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"Charlie,"development of a light-weight, virtual reality trainer for the LSO community: time to make the leap toward immersive VR

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THESIS

"CHARLIE," DEVELOPMENT OF A LIGHT-WEIGHT, VIRTUAL REALITY TRAINER FOR THE LSO COMMUNITY: TIME TO MAKE THE LEAP TOWARD IMMERSIVE VR

by

Larry C. Greunke

September 2015

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Landing Signal Officers (LSOs) are the backbone of tailhook naval aviation. Currently, once a junior officer is selected from a squadron to become an LSO, that person typically will go through an entire workup cycle before going to the Initial Formal Ground Training (IFGT) course. This means that an LSO will undergo months of on-the-job training at sea and assume different roles needed to recover aircraft before that individual receives his/her first formal training during IFGT. At the center of IFGT is the LSO Trainer, Device 2H111, in which the LSO receives a series of six one-hour long sessions. For many LSOs, this will be the only interaction will this training simulator.

The aim of this thesis was to develop and evaluate whether major training objectives for the 2H111 could be supported using a proof of concept, light-weight, portable VR trainer with a VR HMD as its display solution. Thesis work included feasibility testing of a Graphical User Interface and voice recognition integration into a simulation to facilitate both an individual and a team training environment. The result of the study is that technology has come far enough to support a commercial-off-the-shelf technology solution.

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“CHARLIE,” DEVELOPMENT OF A LIGHT-WEIGHT, VIRTUAL REALITY TRAINER FOR THE LSO COMMUNITY: TIME TO MAKE THE LEAP TOWARD IMMERSIVE VR

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

ACLS	Automatic Carrier Landing System
APARTS	Automated Performance Assessment and Redial Training System
ARB	Aircraft Recovery Bulletins
AR	Augmented Reality
CAG	Carrier Air Group
CATCC	Carrier Air Traffic Control Center
COTS	Commercial-off-the-shelf
CV	Aircraft Carrier
DK2	Developmental Kit 2
FCLP	Field Carrier Landing Practice
FOV	Field Of View
FPS	Frames Per Second
FRP	Fleet Replacement Pilot
HMD	Head Mounted Display
IR	Infrared
IFGT	Initial Formal Ground Training
IFLOLS	Improved Fresnel Lens Optical Landing System
IVE	Immersive Virtual Environments
LSO	Landing Signal Officer
LSODS	Landing Signal Officer Display System
LSOT	Landing Signal Officer Trainer
MOVLAS	Manually Operated Visual Landing Aid System
MVC	Model View Controller
ONR	Office of Naval Research
NATOPS	Naval Air Training and Operating Procedures Standardization
NCLT	Night Carrier Landing Trainer
UHF	Ultra-High Frequency
VE	Virtual Environment
VR	Virtual Reality

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I. INTRODUCTION

A. RESEARCH DOMAIN

The act of landing aircraft aboard an aircraft carrier is inherently dangerous. Through the use of technology, consistent training, and verified standard operating procedures, this activity has become largely uneventful.

The individuals who help ensure that the thin line between the routine and tragedy does not get crossed, are a group of pilots who stand watch at the back of the aircraft carrier. This team of officers, all naval aviators, takes its role as a group of Landing Signal Officers (LSOs), whom are referred to as “Paddles” by the inner circles of naval aviation.

Currently, the trade of learning how to “wave” aircraft (i.e., having the ability to control an aircraft and provide assistance to the pilot during the landing phase of flight) is done through many hours of “on the job” training. During this training, the LSO will learn to combine factors of aircraft capabilities, pilot performance, and environmental conditions. This is done to determine if a pilot is in a safe position to land, and when needed instruct the pilot on how to fly to get to an optimum position. On board the aircraft carrier, LSOs will typically see months’ worth of aircraft passes before they experience their first and for many the only form of formal training at the LSO School in Oceana, Virginia. During this Initial Formal Ground Training (IFGT), LSOs will have two areas of focus:

1. Learn the principles and lessons that the naval aviation community has built on for the last 100 years with waving aircraft, and

2. Reinforce the practical knowledge to facilitate successful aircraft recoveries by practicing waving as teams of LSOs in the 2H111 LSO trainer (LSOT).

Utilizing the 2H111 trainer, LSOs will take turns and rotate between different positions that collectively make up an LSO wave team. They will encounter different aircraft recovery environments from very easy to extremely complex. During IFGT, LSOs will have these training environments available for only six hours that are spread out over the course of a week and a half. During this time, the teams of LSOs will have to cover a spectrum of concepts from introductory to advanced. According to the LSO School, the number one feedback item that they get on exit surveys is that the students would like to have more time working with the simulator.

The stakes of naval aviation are extremely high, especially around the aircraft carrier; every pilot and every LSO must have the confidence in themselves and earn the trust of the other partner in order for the pilot-LSO relationship to function. While the confidence of a pilot comes from a combination of live and simulated repetition, confidence of an LSO comes as the combination of knowing the reference knowledge along with the practical experience of repetition of waving aircraft in many different situations. For reference knowledge, an LSO has several publications that he or she can refer to such as the *Landing Signal Officers Naval Air Training and Operating Procedures Standardization (NATOPS) Manual* and the *aircraft carrier (CV) NATOPS* Manual. While these publications are essential, having them alone does not allow the capacity for an individual to go through the mental exercise of having a diverse set of recovery situations to think and react to, as well as to understand the procedures and interactions that take place on the LSO platform. The LSO trainer is able to provide this environment for LSOs, however due to the limited access of the simulator this is a short-lived experience. Additionally, months or even more than a year can go by between times that an LSO is able to wave live aircraft. Concepts that can be demonstrated with the LSO trainer are essential to maintain a confident and competent LSO.

B. RESEARCH PROBLEM AND MOTIVATION

As a field, Naval Aviation has continually sought to improve the safety and training of the domain, and the motivation behind this thesis is in line with that tradition.

1). **Mishaps are costly**. According to the Naval Safety Center, from 2005 to July of 2015, there were 108 landing-related mishaps on aircraft carriers. “Of those, 99 involved the LSO in some manner, 41 events reported damage to property, and 2 reported injuries to personnel” (Jones, 2015, p. 1). The Naval Safety Center’s database does not have a specific code for a mishap involving Manually Operated Visual Landing Aid

System (MOVLAS) and Improved Fresnel Lens Optical Landing System (IFLOLS), so if the writers of the safety report felt that the landing was a significant enough contributor to the incident they would mention it in the narrative of the incident. Of the 108, 5 referenced MOVLAS and 2 of the events mention IFLOLS in the narrative. The Naval Safety Center does "not believe the MOVLAS/IFLOLS numbers are accurate since they are not consistently captured" (Jones, 2015, p. 1). While the breakdown of mishaps into classes was not provided, it is still beneficial to understand how mishaps are categorized. The Office of the Chief of Naval Operations defines Class A, B, and C Mishaps in the following manner:

> **Class A Mishap.** The resulting total cost of damages to Government and other property in an amount of $1 million or more; a [department of defense] aircraft is destroyed; or an injury and/or occupational illness results in a fatality or permanent total disability.
>
> **Class B Mishap**. The resulting total cost of damage is $200,000 or more, but less than $1 million. An injury and/or occupational illness results in permanent partial disability or when three or more personnel are hospitalized for inpatient care (which, for accident reporting purposes only, does not include just observation and/or diagnostic care) as a result of a single accident.
>
> **Class C Mishap.** The resulting total cost of property damage is $20,000 or more, but less than $200,000; a nonfatal injury that causes any loss of time from work beyond the day or shift on which it occurred; or a nonfatal occupational illness or injury that causes loss of time away from work or disability at any time.
>
> (Navy & Marine Corps Mishap and Safety Investigation, Reporting, and Record Keeping Manual, 2005, pp. G1-3–4)

2) **Current practices have gaps in training.** The potential for informal individual training and team training does exist for LSOs. The 2H111 can provide this learning environment for training, but only within the following situation. First, the squadron(s) that the LSOs are a part of must not be embarked during the deployment cycle, and the squadron(s) must be stationed at NAS Oceana (because of travel funding considerations). Secondly, the trainer (Device 2H111) must be available and not being used by an LSO class going through formal training. This arrangement leaves three large areas where LSOs have a lack of training: (1) the need for training in preparation for

deployment prior to attending IFGT, (2) need for more hours of training with 2H111, and (3) need for refresher training once the LSO departs from NAS Oceana. In a survey given to LSO and discussed in Chapter V, over 90% of the LSOs said they wanted refresher training.

3) **Warfighter performance**. Office of Naval Research (ONR) states the following as a part of their *Naval Science and Technology Strategy* (2015): To advance innovations for the future force, ONR identified the need to produce training environments that "enable effective human-machine interaction and mission readiness across individual, team, platform and integrated levels" (p. 42). The vision of the ONR is that the trainees will be able to access these training environments at any time and any location. Using the laptops as the means of computer support for the simulations, provides the users with an added level of flexibility and the best possible means currently available to accomplish this goal.

C. RESEARCH QUESTIONS

The following research questions are the focal points for this thesis:

- Is it feasible to use commercially off-the-shelf (COTS) technologies to develop a virtual reality (VR) trainer for the Landing Signal Officer community?
- Can major training objectives for the 2H111 be supported using a proof of concept, light-weight, portable VR trainer and a VR head mounted display (HMD) as its display solution?
- What are the additional computational and training capabilities that go beyond the functionalities provided in 2H111, that this novel setup can support?

D. SCOPE

The scope of this thesis is to investigate the technical capabilities of a light-weight trainer, and examine the potential for effective training. This thesis does not include a formal study of training effectiveness. The thesis effort therefore targets COTS technology, to determine if it has progressed to the point of being able to support a light-weight virtual reality trainer for the Navy and for the Landing Signal Officer community in particular.

E. APPROACH

The process that was used for this study was to determine the functionality that is available for LSO training in the 2H111. This included the visual, audio, and haptic interactions that were present and available in that system. The prototype light-weight LSO trainer would then be compared to the 2H111 to see what functionalities were possible and additionally, what could the prototype LSO trainer do that that the 2H111 is incapable of doing. The conclusions to these comparisons can be found in Chapter VII: Feasibility Study and Analysis of Results.

F. THESIS STRUCTURE

The remainder of this thesis is structured as follows:

Chapter II details the evolution of the Landing Signal Officer as well as current training methods used to train the officers with this specialty.

Chapter III has a brief history and definition of virtual reality and a subset of human factors significant for our domain of research.

Chapter IV constructs the task analysis done for each of the three LSO positions that the prototype system would support.

Chapter V presents and discusses the results of a survey given to LSOs about the current state of training as well as the features that are liked and features that are not seen as favorable in LSOT 2H111.

Chapter VI details the construction of the light-weight LSO prototype trainer and the assets, tool-chain, and methods used.

Chapter VII describes the results of prototype’s ability to support LSO training through both objective and subjective analysis.

Chapter VIII summarizes the conclusions made about the prototype system and details the future work.

II. BACKGROUND

This chapter discusses how the LSO community had been established and how it advanced with technology to the state that it is in today. The issues connected with the training domain are discussed, in addition to how the LSO School provides instruction for the students with the 2H111 simulator during the Initial Formal Ground Training (IFGT) course. The text also provides remarks on the differences between the two Virtual Reality approaches: the 2H111 training system and the immersive VR HMD-based light-weight system.

A. PROBLEM SPACE

The first official carrier was the *USS Langley* (CV-1), commissioned in 1922. The executive officer of the ship, CDR Kenneth Whiting, would when not flying, observe all of the landings from the port-aft corner of the ship. It was there that pilots recognized the importance of having a pilot at the back of the ship; the information that could be presented to them from that place was helpful in putting their aircraft in a better position, and that in the end resulted in a safer pass. The collaboration of that group of aviators, resulted in creation of the position of Landing Signal Officer—LSO (Tate, 1978). That effort also generated a body language that was meant to convey the information to the pilot in the aircraft. This body language soon gave way to hand paddles, as the means of delivering information and became the origin of the name "Paddles" which was the nickname given to pilots standing this watch position.

The Navy has consistently sought ways to make the business of landing on a ship more safe, starting from making the structure of the boat better to improving the pilot-LSO interaction. Switching the flight deck from a straight deck to an angled deck had several positive effects on safety. For one, it allowed for a longer landing area, a clear area in front of the landing area to enable go-arounds in the case that a trap was not successful, and additionally it allowed the wires to be shifted closer to the bow to enable a greater chance of trapping and increased margin of safety (Australian Navy, n.d.). There was also a desire to allow more precise glideslope information to the pilots, and that resulted in integration of an optical lens systems into the aircraft carrier. The current generation of optical lens systems integrated into aircraft carriers called the Improved Fresnel Lens Optical Landing System (IFLOLS), is dynamically stabilized to compensate for the pitch, roll and heave of the ship's motion (Naval Air Systems Command, 2013). A Manually Operated Visual Landing System (MOVLAS) controlled by LSOs was created for situations when deck motion pushes IFLOLS outside of its operating limits (Naval Air Systems Command, 2013). LSOs have also changed the way in which they operate—they no longer use paddles and instead now use both voice and light signal communications with the pilot through Ultra-High Frequency (UHF) and through either the IFLOLS or MOVLAS as appropriate.

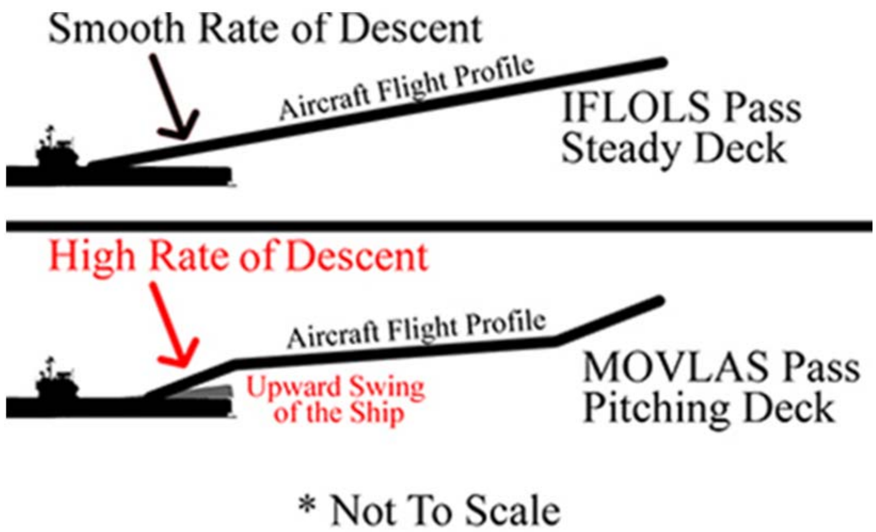
Additionally, the Navy has made investments in the technology and procedures of LSOs. The LSO officer at first had no support other than himself; he was a single individual on the aft end of the aircraft carrier. In an effort to provide information and enhance situational awareness, landing aid instruments were placed within a view of the LSO (U.S. Navy, 1963). These instruments started out as a few rudimentary analog outputs and eventually were updated to digital display systems with the current version called Landing Signal Officer Display System (LSODS); this system is capable of showing everything the platform camera (a live video feed of center of the landing area), gear and lens status, to even divert information (Naval Air Systems Command, 2013). From the procedural aspect, the role of LSO transitioned from a single LSO to a two persons job (the LSO and an assistant to take notes), and then eventually it encompassed a team of typically five to six individuals where each officer had his own set of tasks to accomplish (U.S. Navy, 1963; Naval Air Systems Command, 2013).

However, one element that has stayed constant from the first pass that an LSO waved until today, is the task that has been known as the "eyeball calibration." An LSO must be able to properly judge and visualize in the airspace behind the carrier what the proper glideslope is and where the aircraft is in relation to it. Following the completion of a pass, the LSO will debrief the pilot on how the pilot flew the pass. Ideally, what the pilot saw on IFLOLS and what the LSO says on how the pilot flies the pass correlate, otherwise it risks undermining the trust between the pilots and LSOs.

In the late 1970s, in an effort to strengthen pilot-LSO interaction, the Navy chose to attack the problem from both the pilot side of the equation and the LSO component. The creation of Automated Performance Assessment and Remedial Training System (APARTS), had the original intent of being able to automatically analyze Field Carrier Landing Practice (FCLP) performance of Fleet Replacement Pilots (FRP) and then tailor remedial instruction in a Night Carrier Landing Trainer (NCLT). The Navy has even investigated putting a general purpose NCLT on an aircraft carrier for remedial training (Brictson & Breindenbach, 1981). APARTS evolved into a full database that stores a history of passes for the pilots. LSOs leverage this information to understand pilots' performance trends connected with landing aircraft on carriers. Once a pilot's trend is understood, ways to correct these deficiencies will be conveyed to the pilot and additionally, the information will be used as a means to anticipate future performance while an LSO is waving that pilot (Naval Air Systems Command, 2013).

The use of MOVLAS on an aircraft carrier represents a direct communication link between the LSO and pilot. As a backup landing aid system to IFLOLS, there are a couple reasons why MOVLAS would be utilized rather than IFLOLS. Those reasons include the situations when IFLOLS is inoperable, when deck motion exceeds the stabilization limits of IFLOLS, or when it is used to support pilot or LSO training (Naval Air Systems Command, 2013). Utilizing MOVLAS comes with its risks (Figure 1). Because of these risks, it is important to increase exposure to MOVLAS both for the pilots who have to fly differently and for LSOs who have to operate that device. It is worth mentioning that this builds the confidence between the pilots, who have to know that the LSOs will get them on the deck safely, and the LSOs to know that a pilot will follow his/her instructions.

Figure 1. IFLOLS Pass of Aircraft versus MOVLAS Pass of Aircraft



Potential differences between an IFLOLS pass and a MOVLAS pass with aircraft. With a MOVLAS pass the LSO has to make sure the aircraft has enough altitude to clear the back of the boat with a pitching deck, at the same time in order to land at the same spot the aircraft will have to have an increased rate of descent (ROD) in order to land. This is the part of the balance between safety and efficiency the LSO has to balance, an increased ROD causes additional stress on the aircraft and can cause enough damage to warrant a mishap.

The LSO NATOPS produced recommendations in support of training sessions that teach how to operate MOVLAS; they suggest that LSOs "shall acquaint themselves and receive adequate training with the MOVLAS ashore prior to using it aboard ship" (Naval Air Systems Command, 2013, p. 6–15). In practice, LSOs from the various squadrons of an airwing will typically have only a one-day-long dedicated training session where the pilots will fly while the LSOs operate MOVLAS during FCLPs before the squadron embarks at sea. This will translate to about 10–20 passes per one LSO (the session will be split among all of the squadron's LSOs).

Operating MOVLAS at the airfield prior to arriving at the ship allows the LSO to gain a couple of benefits:

- LSO is able to "get a feel" for mechanically operating the mechanism for MOVLAS and an understanding of what physical position of the switch will translate into which lights will light up on the rig,

- LSOs get to practice multitasking—they need to be able to analyze the aircraft's position and put the light source in an intentional position to force a reaction from the pilot, and
- This type of practice gives the LSOs a chance to see how every pilot in the squadron reacts to MOVLAS, and correct any bad habit that pilots may have before the squadron arrives at the ship.

Practice at the airfield, however, lacks the ability for the LSOs to operate MOVLAS in a dynamic environment—this is an extremely important characteristic of an operating situation at the sea (i.e., a moving deck). Practice at the ship has all benefits of operating at the field and, in addition, also provides the opportunity to use the device in an environment that is as close as possible to conditions and situation when MOVLAS is really needed such as a pitching aircraft carrier deck. Practice at the ship is encouraged by the *LSO NATOPS Manual* for at least one recovery cycle during the day (about 10 aircraft) and one during the night. Since the *LSO NATOPS Manual* states that this "should" happen and not "shall" happen, there is nothing that requires the airwing to have these dedicated MOVLAS recoveries. Beyond this, currently the best practice an LSO can get with MOVLAS is to attend training sessions organized at NAS Oceana with the LSO Trainer 2H111.

When the LSO trainer 2H111 was developed several outcomes were sought for the LSO community. One of those outcomes was to have a training simulation capable of supporting the practice of initial "eye-calibration," but also being an advanced "refresher" (McCauley, Cotton, & Hooks, 1982). Something that was initially seen as ideal, but not possible at the time to accomplish, was to have that system operate as an "instructorless" trainer. McCauley's research states that the limiting factor in development was the reliance on an accurate, real-time speech recognition system. Since LSOs' main way of communication with pilots is through UHF radio, having a system that could recognize phrases or commands by the LSO would be a requirement. According to a previous assessment for LSO needs, the ideal system must quickly be able to recognize the LSO's command (less than one second) and must be accurate (approximately 99 percent) (Cotton & McCauley, 1983).

B. CURRENT LSO TRAINING SOLUTION (DEVICE 2H111)

The following section describes the LSO training system 2H111. The trainer is currently the only means that an LSO has to practice and interact in a team environment to perform the tasks that are required for LSOs (Figure 2).

Figure 2. LSO Instructor Operating 2H111 with LSO Team Training

The training system that serves as a reference system for the purposes of this thesis research effort is Landing Signal Officer Trainer, Device 2H111, located at NAS Oceana. The simulator is built within a large two story room and it takes one person to operate (typically an instructor). The 2H111 is capable of simulating a fully functional LSO platform on a 3 or 4-wire ship, and it is able to customize the training to suit the specific needs of the group of students. It has models of nearly all types of aircraft that currently *could* land on aircraft carrier and *all* current fleet aircraft. It is able to change the conditions of recovery by changing the environmental conditions (e.g., day, night, limited visibility), and it has ability to switch from IFLOLS to MOVLAS. The system serves as both a procedural and possible refresher trainer for individual and team training, and it supports both normal and emergency recovery conditions. “The use of the trainer is highly recommended for LSO turnaround training on both a squadron and air wing level, to enhance the overall preparedness of LSO teams prior to embarked operations.” (Naval Air Systems Command, 2013, p. 2–3).

1. Output Devices

a. Projector Screens

A projector based system,which blends multiple projectors to display a 270 degree field of view (FOV) around the LSO Workstation, is shown in Figure 2. The ambient light that does not originate from the projectors has to be kept to a minimum, so that the images generated by the projectors do not to look “washed out.” Part of the training syllabus for IFGT has LSOs waving in a pitch black (no horizon) environment. The projectors installed in a recent upgrade are unable to support this, because their black level is too high and the horizon can still be seen.

b. LSO Display System (LSODS)

The LSO Display System (Figure 3), is a complex interface that allows the LSO to access different pieces of information that are important to recover aircraft, and information that would be required in an emergency aircraft recovery situation. There are two sets of displays that operated independently of each other.

Figure 3. LSO Display System

The setup for LSODS consists of two LSO Display sets, each set is composed of four boxes (the two boxes on the left are output displays, the boxes on the right are for system inputs).

The LSODS will show the LSO status information about the pilot and aircraft that are recovering. Additionally, the LSO will be able to verify the status of the flight deck to be sure that it is setup to recover the incoming aircraft (i.e., the arresting gear and IFLOLS lens setting). Both screens on the left side of each set of displays are used for viewing the information. The bottom right box of each display set consists of a touch-screen that is used to manipulate radio frequencies and to enable the LSO to directly communicate with various parts of the ship.

c. Speaker

A speaker is located in each phone headset that the Controlling LSO, Secondary LSO, and the carrier air group (CAG) LSO will carry (Figure 4). They allow the LSO to hear the current radio frequency that is selected on the LSODS.

Figure 4. LSO Holding Pickle and Headset in an Operational Environment (from Pittman, 2012)

2. Input Devices

All of the signals that the 2H111 device receives are analog inputs, with the exception of two touchscreen panels in the LSODS. One of the distinct advantages of this system is that it is an exact replica of the current system.

a. LSO Display System (LSODS)

The LSODS is able to take user inputs to manipulate the system. Figure 3 shows the layout of the LSO Display System, the right two boxes in each LSO Display Set handle inputs from the LSO. The top box, referred to as the “control panel” handles inputs that will change the two LSO Displays on the left half of the set. The bottom box, referred to as the “phone box” allows the LSO to change radio frequencies and to call different departments or squadrons in the ship.

b. Pickle

The “Pickle” is a device that allows the LSO to communicate with the pilot with light signals that are attached to either IFLOLS or MOVLAS. The device can be seen in the right hand of the LSO in Figure 4.

c. MOVLAS

The Manually Operated Visual Landing Aid System is the backup landing aid on the aircraft carrier that will be referenced by the pilot landing on the boat. The system is directly manipulated by the Controlling LSO using the rig shown in Figure 5.

