# VLA Experimental Resource for Testing Innovative Configurations and Lightings (VERTICAL)

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*Abstract*—[1] [2] Stottler Henke is developing VERTICAL (VLA Experimental Resource for Testing Innovative Configurations And Lightings) for the US Navy; a test and design tool that can be used to support vertical takeoff and landing/rotorcraft ship VLA design and testing at the test team members' work area. This is being accomplished by utilizing MS Flight Simulator, FSUIPC and Java.

Visual landing aids (VLAs) provide 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 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 is allowed today.

In order to improve decision-making in this complex domain in an affordable manner, design and testing in simulated situations is critical. VERTICAL provides this solution by providing a test and design tool on a PC allowing one to 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. VERTICAL combines an interactive graphical user interface with various aircraft and custom built ships which are controlled and rendered by Microsoft Flight Simulator 2004. By utilizing Microsoft's off-the-shelf simulator package, we are able to render extremely detailed three-dimensional graphics (with accurate physics) that simulates visual scene properties relevant for simulating low-altitude flight at low cost, and with significantly reduced development time compared to custom tools.

Users 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. 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 GUI. The *VLA Modification GUI*, developed as a separate application developed in Java provides an intuitive interface for modifying the VLA components.



## 1. INTRODUCTION

Visual landing aids (VLAs) provide necessary support to the landing of aircraft on ships, see 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

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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 is allowed today.

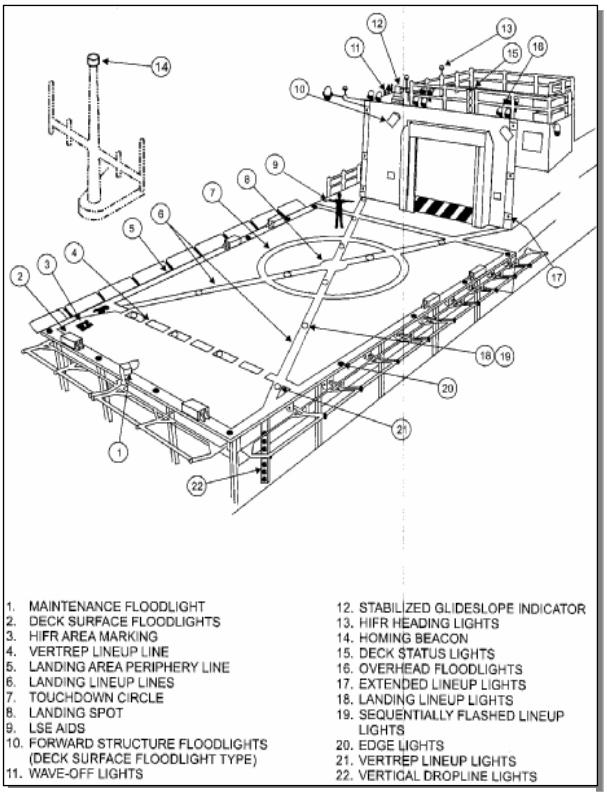


Figure 1. Flight Deck with Visual Landing Aids

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, complexity of visual landing aids (VLA) markings and lighting has increased as well. In the 1950s and 1960's, 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 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 are still dependent on the weather.

In the 1980s, computer advances allowed for the development of highly accurate flight simulator facilities, which boasted mainframe computers with high resolution video screens, which 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 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 it was available on the nearly ubiquitous Windows personal computer (PC). This would allow for the greatest access to the tool, for PCs are usually shared resources at training locations and 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, since 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, in order 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 an test and design tool on a PC at their workstation, allowing them to 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 are developing 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 is being accomplished by utilizing MS Flight Simulator, FSUIPC and Java.

The test team members' high-level interaction with VERTICAL is as shown in

Figure 2 above the dotted line. 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.

The *VLA Modification GUI*, developed as a separate application developed in Java 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 which 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.

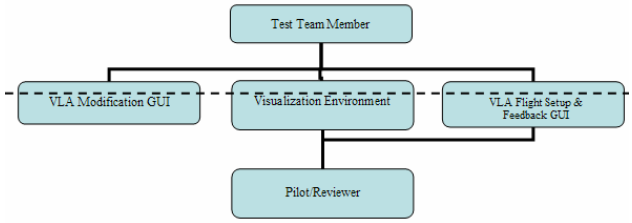


Figure 2. VLA Test Team Member High-Level Interactions

The area below the dotted line in

Figure 2 represents the pilot / reviewer's high level interaction with the system. Pilots testing VLA designs will be provided with the same three-dimensional environment as testers. Pilots / reviewers will have access to the same VLA Setup & 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.

