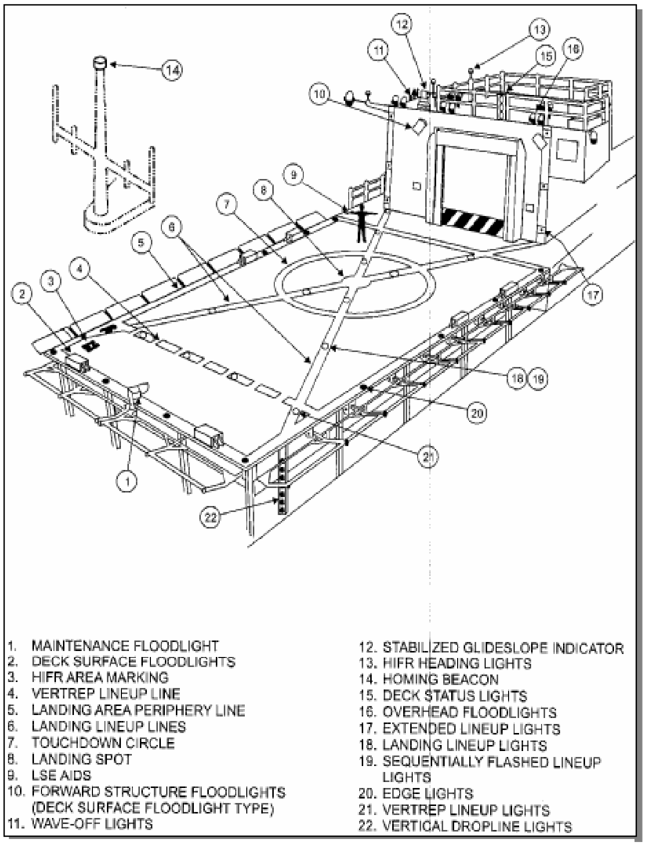

Figure 1. Flight Deck with Visual Landing Aids

The design of safe and effective VLAs requires that the pilot be presented with cues that are conspicuous and easily comprehensible during the approach [3]. These cues must be of a nature that is consistent in different circumstances, and requires little training for effective use [4]. The goal of any shipboard VLA system is to, as much as possible; enable pilots in low visibility situations to follow a similar approach path and landing sequence afforded by day Visual Meteorological Conditions (VMC) cueing.

The first shipboard rotorcraft landing, conducted in 1943, employed specialized flight deck markings to facilitate safety. Since then, as the scope and frequency of shipboard rotorcraft operations has increased, the complexity of VLA markings and lighting has increased as well. In the 1950s and 1960s, a variety of shipboard flight tests were conducted to define optimal lighting and markings for routine operations. Although realistic, these tests were logistically and financially expensive, and they required optimal weather conditions for successful evaluation efforts.

In the 1970s and 1980s, the USN developed land-based flight test facilities at various locations, including Lakehurst, NJ, to improve the accuracy and reduce the costs associated with VLA evaluations. These land-based VLA evaluation facilities, which are still in use to this day, replicate the aft portion of various USN ships and feature identical versions of standard shipboard VLA lighting components, as well as prototype versions of potentially new components. Although extremely valuable in terms of data collection, they still require a fair amount of logistic and financial expense associated with flight operations of actual rotorcraft, and they are still dependent on the weather.

In the 1980s, computer advances allowed for the development of highly accurate flight simulator facilities that boasted mainframe computers with high-resolution video screens. These screens could also be used to evaluate VLAs without the need for expensive rotorcraft flight operations. Although a cost savings in comparison to actual aircraft operations could be realized, the degraded field of view and generally non-realistic visual scene content permitted only slight advantages in the area of VLA evaluations, and these typically were limited to night operations only.

In the 1990s, the incorporation of very high-resolution textured mapped graphics engines into the mainframe computers employed in existing USN flight simulation facilities permitted the USN to conduct many dedicated VLA evaluations for a variety of ship classes. Several ship classes in operation today still employ the markings and lighting configurations developed and evaluated during these efforts. Nonetheless, these efforts still lacked the extreme realism required for shipboard safety, and most of the USN's VLA visual simulation efforts conducted in the 1990s involved determination of candidate VLA configurations, which would still have to be flight tested while shipboard. Although useful in weeding out undesirable VLA configurations, the 1990s efforts were still impractical because of their limited scene content (a typical image generator could barely draw 3,000 faces per channel at 30 Hz) dependence on mainframe computational capabilities. By the turn of the century, however, PC technology had improved so drastically as to facilitate VLA evaluations in the desktop environment.