Figure 5. MOVLAS Rig in Use

The Controlling LSO operating MOVLAS in 2H111 with Backup LSO Monitoring (left). MOVLAS rig with pickle attached (right).

d. Microphone

A microphone is contained inside a phone that the LSO will hold (shown in the left hand of the LSO in Figure 4). There are three phone headsets attached to LSODS. They allow a hierarchically based communication between the LSOs and the pilot. The CAG LSO has the highest priority, followed by the Backup LSO, and then the Controlling LSO. In order to transmit voice communications a button on the phone must be pressed.

3. Training Approach

During the Initial Formal Ground Training (IFGT) course, there are, six hour-long sessions. The Instructor LSO, who is running the simulation, has a framework on how each simulation session should be structured. The main variables for each session are what is the lens that is being used, environmental conditions, time of day, and whether emergency aircraft are being recovered. The following is a brief synopsis on each of those training session that a student LSO will experience. For full details relating to each simulator session, a reader should refer to Appendix A. LSO School Documentation.

Session 1 (IFGT 1.1—DAY FUNDAMENTALS107): Review of the basic waving procedures, reinforcing scan techniques. Work 60 passes.

Lens—IFLOLS

Environment—Day, Case I, beginner deck motion.

Introduces malfunctions—(e.g., wrong cross checks, winds out of limits, and foul deck with no calls)

Session 2 (IFGT 1.2—DAY MOVLAS INTRO107): Introduction to MOVLAS. Focuses on pilots and their response to MOVLAS. Brief techniques to controlling the aircraft. The simulator will always respond to the MOVLAS position, instructor can take manual control to induce errors to test wave off criteria. No malfunctions or emergencies during session. Work 60 passes.

Lens—MOVLAS

Environment—Day, Case I, moderate deck motion.

Session 3 (IFGT 1.3—DAY MOVLAS PRACTICE109): Build off of the first MOVLAS simulation (1.2). Introduce emergencies and malfunctions during the sim.

Lens—MOVLAS

Environment—Day, Case I, advanced deck motion

Session 4 (IFGT 1.4—NIGHT MOVLAS INTRO109): Introduce MOVLAS operation during the nighttime. Explain the use of a plane guard for the referencing of the horizon. Cover responsibility of changing radio frequencies to the Backup position. Introduce an aircraft's approach light being out as an emergency.

Lens—MOVLAS

Environment—Night Case III, moderate deck motion.

Session 5 (IFGT 1.5—FOUL WEATHER/NONSTANDARD111): Introduce LSO talkdown procedures and techniques. Start waving aircraft in poor weather. Work 60 passes.

Lens—MOVLAS

Environment—Day/Night case III, varying deck motion moderate to extreme. Poor visibility conditions introduced.

Session 6 (IFGT 1.6—BARRICADE SIM112): Introduce barricade procedures. LSO team will look through Aircraft Recovery Bulletins to deal with varying aircraft emergencies. Work 60 passes.

Lens—IFLOLS

Environment—Day/Night straight-in approaches. Beginner deck motion.

The training period for all of these sessions is spread over the two week period of IFGT. For many LSOs in fleet, this will conclude the formal training that they receive; it may also be the only experience they will have in the 2H111.

C. EMERGENCE OF VR BASED SIMULATIONS

Virtual environments have tremendous variation between one another. While both the 2H111 and the prototype light-weight LSO VR trainer designed and developed in support of this thesis make use of virtual environments and simulation technologies, they have significant differences between them.

A major difference between these two systems is the level of flexibility that each system offers. For an LSO to engage with the virtual environment created by the 2H111, he or she must travel to NAS Oceana and visit the LSO schoolhouse during the constrained conditions discussed in Chapter I. While it would be physically possible to move the LSO Trainer 2H111 around, it would be both cost prohibitive, and it still would not solve the problem of only being in one location at a time. Meanwhile a light-weight LSO trainer not tied to any physical room can go anywhere the LSO needs to be located physically.

A second major distinction in flexibility between the two is related to changes in hardware. Both simulations can respond to changes in software (e.g., a new aircraft gets added to the Navy's inventory, or voice recognition needs to be incorporated). However, both simulators would respond differently to any change in hardware (e.g., LSO Display Station or MOVLAS controller). A light-weight trainer would be able to reproduce the change digitally, and once coding was complete an update would be pushed to the individual machines nearly immediately. The 2H111 trainer, however, would need to be shut down during the upgrade and no training would be possible during this time. This installation would take far longer than the installation of a new version of software.

The field of virtual environments has seen a tremendous shift in investment and advancement over the last couple years, especially since Oculus made its Kickstarter debut and was purchased for $2 billion by Facebook (Constine, 2014; Hof, 2015). The virtual environment field has not just seen the advancements in virtual reality headsets and augmented reality (AR) headsets, but the peripheral controllers used to interface with systems are advancing as well.

These input controllers and headsets contribute to the final major difference between the LSOT 2H111 and the light-weight LSO trainer. That item is the portability and flexibility of the graphics rendering engine used to develop code for the light-weight LSO prototype. The use of that particular software, the Unity game engine, is significant because the companies that create light-weight solutions like Oculus and Sixense, also make the plugin code to work with Unity, among other environments. This means that the upgrade of the controllers and visual display solutions for the system could happen at a regular technology update cycle as more advanced technology comes out. Additionally, the Unity game engine software is available for 22 different platforms, which allows for easy deployment on a variety of systems (e.g., Apple, PS4, Xbox One, Windows, Android) (Build Once Deploy Anywhere, 2015). This also indicates that different learning objectives potentially could be supported by different systems, which is currently not feasible using the 2H111 system. Further discussion of this topic is provided in the results chapter (Chapter VII).

D. CHAPTER SUMMARY

In order to develop a light-weight training system that uses the 2H111 as a reference system for our analysis, it was essential to understand how the 2H111 works. This chapter provided details about the 2H111 training system, and elaborated on how the LSOs currently learns the skills required to perform their job. This included a description of training needs and approaches currently in use with the 2H111.

III. VIRTUAL-REALITY TECHNOLOGY

A. INTRODUCTION

Immersive Virtual Environments (IVE), which distinguish themselves from traditional vehicle simulations are environments where the users are directly immersed in the environment rather than placed in a vehicle simulated to be in an environment (Elis, 1994). Brooks (1999) defines a "virtual reality experience as any in which the user is effectively immersed in a responsive virtual world. This implies user dynamic control of viewpoint" (p. 16). In an effort to better understand what technologies are critical for VR Brooks' research devises the following as requirements:

> **Real Time**—As the user's head moves the viewpoint changes accordingly (Brooks, 1998)
>
> **Real Space**—3D environments, where they can be either concrete or abstract (Brooks, 1998)
>
> **Real Interaction**—User has the ability to manipulate objects in the environment (Brooks, 1998)
>
> **Real Immersion**—Fill the senses of the user with displays from the virtual world blocking contradictory senses from the real world (Brooks, 1999)

Virtual reality offers the ability to be immersed and interact with places, people and objects in real time where none of it is limited to the physical place where the user is actually located. This is attractive to the military, because it provides significant flexibility in the training domain. Virtual reality represents a tool that can be both efficient and economical, when it comes to training of military personnel in a variety of situations (Wilson, 2008). However, for virtual environment (VE) systems to have the best outcomes with training, a number of contributing factors, like human factors considerations and training approaches must be investigated and understood in the context of training objectives as an input to training sessions, and requested trainee performance as the most important outcome of the same training session.

B. VR IN MILITARY TRAINING

In 1962, the first system that resembled the virtual reality system, as we know it today, was created by Morton Heileg and called the Sensorama. Before the age of ubiquitous computer graphics, Heileg used 35 mm film obtained from side-by-side cameras to present video feedback to the user (Burdea & Coiffet, 2003). For immersion, Heileg had a structure that blocked the vision of the user from the real world, and also he integrated stereo sound, aromas (olfactory sensory input), installed small fans to give the sensation of wind, and a seat that vibrated. These features enabled the person to feel like they were riding a motorcycle through New York (Burdea & Coiffet, 2003).

Ivan Sutherland started working on HMDs in the mid-1960s and realized the potential application of computer-generated scenes as replacement of images taken by cameras. Sutherland gave the future VR field a vision and perspective on what an ideal system should do, in his work "Ultimate Display" (Brooks, 1999).

As HMDs advanced the military realized the scores of potential applications that these systems could support. The military viewed these systems as a potential disruption to not just live training but to traditional military simulators (Burdea & Coiffet, 2003). When describing the potential of training for one HMDs, Berbaum and Kennedy (1985) reported that "this device may offer an alternative technology to more traditional multichannel simulation displays at a fraction of the cost but with the same or better spatial resolution and detail density" (p. 2).

Technology has improved, but the goals and rationale of utilizing this technology remained largely the same. Virtual reality technology in military training is driven by a desire and need for getting access to virtualized versions of actual (physical) environments that are not accessible for different reasons. Those reasons fall under a couple of categories: the physical environment for training can be cost-prohibitive (e.g., certain location in the world, flying a mission in a jet just to learn how a button works when the aircraft is in flight), or the training events and situations are too dangerous to do in a live setting. In addition, using virtual training systems can be even more efficient than live training, with the ultimate goal of having personnel finish the training event achieving a higher readiness level, which ultimately reduces time and resources needed to achieve proficiency (U.S. Army, 2014).

It is highly likely that the use of virtual environment training will continue to grow its share of training time, at the expense of live training for certain jobs in the military. Cost-saving measures in the Department of Defense, along with the cyclic increases in the performance of hardware, makes transitions to simulation training an attractive choice that both decision makers and users.

C. IMMERSIVE VR AND TRANSFER OF TRAINING

To make the case for using immersive VR for a trainer, it is critical to understand its relationship to transfer of training. "Immersion is a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" (Witmer & Singer, 1995, p. 227). These stream of experiences include perceiving oneself as moving through the environment and interacting with other entities.

Transfer of training is "the extent of retention and application of knowledge, skills, and attitudes from the training environment to the workplace environment" (Bossard, Kermarrec, Buche, & Tisseau, 2008, p. 151). Mestre (2002) describes two types of transfer, near and far transfer. The former being the transfer of learning to using the newly understood material in a similar setting to which it is learned. The other is the application of the learned material to an unrelated setting, as well as the ability to solve novel problems. For the scope of the thesis, only near transfer will be discussed.

Transfer of knowledge and skills has a potential of occurring at a higher rate in a virtual environment than compared to paper and pencil, or equal to or higher than the real world setting (Dede, 2009). The LSO community does possess a VE trainer with the LSO Trainer 2H111, but to our knowledge a formal study focused on testing skill acquisition in that trainer has never been conducted. However, based on the positive feedback the LSO community has towards 2H111 since this device has been in use (Discussed in Chapter V), it is reasonable to assume that a good level of skill acquisition occurs with the trainer. Additionally, one way in which LSOs train is that when out to sea, they perform paper drills: practice emergency recovery drills of aircraft. Research done in the domain of VR suggests that interactive, real time virtual environments, with appropriate scenarios and effective training approaches, could be an even better tool to learn how to handle emergency aircraft situations (Eddowes & Waag, 1980; Wiekhorst & Dixon, 1987; Dalgarno & Lee, 2010). Both of these reasons provide a solid basis for a creation of an accessible immersive VE.

Large majority of VEs are presented using either a monocular or a stereoscopic visual display solutions (note: VE can even be presented to the user only using an auditory display, with no visual display). When deciding which type of visual display solution is best suited for the specific VE, it is important to consider the nature of the tasks that are to be performed. When tasks are complex and require spatial-awareness, the stereoscopic display will generally have better performance (Stanney & Mourant, 1998; Bennett, Coxon, & Mania, 2010). The LSO's tasks are a complex set of motor and non-motor tasks (which will be discussed in Chapter IV). This suggests that the best outcomes could be reached utilizing a stereoscopic system, in this case a helmet mounted display (HMD) was selected. Utilizing an HMD not only gives the benefit of getting a performance advantage over monocular systems, but an HMD provides isolation to the user (i.e., the visual component of physical world is "shut off").

The rationale for utilizing immersive VR display for the LSO trainer prototype comes from these two major areas:

> **Everything is virtualized**—There is no need for physical artifacts such as the LSO Display System or MOVLAS rig in order to operate the system and receive training.
>
> **Support for natural interaction**—Enabling the user to navigate around in the virtual environment, while doing natural head rotation, hand gestures and interaction with object depicted within the VE.

D. EVALUATION OF HUMAN PERFORMANCE

Human performance in VEs is likely to be influenced by several factors (Stanney & Mourant, 1998).

> **Task Characteristics**—certain tasks lend themselves better to VEs, while others may not be able to be effectively performed in such an environment (Stanney & Mourant, 1998). The authors suggest that it is necessary to understand a relationship between the task characteristics and characteristics of the corresponding VE that is used to support that task (e.g., pushing an actual button

in a real world system and "pushing" a virtual button in a VE for the same action to occur).

User Characteristics—Users of a human-machine interface can range from novice to expert in their expertise with the system or job itself. Additionally, users can range from novice to expert with respect to their experience level of a VE. An individual, who is an expert with a real-world system (task), but a novice in experience with VEs, may have the same performance in a VE as an individual whom is novice with the real world system (task), but who is very experienced in VEs. Differences in these levels "could affect the perceived navigational complexity of a VE and the benchmark performance of user" (Stanney & Mourant, 1998, p. 333).

VE Design Constraints Related to Human Sensory Limitations—Considerations of a VE system need to take in account different sensory systems that humans have such as visual, auditory, and haptic perceptions (Stanney & Mourant, 1998).

- **Visual Perception**—VEs should try to generate fairly accurate optical flow patterns for users, otherwise the experience will feel unnatural (Stanney & Mourant, 1998).
- **Auditory Perception**—VR research suggests that 3D audio can aid the user in localizing audio signals and distinguish separate sound sources (Stanney & Mourant, 1998).
- **Haptic Perception**—Integrating the ability for the VE to produce haptic feedback to the user, when a certain intended action is completed (e.g., pushing in a button and "feeling" the detent) has been shown to increase performance (Burdea & Coiffet, 2003; Jacko, et al., 2002).

Integration issues with multimodal interaction—A unique aspect to VE compared to other interactive technologies, is the ability to have multiple inputs and outputs presented to the user simultaneously (Stanney & Mourant, 1998). Stanney et al. continue by saying, these multimodal interactions "may be a primary factor that leads to enhanced human performance for certain tasks presented in a virtual world" (p. 338). Additionally, the authors suggest that the capability to have redundant forms of inputs could support user preferences (e.g., game controller, voice, or "touch" with a virtual hand).

Specifically Optimized Metaphors for Virtual Environment—Careful attention must be paid to how users interact in a VE with respect to metaphor selection. Stanney et al. note that traditional computer interface metaphors such as windows and toolbars may not be appropriate for human-virtual environment interaction.

Creating realistic virtual worlds through systems that leverage computer power, tracking mechanisms, and synthetic sound in the pursuit of training is fruitless if the user cannot perform efficiently inside of the VE (Stanney & Mourant, 1998). Their research describes that instead of relying solely on task outcomes, multicriteria measures such as navigational complexity, degree of sense of presence, and establishing benchmarks for performance also need to be considered in order to evaluate the performance of a user inside of a system.

In simulation based training, the importance of measuring trainee performance is well understood. The construction of such measures is a challenge, when the focus is on the performance of one individual (user), and is even more complex when the measurements need to be devised for team performance (MacMillan, Entin, Morley, & Bennett, 2013). Simulations offer the ability to capture trainees' data and analyze it both at runtime and during a post-training session, however the problem that still remains is a definition of what data is meaningful. Whether the performance measurements are for an individual or a team:

> A suboptimal approach to performance measurement not only squanders the time and other resources required to implement a performance measurement system but also may incur additional costs engendered by poor decision making and improper actions made on the basis of data derived from poor performance measurement practices (Salas, Rosen, Held, & Weissmuller, 2009, p. 329).

LSOs often talk about the importance of judgment, in the context of situations of when the LSO needs to allow a pilot to continue his or her approach to land or when to reject the attempt if it is not going to be suitable for landing. Additionally, there is a pervasiveness of "techniques" on how to accomplish the tasks. It is necessary to developed guidelines to understand these methods and define them effectively in the context of performance. Salas puts forward that simulations have the ability to *study* expertise, as well as *develop* expertise. Qualitative approaches should be used to understand the expert, however once "specific mechanisms of expert performance have been identified, these can guide the development of more quantitative techniques for capturing performance of developing experts within the same simulation" (Salas, Rosen, Held, & Weissmuller, 2009, p. 339).

E. PERCEPTION OF DISTANCE IN VR SYSTEMS

The perception of distance in a simulated environment for a user of an LSO VR training system is an important consideration given the specifics of the tasks requirements for LSOs (a further discussion on tasks analysis will occur in Chapter IV). These requirements include the need for both far and near distance perception; an example of both is the need for the LSO to be aware of the aircraft's position relative to the aircraft carrier and for pressing buttons on the LSO Display System.

When an individual is first introduced to an environment, his or her perception of distance may vary from the actual modeled distance (Allen, Siegel, & Rosinski, 1978); this is an issue irrespective of the quality of the graphics (Thompson, et al., 2004). Allen et al. show that this difference between the perceived distance and the actual distance is reduced with repeated exposure to an environment. Studies done by Allen et al. and Thompson et al. show the existence of distance compression in judgment of distance by a user who is immersed in new VE. One study of note is work done by Interrante (2006), where users were put in a virtual environment that depicted the same exact room they physically occupied in the real world. Their research indicated that distance perception in the VE was not significantly compressed. It also showed that distance compression may not be due to the technology, but inherent to the technology, and that it may be derived from "higher-level cognitive issues in the interpretation of the presented visual stimulus" (Interrante, Anderson, & Ries, 2006, p. 10).

Given the fact that there are identified issues with user's perception of both the near and far distance in VEs there are several factors that can be used to mitigate the perceived offset. The work by Kelly et al. (2014) suggests that the ability to "walk around" will dramatically improve a user's judgment for perceived distance. Additionally, it has been shown that users who are familiar with computer generated environments will behave similarly in VR as in the real world, which suggests that users, unfamiliar with a VR environment of a proposed system would get better at estimating distance over time (Popp, Platzer, Eichner, & Schade, 2004).

F. CYBER SICKNESS

When a user experience VEs there exists the possibility that he (she) will exhibit symptoms analogous to those seen in motion sickness both during and after the experience (LaVoila, 2000). However, LaVoila notes that cybersickness is "distinct from motion sickness in that the user is often stationary but has a compelling sense of self motion through moving visual imagery" (p. 47). The symptoms range from headache to emetic response (vomiting), and they are commonly understood as a threat to usability of VR systems as well as for general user acceptance of those systems.

Some factors that have been associated with cybersickness are vection, lag, and field of view. Vection "is the illusion of self-movement within a VE" (Stanney & Mourant, 1998, p. 341); "visual and vestibular sources of information specifying dynamic orientation are in conflict to the extent that the optical flow pattern viewed by the [user] creates a compelling illusion of self-motion, which is not corroborated by the inertial forces" (Hettinger, Berbaum, Kennedy, Dunlap, & Nolan, 1990). For the VE used in our prototype, the user will have an egocentric point of view. Additionally, a careful consideration must be paid to reduce causes of cybersickness like inputs to the HMD that the user could interpret as self-movement (LaVoila, 2000). Additionally, free navigation throughout the environment must be given thoughtful attention.

In the context of cybersickness, a lag is understood as latency between the moment when the user repositions his/her head and the time that the new view of the scene that corresponds to that head movement is presented to the user on the visual display system. Navy simulators with the longest delays have had the highest rates of sickness (Stanney & Mourant, 1998). However, it is also noted that users can adapt to lag rapidly as long as the lag is constant and not variable.

Field of view, whether wide or narrow, has been suggested to lead to motion sickness, but there have been conflicting results (Stanney & Mourant, 1998). An aspect that may lead to more positive results by reducing cybersickness is having the internal camera FOV match the user's display FOV (de Vries, Bos, van Emmerik, & Groen, 2007).

User adaptation may reduce some effects of cybersickness over time, however this should not be the only mitigation one would rely on in implementing a new system. Prescreening and coping methods along with a design of syllabi that are congruent with short sessions inside the VE, represent examples of techniques that should be tested and possibly applied in training sessions. In addition, tasks that require “high rates of linear or rotational acceleration should be gradually worked into the simulation so as to not shock the user’s vestibular and visual system” (LaVoila, 2000, p. 54).

G. CHAPTER SUMMARY

Creating an interface that will support interaction of an immersed individual should be done with great care. It is necessary to be fully aware of all issues briefly discussed in this chapter, as well as the larger domain of human factors in VR; that approach will help reach the goal of achieving a fine-tuned training solution. It is commonly understood that the elements of the computer-based system, presentation of VE (including human factors in VE), and training approaches are the most significant elements one should focus on to maximize skill gain and minimize user discomfort.

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IV. TASK ANALYSIS

A. INTRODUCTION

In order to create a feasible environment for training of LSOs, it is necessary to understand the work that each of the individual positions on the LSO team does. For this prototype system, the three most important positions on the LSO team have been identified, and were supported in the system: (Controlling LSO, Backup LSO, and Deck Caller LSO). There are two more minor roles that are not as critical and are in support to the Controlling LSO (Book Keeper LSO, also known as the “Writer” [transcribes the aircraft passes] and Timing LSO [Measures time for certain aircraft events]). A thorough search was made to find past task analysis done for all of the LSO positions but we were not able to find one. The only task analysis done for the LSO position was when the LSO role did not consist of a team of LSOs the way it is constructed today (Borden, 1969).

Task analysis is the “study of what an operator (or team of operators) is required to do, in terms of actions and/or cognitive process, to achieve a system goal” (Kirwan & Ainsworth, 2003, p. 1). Kirwan further says that understanding these processes helps with decisions on how to instruct staff and ensure efficiency. For the full spectrum of task analysis, it is a six factor process:

> **Division of function**. Their research defines this as the interaction between personnel and machines, and defining what the operator involvement is with respect to the control of the system. The majority of the tasks described in this chapter fall in this portion, with respect to the operator’s interaction with the equipment.
>
> **Personnel Specification**. This component defines the skills of the personnel to carry out the tasks effectively (Kirwan & Ainsworth, 2003). This area is out of the scope of this thesis, however it worth mentioning that there is a rough specification of those skills for an LSO candidate, as defined by the LSO NATOPS. The individual must be a naval aviator, have enough time remaining in his operational tour to achieve a wing qualification, and, in addition to that, the “consideration should be given to motivation, aviation ability, and potential as an instructor” (Naval Air Systems Command, 2013, p. 2–1).
>
> **Tasks and Interface Design.** Kirwan’s research describes this as the portion of the process needed to understand what the user needs to perform the job, and the

way the necessary information is to be conveyed to him/her. This portion is also out the scope of this thesis.

Organization of Staff and Jobs. "Defining the number of staff required, the organization of team members, communications requirements, and the allocation of responsibility" (Kirwan & Ainsworth, 2003, p. 3). This thesis will discuss the current roles, communications, and responsibilities, but will not define the number of staff required, just what the current practice is.

Skills and Knowledge Acquisition. The area defines the "training and procedures design" (Kirwan & Ainsworth, 2003, p. 3). Training was previously discussed in Chapter II; design of the procedures is out of scope of this thesis.

Performance Assurance. "Assessment of performance predictively via human reliability assessment, retrospectively via incident investigation or analysis or concurrently via problem investigations" (Kirwan & Ainsworth, 2003, p. 3). The paper will discuss human reliability assessment, but the other two issues are out of scope of this thesis.