To date we have developed a prototype of the system as described below.

## 3. VERTICAL PROTOTYPE DESCRIPTION

Our prototype application combines an interactive graphical user interface with a custom ship models (e.g., DDG and LHD) and aircraft models which are controlled and rendered by Microsoft Flight Simulator 2004. By utilizing Microsoft's off-the-shelf simulator package, we are able to render extremely detailed three-dimensional graphics (with accurate physics) that simulates 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 or our overall design, and the shaded circles represent those demonstrated in the prototype.

A requirement for analysis is ship motion, we have developed the ability for the ships to pitch and roll, as well as have a forward motion. Of course, the relative motion of the ship has a significant influence on many aspects of the design of the complete VLA configuration, so realistic motion is essential to any design process or testing regime.

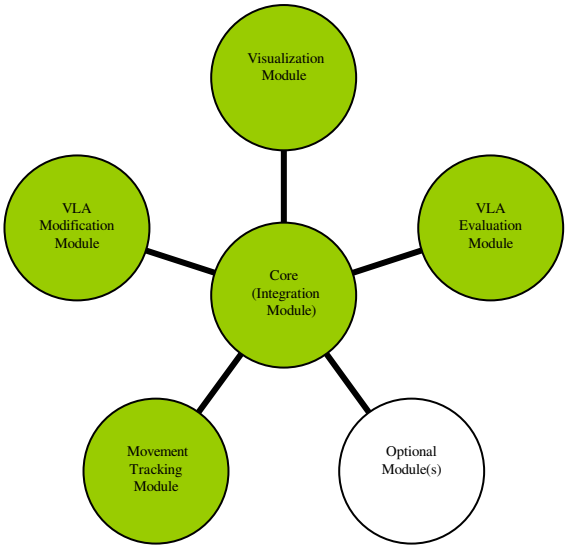


Figure 3. Shaded Modules Demonstrated in Prototype

The following subsections describe the prototype and its modules.

*Visualization Module*

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

The ships are dimensionally accurate, richly detailed, and includes a large number of dynamically-modifiable VLA lights. This extremely high level of detail (see Figure 4,

Figure 5 and Figure 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.

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 further discussed below.

Figure 4. View of DDG Destroyer

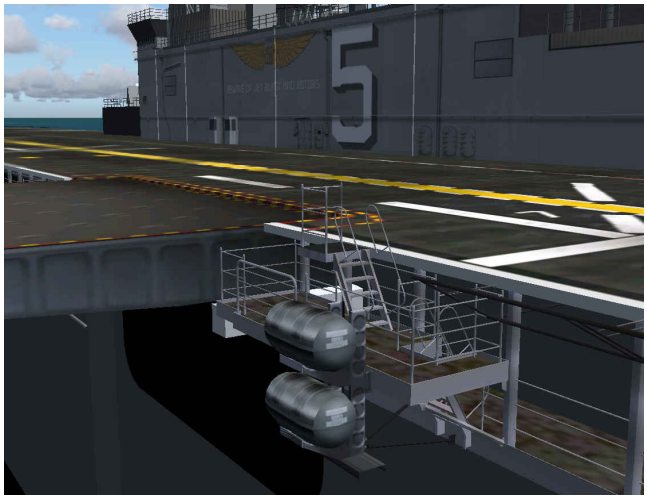

Figure 5. Close-up 1 of LHD

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 or 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 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 shows 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 shows 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 their 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 can be done via keyboard commands, the "hat" on many joysticks and simply by moving ones head if wearing a head tracking device. See the Movement Tracking Module section for more information.

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.