To be able to provide VLA test team members with the greatest access to the analytic test tool, it would be advantageous if the tool was available on the nearly ubiquitous Windows personal computer (PC). This approach would allow the greatest access to the tool, for PCs are usually shared resources at training locations. Anywhere a PC of sufficient capabilities to host the tool was available, the tool itself could be made available. In addition, the tool could optionally be hosted on private PCs, so VLA test team members could design and test at their personally owned computer. In addition, because many computers are now laptops, the tool could be easily transportable when installed on a laptop and brought onboard ships when actual landing tests are conducted to test VLA configurations. These tests are referred to as Dynamic Interface Trials.

To summarize, to improve decision-making in this complex domain in an affordable manner, design and testing in simulated situations is critical. Therefore, the immediate challenge is to provide test team members with a test and design tool on a PC at their workstation. Members can fly shipboard approaches in specific aircraft, to the deck of a specific ship class, with a realistic view in day and night operations and under a variety of weather conditions, while providing an easy method of adjusting ship VLA components and environment lighting.

2. Overview of Solution

We have developed and continue to enhance VERTICAL (VLA Experimental Resource for Testing Innovative Configurations And Lightings), a test and design tool that can be used to support vertical takeoff and landing (VTOL)/rotorcraft ship VLA design and testing at the test team members' work area. This effort is being accomplished by utilizing MS Flight Simulator, and FSUIPC.

The test team members' high-level interaction with VERTICAL is shown above the dotted line in Figure 2. Test team members are presented with a fully navigable, three-dimensional environment (the visualization environment) provided by MS Flight Simulator containing the ship being targeted for VLA design. The environment may include other aircraft flying or on the ship; essentially, the environment is able to replicate whatever should be simulated to duplicate realistic conditions.

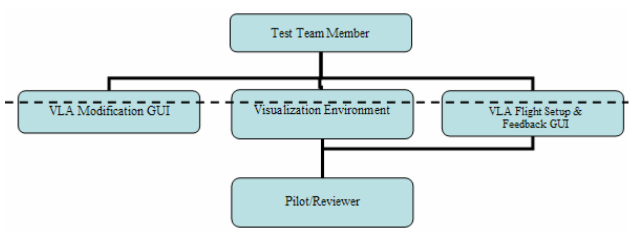

Figure 2. VLA Test Team Member High Level Interactions

The VLA Modification GUI, developed as a separate application, provides an intuitive interface for modifying the VLA components. In the future, test team member and pilot feedback will be collected in real-time by the VLA Setup & Feedback GUI, a mostly non-visual module that records typed or spoken comments, and provides facilities to associate those comments with discrete, user-defined states in the VLA design. This module will also provide a simple, non-visually-invasive tool for saving and reloading "checkpoints" in the test process, allowing new VLA layout ideas to be implemented and reverted with minimal hassle.

The area below the dotted line in Figure 2 represents the pilot/reviewer's high level interaction with the system. Pilots testing VLA designs are provided with the same three-dimensional environment as testers. Pilots/reviewers will have access to the same VLA Setup and Feedback Interface as their test team member counterparts, though their feedback (primarily spoken but with facilities for written comments) will be recorded in a separate time-matched stream for later review and comparison with those of the test team member.

3. VERTICAL: Current Implementation

The current implementation application combines an interactive graphical user interface with custom ship models (e.g., DDG and LHD) and aircraft models controlled and rendered by Microsoft Flight Simulator 2004; all the software runs on today's PCs. By utilizing Microsoft's off-the-shelf simulator package, we are able to render extremely detailed three-dimensional graphics (with accurate physics) that simulate visual scene properties relevant for simulating low-altitude flight [5] at low cost and with significantly reduced development time compared to custom tools. Figure 3 shows modules of our overall design, and the shaded circles represent those demonstrated in the current implementation.