For the tasks covered in this chapter, the details of task analysis were constructed utilizing information from the LSO NATOPS Manual (2013). Additional tasks or changes were made using the author's current working knowledge; they were all discussed with and vetted by the LSO School for validity. Case I recovery will be assumed (<u>Case III differences will be underlined</u>).

B. CONTROLLING LSO

The Controlling LSO is responsible for controlling aircraft within the 180 degree position during case I and II approaches, and within 1-mile during case III approaches (Naval Air Systems Command, 2013). Additionally, NATOPS says that the primary focus of this position is monitoring the aircraft's glide slope and ramp clearance. This is the only position that an LSO can practice outside of aircraft recovery operations on the aircraft carrier (apart from some equipment checks and waveoff window monitoring) such as during Field Carrier Landing Practice (FCLP) and in the 2H111 simulator.

1. Equipment Checks

A. Check the alignment of the platform camera (Naval Air Systems Command, 2013)

B. Confirm the operation of the radio handset (Naval Air Systems Command, 2013)

i. Give a radio check on the Tower's frequency

ii. Give a radio check on CATCC (Carrier Air Traffic Control Center) frequencies Alpha and Bravo

C. Confirm the operation of the cut light switch\IFLOS cut lights

D. Confirm the operation of the wave off switch\IFLOS wave off lights

E. Adjust the IFLOS lighting to be adequate for the recovery (Naval Air Systems Command, 2013)

2. Aircraft Control

A. Monitor aircraft's approach from the 180 to the Start position (Naval Air Systems Command, 2013)

B. If needed provide a radio call to get the aircraft an acceptable position on the approach

C. Provide a 1–2 second actuation of the cut lights to tell the pilot that he/she should have the source visible on the IFLOS. Provide a "Roger Ball" with any additional remarks after pilot provides the "Ball Call"

D. Monitor aircraft's approach from the Start to the completion. For the Controlling LSO position this will normally be considering the aircraft's glideslope (Naval Air Systems Command, 2013)

i. Provide "Informative" calls if needed from the Start to the Middle position (Naval Air Systems Command, 2013)

ii. Provide "Imperative" calls when needed (Naval Air Systems Command, 2013)

E. Monitor aircraft until aircraft completely stops because of an arrestment or when the aircraft establishes a positive rate of climb on a wave off

F. Waveoff aircraft if:

i. Aircraft is in an unsafe position to land (Naval Air Systems Command, 2013)

ii. A clear deck has not been established and the aircraft enters the 100' or 10' wave off window (Naval Air Systems Command, 2013)

3. Grading and Describing Approach

A. Provide the LSO who is recording the passes (Writing LSO) with a reconstruction of the approach in LSO terminology

B. Provide any additional comments to be used in the debrief of the pass

C. Provide a grade for the pass

4. Interactions with Other Team Members

A. Keep right hand in the air, acknowledging the status of the deck as foul

B. Lower right hand when the status of the deck is declared clear

C. Listen to Deck Caller to know what wave off window to adhere to as well as listen to the Backup LSO for aircraft type, correct aircraft configuration, weight setting, lens setting, and deck status.

D. Communicate aircraft pass information to writer

5. Monitor equipment for information pertinent to the next approach

C. BACKUP LSO

In general, the Backup LSO will back up the Controlling LSO with his/her responsibilities, and he or she will have additional independent tasks. Because of the resultant increased workload, the Backup LSO will have more experience. There is no ability to practice this position during FCLP, so the only opportunity to experience this position is during actual aircraft recovery operations on the aircraft carrier or in the 2H111 simulator.

1. Equipment Checks

A. Perform Equipment Checks as described in Controlling LSO's tasks B.1.

B. Adjust LSO Display System (LSODS) screens if needed

2. Aircraft Control

A. Radio Frequency Selection: Tower frequency or UHF Channel A/B

B. Confirm correct aircraft type and aircraft configuration (Naval Air Systems Command, 2013)

C. Confirm weight and lens settings on the LSODS as well as deck status (Naval Air Systems Command, 2013)

D. Monitor the wind on the LSODS and deck motion and that it stays within an acceptable envelope (Naval Air Systems Command, 2013)

E. Monitor aircraft's approach from the Start to the completion. The Backup LSO will normally be concerned with the aircraft's lineup, but will provide glideslope calls as required (Naval Air Systems Command, 2013)

i. Provide “Informative” calls if needed from the Start to the Middle position (Naval Air Systems Command, 2013)
ii. Provide “Imperative” calls when needed (Naval Air Systems Command, 2013)

F. After the LSO determine the aircraft will clear the ramp, keep the scan solely on the LSO Display System for the remainder of the pass until the aircraft passes the centerline camera

G. Monitor aircraft until aircraft completely stops because of an arrestment or when the aircraft establishes a positive rate of climb on a wave off

H. Waveoff aircraft if:

i. Aircraft is in an unsafe position to land (Naval Air Systems Command, 2013)
ii. A clear deck has not been established and the aircraft enters the 100’ or 10’ wave off window (Naval Air Systems Command, 2013)

3. Comments to the Approach

Supply supplemental calls to the Writing LSO to incorporate into the pass. These will typically take form of converting the Controller’s originally called pass and incorporating lineup deviations.

4. Interactions with Other Team Members

A. Keep right hand in the air, acknowledging the status of the deck as foul

B. Lower right hand when the status of the deck is declared clear

C. Parrot gear, hook, and aircraft status for upcoming pass from the enlisted hook-spotter

D. Parrot lens and weight settings from enlisted phone talker

E. Communicate aircraft pass information to writer

D. “DECK CALLER” LSO

The Deck Caller is a position that is recommended by the LSO NATOPS. In practice, unless there are extenuating circumstances, one such LSO will always be present. This will be one of the first positions an inexperienced LSO will learn. It is important to note that the Deck Caller position is one LSOs do not have ability to practice during FCLPs. According to the LSO NATOPS Manual the following are responsibilities for the Deck Caller:

- “Stand in a position visually in front of the controlling LSOs with an unobstructed view of the angle deck and signal if men or equipment are in the landing area” (Naval Air Systems Command, 2013, p. 6–10).
- “Signal an obstruction in the landing area (LA) by raising his hand over his head” (Naval Air Systems Command, 2013, p. 6–10).
- “When all obstructions are clear of the LA, he lowers his hand and moves behind the controlling and backup LSOs, where he continues to monitor deck status for the remainder of the pass” (Naval Air Systems Command, 2013, p. 6–10).

From the responsibilities outlined in the LSO NATOPS, along with the author’s previous experience and validation from the LSO School, the following tasks were identified:

1. Monitoring of the Flight Deck

A. Monitor Flight Deck Personnel for arm signals (wand signals at night) of the Landing Area being clear or subsequent foul deck indications

B. Stand in a position visually in front of the Controlling LSOs with an unobstructed view of the angle deck and signal if personnel or equipment are in the landing area (Naval Air Systems Command, 2013)

C. Signal an obstruction in the landing area (LA) by raising their hand over their head (Naval Air Systems Command, 2013)

D. When all obstructions are clear of the LA, the deck caller will lower his or her hand and move behind the Controlling and Backup LSOs, where he or she will continue to monitor deck status for the remainder of the pass. (Naval Air Systems Command, 2013)

E. Monitor Deck Status lights for changes to the flight deck

F. Monitor port foul line for personnel or objects fouling the deck

G. Monitor aircraft canopy positions on the flight deck for possible obstructions to the IFLOLS for incoming aircraft

3.

2. Interactions with Other Team Members

A. When the deck is foul and an aircraft is within the 180 position during case I/II (within 2 miles case III), stand visually in front of the Primary LSO.

B. Yell the current wave off window, either 100’ or 10’

C. 100’—When there is an obstruction in the Landing Area or the IFLOLS is not configured correctly for the approaching aircraft (Naval Air Systems Command, 2013)

D. 10’—When there is no obstruction but the deck is not ready to accept the aircraft. (Naval Air Systems Command, 2013)

E. Alert the Controlling LSO of any change in deck status (e.g., going from a clear deck to a foul deck), if he/she is unaware

E. CHAPTER SUMMARY

The LSO task has grown from the responsibility of one person to an entire team. The three roles that were presented in this chapter, Controlling LSO, Backup LSO, and Deck Caller LSO are imperative to be supported if a simulator is expected to be operational viable for the LSO community. As technology has advanced in the past 100 years, the LSO role has matured. With upcoming technology such as unmanned aerial vehicles and further reliance on automated systems in controlling manned systems, the LSO’s role can be expected to evolve as well.

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V. USER STUDY: SURVEY OF CURRENT STATE OF LSO DOMAIN

A. INTRODUCTION

The design and development of a light-weight VR simulator for LSOs started by acquiring comprehensive information about current training in this domain. One of those necessary data sets concerned an accurate understanding of the current state of training practices and LSOs' perception of different elements of training with the 2H111 simulator. This was accomplished by conducting a survey that captured an array of subjective and objective information from this community. This survey served as guidance for the development of the prototype system; the comments and recommendations of LSOs to include the features they deemed necessary in a new training system were considered when the new prototype training system was designed.

B. METHODOLOGY

The questions in the survey addressed the items and issues that were believed to be important to training of LSOs. Prior to its distribution, the survey was submitted to the Institutional Review Board (IRB) for their review; this committee determined that survey did not aim to collect personal identifying information about individuals and as such it did not require IRB approval. Distribution of the survey questions to the LSOs was accomplished by using a form of web survey; an in-person format of the survey was not feasible as LSOs were dispersed throughout the country. In order to ensure that only LSOs would take part in this survey, the web link was distributed directly by email to qualified LSOs through the LSO School. All participants were active duty LSOs; they ranged in experience levels from newly appointed LSOs to experts in this field.

C. SUBJECTS

The LSOs experience directly translates into levels of qualification. The typical hierarchy of qualification includes following levels (note: Field and Squadron qualification can occur in the reverse order depending on the squadron's deployment cycles):

1. **No qualification**—This is the entry position for a newly appointed LSO into a fixed-wing aircraft carrier squadron; a selection of an individual into this level is recommended by the squadron's commanding officer and ultimately signed off by the aircraft type command (Naval Air Systems Command, 2013). All training for an individual without any qualification will come in a form of "on the job" training.

2. **Field LSO**—This qualification represents the ability of the LSO to wave the same airframe (i.e., the same aircraft model) that he or she is qualified to land on the carrier ("carrier qualified") during FCLPs and during necessary emergency recoveries at home. At this point in the LSO's career, he or she can "maintain and interpret LSO records of FCLP periods conducted for the purpose of making recommendations to the commanding officer regarding pilot readiness for CV landings" (Naval Air Systems Command, 2013, p. 1–5).

3. **Squadron LSO**—This qualification represents the ability of the LSO to wave the same airframe that he or she is carrier qualified in aboard the ship in both day and night conditions and operate the MOVLAS in day conditions. LSOs will need to have completed the Initial Formal Ground Training (IFGT) before they will be able to receive this designation (Naval Air Systems Command, 2013).

4. **Wing LSO**—This qualification represents capacity of the LSO to wave all fixed-wing aircraft models that are attached to the air wing during "FCLP and aboard ship in all conditions and operate the MOVLAS in both day and night conditions" (Naval Air Systems Command, 2013, p. 1–5).

5. **Training LSO**—"This qualification reflects the individual's ability to control all pilots, including student and replacement pilots, in the specific model aircraft the LSO is carrier qualified in, both during FCLP and aboard ship" (Naval Air Systems Command, 2013, p. 1–5).

6. **Staff LSO**—"This qualification reflects the individual's ability to control all aviators in all aircraft during FCLP and aboard ship under all operating conditions. Further, it reflects attainment of the highest level of qualification and experience gained as a result of performance in subordinate categories" (Naval Air Systems Command, 2013, p. 1–5).

The data set presented in Table 1 reflects the diversity of the participants who took the survey:

Table 1. Diversity of LSO Participants in Study

Staff LSO	6
Training LSO	4
Wing LSO	6
Squadron LSO	7
Field LSO	9
No Qualification	3
Total	35

Participants were asked if they have attended IFGT; if they selected that they had not attended the school yet, the online survey did not present them the questions related to 2H111 Trainer (six individuals—one Squadron LSO, two Field LSOs, and three No Qualification LSOs had not yet attended IFGT). A full survey form and responses collected from the participants can be found in Appendix C. Survey.

As shown in Table 2, almost all LSOs had experience in the position of Controlling LSO as well as other positions that require less experience to perform (Deck Calling LSO, Book Writing LSO, and Timing LSO). Roughly half of the participants had experienced the Backup position before attending IFGT.

Table 2. Position Experience on the Platform that the LSOs Had Prior to Attending IFGT

Position	Yes	No	Did Not Respond	Not able to Answer	Total	Percentage of LSOs who experienced position prior to LSO School IFGT.
Backup LSO	16	13	0	6	35	55%
Controlling LSO	28	1	0	6	35	97%
Deck Calling LSO	29	0	0	6	35	100%
Book Writing LSO	29	0	0	6	35	100%
Timing LSO	29	0	0	6	35	100%

D. RESULTS

To get an added perspective and better foundation for what functionality should be integrated in the prototype trainer, it was necessary to identify what skills the LSO community felt were the most difficult to acquire and retain for an LSO. Any training prototype would need to consider supporting these elements if found feasible and justifiable in the larger context of LSO training.

Further, we wanted to better understand the unique benefits of the 2H111 with regards to the training of LSOs and, as a result, incorporate its most prominent and much needed features into a light-weight prototype when its technical characteristics could support it. Parallel to this, we also sought to identify currently perceived drawbacks of 2H111, with a goal to avoid inheriting the same problems if they were avoidable.

1. LSO Skill Sets That Are Difficult to Acquire and Most Perishable

One of the understandings collected in the survey concerned the skills that the LSO community judged are important to them. The analysis of Figure 6 and Figure 7 suggests that one skill that does not appear on both lists is the leadership. This could mean that the LSOs consider leadership to be the skill that once they possesses it they do not need additional training to support it; in their view all other skills need to be reinforced to some degree. Most significantly, 30 of the 35 LSOs found procedure knowledge to be a highly perishable skill. "Eye Calibration" appears to be hard to learn and highly perishable according to the surveyed LSOs.

Figure 6. Concepts Identified by LSO Community as "Most Difficult to Acquire"

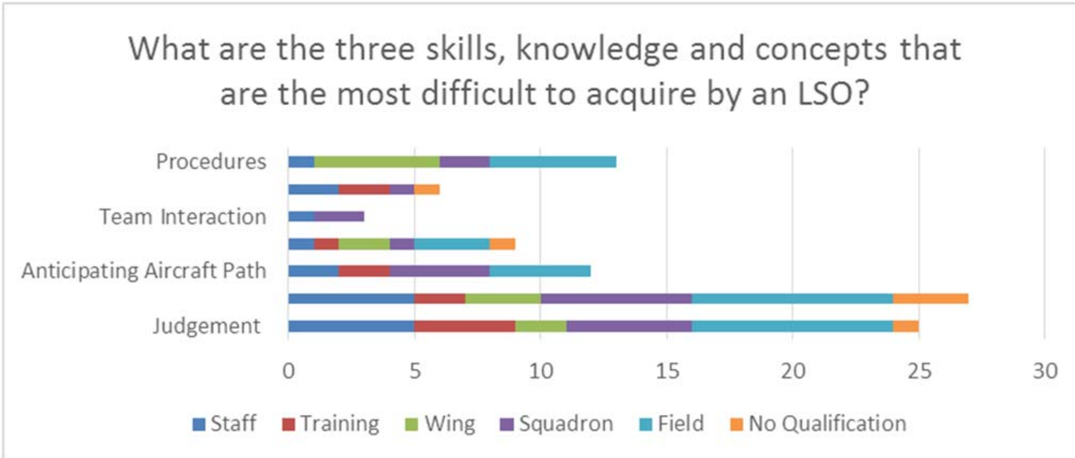
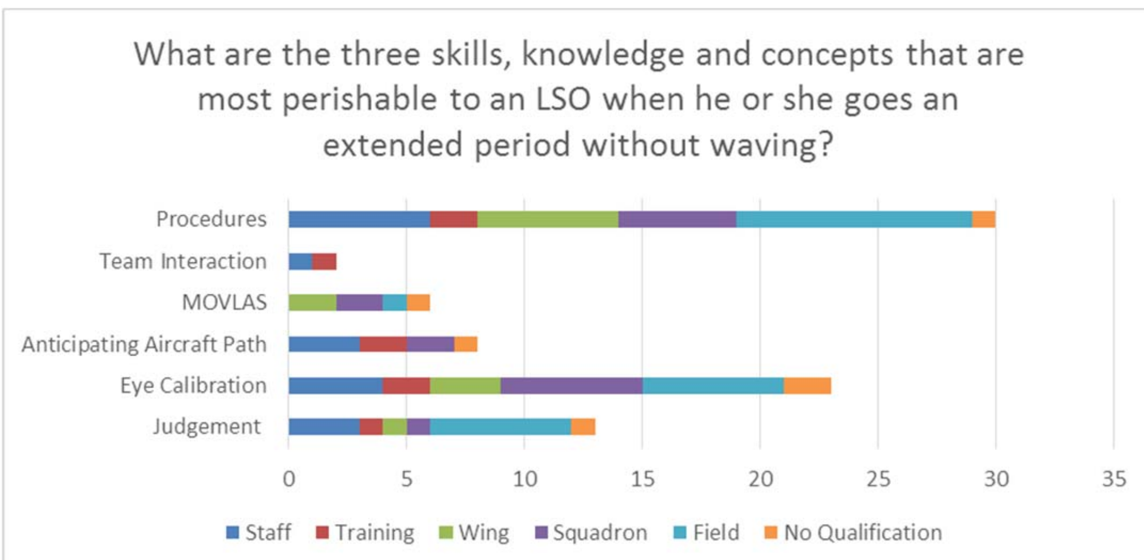


Figure 7. Concepts Identified by LSOs as "Most Perishable"

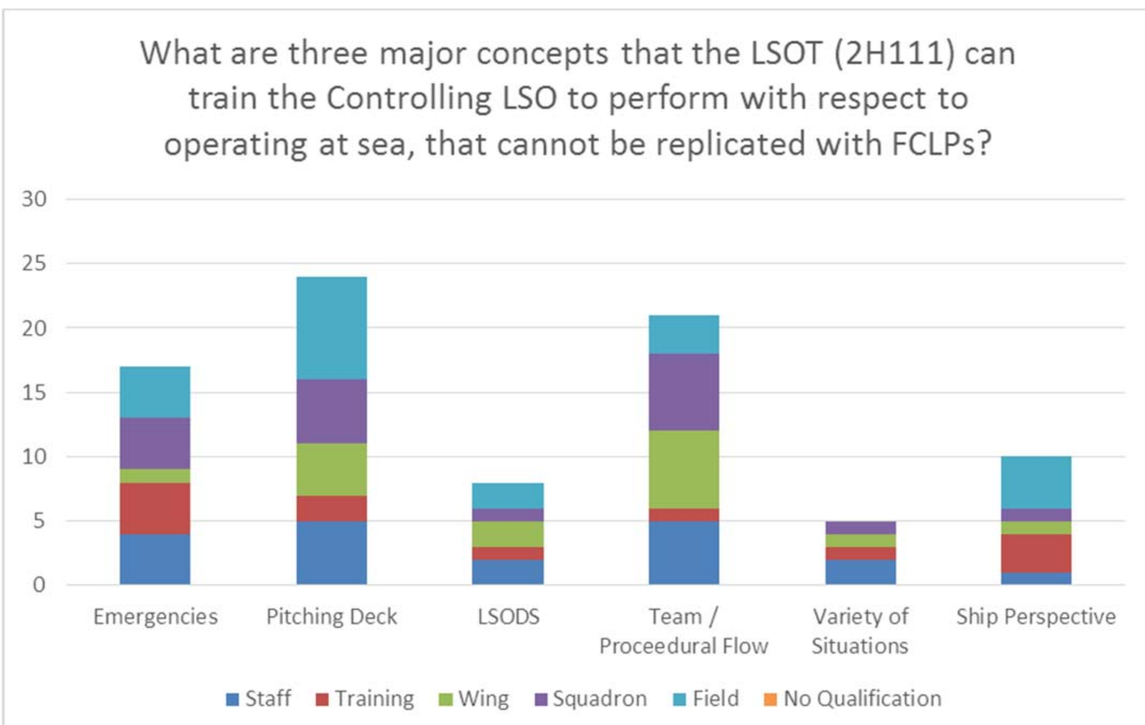


2. Strengths of LSOT 2H111

Obtaining an understanding of the LSO's perceived positive values of the 2H111 system provided features that should be incorporated into the prototype to demonstrate feasibility. For this it was important to look at each of the three positions that ideally would be supported by the prototype (Controlling, Backup, and Deck Calling LSO), as well as the system as a whole.

The first question the survey asked for the LSOs to identify the concepts the LSOT 2H111 was suitable for in training an individual at the Controlling LSO position, but that FCLPs could not (Figure 8). The remaining two questions presented in Figure 9 and Figure 10, asked the LSOs to name tasks that the 2H111 would be appropriate to train individuals for the Backup and Deck Calling LSO positions, respectively. Scan/LSODS and team interaction/procedural flow on the aircraft carrier were the two responses that were consistently noted for the Controlling, Backup, and Deck Calling LSO roles. For Scan/LSODS, this conveys the responsibility of knowing “what” to look for with those positions. The team interaction/procedural flow and visual recognition of the wave off window is training the LSO to know “when” something is supposed to occur.

Figure 8. Concepts that LSOT 2H111 Can Train a Controlling LSO to Perform that FCLPs Cannot



The Controlling LSO position is the only overlapping position an LSO could experience on land (FCLP) and sea (2H111 trainer).