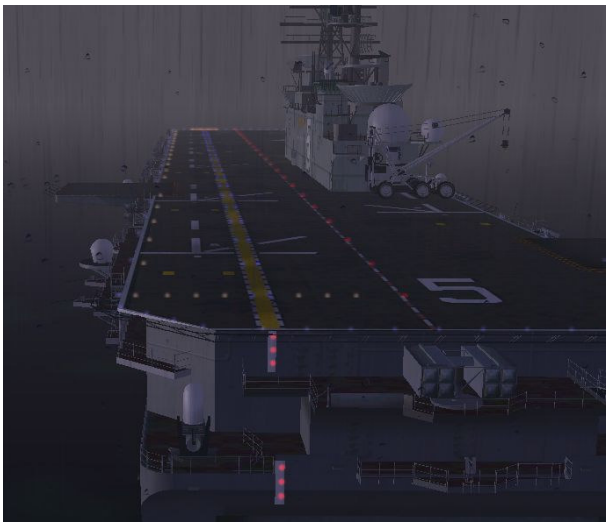

Figure 8. Field-of-View: From Cockpit: Not Occluded

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


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

*Aircraft*

Microsoft Flight Simulator has most Navy and Marine aircraft available for it. Some of the few that were not already available commercially were the new MH-60S and MH-60R helicopters. Fortunately, these 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; Figure 12, and Figure 13 show the interface for the LHD. State (on/off), color, and intensity can be interactively modified with real-time feedback from the ship model. The large number of controllable lights is broken into subgroups by function, with each subgroup receiving its own tab on the main GUI panel to prevent the interface from becoming overwhelming.

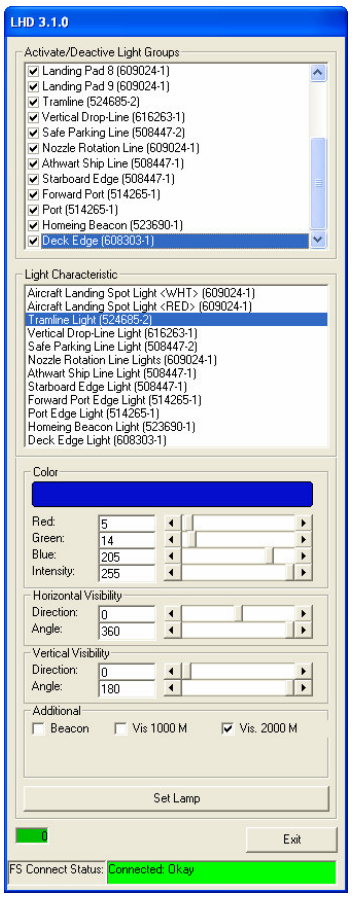


Figure 12. Light Controls Main Interface

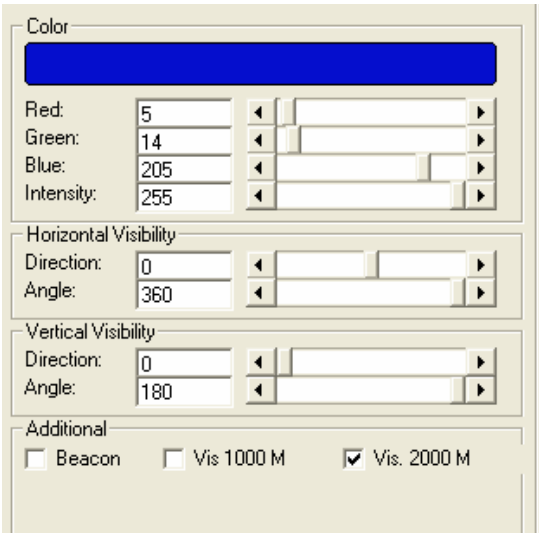


Figure 13. Light Color Selector: HSB Option

Using this tool, test team members are able to get 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 amount of time.

*VLA Flight Setup & Evaluation Module*

Some aspects of a VLA Flight Setup & Evaluation Module are demonstrated in this prototype. MS Flight Simulator provides facilities for flight setup including weather conditions as just 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 that is being flown. The replay can be seen at different replay speeds, in addition, 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 the *Flight Video* option where before starting the flight you state that a flight video should be made. 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. There are many such movement tracking units that 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 (ESIs)*

The ESIs, or 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.

*Hardware*

The VERTICAL Prototype software runs on today's PCs. The system has been successfully demonstrated utilizing COTS hardware including the following configurations.

1. A 3GHz Pentium-4 processor with a 256 MB OpenGL graphics card. Under the highest reality settings the system ran at 15 frames per second.

2. A laptop with a Pentium-4 with a 64 MB OpenGL graphics card. This arrangement provides usable performance with some reality settings set to less than maximum.

## 4. CONCLUSION

The VLA Experimental Resource for Testing Innovative Configurations And Lightings (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 prototype 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 has been made possible via the use of FSUIPC and the development of an external program for controlling the lights.

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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 Ph.D. from Stanford University in mechanical engineering with an emphasis on machine learning and artificial intelligence.*