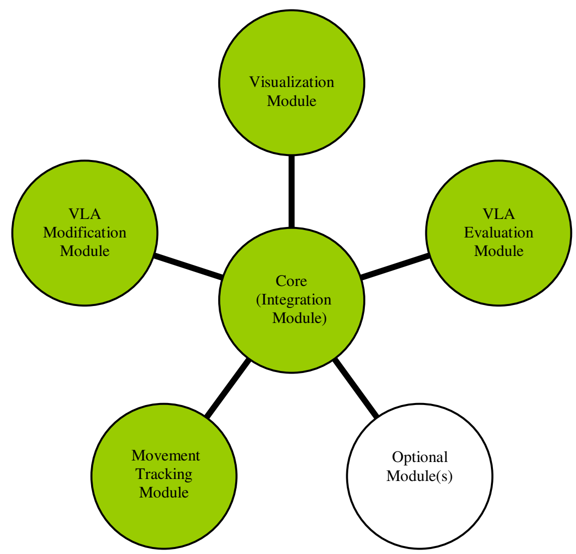

Figure 3. Shaded Modules Demonstrated in Prototype

A requirement for analysis is ship motion. We have developed the ability for ships to pitch and roll, as well as have a forward motion. The user can control this motion via the VLA Modification Module as described below.

The following subsections describe the current implementation's modules.

Visualization Module

The visualization module utilizes Microsoft Flight Simulator 2004 ("MS FS") for the visualization engine. The ships were developed utilizing COTS tools (e.g., gmax®, see www.discreet.com/products/gmax) and proprietary tools that can create models in MS FS and OpenFlight formats.

The ships are dimensionally accurate, richly detailed, and include a large number of dynamically-modifiable VLA lights. This extremely high level of detail (see Figure 4 and 6) provides lighting designers and test pilots with a far more accurate representation of the "final product," reducing the simulator-induced error that has occurred with less detailed models.

Figure 4. View of DDG Destroyer

Figure 5. Close-up 1 of LHD

The visualization module communicates with the core (integration module) via an External System Interface (ESI) written in a product called FSUIPC. The lights on the ship can be controlled via the VLA modification module discussed below.

Figure 6. Close-up 2 of LHD

Weather conditions and the day/night settings are handled in MS FS and allow the setting of any weather condition desired. The current conditions can be downloaded from the internet for any location. For example, Figure 7 shows the LHD in a foggy dusk condition with many of the LHD's lights on.

Figure 7. Foggy Conditions at Dusk

A beneficial aspect of the MS FS is slew mode. This mode allows the user to easily change the location of the aircraft approaching the ship without having to actually fly. By using simple keyboard commands one can move forward, back, left, right, up, down, etc. Of course, one can fly also using various joysticks or add more realistic flight controls.

Field-of-View

The external field-of-view is available with multiple perspectives in the prototype, including:

- From cockpit: not occluded
- From cockpit: showing cockpit
- From spot outside of aircraft, showing aircraft.

The field-of-view can be easily changed while flying.

Figure 8 presents a Harrier on approach showing the view from the cockpit, with the view unobstructed by the cockpit. Figure 9 shows the Harrier on approach from a "spot plane" location; this spot plane can be anywhere with any zoom level. Note also in this figure that the weather conditions have been changed and smoke is shown. The smoke is dynamic and will be effected by the conditions, e.g., the ship speed and wind direction. Figure 10 depicts an MH-60S on approach to a DDG, showing the view from the cockpit, with the cockpit shown. It is also easy for the pilot to move his/her head in the cockpit, that is, one can move forward so less of the cockpit is seen or move one's head from side-to-side to see in directions other than forward. This movement can be achieved via keyboard commands, the "hat" on many joysticks, and by simply moving one's head if wearing a head tracking device.

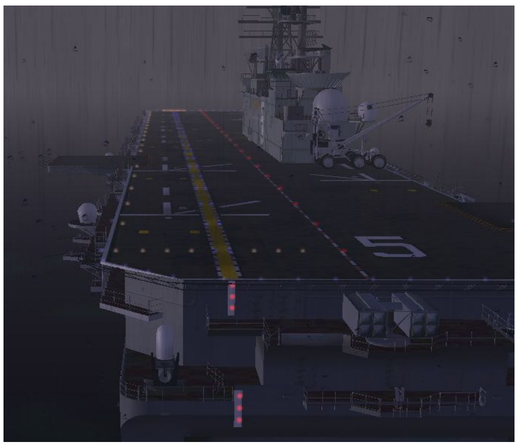

Figure 8. Field-of-View: From Cockpit, Not Occluded

Figure 9. Field-of-View: From Any Spot Outside the Aircraft

Figure 10. Field-of-View: From Cockpit: Showing Cockpit

Note also that any view from the deck or anywhere else on the ship can be obtained easily and saved for quick recall, if desired.