Figure 9. Concepts that LSOT 2H111 Can Train a Backup LSO to Perform

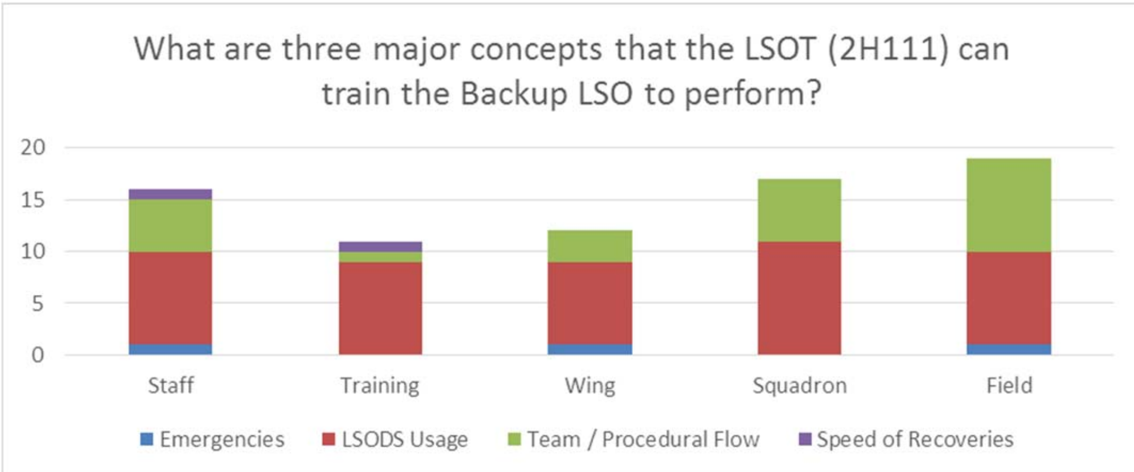
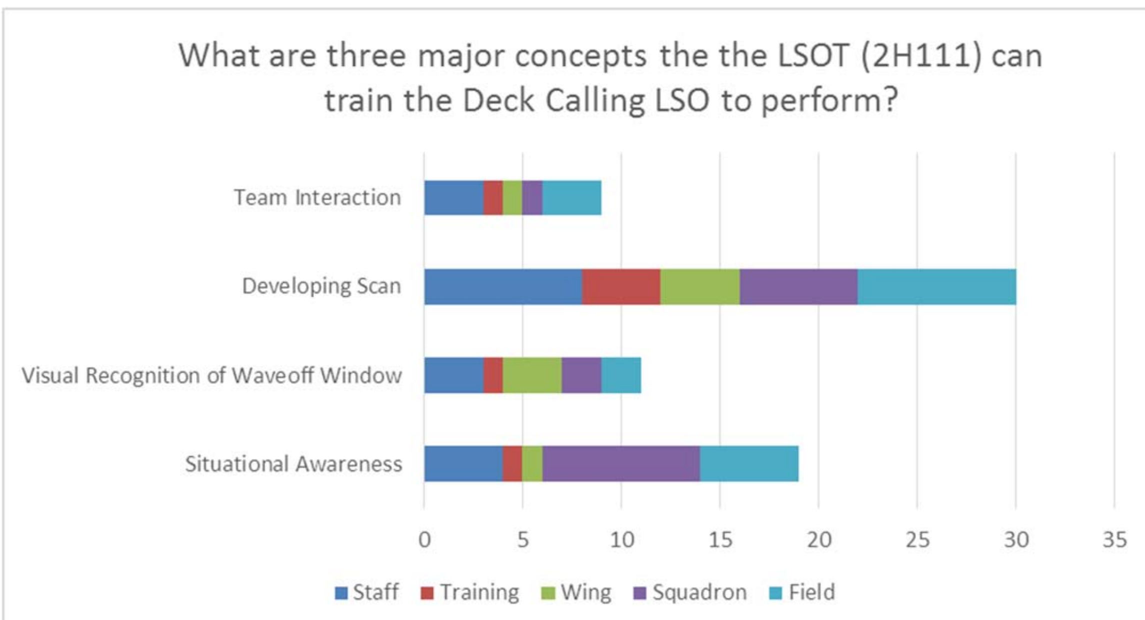


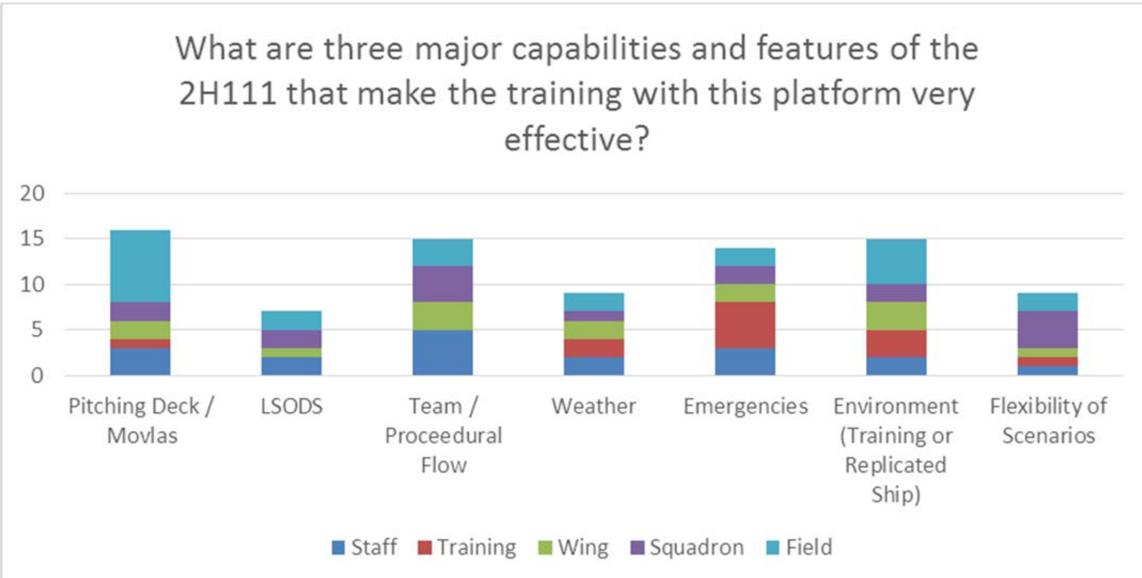
Figure 10. Concepts that LSOT 2H111 Can Train a Deck Calling LSO to Perform



* Of note, when squadrons practice the pattern during FCLPs there is no capability to train for tasks that the Backup LSO or Deck Calling LSO would perform at sea.

Figure 11 looks at the 2H111's features that have broad support among the different qualification groups of LSOs. Interesting points that can be observed from the data are that half of the responses for "Pitching Deck/MOVLAS" came the LSOs who are only Field qualified. These would be LSOs with the least amount of experience operating the device. Three of four Training LSOs mentioned emergencies (two of the three mentioned it on two separate responses—one for "regular" emergencies and the other for "barricade recovery" emergencies).

Figure 11. Major Capabilities and Features of 2H111 that Make It an Effective Training System

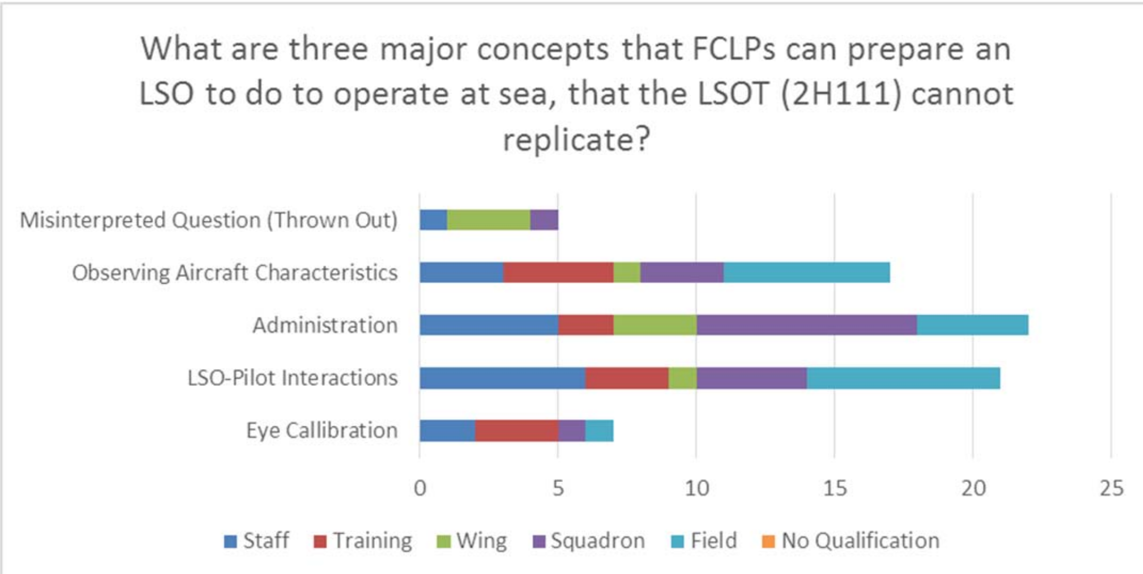


3. Drawbacks of LSOT 2H111

Conversely, it is also important to understand the perceived negative aspects of the 2H111. This would help guide what *not* to implement in the prototype if a feature was viewed as negative (and if it was possible), and alternatively *to* implement if it was a feature the 2H111 lacked but could be incorporated.

When posing the opposite question and inquiring what were the benefits of FCLPs over the 2H111 (Figure 12), the analysis shows that a couple of the items that stood out could be readily realized in software, however there were also some which would be a little more difficult to implement. Since the question took free-text answers, four broad categories were created (Observing aircraft responses, Administration, LSO-Pilot Interactions, and Eye Calibration) by abstracting the responses. These will be detailed in the text that follows, noting either a straight forward implementation or difficult one.

Figure 12. Concepts that FCLPs Can Train an LSO that LSOT 2H111 Cannot



* Five responses were "thrown out" because the responses were clearly a benefit of 2H111 vs FCLP (e.g., "pitching deck" and "barricade utilization")

The *Administration* component was broken down into two sub-sets: (1) a set that included situational awareness (SA) or pattern management (e.g., aircraft spacing, fuel states, and knowing the trends of pilots), and (2) administration of issues "on the ground," that help derive pilots' trends and debriefing pilots on their passes. All of these features could feasibly be supported in a simulation.

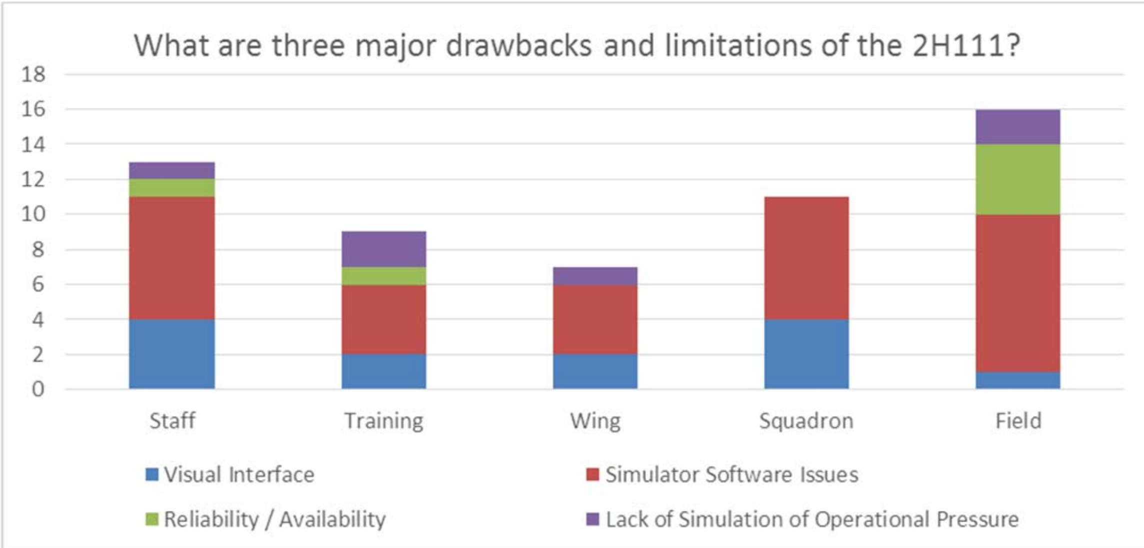
Observing aircraft characteristics component was broken down into engine sound and aircraft performance. The LSOT 2H111 uses several audio segments of engine sounds per airframe (broken down into where the aircraft is spatially in the pattern, such as the "45," or the "Start"). The frequency of engine sound is then modified to demonstrate the "spool" of an engine. The collected data set suggests that the LSO community does not consider the current sound model to be a good representation of the aircraft's true sound and that they demand something with more fidelity and realism. Developing a model of the actual aircraft behavior and performance is technically possible, however that model would need to be verified and validated. Even with a perfect model an LSO might still view a specific pass of an aircraft as unrealistic. In our experience, even some actual passes by aircraft at the aircraft carrier might be characterized as "unrealistic" if they were replicated in the LSOT or any other simulation.

The *LSO-Pilot interactions* include the dynamics of human-human interactions that exist between the two very different positions. Landing an aircraft on a boat, in the middle of the ocean, can be stressful. Just before an aircraft is ready to land on the boat during the case III pattern, the pilot will give a voice call reporting identification, how much fuel they have, and any emergency the pilot may have; this is known as the "ball call." This call does two things for the LSO: it makes them aware of the straight (raw) verbal information transmitted by the pilot, and it also allows the LSO an indication of the state of mind of the pilot. LSOs have a vital role in being able to relax and reassure the pilots in the carrier environment. Being that the main means of communication with the pilots are the LSOs voices, the LSOs are very conscious of the way they speak over the UHF radio.

For the final group, *Eye Calibration* has to do with determining the aircraft's position as it relates to the ideal glideslope angle. At the start of FCLPs, it is not uncommon for an LSO to ask a pilot to give a running verbal commentary over UHF on where the pilot sees the "ball" location on the IFLOLS lens (e.g., "two balls high," "on [glideslope]," "one ball low") to recalibrate the LSOs perception of glideslope. Further study would need to be conducted to examine if and why the visual representation of an aircraft's position on the 2H111's screen is identified as a drawback compared to FCLPs.

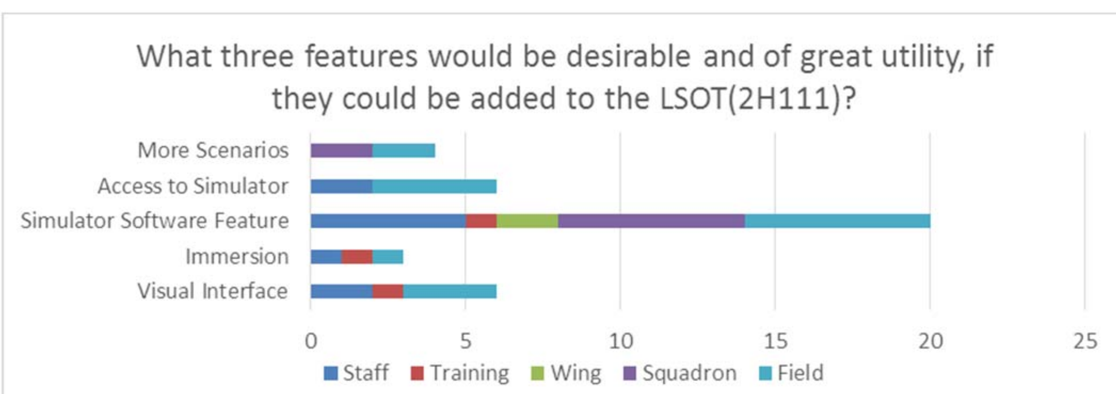
LSOs were asked directly about the drawbacks and limitations of the 2H111 (Figure 13 illustrates the responses to that question). In the group "simulator software issues," 14 of 30 of the responses had commented that the sound is unrealistic, that the aircraft does not respond as one would expect a real aircraft to, or that the pilot's reactions were not what would be expected in reality (both issues were also identified and presented in Figure 12). It is worth noting that of the Field Qualified LSOs and those with the most recent experience in the 2H111 through IFGT, one-quarter of their responses were directed towards either the availability of the trainer or its overall reliability.

Figure 13. Drawbacks and Limitations of 2H111



Another way to identify current limitations of the 2H111 was to ask LSOs about the features they consider desirable and of great utility that they would like to see added to the 2H111 (Figure 14). The responses that fell into the category of *Visual Interface*, referred to improving in the current projector-based visual system. As that was the case with responses illustrated in Figure 13 with *Reliability/Availability*, Field Qualified LSOs suggested that they would like to have greater *Access to* [*the*] *Simulator*. The *Simulator Software Feature* category of responses included the concepts like better graphics and more realistic pilot's response.

Figure 14. Features Perceived to be Desirable to Add to the 2H111



4. LSOs Desire for Additional Training

Another way to view the perceived value of the 2H111 system, as well as identify whether a gap in training exists with the LSO community, was to ask about their desire to attend the school again during each workup cycle as well as an accessible way to practice MOVLAS.

The data presented in Table 3 suggests that the LSOs showed an overwhelming support for refresher training as part of the workup cycle for both individual and team training.

Table 3. LSOs Desire to Have Timely Visits to LSO School for their Refresher Training

If money and time were taken out as limitations, would it be beneficial for an LSO to attend LSO School for a refresher as part of his/her workup cycle to practice ...	**Yes**	**No**
...individual positions?	**93%**	**7%**
...as a **wave team?**	96%	4%

Figure 15 indicates a desire to attend LSO School both to gain additional training and for the interaction with the 2H111 itself. As previously mentioned in Chapter I, the Initial Formal Ground Training (IFGT) at the LSO School has both academic and practical components. In retrospect, the question of "how valuable would it be to attend the LSO School as part of a work up cycle if the LSOT 2H111 would not be available," could also be asked, to isolate the practical component (training with 2H111) provided by the school from its academic component.

Figure 15. Value of Experience with 2H111 at LSO School

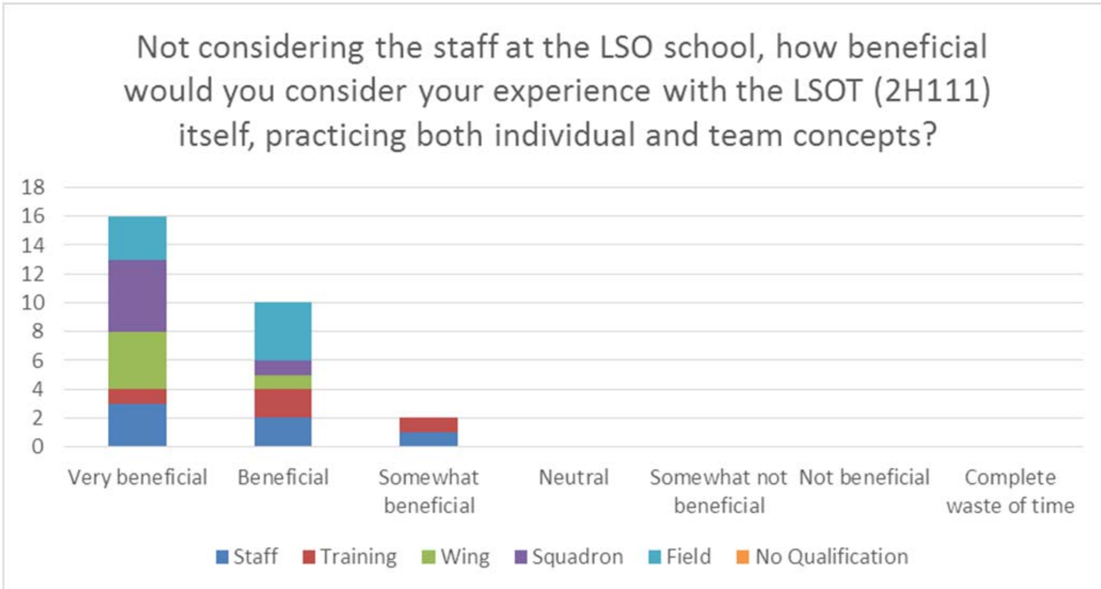
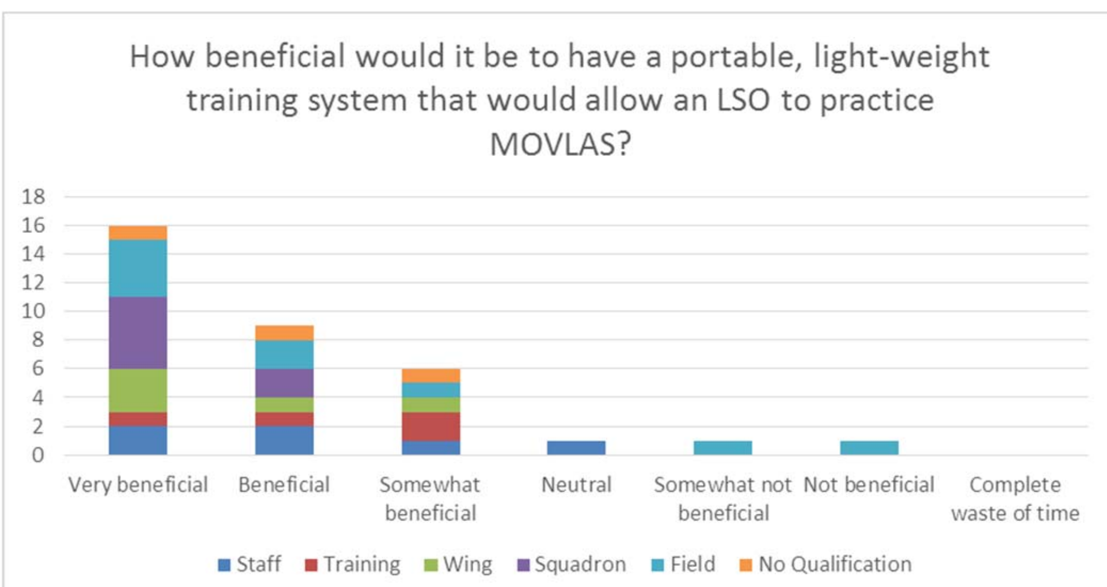


Figure 16 shows that the LSOs would look favorably on having access to a portable trainer to practice MOVLAS. An additionally question that could have been asked was about the capability to practice manipulating LSODS, based on the results of LSODS training being mentioned favorably in Figure 11.

Figure 16. LSOs Opinion on Having a Portable, Light-Weight Training System to Practice MOVLAS

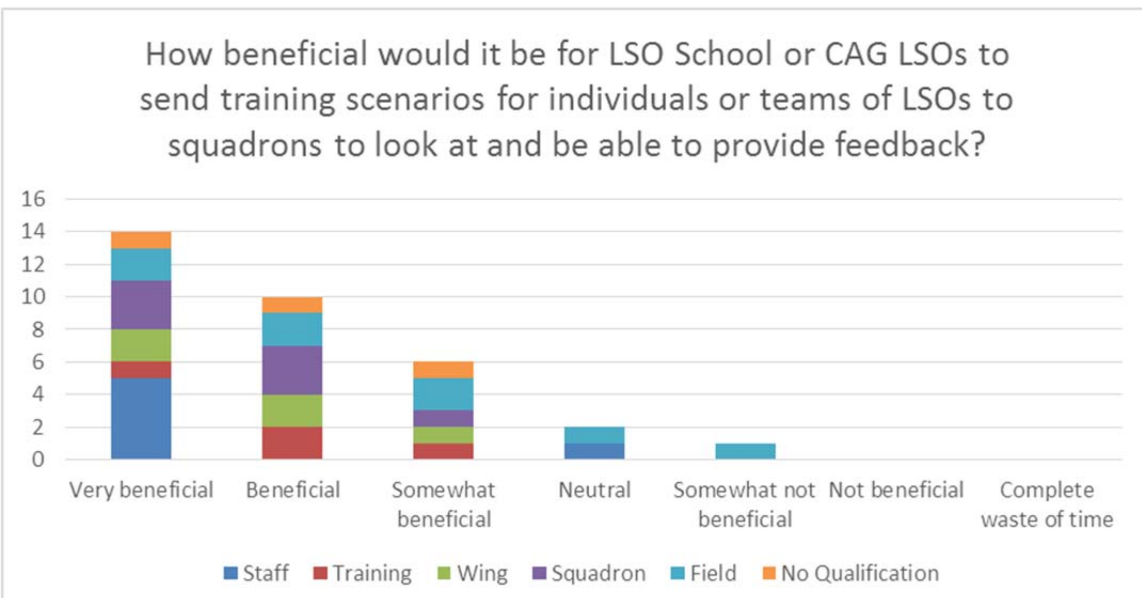


5. LSOs Opinions of Future Training System Capabilities

Survey questions also included questions to allow us insight into LSOs' perceptions of the value of potential future training capabilities; those pointers were seen as very valuable in our effort to develop the prototype of new training system.

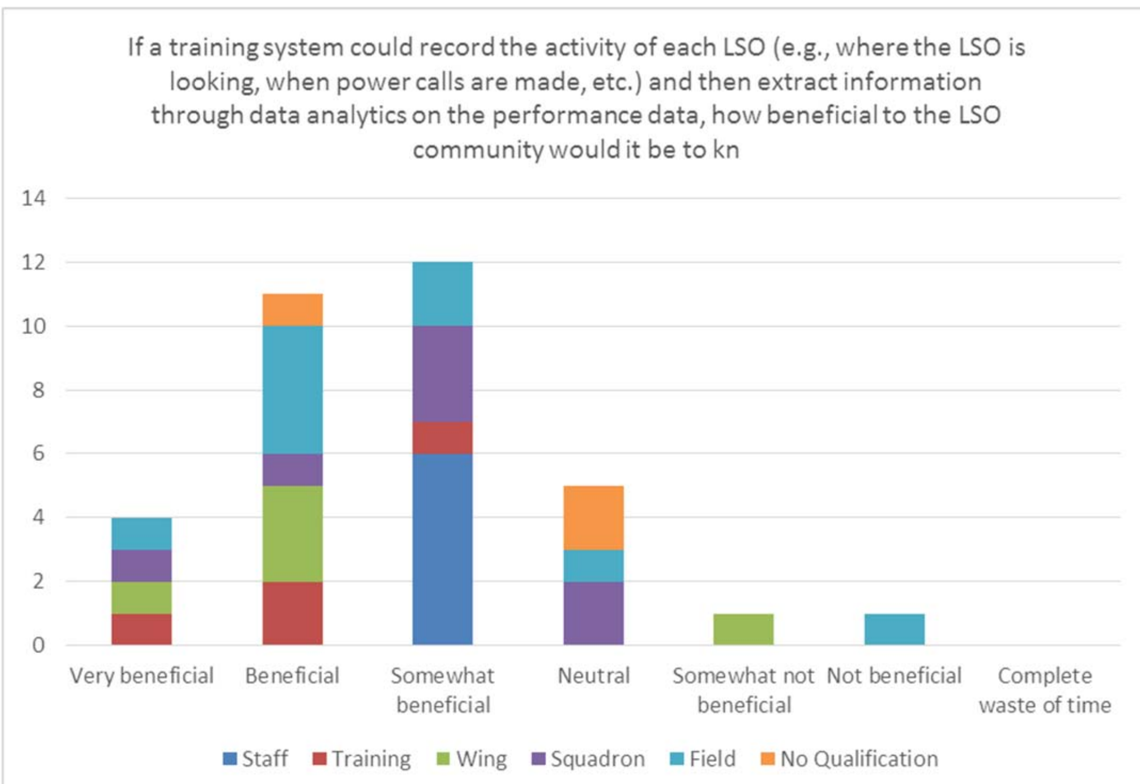
The idea of sending out training scenarios from the LSO School or CAG LSOs to squadrons was looked on very favorably by the LSO community (Figure 17). This idea did not have time to be developed and integrated into the prototype LSO trainer. The conceived method of accomplishing this would not be for the LSO School to send out full files containing the passes for the squadron LSO to then load in the simulation, but rather, just sending out an "activation code" (or a string of alphanumeric characters) that the simulation would parse into usable passes. This type of scenario exchange would allow a squadron LSOs a simple method to access the material, study it, and then send feedback to the LSO School.

Figure 17. LSOs Opinion on the Capability to Trade Training Scenarios



LSOs who participated in the survey were not as supportive of the possibility of using data analytics (Figure 18) in the function of training as they were about the idea of sharing scenarios and getting feedback from squadrons (Figure 17). Feedback from a trainee could be either verbal (e.g., comments reported by the trainee), nonverbal (gestures), or data captured by the system, such as: LSODS screen selection, information on what object(s) the LSO is looking at during particular portions of his or her scan, and specifically when voice calls were made. All of these could be valuable information to the LSO community that needs to get an insight into LSOs' performance. Such a system would have the ability to record and store verbal, navigation, and object selection easily, but other data capture such as with gestures would be more difficult. Once captured, while this data could all be easily stored, the analysis of some types of data however is not as straightforward.

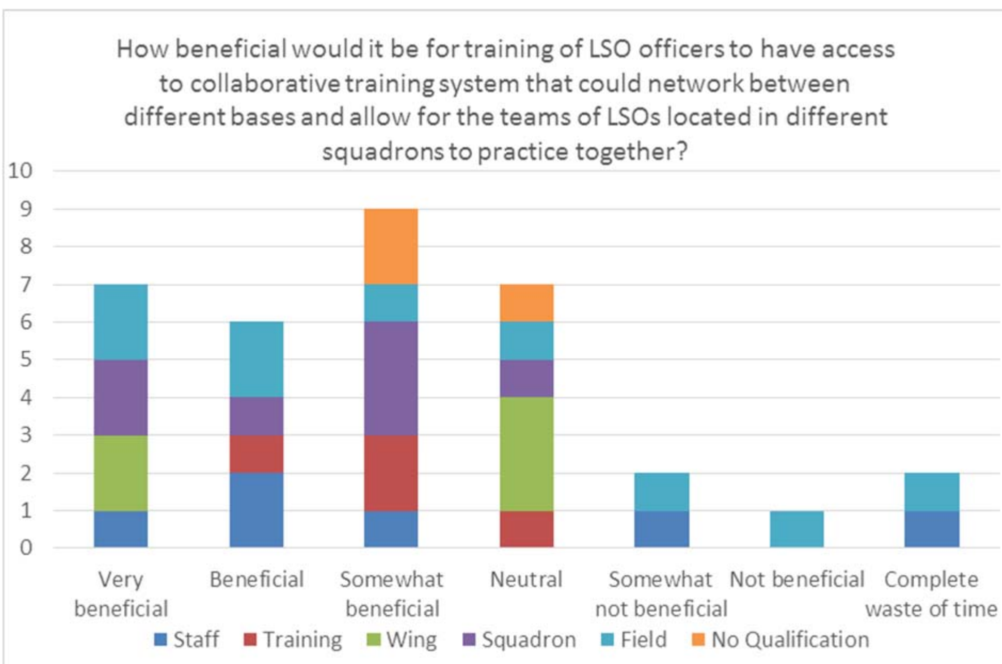
Figure 18. LSOs Opinion of the Usefulness of Data Analytics



Leveraging the idea of being able to distribute scenarios to LSOs throughout the Navy on a regular basis, the performance data analytics could be sent back to the LSO School, creating a feedback loop within training community. Such an arrangement could, for example, analyze the LSOs' scan patterns for different wave team positions, their recognition/reaction times to certain situations, and then from that derive a useful understanding on what elements should be addressed in future training. This could further help identify areas of emphasis for future formal and informal training.

The final question asked in the survey with regards to future technology capabilities was related to LSOs' perception of the value of having a collaborative virtual environment for LSO training (Figure 19). It is interesting to note the distribution of different qualification levels. The group as a whole was favorable towards the concept, but the bulk of that perception was supported by the intermediate qualifications (Squadron, Training, and Wing) and those first starting out (No Qualification). However, the expert qualification (Staff qualified) and beginning experience (Field qualified) were evenly distributed (no more than two votes in any one answer). Currently, fixed-winged Naval Aviators do not interact with any system that connects over a distributed network spanning multiple bases for training purposes. This lack of any familiar reference may be a contributing factor in such wide range of responses.

Figure 19. LSOs Opinion on Distributed, Shared Training Environment



E. CONCLUSION

Based on the views of the LSO community, the results of our survey clearly indicate a desire for further training beyond currently available methods, represented by the 2H111 device. The design of the light-weight prototype training system took into consideration many features that were declared as desirable in the 2H111, however the limitations of technology used to develop the prototype system prevented implementation of all those features (in depth discussion is presented in Chapter VII). The time and compressed schedule to produce a prototype also necessitated inclusion of only the most significant features that were seen as essential for this thesis's major objective—testing the feasibility of building such a system. Additionally, the design of the prototype tried to avoid the traits that were identified by the LSOs as undesirable and detrimental to the 2H111. Other questions were asked in the survey, however this chapter provides a commentary only on the most significant subset of those questions. The full set of questions and analysis of participant's responses collected in this survey can be found in Appendix C. Survey.

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VI. PROTOTYPE SYSTEM

A. INTRODUCTION

This chapter introduces the rationale for using immersive technology for the prototype training simulation, it discusses why certain design decisions were made and it details all solutions that were incorporated in the prototype system. The overarching goal of the system was for it to be light-weight—easy to move and not tied to a special physical space; the selection of all input and output modalities needed to support that. The ideal concept proliferated for the devised simulation/trainer was for that system to be distributed to individual squadrons. In order for a computer to be truly portable and go with the personnel no matter where they are with a squadron, it needed to be installed on a laptop—space onboard the aircraft carriers is highly limited. Our understanding is that every squadron has a dedicated laptop for LSO use already. It would then be optimal if a simulation could be operated off of the laptop that the squadron would be bringing to the aircraft carrier—this would make it even better utilized asset.

The LSO School has an instructor operating the 2H111 whenever a team of LSOs is in training. Therefore, the initial setup for our prototype was to have the capability for a second LSO to run the prototype trainer. For the next iteration the steps were taken to build an environment where the LSO who was using the prototype would be able to run the trainer himself/herself, without the need to take off the headset. The goal of creating a simulation/trainer that does not require an instructor to operate it has been looked into by the LSO community in the past (McCauley, Cotton, & Hooks, 1982). Having a design that could accommodate both individual(s)/trainees that would not need to break their immersion and an instructor/peer to operate the simulation was sought from the onset. Additionally, the system's ability to support the multiple roles that LSOs would perform was also an important consideration.

As previously discussed in Chapter II, the current format for each 2H111 simulator event and the guidance for each can be found in Appendix A. LSO School Documentation. The current way the 2H111 device is operated with respect to scenarios is that LSO instructor has a framework for each simulation for the content that is supposed to be covered, but the details for the individual passes of aircraft are left to the discretion of the LSO instructor to accomplish those goals. For feedback, the LSO instructor has a repeater display of the screens that are on the LSODS, as shown in Figure 2. The LSO instructor provides feedback for screen selection or any procedural errors anytime he or she sees something pertinent that can viewed as a learning point. Currently, the prototype simulation that mirrors the sensory functionality of the 2H111 device does not provide any instructional feedback to the LSO when a procedural error or error in judgment occurs. It is desired to remedy this in the future development of the system when the concept of an automated tutor would be added.

B. ARCHITECTURE OF THE SYSTEM

This section discusses the actual design tools that were used for development of the prototype system. In addition, where it is beneficial for better understanding of the problems encountered during the development of the project, the text discusses the workarounds that were selected and integrated.

Hardware and Software Environment

The system in order for us to consider it to be light-weight, it had to be transportable. For the project and continuing with the theme of using COTS hardware a high-end laptop was acquired.

Model—Alienware 17 R2

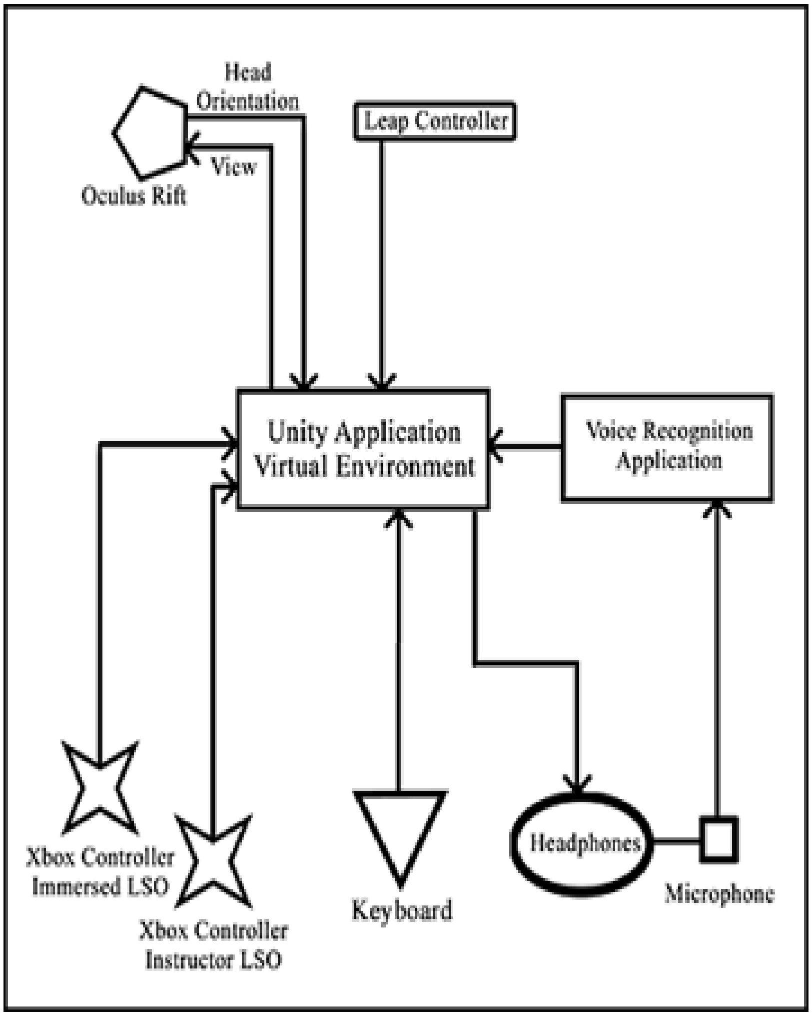
Processor—Intel Core i7-4980HQ CPU @ 2.80 GHz

RAM—16 GB

GPU—GeForce GTX 980M

Additionally, a new set of user interfaces had to be constructed and implemented (Figure 20).

Figure 20. Hardware/Software Architecture



C. PROGRAMMING AND DEVELOPMENT ENVIRONMENT

Following elements of programming environment have been used during our system development:

1. Unity

Unity was chosen as the game engine to help us create the desired interactive simulation; the main reasons were its performance and the wealth of development assets that were available to be leveraged to foster system development. As previously mentioned in Chapter II, the virtual reality HMD plugins were already available, along with Leap motion controller plugins. This took care of the controller and view portions of the typical model-view-controller (MVC) GUI design pattern. Along with streamlining this interaction, the user friendly Unity editor is able to work with various 3D modeling formats, and also supports 3D sound. The professional version was acquired, as it was needed to support specific assets needed for different functions of the system.

2. Blender

Blender is open source software that supports the entire graphics pipeline. For the purposes of this project it was used for creation and editing of the "Platform," the location on the flight deck where the LSOs perform their tasks. In addition the aircraft carrier model and F/A-18D were edited with Blender.

3. 3DS Max

3DS Max was used as a modeling software partially because of proliferative use among professional modelers and certain 3D models that were obtained worked best in 3DS Max (T-45C, EA-18G, X-47B, and E-2C).

4. Photoshop

Photoshop was used for the creation and editing of textures that would be used inside the simulation. Batch processing was found to be extremely useful and made creation very efficient during portions of development.

5. Audacity

The simulation uses segments of sound to support different parts of the scenarios. The Audacity audio editor was used to edit and prepare audio files used in the simulation.

6. 3D Models (Metadata, Behaviors, Geometry, Textures)

In order to show LSOs the proper scenarios and virtual environments associated with them, multiple types of 3D models needed to be acquired. The initial focus was on models that the LSO would directly operate with (e.g., accurate models of the aircrafts, the aircraft carrier, as well as the LSO Display Station), and then the work expanded on auxiliary elements that were used to enhance the level of realism and positively affect a sense of presence.

1. Aircraft

There are multiple aircraft platforms that would be encountered by an LSO while performing their duties. Because of the differences in aircraft performance characteristics, it was necessary to provide a variety of aircraft in the system. The first series of aircraft models that were used inside of the simulation were acquired from the Google modeling database "3DWarehouse." The modeling software 3DS Max was then used to import the model's native SKP format and convert it to a format that Unity could utilize for the purposes of the simulation. Google's 3DWarehouse had only two models that were viewed as having a high enough fidelity for the simulation. Later in development, these 3D models were replaced by other aircraft models purchased on a 3D modeling website (Turbo Squid). Figures 21, 23, 25, 27, 29, and 31 show the six types of aircraft that were incorporated into the simulation, while Figures 22, 24, 26, 28, 30, and 32 show their real life comparisons, respectively.

Figure 21. E-2C 3D Model Acquired from Turbo Squid During Runtime

Figure 22. E-2C Reference Photo (from Hendrix, 2015)

Figure 23. EA-18G 3D Model Acquired from Turbo Squid During Runtime

Figure 24. EA-18G Reference Photo (from Wagner, 2014)

Figure 25. F/A-18D 3D Model Acquired from 3DWarehouse During Runtime

Figure 26. F/A-18D Reference Photo (from U.S. Navy, 2011)

Figure 27. F-35B 3D Model Acquired from Turbo Squid During Runtime

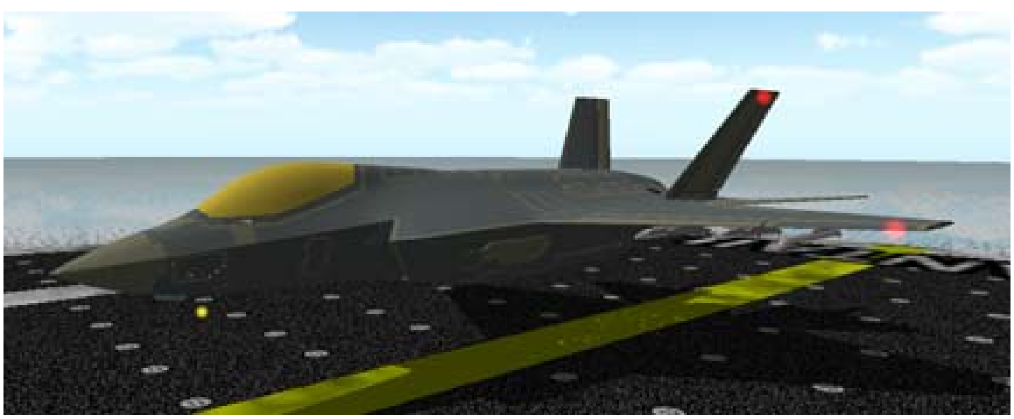


Figure 28. F-35C Reference Photo (from Wolfe, 2014)

Figure 29. T-45C 3D Model Acquired from Turbo Squid During Runtime

Figure 30. T-45C Reference Photo (from Fenaroli, 2014)

Figure 31. X-47B 3D Model Acquired from Turbo Squid During Runtime

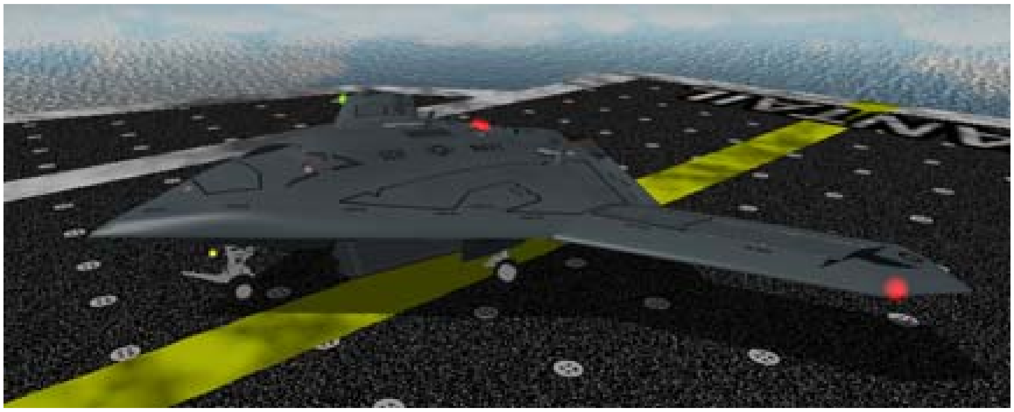
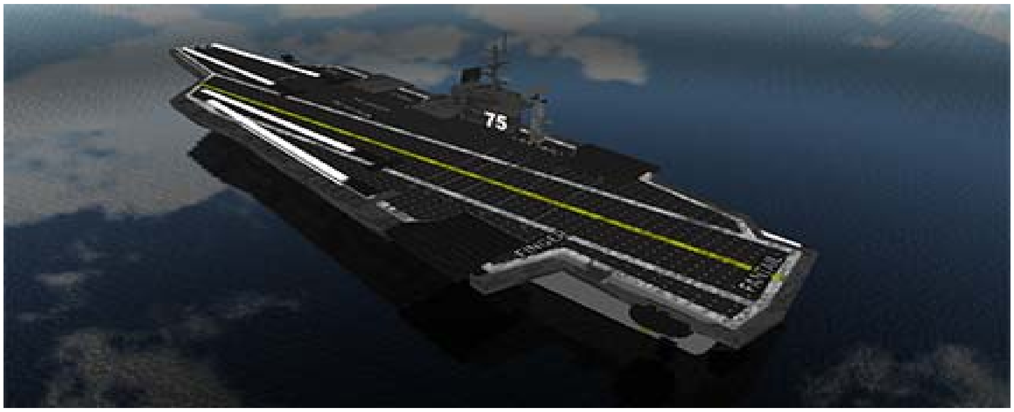


Figure 32. X-47B Reference Photo (from Hilkowski, 2013)

a. Aircraft Carrier

Since the simulation would immerse the LSO in an operational environment, a detailed 3D model of the aircraft carrier was needed (Figure 33. Figure 34 shows real life comparison). The initial focus has been on details located on the "platform," the portion of the ship where the LSOs execute their duties (Figure 35. Figure 36 shows real-life comparison).

Figure 33. Nimitz Class Carrier Model Acquired from 3DWarehouse During Runtime



Model shown in Figure 33 was acquired from Google's 3DWarehouse and custom textures were created using Photoshop application. "Platform" component did not come originally with the model and a custom addition was created using Blender.

Figure 34. Reference Photo Nimitz Class Aircraft Carrier (from Cavagnaro, 2015)

Figure 35. Orthographic View of the Custom Platform 3D Model during Runtime

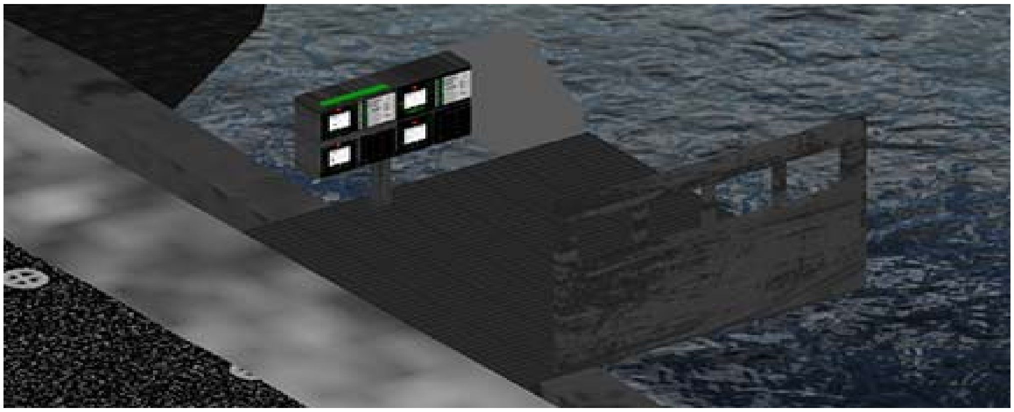


Figure 36. Platform Reference photo (from McLearnon, 2013)

b. Humans Model

The position and the role of the deck-caller, has tasks that involve watching for specific hand signals that are given by personnel on the aircraft carrier. This type of model behavior was not created due to the time constraints, however the actual 3D models were acquired to support the future work.

c. Ocean Model

Part of the LSO's decision-making process in the operational environment includes anticipation of the wave motion and the effects of a pitching flight deck that needs to be compared with the aircraft's trajectory. In order to create a believable scene, a 3D model of water (ocean) with underlining physics (behavior) was implemented from Unity. Adjustable sine rotation movements were added to the aircraft carrier to allow for believable movement in the pitch, roll, and heave of the ship.

d. Skyboxes

The LSO's task of recovering ships occurs on the outside of the ship and in varying conditions, so it was necessary to provide variable sky scenes. Skybox assets were also leveraged from the standard Unity collection. Several skyboxes were chosen to portray multiple environments like a clear day, clear night, and overcast day.

e. Visual Display (HMD)

The duties of the LSO require having a wide field of FOV. In order to provide a wide FOV to the LSO, and support most intuitive mode of navigation a virtual reality headset, the Oculus Developmental Kit 2 (DK2), was chosen as the visual display for simulation. This particular headset was chosen because of the ease of integration with the Unity development environment and low cost of the headset itself. The unit has the following specifications (The Verge, 2015):

- Tracking:
  - Internal: Accelerometer, Gyroscope, Magnetometer
  - External: Near Infrared (IR) CMOS
- Resolution (per eye): 960 x 1080
- Max refresh rate: 75 Hz
- Field of view: 100°
- Weight: .97 lbs.

f. Auditory Display

The LSO uses an audio headset to hear the UHF communication occurring in the carrier environment. In our prototype simulation we needed to present the LSO with the voice communication coming from the pilots and to bring ambient sounds of the aircraft carrier—a set of stereo headphones with an incorporated microphone were used to support this functionality.

g. Input Devices and Interaction Modalities

Audio Microphone: The LSO communicates with the pilots through a UHF headset during actual job execution. To achieve this in the simulation, a microphone attached to the headset was used. These communications were processed by a voice recognition application that will be discussed later in the chapter.