Aircraft

Microsoft Flight Simulator has many Navy and Marine aircraft available for it. The new MH-60S and MH-60R helicopters were some of the few aircraft not already available commercially. Fortunately, these aircraft have been developed by Stottler Henke for one of our other projects [6], so it is available in VERTICAL. Figure 11 shows an example aircraft, the V-22 Osprey.

Figure 11. V-22 Osprey

VLA Modification Module

A graphical user interface allows individual customization of every modifiable light on the ship. Figures 12 and 13 show the interface for the LHD. State (on/off), color, intensity, and visible range can be interactively modified with real-time feedback from the ship model. To simplify the determination of lights, a graphic of the ship is provided with light locations so a user can simply click on the light(s) of interest. Users are provided with a top view, left view, and back view of the ship in order to view all available lights. A user can select individual lights, groups, or light styles and then modify them in the panel that opens to the right, (Figure 13).

Using this tool, test team members are able to obtain a realistic, "in-flight" view of lighting arrangements from a number of relevant aircraft and in all manner of weather conditions. Without leaving the application, lighting parameters can be modified with immediate feedback from the flight perspective, allowing a huge number of potential configurations to be tested in a short time. A configuration can be saved, and any saved configuration can be opened via the load command.

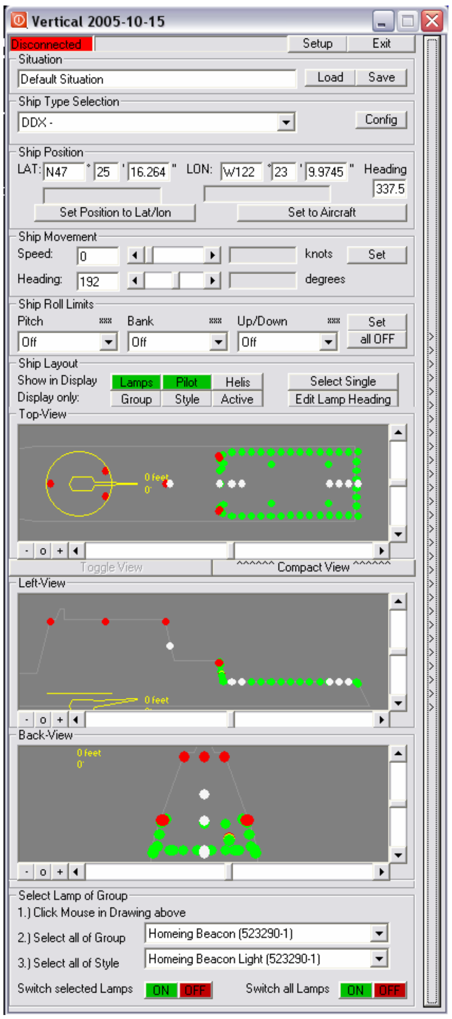

Figure 12. Light Controls Main Interface

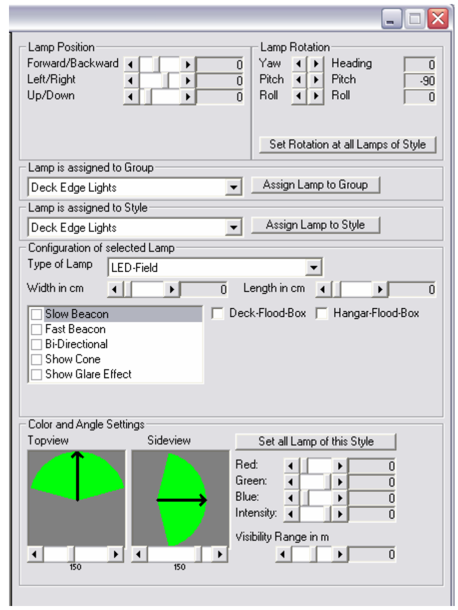

Figure 13. Light Color Selector

Automated Approach

When using the DD(X), DDG, or LCS ships, two automated approaches are available. They provide the user with a demonstration of a helicopter landing on one of the ships. One approach starts at two miles from the ship, on a six degree glideslope at 35 knots in thunderstorms, gusting wind, and turbulence.