Leap Motion Controller: The LSO's task includes manipulation of the LSO Display System through physical button inputs. In order to replicate this process, the Leap Motion controller was utilized. This system was used not only to support the interaction with the LSODS, but also for object selection as well as navigation through the scene with both in a set of predetermined positions. Predetermined navigation points were shown to be possible when the LSO pushed a virtual button located on their virtual self.

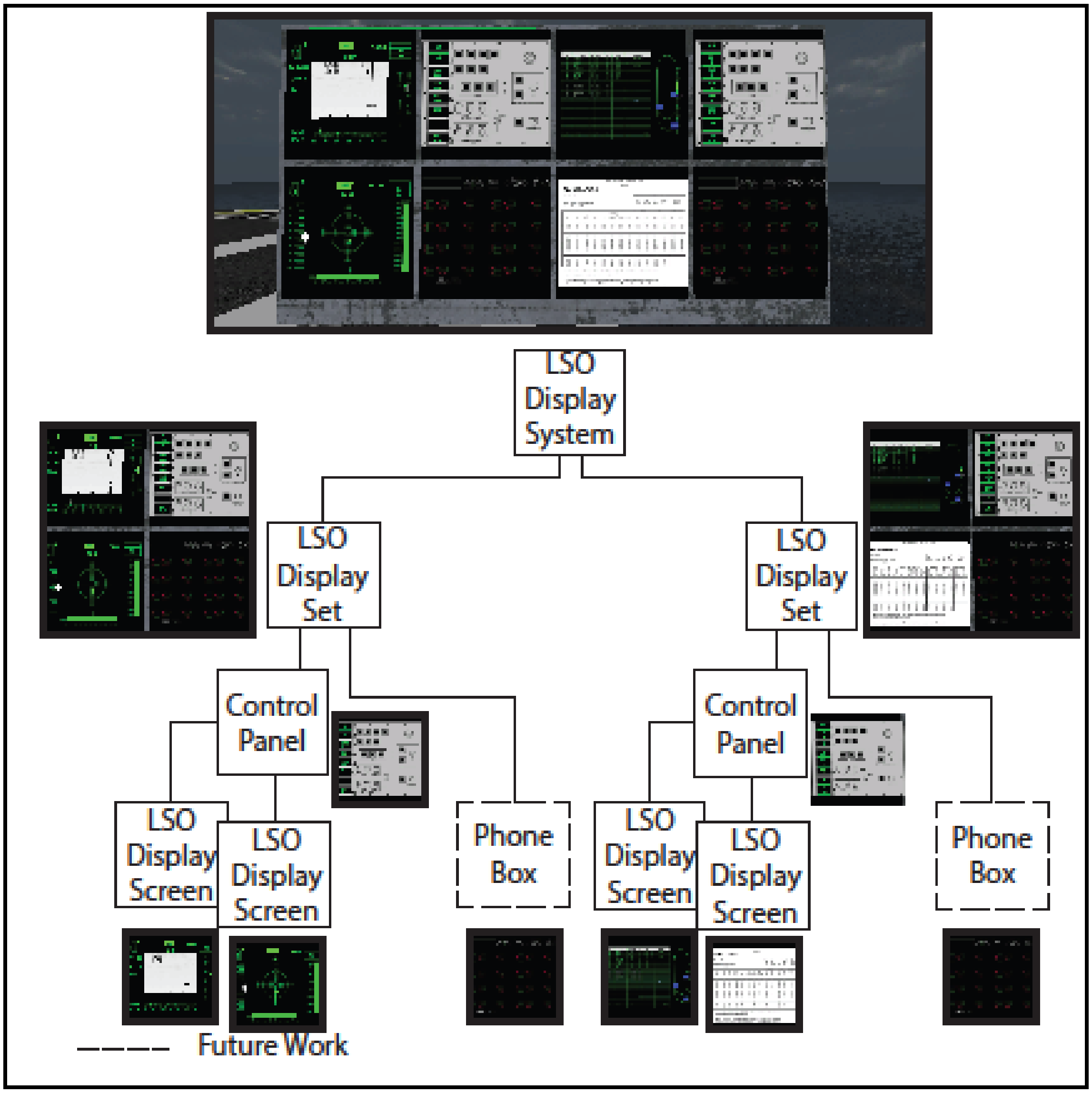
Xbox Controller: The use of Pickle device by the LSO in operational environment was replicated by incorporating the functionality of Xbox controllers. These controllers are used by LSO trainee immersed in the simulation to provide pickle functionality, LSODS manipulation, and navigation, but also by an instructor who could present the scenarios to the LSO trainee.

Keyboard: A typical keyboard as an input device does not provide a suitable way of interaction to a user immersed in the virtual environment. Keyboard inputs were supported, mainly for debugging purposes during development. Additionally, it also supported LSO's navigation through the scene, interaction with LSODS, and it also enabled an instructor to select and present scenarios to the trainee.

2. LSO Display System (LSODS)

This is a device that LSOs use on the aircraft carrier; currently the only other working example not on a CVN is located in the 2H111 device. In order to support the tasks of the backup LSO, a faithful representation of this display system needed to be recreated. The LSO School provided the design documents for the LSODS system, logic was coded inside of Unity, and textures that depict each screen were created in Photoshop. The eight push buttons in the control panel were made about 50% larger, for both easier visual identification and ease of selection by the means of Leap Motion controller (Figure 37).

Figure 37. LSO Display System Architecture



3. Sound

Presence of sound segments—auditory sensory stimuli—supported simulated voice communications over the UHF radio, as well as team communication among multiple LSOs. Additionally, sounds increased a level of realism in the environment (e.g., ambient jet noise). The first method we used to incorporate realistic sound into the simulation was to pull sound off of actual videos clips that were taken from the LSO platform, all available on YouTube. The sound clips were then edited to fit the needs of the simulation by Audacity software. This would have been successful enough to show a proof of concept, however the final samples of sounds provided to the project were the same sound clips utilized in the 2H111 simulator. This helped us emulate the auditory capabilities of the 2H111 device as much as possible.

4. Speech Recognition

The best tool that an LSO can use to facilitate a safe recovery of the aircraft is his or her voice. In order to support spoken language, the LSO Trainer (2H111) integrated a speech recognition system. For this reason, from the beginning we decided to incorporate and support voice control of an aircraft and use a speech recognition system in the light-weight prototype. From discussing the capabilities of the 2H111's speech recognition module with the LSO School, each LSO has to give several voice samples of each call to be registered into the system. Ideally, a system would not require this task load on the end user, so the initial intent was to strive to develop a solution that would not require voice samples in order to be operational. If a solution could not be found to work without taking voice samples then one requiring sampling would be acceptable.

Several different approaches were taken before we succeeded in this endeavor. The first approach was to leverage libraries available inside Unity, followed by working with a speech recognition package within Unity's asset store, both of which were not shown to be a viable solution. Finally, we built an application outside of the simulation that could communicate with the LSO program running within. The latter solution was successful, and was used in the prototype.

One of the popular Integrated Development Environments (IDE) for the .NET framework for Windows is Visual Basic. The first approach for speech recognition integration was to take an application created in Visual Basic and then create the same code within the Mono environment so that it would be able to run in Unity. A straightforward search on YouTube for "Speech Recognition C#" yielded a variety of applications that could be created in Visual Basic. One of these tutorials was chosen (Nerd's Best Advice, 2013) and the code was made to work without a GUI implementation. This route ultimately did not work out because Unity's .NET libraries were missing some classes necessary for functionality.

The second approach involved using assets that were available for purchase in the Unity asset store. One of the big advantages of developing within Unity is the asset store itself, which contains a myriad of solutions that a game developer could bring to his or her project. Some of these solutions work as plugins, which help bridge the divide between what Unity can provide and what the developer wishes to do. Since there was no native solution for voice recognition, we looked for appropriate a plugin. "Word Detection" was the only application available in the asset store that could possibly meet the requirements set by our simulation. However, in order for Word Detection to work correctly, a sample sound would be required from the user for every word or phrase that would be used in the application. The process of entering each individual word into the database would take about 20 seconds. Although there was no initial requirement for this pre-processing time, this burden on part of the user was viewed as too long, especially if one takes into consideration the number of key phrases that are used by the LSO community. Moreover, even when samples were provided, the frequency of false-positives and false-negatives were unacceptable—they would inevitably lead to negative training transfer for the users. In the end, this approach was also abandoned.

The final approach was to take the original Visual Basic Speech Recognition application and make it communicate with Unity through network messaging (Figures 38 and 39).

Figure 38. UDP Message to Speech Recognition Program Boundary

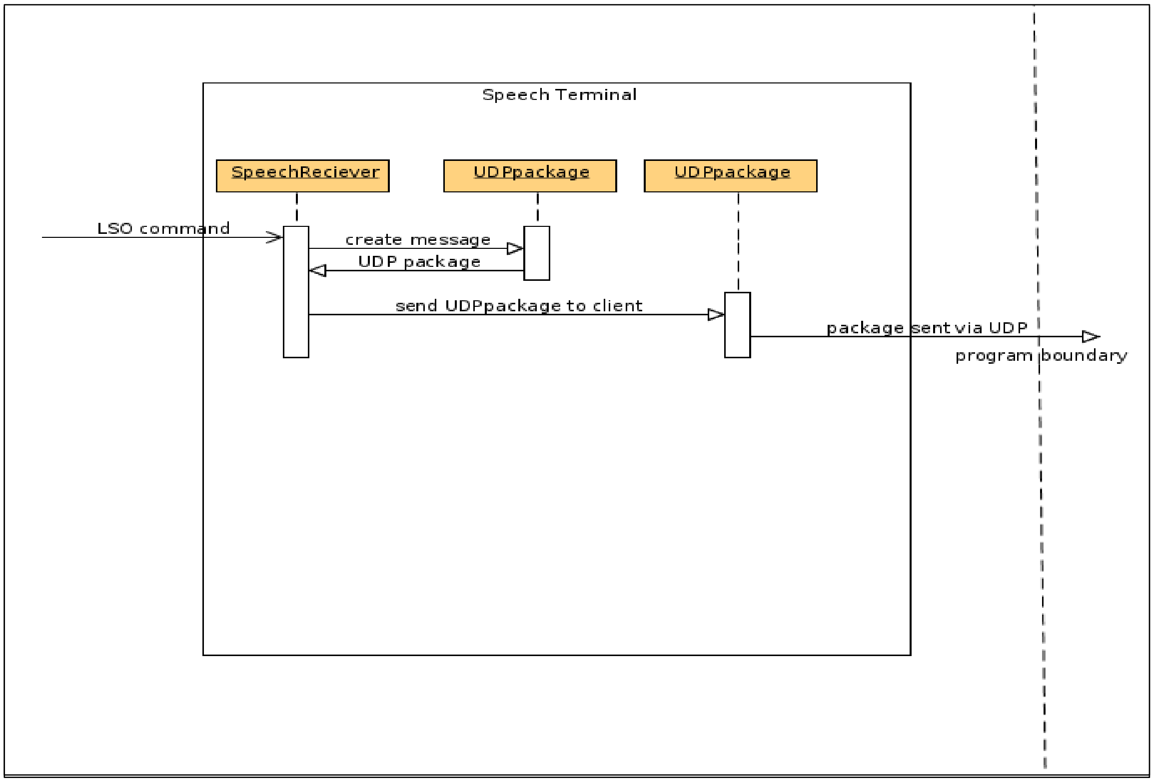
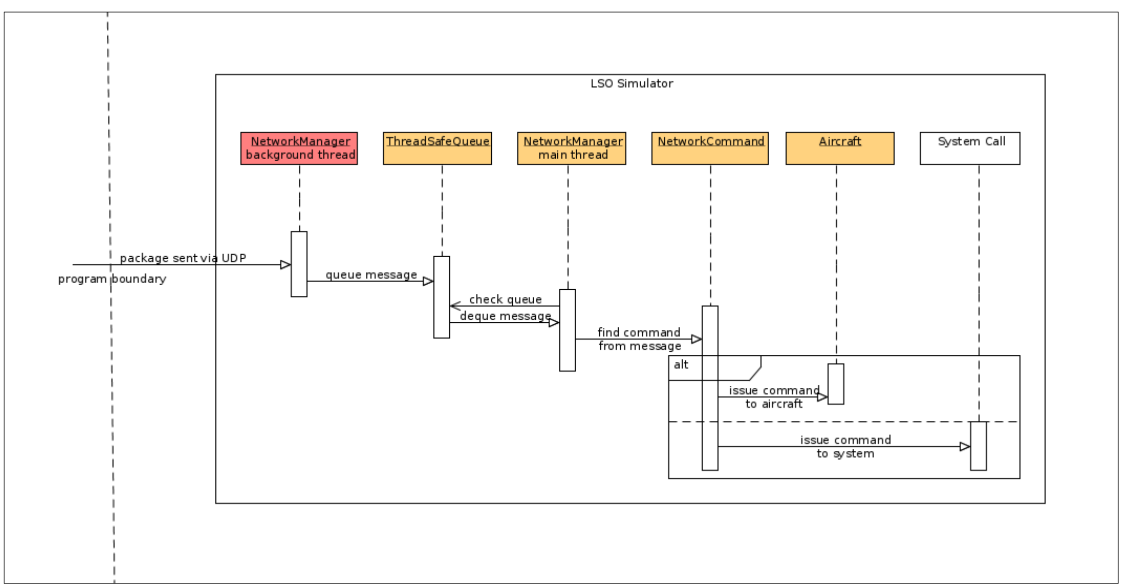


Figure 39. UDP Message from Simulation Program Boundary to Method Calls



There are two components in every LSO voice call that is given to a pilot—one is the word or phrase itself (e.g., power—Aircraft is low/slow), and the other is inflection (“power” vs. “POWER!”). The ideal system would be able to discern LSO’s command with the correct meaning and inflection. At the time of developing our prototype, there was no known viable solution that would address this problem, so the solution integrated in the system was viewed as acceptable with the lack of detecting the inflection in the LSO’s voice.

D. CHAPTER SUMMARY

Building the virtual environment for the aircraft carrier would not have been possible without the wealth of off-the-shelf resources that were available during that process. The fact that companies such as Oculus and Leap build plugins for their hardware to Unity allowed the author to treat these devices as black boxes, effectively shortening the time to develop the prototype and increase the functionality of the overall system. The value of the Unity editor is that it is extremely user-friendly; it has very good documentation, and a large community of users. These features allowed for minimal time to be spent on code development. Additionally, Unity’s ability to build for different platforms using the same code allowed us to quickly develop the augmented reality application for a tablet and phone. Present chain of tools allows a developer with an intermediate understanding of programing languages to create a fully functional immersive virtual environment in less than six months; a feat would not be possible in even the recent past.

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VII. FEASIBILITY TESTING AND ANALYSIS OF RESULTS

A. INTRODUCTION

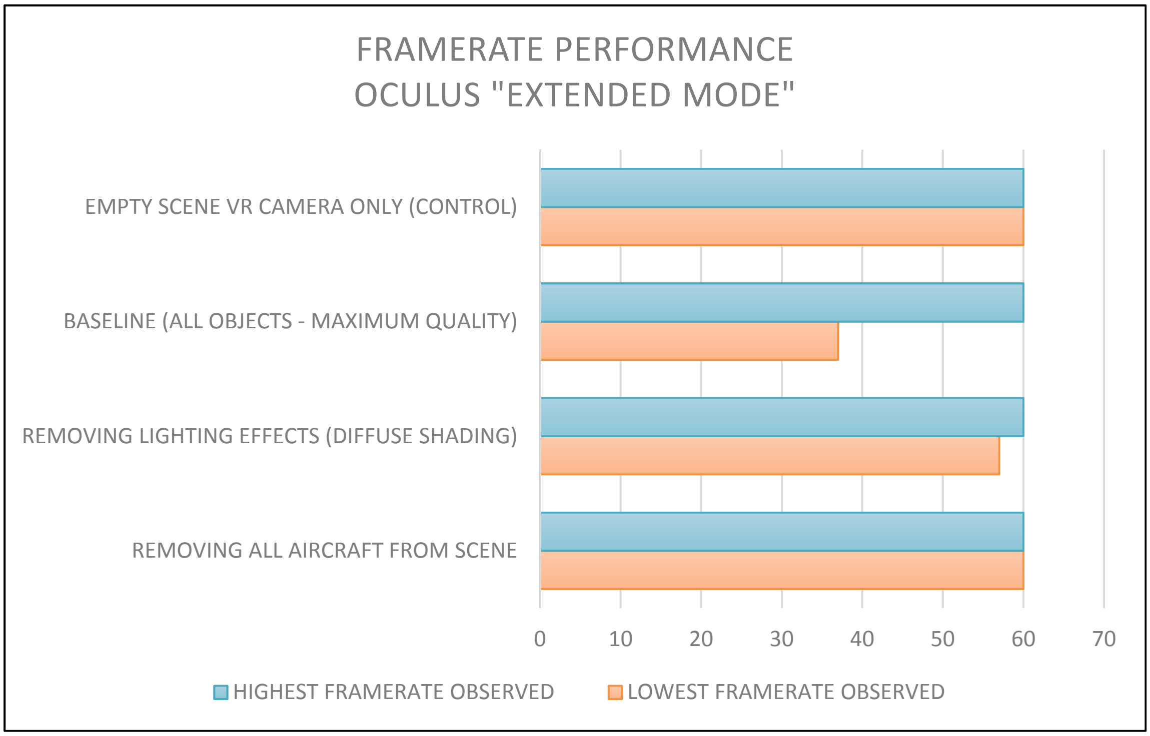
This chapter details the elements of the feasibility study and accompanying results. For the majority of the results, it provides the researcher's assessment of "how well" the technology works both for a single user (one LSO) and for multiple users (a team of LSOs) as a training environment. These are, respectively, the tasks that need to be accomplished by an individual and tasks that need to be done by the team. Additionally, parts of the results represent subjective responses drawn from Landing Signal Officers at the LSO School during a demonstration of the project. The major goal from the onset was to find out whether or not technology could support a light-weight trainer, and what would be the receptiveness of LSOs to system of that kind.

B. SYSTEM PERFORMANCE MEASUREMENT

In order to understand how to improve the light-weight prototype in anticipation of user studies, it was important to get a baseline of how the present system performs. Given the fact that current 2H111 training system is highly complex and had limited time available for execution of this thesis project process, a decision was made to develop and integrate the essential subset of what current system has, add some new capabilities and examine the feasibility of that prototype, rather than implement all features of the system and pursue system optimization.

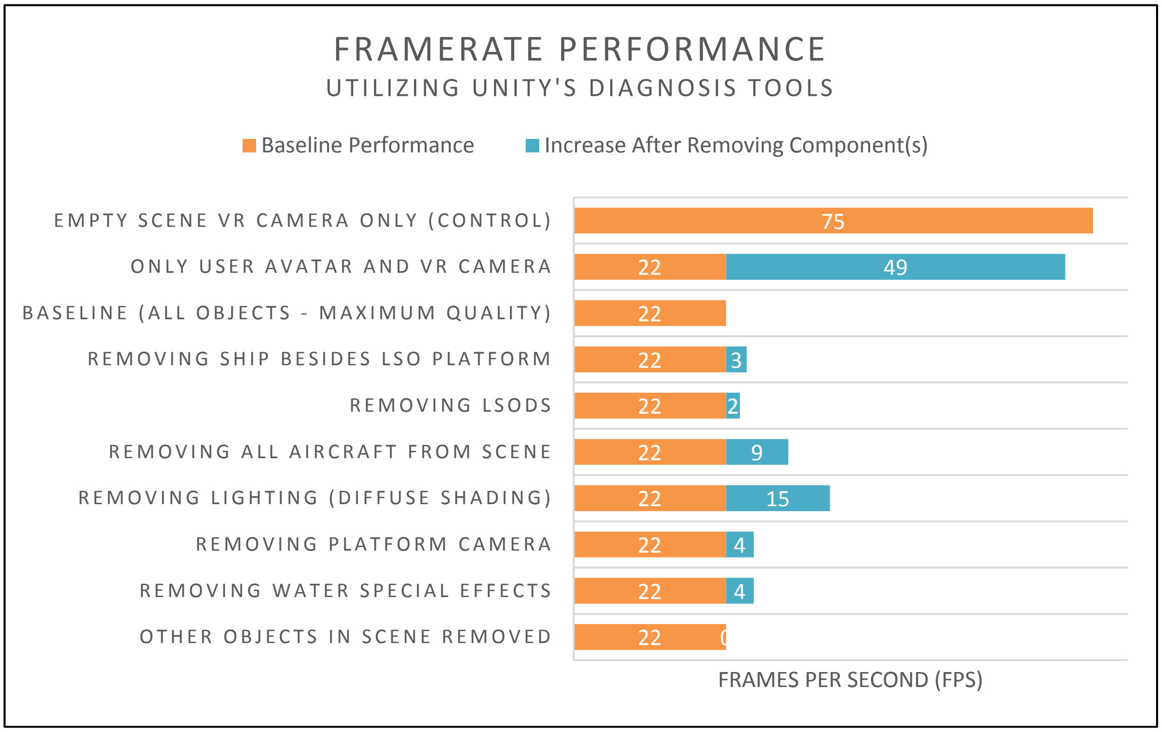
Best performance for the prototype simulation was achieved utilizing Oculus' "Extended Mode," instead of the preferred "Direct to HMD" mode. Extended mode will cap the performance to the refresh rate of the laptop screen, in this case 60 Hz (Figure 40). The simulation if run on another system could possible achieve up to the Oculus DK2's refresh rate of 75 Hz, however this was not pursued because of time constraints. The drop in maximum FPS and minimum FPS observed in both the "Baseline" and "Removing Lighting Effects" had the same perspective in the scene (i.e., the same segment of the virtual scene was displayed at the time).

Figure 40. Performance Obtained Running as a Standalone Simulation



Performance of the simulation was tested inside Unity, utilizing the programs built in statistics function (Figure 41). The view of the camera was not changed during the experiment and objects in the scene were systematically disabled and then re-enabled to capture their effect on the runtime rendering of the system. This data collection helped us understand where the effort should be placed for optimization of the simulation's frame rate performance.

Figure 41. Runtime Framerate Performance of System during Diagnosis Testing Inside Unity Editor



In order to maximize users' immersion to the greatest extent possible, it is helpful to look at the input and output devices and make sure that their integration in the application is seamless. Since visualization is considered to be an extremely important element to the user's immersion it required specific performance testing to establish its baseline capability. The assessment was that the simulation should run at least 60 Hz (i.e., it should produce and display 60 frames per second—[FPS]). The drop in frame rate from 60 FPS to 37 FPS during the full quality settings could cause jitter and result with cybersickness symptoms to the user. A rough assessment of which elements were taking up the largest amount of GPU resources was conducted and results are presented in Figure 41. By learning what objects or features were taking up valuable resources, one could gain the useful understanding on where to do the optimization. It would be ideal if a requirement study for features that LSOs would need in a trainer was performed, since there are several features such as lighting and water effects that may not be that important to the LSO and they could possibly be either altered (simplified) or eliminated.

According to Brooks (1999) the frame rate of 20 to 30 is a critical requirement for interactive VR. This system is current able to achieve that mark 2 to 3 fold.

The remainder of the feasibility analysis was performed by getting subjective measures on different methods of interaction with VE. While all input methods worked and are considered successes for feasibility, there is still space for improvement.