The other approach starts at one mile from the ship, on a six degree glideslope at 35 knots. The weather is calm, but there is only visibility for three miles. The flight starts slightly above the glideslope and will intercept the glideslope at about 0.60 mile.

Figure 14 shows a helicopter landing on the back of a ship, and the automated approach window that shows the speed and direction of the helicopter and its position in relation to the ship.

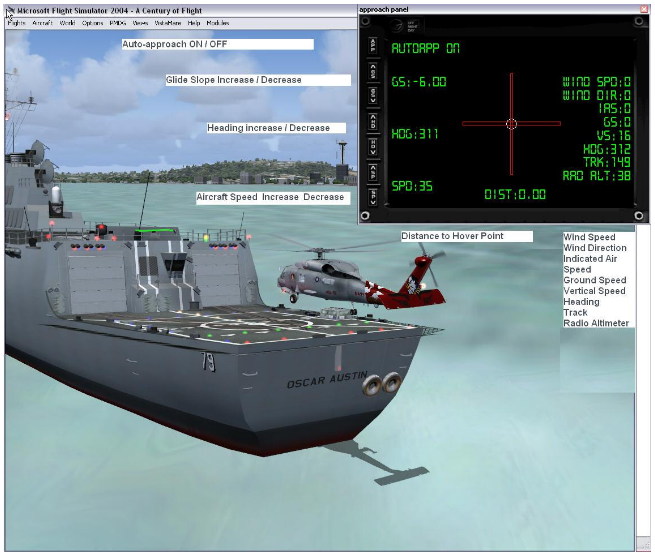

Figure 14. Automated Approach

VLA Flight Setup and Evaluation Module

Some aspects of a VLA Flight Setup & Evaluation Module are demonstrated in this current version. MS Flight Simulator provides facilities for flight setup, including weather conditions as mentioned in the previous section. The flight setup portion of the MS FS allows the user to setup initial conditions, such as the aircraft and ship to be utilized in the evaluation, the locations of each, the weather conditions, and the day/night settings.

The VLA configuration portion of the flight setup is handled via VLA Modification Module save and load commands described above. So a complete flight setup facility is already provided in the prototype.

Per the evaluation part of the module, MS FS provides a very powerful tool right out of the box, Instant Reply. At anytime during a flight/approach one can use the instant replay function to see a portion or all of the flight being flown. The replay can also be seen at different replay speeds. During the replay the view can be adjusted (e.g., change to spot plane view), so the actual view during the replay can be different during the actual flight.

A similar option is Flight Video, in which the user states that a flight video should be made before starting the flight. These flight videos are saved to disk so they can be stored and replayed at any time, and any number of videos can be made.

Movement Tracking Module

This module tracks the location of the user if the user is utilizing a movement tracking unit. Many such movement tracking units are compatible with MS FS, so no separate processing needs to be performed. When combined with a head-mounted screen, an immersive virtual reality environment can be created.

External System Interfaces

The External System Interfaces serve as the middlemen between the different modules. The visualization module communicates with the core (integration module) and the VLA modification module via an external system interface (ESI) written in a product called FSUIPC.

4. CONCLUSION

VERTICAL provides a test and tool to support (VTOL)/rotorcraft ship VLA testing and design. With the added value of Microsoft Flight Simulator and its many low-cost add-ons and its ability to provide real world and user-set weather, this tool allows users to fly specific aircraft shipboard approaches on a personal computer with a realistic view from the cockpit; adjust ship VLA components and environment lighting; and conduct operations during day and operations and under a variety of weather conditions. The dynamic adjustment of the ship's lights and motion has been made possible via the use of FSUIPC and the development of an external program for controlling the lights and motion.

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BIOGRAPHY

Robert Richards is a Principal Investigator and Project Manager at Stottler Henke. Current and past projects range from training system development spanning from aviation to medicine, to applying automation and artificial intelligence techniques to data and voice network configuration and optimization, to machine learning techniques for real-time data mining, and to decision support tool development for high-stress life-critical situations such as landing signal officers on aircraft carriers. He received his PhD from Stanford University in mechanical engineering with an emphasis on machine learning and artificial intelligence.