- **Voice**—Works very well with recognition of word(s) and phrases that the system searches for when a phrase is uttered. False positives were an issue, however this could largely be remedied by requesting the LSO to hold down a button on the controller when he wants the system to recognize a command. This would be not unlike the LSOs natural actions when LSOs push down the transmit button on their UHF handsets when they want to talk.
- **Hand Controllers**—LSOs who tested it reported that it felt natural within the virtual environment when they needed to navigate (move) through VE and interact with the LSODS interface. Using a controller as the interface for the instructor to manipulate scene environments may not be ideal due to the complexity of potential variables that one would want to modify. Additionally, for the user immersed in VE, it may be adequate to manipulate MOVLAS by using a controller with a joystick, however that is not ideal because of the range of motion. An ideal system would have the same range of motion as the actual system (~1 ft. arc) and to keep in line with the system being light-weight it should be implemented using a controller with wireless positional tracking and haptic feedback.
- **Leap Motion Controller**—This input device worked better than what was anticipated. Having the ability to reach out and 'touch' a button and see it react, felt very natural. A couple of issues though would still have to be mitigated or resolved. First, although the line of sight generally had no issues, there were times where the user had to position his hand to make it as perpendicular as possible to the IR cameras on the Leap to get precise 3D coordinates. This was most noticeable when user tried to push a button. Our tests found that pushing a button with two extended fingers (index and middle fingers) while other fingers made a fist led to the greatest amount of success (Figure 44). Oculus also has an IR sensor to help with head tracking, so the best results were achieved by placing the sensors out of each other's FOV.

C. CROSS-COMPARISON OF TRAINING CAPABILITIES IN THREE SYSTEMS (ENVIRONMENTS)

In order to examine the capabilities of our prototype system we felt it was necessary to make a cross-comparison between our prototype, the 2H111 training device, and the “Real World” that represents the way LSOs’ training is done on the ship (i.e., the way most of the training for LSOs is currently done—on the job. Assumptions were made about the 2H111 and its potential evolution, as discussed in the caption of Table 4.

Table 4. Training Capability Comparison

LEGEND:

Presently Working (dark green)	Straight forward implementation using current libraries and existing hardware (light green)	Solution possible hardware / libraries, but would need to be designed and manufactured (orange)	Solution not practical/possible (red)

Feature	Real World	LSOT 2H111	Prototype LSO Light-weight System	Justification
SYSTEM AS A WHOLE				
Transportable and able to do training on user’s time	Red	Red	Dark green	Both for the real system and 2H111, the users need to go to where the system is located at; access is restrained to certain times. The prototype is designed to be portable; it does not require dedicated facilities and personnel.
Unrestricted FOV	Dark green	Red	Dark green	Because of the projection system that the 2H111 uses, it limits to the possible FOV the LSO could experience
Feature	**Real World**	**LSOT 2H111**	**Prototype LSO Light-weight System**	**Justification**
HARDWARE REPRESENTATION				
Faithful MOVLAS representation	Dark green	Dark green	Dark green	Having a physical analog (artifact) is better than what can be constructed digitally as it represents faithful look and feel of the system.
Faithful LSODS representation	Dark green	Dark green	Light green	Having a physical analog (artifact) is better than what can be constructed digitally but it represents faithful look and feel of the system. Some more senior LSOs noticed the discrepancies between virtual and real LSODS. Additionally, not all screens were fully implemented; once that is done it would be necessary to validate all screens that can be accessed.
Headset	Dark green	Dark green	Light green	Having a physical analog (artifact) is better than what can be constructed digitally as it represents faithful look and feel of the system.
Pickle Switch	Dark green	Dark green	Dark green	Having a physical analog (artifact) is better than what can be constructed digitally as it represents faithful look and feel of the system.

Feature	Real World	LSOT 2H111	Prototype LSO Light-weight System	Justification
		SOFTWARE		
Voice Recognition				LSOT 2H111's voice recognition processes what an LSO says after the LSO releases a microphone pushbutton after a preprogrammed 1-second delay. The length of time it takes for the LSO to release the microphone switch is also added to the artificial 1 second delay. This introduces an unrealistic delay unless the LSO releases the microphone button immediately. This system also requires voice sampling. For these reasons, the LSO school typically does not allow the 2H111 to respond to voice commands. The prototype LSO system does not require sampling and can process what the LSO says without any unwanted or perceived delay.
Voice inflection recognition				Currently the voice recognition software does not support recognition of inflection in users' speech.
Variable Environments and conditions on demand				Both artificial systems are capable of representing desired environmental conditions as desired.
Manual Control of aircraft flight path				LSOs are unable to directly control manned aircraft during CV operations.
Automated Control of aircraft flight path				For the prototype LSO system, a crude implementation for automated flight path was used. Any implementation that would be in an actual system would need to be more robust with varying pilot behaviors.
Analyze scan behavior patterns for LSOs				The Real World and 2H111 would need to construct devices that would be able to determine where the LSO(s) were looking between actual hardware and the virtual or regular environment, because of this it is viewed as not plausible. Since the prototype constructs every item in the environment digitally, it is straight forward to get information on where the LSO is looking. This information could then be processed into usable statistics.
Feature	**Real World**	**LSOT 2H111**	**Prototype LSO Light-weight System**	**Justification**
		INDIVIDUAL TRAINING		
Train just an individual at a single task				In real world operations, in order to receive an aircraft on the flight deck an entire team is needed. This precludes ability to train just one LSO.
Train just one LSO on the entire suite of tasks for that				Same rationale as above for real world. The 2H111 requires all members of an LSO team to be present to show the full procedural flow on the LSO platform. Simulating other

position. **Audio representation of other positions available**				positions would require speakers to be placed in the other LSO positions and well as the code and logic to support a full simulated version of a wave team. The prototype LSO trainer demonstrated this ability to present the Deck Caller position to an LSO that is being trained, code would need to be created to support the other positions (e.g., controlling and backup LSO).
Train just one LSO on the entire suite of tasks for that position. **Full avatars/physical representation capable of animation of other positions available.**				Same rationale as above for real world. For the 2H111, investing in full mechanical representation of other positions would not be practical. For the prototype LSO trainer, models could easily be inserted into the virtual environment and given the audio representation of the other positions.
Train just one LSO on the entire suite of tasks for that position. **Physical interactions from avatars/physical representation of other positions available.**				Same rationale as above for real world. For the 2H111, this problem would be even more difficult than just having physical representation of other positions. Having physical interaction with other individuals in a virtual environment is a known problem that is being pursued by multiple companies. If a system is built using off the shelf technology, when it becomes available on the commercial sector it will most likely be able to be easily integrated into the proposed training system.
Feature	**Real World**	**LSOT 2H111**	**Prototype LSO Light-weight System**	**Justification**
TEAM TRAINING				
Supports a team training environment				The libraries exist to implement a networked solution with the proposed trainer, however due to time constraints code development was not pursued.
Feature	**Real World**	**LSOT 2H111**	**Prototype LSO Light-weight System**	**Justification**

SQUADRON TRAINING				
Contribute material to "chalk talks" for squadrons				With the real world, one could take a camera flying and film aspects that could be used for reference material. However, it is not dynamic and is not able to change conditions (e.g., overcast, different wind conditions) The prototype trainer can easily incorporate views from different aspects that could be of use to the squadron as they train to deploy to a ship.
Spatial view of carrier pattern				For the real world same rationale as above, one could do it to a certain degree. Users would not be restricted to the view that is possible for the prototype system.

Assumptions that were made for the 2H111, are that system will retain its current form and just make systematic or routine upgrades (e.g., employ more advanced graphics, modify code in application, and use higher quality projection systems). If the 2H111 was radically changed, (e.g., switch to an augmented reality hybrid with current LSO equipment) then this table and its comparisons with the prototype would need to be adjusted.

D. INFORMAL DEMO FEEDBACK

LSO School leadership was contacted during the development phase and they agreed to both lend their support with current documentation for their training practices, and to provide an opportunity to demonstrate the training prototype at the LSO School Command and provide their comments on the system. The comments received on that visit are presented in this section.

1. System Interactions

When an immersive system gets demonstrated to a user, a usual challenge is a type of camera view that can be presented to the rest of the audience during simulation runtime. The prototype, when it was demonstrated in LSO School Command, was built using Unity 4.6, which constrained the camera view to a stereo view on the laptop screen—the audience could see a "copy" of both images (one for the left eye and one for the right eye) as they are viewed by the user inside Oculus headset. With Unity 5, this has since been changed and a monocular repeater that shows a single image is available on the laptop screen. Regardless of the version, if one wanted to see another camera view of the scene while the user wears Oculus headset, an additional application would need to be built. This type of requirement—having an independent camera view—is usually exhibited when an instructor needs to monitor and inspect the performance of the trainee.

A separate problem occurred, when we worked with the Xbox controller as the means of interacting with the virtual environment. One limitation was the inability of Xbox controller to register fine float inputs, because of the limited range of motion on the controller. The Xbox controller's thumbsticks, Directional Pad, and triggers are all available for these types of user inputs, and while they proved to work very well for navigation inside the VE, precisely controlling aircraft was at times challenging.

2. Visual Appearance

A general impression of the LSOs was that the system was visually better than what they expected. Some LSOs suggested that the system would benefit from more accurate models of 3D objects like an aircraft carrier. Additionally, they advised adding the animations that would make simulation more realistic (i.e., arrestment of the aircraft, payout of the arresting wire). At the time of our demonstration to the LSOs, only three aircraft models were available in the prototype (two were of lower quality). Since then, several additional high quality models of the aircrafts have been added.

The aircraft carrier pitching motion was looked at very favorably by the LSOs; its overall behavior and appearance seemed to be realistic to them. LSOs also made a request for the program to be able to manipulate the pitching motion of the aircraft carrier.

3. Aircraft Models

As was previously mentioned, when the simulation was demonstrated to the LSO School only three models were used: an F/A-18D, E-2C, and an EA-18G. The first two models were not as high quality as the EA-18G. The majority of the LSOs noticed a significant difference between the high quality model and a two lower quality models when the following conditions were met: LSOs were up close to the aircraft (the aircraft filled their field of view from side to side in the Oculus Rift) and they were in daylight conditions. As the distance between the view point and the aircraft increased the difference between the low quality models and the high quality model became less pronounced. The LSOs agreed that they could fully distinguish between the F/A-18D and EA-18G which have similar visual profiles, at the “In Close” position (about the last 8–10 seconds of flight) inside of the VE. In the real world one could distinguish them easily about the “In the Middle” position (~4 seconds prior). If the aircraft was an E-2C the LSOs would be able to visually define it a couple of seconds prior to the “In Close” position.

One of the critiques from LSOs was related to incorrect strobe light patterns for the aircraft and the lack of “day ID light” that exists on the Super Hornet variants (F/A-18E/F/G) to help distinguish them from legacy hornets (F/A-18A/B/C/D). The anti-collision light strobe patterns are important during the nighttime conditions (Figure 42), because it is the only way possible for an LSO to verify if the aircraft flying in the simulation was the anticipated aircraft.

Figure 42. Nighttime Recovery of F/A-18D Hornet from the Deck Caller LSO’s Perspective

4. Visual Interface in Support LSO Display System (LSODS)

The consensus of the LSOs was that the visual representation of the LSODS was done very well (Figure 43). This can be credited to the documentation we received from the LSO School to design and develop the logic for the interface.

Figure 43. LSODS Comparison between 2H111 and LSO Prototype Trainer

Side by side comparison of two implementations of the LSODS system from the 2H111 trainer (top) and LSO Prototype Trainer (bottom). The 2H111 portrays a night time scene, and the LSO Prototype shows a daytime scene.

One general type of critique was that some of the fonts and symbols on the display could be read in only near-optimal situations with LSO directly in front of the display and at a relatively close distance. The LSOs understood that this was not due to a lack of contrast, but due to the low resolution of the display inside the Oculus Rift headset.

A few of LSOs with more experience noticed some discrepancies between the text on screen in the prototype and the real world LSODS, as well as some information that was not present that was expected. The information that was pointed out as missing or incorrect was not available in the written documentation that was provided to us as a resource for the development of the LSODS in the prototype simulation.

In our opinion the best and easiest way of interacting with the LSODS, was a combination of "touching" the buttons that used information from the Leap Motion controller (Figure 44), as well as interaction using the Xbox controller. The Keyboard was too cumbersome and impractical while wearing the VR HMD, and utilizing the voice commands did not feel natural. The Leap Motion controller was not incorporated until after the demonstration to the LSO School, so we did not collect LSOs comments regarding its usability.

Figure 44. User Demonstrating Interaction with LSODS with Leap Input

The Aircraft Recovery Bulletins (ARBs) are documents that can be referenced within the LSODS screen during an emergency aircraft recovery situation (Figure 45). The LSOs agreed that it was easy and efficient to access that information in our prototype. The concern that was shared by all LSOs during the demonstration was "How would you keep track of individual pieces of information, if you were wearing an Oculus?" In normal operations, LSOs would write down applicable numbers on a piece of paper to reference at a later time. We were aware of this fact before the demonstration, but time available for development did not allow us to pursue a viable solution to this problem. This problem is not unique and it will need to be addressed in any VR HMD based system by developing an appropriate user interface to support note-taking. It was also suggested that just being able to show the LSODS on a computer screen to solve ARB problems and utilize the VR headset was valuable.

Figure 45. LSODS Displaying ARB Information

5. Visual Interface in Support of Manually Operated Visual Landing Aid System (MOVLAS)

The button layout on the Xbox controller was mapped to allow the selection of MOVLAS by pressing a single specific button. The interaction with the system could be accomplished by moving the thumbstick's vertical axis. There were mixed sentiments on whether the physical range of the thumb-stick axis provided enough acuity to represent what the LSO wanted to show without becoming a hindrance. That interface was noted as being "too sensitive." Additionally, there were also mixed sentiments on having an inverted axis control (pulling up on the thumb-stick results in an upward movement). The final critique was related to what happens when an LSO releases pressure on the (spring-loaded) thumb-stick—it was unclear to the LSOs whether the light position should remain the same or reset back to the neutral position.

Figure 46 shows a comparison between 2H111 trainer (top image) with LSOs manipulating MOVLAS and the LSO trainer prototype (bottom image) as it demonstrates

MOVLAS capability. In an operational situation, LSOs will reference the LSODS to know what lights are currently illuminated for the pilots.

Figure 46. Demonstration of MOVLAS Interface Capability with LSODS in both the 2H111 and LSO Trainer Prototype

The light system could be seen on several screens in the LSODS when MOVLAS was active. The LSOs agreed that this was a good representation of what they would be able to see in the actual use of the system; it was easy to interpret the current position of the light setting.

6. System Support for the Role of Controlling LSO

The LSOs agreed that using an Xbox controller felt natural for an analog of the pickle controller (Figure 4) that is used during actual flight recovery operations. One item that the LSOs would like to be changed in the prototype simulation had to do with the mapping of the cut lights when in MOVLAS mode on the controller. The current layout does not allow the LSO to select the cut lights without releasing the thumb-stick corresponding to the MOVLAS.

LSOs agreed that they could determine the position of the aircraft during the "pass" of the aircraft; for example the LSO would know that the aircraft was "In-the-middle" position. They felt that this knowledge of spatial awareness was due to the timing of the aircraft on the pass, more so than the actual size of the aircraft when displayed in the headset. This is consistent with waving in actual operations; things such as wind can affect the ground speed of the aircraft so that the same distance of offset between the LSO and the aircraft could be viewed as two different conditions.

Figure 47 demonstrates pass segmentations and vertical deviations of aircraft from the LSO perspective: the aircraft's "pass" is broken into four sequential portions: start, in the middle, in close, and at the ramp. The color green signifies "little" deviations from the optimum flightpath (glideslope) and yellow signifies "full" deviations. The cone is meant to represent the viewing angle limits of IFLOLS. For the scope of this thesis, any flightpath that is in red or outside of the viewing area of the IFLOLS lens would be unacceptable. In an operational situation LSO's judgment defines the boundaries (Figure 48).

Figure 47. Pass Segmentation Positions and Glideslope Deviations for Aircraft

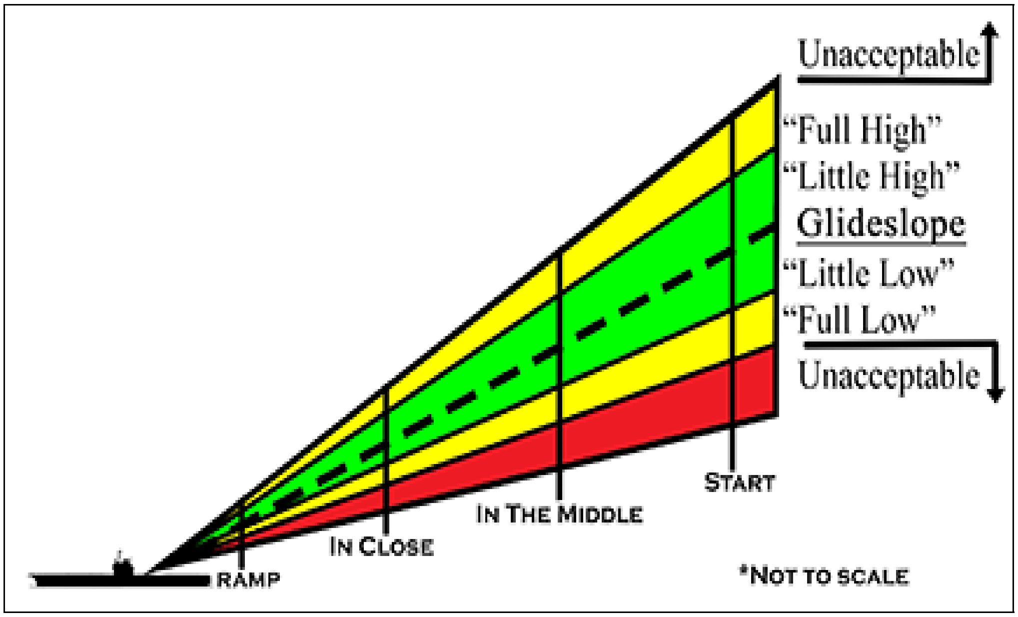


Figure 48. Daytime Recovery of an E-2C Hawkeye from the Controlling LSO's Perspective

The E-2C shown could be called a "little low" or "[full] low" according to the Controlling LSO's judgment.

LSOs felt comfortable in judging vertical deviations in glideslope. They felt that they could definitely pick out "full" deviations in the aircraft's flight profile and possibly "little" deviations.

7. System Support for the Role of Backup LSO

The LSOs agreed that the elements a Backup LSO would be looking at during a recovery were present in the simulation, except for the ability to change radio frequencies. Also part of the task requirements for the Backup LSO is to make sure that the aircraft has little lateral deviation away from centerline and therefore be as safe as possible. LSOs said that it would be easy to discern a "full" deviation from a "little" deviation, similar to the sentiment for glideslope errors noted in the Controlling LSO appearance section.

Figure 49 depicts lateral deviations of aircraft from the LSO perspective. The color green signifies "little" deviations from the optimum flightpath (centerline) and yellow signifies "full" deviations. In an operational situation the LSO's judgment defines the boundaries of the segments (Figure 50).

Figure 49. Lateral Deviations from Centerline

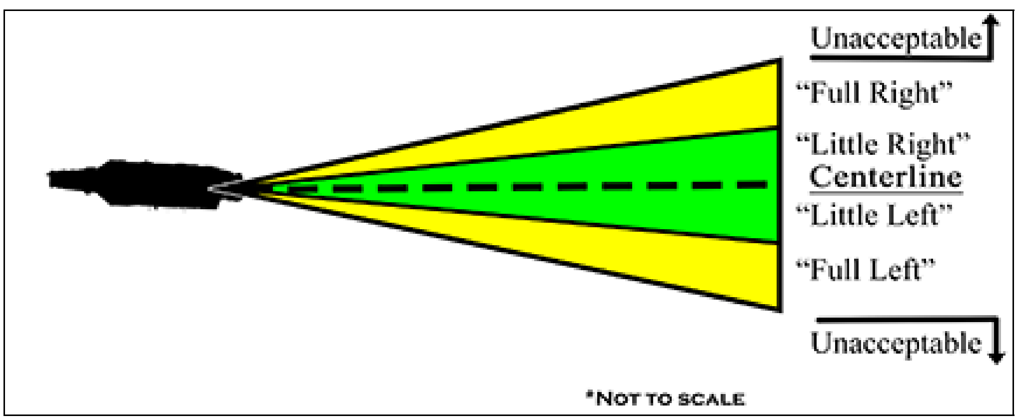


Figure 50. Daytime Recovery of an X-47B UCAS from the Backup LSO's Perspective

The Backup LSO in this scenario could call the X-47B to be a "little left" or "[full] left" of centerline.

Originally described in the LSODS appearance section, there were discrepancies between the actual system and the version created for this simulation. These inconsistencies were noticed by LSOs who were looking at the LSODS for tasks that needed to be performed by the Backup LSO position.

8. System Support for the Role of Deck-Calling LSO

In order to support the role of the Deck-Calling LSO, a user would have to have a capability of visually looking around the flight deck and be able to freely navigate on the flight deck. While there were no scenarios that were built specifically for the Deck-Calling LSO, the elements integrated in the simulation would support the scanning patterns required by the Deck-Calling LSO, and system could support that position.

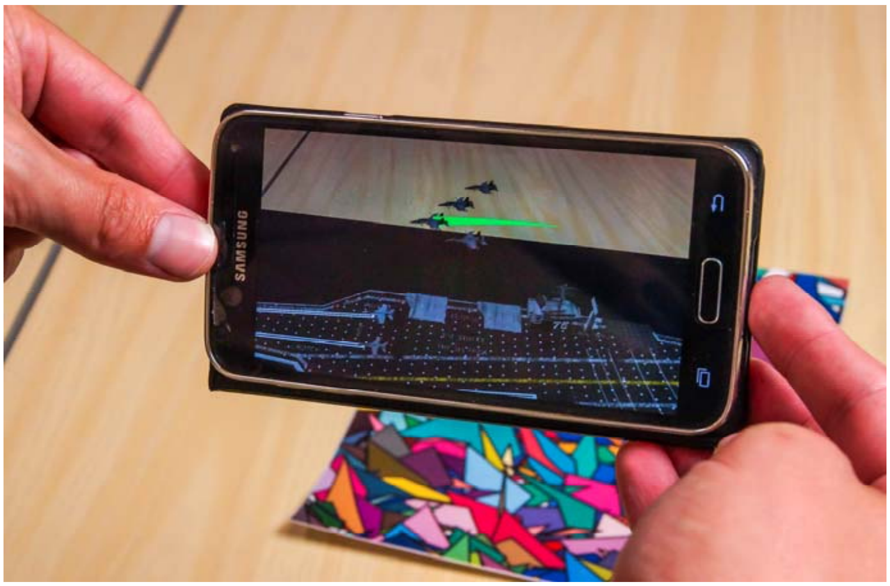
Figure 51 demonstrates that testing the feasibility of training Deck Calling LSOs whether or not all functions in their job could be put into the simulation. The visual extreme of their scan includes obtaining the signals from Arresting Gear Officers (AGOs) on the flight deck, who are located in particular locations on the flight deck. In our prototype two virtual humans (avatars), representing Arresting Gear Officers (AGOs), were placed at these distinct locations and were visible from the Deck Caller LSOs perspective in the VE, when the LSO was in a proper position. Additionally, the flight deck was also textured to show lines of paint that have a specific meaning for the LSOs. The consensus from the LSOs during the demonstration was that elements needed to support the Deck Calling position were easily visible and that the prototype could support the specific tasks needed to train that role.

Figure 51. Portion of Deck Caller LSO's Perspective

E. AUGMENTED REALITY APPLICATION AND MAGIC BOOK INTERACTION

Several methods of interaction were incorporated for users to be able to interact with the system. The use of voice, hand controllers, and Leap Motion controller was discussed previously in the chapter. There was however, one additional form of interaction that was developed towards the end of the project—an AR interface (Figure 52).

Figure 52. Augmented Reality Demonstration of the Created Virtual Environment (VE)



We experimented with the AR feature on a smart phone that uses a version of the prototype LSO Trainer. In that application, the camera on the phone tries to “find” a predetermined image target it is looking for. When target is found it then orients the whole simulation around it. The user can manipulate the phone and he can orient himself anywhere in the scene to get desired perspective. This type of interaction provides a feasible way of viewing the tasks and environment from an exocentric point of view. This could potentially lead to a greater transfer of learning to the trainee, but more exploration and testing will be required to prove it. Additionally, this method of interaction and scene viewing could provide a natural way for the instructor to manipulate the simulation.

F. CHAPTER SUMMARY

The majority of the issues discussed in Chapter V and reported in the LSO survey, were incorporated into the prototype trainer. The LSO community saw the prototype system as a feasible part-task trainer for the individual positions on the LSO platform (i.e., Deck Calling LSO, Controlling LSO, and Backup LSO). In order for the trainer to reach its full potential, it needs to incorporate a networked solution and support multiple users who would be coupled simultaneously in the same virtual environment.

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VIII. CONCLUSIONS AND RECOMMENDATIONS

A. MAIN CONCLUSION AND RECOMMENDATIONS

This chapter summarizes the main elements of the overall feasibility of the prototype light-weight system. The text also discusses recommended future avenues of development and what further work will need to occur before engaging in a full usability study and training effectiveness study.

1. Main Conclusion

The thesis set out to look at the following three questions:

- Is it feasible to use commercial off-the-shelf (COTS) technologies to develop a virtual reality (VR) trainer for the Landing Signal Officer community?

  Findings from the research and development conducted for this thesis suggest that a light-weight VR trainer for the LSO community is feasible. According to Brooks (1999) the four technologies that are critical for VR:

  - Requirement—Visual, aural, and haptic displays "that immerse the user in the virtual world and block out contradictory sensory impressions from the real world" (p. 16)

    Achieved—Prototype LSOT is able to immerse the user with both a visual and aural displays. The technology does exist to support a haptic display, however this will be recommended follow on work.

  - Requirement—Graphics able to render at 20–30 fps (Brooks, 1999)

    Achieved—The simulation was able to produce a constant framerate above what is described by Brooks. Current standards in VR technology view a framerate below 60 fps as not providing a good experience, because each missed frame is visible (Binstock, 2015). The simulation was able to achieve 60 fps without optimization of models and with the highest quality settings.

  - Requirement—Continuously reporting tracking system of orientation and position of user's head and body limbs (Brooks, 1999)

    Achieved—Oculus provides constant tracking for the head and Leap for the hands (when they are in view of the sensor). Follow on work would use a five point tracking system to keep track of the hand as well as the legs.

- Requirement—"Database Construction and maintenance system for building and maintaining detailed and realistic models of the virtual world" (Brooks, 1999, p. 16)

  *Demonstrated—*Models here can be both 3D geometry and behavior models. Multimillion vertices 3D models were able to be viewed during runtime of the simulation and with the integration of LSODS—a complex interface and its associated behavior demonstrated.

- Requirement—Construct the trainer using all commercial off the shelf (COTS) technology

  Achieved—No specialty ordered or manufactured hardware was used in the construction of the prototype.

- Can major training objectives for the 2H111 be supported using a proof of concept, light-weight, portable VR trainer and a VR HMD as its display solution?

  To provide a firm basis for the claim that it is feasible to support major training objectives with the prototype light-weight trainer, we chose to look at the objectives for each of the simulator sessions for IFGT and see if we were able to integrate the technology or behavior needed to support it.

  - Session 1 (IFGT 1.1)—Review basic waving procedures, reinforce scan techniques

    Demonstrated—Every element that an LSO would use in waving is incorporated in the simulation from devices to the behaviors of personnel in support (e.g., aircraft, LSODS, CATTC, Enlisted Phone Talker, etc.)

  - Session 2 (IFGT 1.2)—Introduction to MOVLAS. Focus on pilots and their response to MOVLAS. Brief techniques to controlling the aircraft. The simulator will always respond to the MOVLAS position, have the instructor take manual control to induce errors to test wave off criteria. No malfunctions or emergencies during session.

  - *Demonstrated*—All elements above are supported including a rudimentary pilot behavior that would respond to the MOVLAS position. Further development would require a more robust behavior model for different versions of the "pilots."

  - Session 3 (IFGT 1.3)—Expand on the first MOVLAS simulation. Introduce emergencies and malfunctions during the simulation.

Demonstrated—The expansion on this from session 1.2, is the ability to access Aircraft Recovery Bulletins (ARBs) for emergencies and malfunctions. The prototype supports the ability to access ARBs in LSODS.

- Session 4 (IFGT 1.4)—Introduce MOVLAS operation during the nighttime. Explain the use of a plane guard for the referencing of the horizon. Cover responsibility of changing radio frequencies to the Backup position. Introduce an aircraft's approach light being out as an emergency.

  *Demonstrated—*Nighttime scenes are available in the simulation including the ability to present "no horizon" scenes. A plane guard was placed in the nighttime scenes and approach lights can be manipulated. One topic not supported with the current implementation is the ability to change radio frequencies. This is straightforward; it can be done easily, and it is marked for future work.

- Session 5 (IFGT 1.5)—Introduce LSO talkdown procedures and techniques. Start waving aircraft in poor weather.

  Demonstrated—The prototype has voice recognition in support of future pilot behaviors. Additionally, the aircraft can be controlled directly by the instructor to enforce learning points.

- Session 6 (IFGT 1.6)—Introduce barricade procedures. LSO team will look through Aircraft Recovery Bulletins to deal with varying aircraft emergencies.

  Demonstrated—ARBs are supported for these learning points, however the one missing piece is the mesh and animation for the barricade. This again is straight forward and it is marked for future work.

- The LSOs that the system was demonstrated to were generally happy with the overall system, and could see the value immediately as a part-task trainer. They did notice some (smaller) discrepancies with the LSODS and some awkwardness in the controller scheme when trying to perform certain actions, but were genuinely impressed by the "look" and "feel" of the simulation.

- What are the additional computational and training capabilities that go beyond the functionalities provided in 2H111, that this novel setup can support??

This was not explored to greater extent because of the time constraints. The three features are recommended for future work (and can be easily supported by the development environment and input/output infrastructure used for the prototype):

- Data Analytics—significance discussed in Chapter V.D.5 and data would be straight forward to collect with the sensors available.
- Networked Training—Question posed to LSOs in Figure 19 in which the idea was viewed as favorable. Unity has the infrastructure to support the capability.
- Exocentric point of view (demonstrated in Figure 52). The ability to view the aircraft recovery process from an unrestricted number of independent viewpoints could be a great improvement from current practice, however formal tests would need to be done to fully validate this claim. With that said, in the author's prior experience during operational workups, LSOs have drawn on a whiteboard to show to the pilots what the sight picture of the aircraft carrier should look like during portions of the recovery. This technology could enable the aircrew to view what the geometry should look like within the VE, and apply that sight picture to actual flying operations.

2. Recommendations

A set of future research and development efforts are recommended on the project to fully implement and test the features that were implemented so far and to construct interfaces noted as desired but which were not pursued because of the time constraints. It would be important to continue the work on this system for three reasons:

- From the Navy operational point of view, the LSOs are a linchpin to the ability to land aircraft on an aircraft carrier, a position where mishaps can occur if the job is not performed well. The current model has gaps in training as identified in Chapter V. Since scaling up the current method of training is not feasible, the alternative and augmented solutions need to be explored to produce, train and maintain the caliber of LSOs that are needed.
- From the standpoint of the human factors and training domain, LSOs could represent a use case community for team performance in virtual environments. To effectively execute the job of an LSO, it requires the acquisition of multiple sensory inputs and strenuous cognitive processing. Additionally, the job of LSO occurs in a condensed amount of time (15–18 seconds), with very little time to make corrections. These qualities make it a good model to test technology for the advancement of extreme

training situations with rigorous performance demands, and apply that understanding not only to the LSO community, but also to other domains that have similar requirements.

- The proposed trainer would be a feasible test bed for integration of future LSO technology. Testing could include augmented reality headset systems used in an operational capacity, as well as a modified interface of the LSO Display System. These systems could both be tested cheaply for their feasibility before expensive hardware prototype gets developed.

B. MAIN CONTRIBUTIONS

The work that was conducted for this thesis contributes to the body of knowledge in several domains. First is the process of testing and acknowledgement of what COTS technology is now able to support. A robust IVE was created on a compressed schedule using multiple pieces of hardware as interfaces. In addition, having constructed the VE to run off of a laptop, it represents a potential disruption to the current methods of training. Further analysis will have to be done to understand the user implications of this (i.e., what are the transfer of training differences between an IVE and a legacy simulator system with an instructor). We believe that it will vary with the type of training and interfaces required; some types of training environments and training procedures are expected to be better suited to IVEs, while others will still be better on traditional simulators. Formal user studies would need to be performed to understand which is better for each use case.

The second advancement is in the body of knowledge for tasks that are performed by the various LSO positions as well as the LSO team as a whole, as outlined in Chapter IV. These tasks, when aligned with the interfaces that these positions work with can be start of the process of identifying formal performance parameters for LSOs.

In the domain of general military research, the work included the construction of a VE that replicated the environment an LSO would encounter in the operational setting. With the VE constructed on a light-weight system, this system would not only serve as a training tool for the LSO community, but it would also enable cognitive scientists more flexible access to a number of data sets that can be collected as they try to evaluate and understand the job and performance of LSOs. This gets back to the emphasis on *access*:

with this novel arrangement, now a number of researchers can go to wherever the LSOs are located to perform data collection and research (this could possibly include tests on an embarked aircraft carrier). Insights that could advance understanding of requirements on LSOs would not only benefit the light-weight system itself where the experiments were being performed, but it should also result in a better understanding of requirements for upgrades to the legacy 2H111 system.

This study has also contributed to the field of VR by putting forward an example of the feasibility of an immersive training system. As noted previously in A.2 Recommendations, as a part of their jobs, LSOs require an array of sensory inputs to process and make cognitive decisions. Lessons derived from cognitive scientists about the way these decisions are made could help yield better understanding about other communities with similar requirements.

C. FUTURE WORK

As mentioned throughout this work, there are many features of the light-weight prototype LSO Training system that are recommended to be implemented at some time in the future, if it is desired to be developed into a robust training solution. A high level list of concepts that should be considered include:

- *Networked environment*: Create a networked environment of federates to support team training and support the inception of a shared virtual environment.
- *Team gestures with haptic input:* Create a mechanism to generate and transmit "touch" in virtual environment. LSOs sometimes pass nonverbal communication to each other by using a touch (e.g., tap on the shoulder or smack on the arm) because of the high noise levels on the flight deck of an aircraft carrier.
- *Auditory communication*: Create multiple levels of communication, from one person to another, to group conversation, to announcements (broadcasts) to every user in the system.
- *Physics*: Add accurate simulation of physics phenomena. It would be necessary to include dynamically accurate aircraft and carrier models to support the work of the LSOs.

- *Simulated audio cues*: Capture a variety of power settings of the aircraft engines while on approach to have more realistic simulation of sounds that an LSO would hear on the real-life platform.
- *Navigation in 3D environment*: Implement a “natural” form of navigation in which the Oculus headset and hand controller hardware work cohesively, and create a method for navigation with Leap Motion controller.
- *Animations*: In order to “give life” to certain objects, it is recommended to introduce realistic animations of some visual events (e.g., wire payout when an aircraft catches a wire).
- *LSO Display System*: Not all segments of LSODS screen behaviors were implemented due to time; future work would include incorporating remaining behaviors, including those which have been further updated since the publishing of the formal LSODS documentation.

Finally, prior to giving this system to LSOs for their training, it is necessary to conduct thorough tests of this system; those would include both a usability study as well as training effectiveness and transfer of training studies.

D. SUMMARY

Using all off the shelf technology and only about 5 months of extensive developmental effort we have successfully shown that a light-weight VR LSO trainer is indeed feasible. “Charlie” is the signal phrase that is used to indicate that the aircraft carrier is now ready for the recovery of the aircraft. The aircraft carrier turns and steams into the wind, effectively making the letter “C” with its wake. The need for the LSOs to have *access* to high quality, dispersed trainers is not a unique requirement to the LSO community, and many domains have gone through that process already. Technology has now come far enough to support the content, procedures, techniques and complex interactions within a VE, and finally support difficult training requirements that this community deems important. Signal “Charlie” Navy—time to make the Immersive VR Leap.

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APPENDIX A. LSO SCHOOL DOCUMENTATION

IFGT 1.1—DAY FUNDAMENTALS

- Day waving techniques and procedures
- Duration: 1.0 hours
- Simulator Load:
  - IFGT Day 60 AC (Consider Growler/Prowler)
  - Deck Motion—1
  - Dutch Roll—1
  - Wind—25–30 kts
  - All rhino 480 SWS

Brief: Discuss team responsibilities. Tell them what type of emergencies to expect. (Gear/lens settings, phone talker says wrong aircraft, foul deck, etc.) Give techniques for scanning LSODS winds, SWS, hook-to-eye, etc.

Conduct: This simulator is designed to review basic waving procedures and techniques. After the students get comfortable, begin to test them by introducing malfunctions. (Wrong cross check, wind out of limits, foul deck with no calls, etc.) If and when instruction takes place, consider freezing and muting the sim so that the entire team can learn from what you are saying.

As the simulator progresses, the students will become comfortable with the fact that the sim flies good passes for the most part. Take control of the active aircraft and test the back-up by flying left or right. Purposely fail to respond adequately to a line-up call to test their wave-off criteria. After the pass, whether they waved the aircraft off or not, freeze and mute the sim to give on the spot feedback for the entire team when needed. Continue to do this with line-up and glideslope as the sim continues.

Debrief: Give a short debrief in the simulator while it is fresh in your mind as well as theirs. Invite questions or discussions as needed. Make sure to cover the goods and others. At a minimum, discuss: Voice inflection, timeliness of power/line-up calls, foul deck awareness, LSOD scan, etc. Stress the importance of the building block approach. Remind them that the basic concepts of good platform discipline must be mastered before foul weather, MOVLAS, and Barricade

IFGT 1.2—DAY MOVLAS INTRO

- Day waving techniques and procedures
- MOVLAS introduction

- Duration: 1.0 hours
- Simulator Load:
  - IFGT Day 60 AC (Consider Growler/Prowler)
  - Deck Motion—2 to 3
  - Dutch Roll—1
  - Wind—25–30 kts
  - All rhino 480 SWS
  - Carrier set to MOVLAS
  - Consider adjusting pilot response time to better reflect a nugget flying MOVLAS

Brief: Focus on the differences associated with MOVLAS (sight picture as compared to IFLOLS, nugget's tendency to not respond to MOVLAS, moving the MOVLAS stick too fast, etc). Ensure they understand the concept of "flying the jet" as compared to being a glideslope repeater. Make large corrections early. Show large deviations at the start to get the jet going in the right direction. Offer techniques for getting ahead of the jet, and staying ahead of the jet. (My technique is an on and on start, show them a little low in the middle to get power on the jet and to preserve hook to ramp, and then show them a rising ball in-close to at the ramp.) Teach them the danger associated with planting the ball at the top of the lens for too long or when an aircraft is in close to at the ramp. Review Hornet 904 codes and Hornet max trap with MOVLAS. Review the use of an "attitude" call to get the Hornet to rotate prior to touchdown and preventing a 904 code. Teach them to use the horizon and to fight the temptation to mirror the deck motion with MOVLAS. Have them start waving the jet at the 90, don't wait until the jet rolls into the grove to show them a deviation with the MOVLAS. Have them put the MOVLAS on the red cell when not waving a jet. Remind them that the pass is called off of the MOVLAS, not off of what the jet actually did.

Conduct: This simulator is designed to get the student comfortable with waving MOVLAS. As the simulator progresses, the students will become comfortable with the fact that the jet responds to the MOVLAS. This will lull them into a false sense of security. Occasionally take control of the active aircraft and milk a low or induce a line-up error to test the wave-off criteria of the LSO team. Additionally, induce a long bolter situation by becoming overpowered in the middle to see if they will hit the lights or not. Focus on waving with MOVLAS, do not introduce any emergencies during this sim. If you see them waving off of the PLAT or mirroring the pitching deck, freeze the sim and debrief. Stress the importance of using the horizon.

Debrief: Give a short debrief in the simulator while it is fresh in your mind as well as theirs. Invite questions or discussions as needed. Make sure to cover the goods and others. At a minimum, discuss: Voice inflection, timeliness of power/line-up calls, foul deck awareness, LSOD scan, MOVLAS technique, etc. Stress the importance of being proactive with the MOVLAS.

IFGT 1.3—DAY MOVLAS PRACTICE

- Day waving techniques and procedures
- MOVLAS practice
- Duration: 1.0 hours
- Simulator Load:
    - IFGT Day 60 AC (Consider Growler/Prowler)
    - Deck Motion—3 to 4
    - Dutch Roll—2
    - Wind—25–30 kts
    - All rhino 480 SWS
    - Carrier set to MOVLAS
    - Consider adjusting pilot response time to better reflect a nugget flying MOVLAS

Brief: Expand on the first MOVLAS sim. Discuss the goods and others of the first MOVLAS sim and review MOVLAS techniques. Explain that emergencies will be introduced in this sim (foul deck, cross check, LSOD failure, etc.) Review wave-off criteria (including line-up) and long bolter considerations. Explain that the deck will be moving a bit more than the last sim, and remind them not to use the PLAT or mirror the deck movement with the MOVLAS.

Conduct: This simulator is designed for the student to practice MOVLAS with a pitching deck and dealing with minor emergencies on the platform. Occasionally take control of the active aircraft and milk a low or induce a line-up error to test the wave-off criteria of the LSO team. Additionally, induce a long bolter situation by becoming overpowered in the middle to see if they will hit the lights or not. Introduce crosscheck failures and other minor LSO Platform emergencies. If you see them waving off of the PLAT or mirroring the pitching deck, freeze the sim and debrief. Stress the importance of using the horizon.

Debrief: Give a short debrief in the simulator while it is fresh in your mind as well as theirs. Invite questions or discussions as needed. Make sure to cover the goods and others. At a minimum, discuss: Voice inflection, timeliness of power/line-up calls, foul deck awareness, LSOD scan, MOVLAS technique, etc. Stress the importance of being proactive with the MOVLAS.

IFGT 1.4—NIGHT MOVLAS INTRO

- Night waving techniques and procedures
- Night MOVLAS intro and practice

- Duration: 1.0 hours
- Simulator Load:
  - IFGT Night 60 AC (Consider Growler/Prowler)
  - Deck Motion—2 to 3
  - Dutch Roll—1 to 2
  - Wind—25–30 kts
  - Dark, no moon, no stars
  - All rhino 480 SWS
  - Carrier set to MOVLAS
  - Consider adjusting pilot response time to better reflect a nugget flying MOVLAS

Brief: Explain that the mechanics are the same at night as during the day. Remind the students that the overwhelming majority of aircraft show up to an "on and on" start at night in the sim and in the fleet. This is a huge advantage to the LSO and helps the LSO proactively "fly" the jet with MOVLAS since we don't have to correct for a poor start. Explain the use of a plane guard for the HRU (horizon reference unit). It is a ship in the simulator and will disappear as the visibility is reduced. Stress the importance of using the plane guard for the horizon and fighting the temptation to use the carrier edge lights on the back of the ship as the reference. The tendency at night is to bring the aircraft in high. Remind the LSO team that the back-up LSO will be responsible for ensuring that the proper radio is selected (button 15 or 17).

Conduct: This simulator is designed to introduce waving at night with MOVLAS. This is the first sim done at night. After turning the lights out, give the LSO team an opportunity to set up the LSOD lighting intensity correctly before bringing the sim off of freeze. Start the sim out with the deck motion on about 2 and move each student through the controlling position after about 4 or 5 passes. Once each student has waved, turn the deck motion up to 3 and begin introducing cross check errors and foul deck scenarios. Try turning the approach light off on the approaching aircraft as far out as possible. If detected before the ball call, the correct procedure is to ask the aircraft to "show me a fast." If detected inside the ball call, the correct procedure is to wave the aircraft off. If not detected and the aircraft is allowed to land, freeze the sim and debrief what happened. Occasionally they will ask to see a fast inside of the ball call. This is not a good idea and needs to be debriefed as well. Additionally, consider taking control of the aircraft and milk a low or introduce a lineup error to test wave-off criteria.

Debrief: Give a short debrief in the simulator while it is fresh in your mind as well as theirs. Invite questions or discussions as needed. Make sure to cover the goods and others. At a minimum, discuss: Voice inflection, timeliness of power/line-up calls, foul deck awareness, LSOD scan, MOVLAS technique, etc. Stress the importance of being proactive with the MOVLAS.

IFGT 1.5—FOUL WEATHER/NONSTANDARD

- Day/Night waving in poor visibility/pitching deck
- LSO talkdowns
- Duration: 1.0 hours
- Simulator Load:
    - IFGT Night 60 AC (Consider Growler/Prowler)
    - Deck Motion—Various
    - Dutch Roll—Various
    - Wind—25–30 kts
    - Weather—Various
    - All rhino 480 SWS
    - MOVLAS and/or IFLOLS
    - Consider adjusting pilot response time to better reflect a nugget flying MOVLAS

Brief: Discuss the procedure for an LSO talkdown. Explain the difference between "Paddles Contact" and "Continue." Explain that the paddles contact and continue calls are often misunderstood in the fleet. As a technique, offer adding "fly your needles" to the end of the continue call. Explain that by adding this, you will remind the pilot to continue only to the DH. Explain that in severe circumstances, a paddles contact call can be made and an LSO talkdown can occur off of the needles only. This is something that will be decided by the CO of the ship and CAG and is an emergency procedure. Offer an example of a good cadence between the controlling and back-up LSO during a talkdown. Remind the students that scan breakdown of the LSODs can and will occur during a low visibility scenario. Recording the pass, other than side number and wire, is pretty low on the priority list during a very low visibility scenario. Stick to the basics and worry more about the next jet than what just happened. The airwing will understand. Brief the use of MOVLAS during pitching deck in conjunction with low visibility. Take into account the amount of time the pilot is looking at the ball. If they are breaking out very late, rigging the MOVLAS may be more of a hindrance. Consider using a paddles talkdown instead of worrying about the MOVLAS. Task saturation on the LSO is a bad thing.

Conduct: Set the sim up for a day case III recovery (using a night setting with the AC so they will be straight-ins). Brief the students that the expected weather for this recovery is a 500 foot ceiling and that the pilot may be in the weather at the time of the ball call. The students should put a "99, taxi lights on" call out. I would recommend putting that call out on buttons 15,16,17, and 2. That will give the tanker pilots SA. Continue to bring the weather down and test the student's SA by noting if they wave the pilot off when he reaches about ½ mile. The pilot should monitor his own approach, but if the LSO has SA that he is at his DH, a wave-off is the correct call from the LSO. Allow the students to practice talk downs and monitor the cadence between the controlling and back-up LSO. Test the student's SA by dropping the ACLS lock or by taking the controls and flying the jet to poor parameters. Change the conditions of the sim (day, night, ceiling, deck movement, etc) Consider bringing the mins below DH and brief the students that they were given permission to report a paddles contact off of needles for a zero/zero or near zero/zero recovery.

Debrief: Give a short debrief in the simulator while it is fresh in your mind as well as theirs. Invite questions or discussions as needed. Make sure to cover the goods and others. At a minimum, discuss: Voice inflection, cadence of controlling and back-up, timeliness of power/line-up calls, foul deck awareness, LSOD scan, MOVLAS technique, etc. Stress the importance of being proactive with the MOVLAS if used and overall SA.

IFGT 1.6—BARRICADE SIM

- Day Barricade
- ARB practical application
- Duration: 1.0 hours
- Simulator Load:
    - IFGT Night 60 AC (Consider Growler/Prowler)
    - Barricade setting on carrier
    - Deck Motion—2
    - Dutch Roll—1
    - Wind—25–30 kts
    - All rhino 480 SWS
    - IFLOLS

Brief: Ensure the team has a copy of the ARBs and something to write on. Explain that you will give them several scenarios that require the barricade. **Deciding on whether or not to barricade is not part of the simulation,** tell them the decision was made by the CO of the ship and CAG and that they are only required to work the ARBs and recover the aircraft. Brief them that the Air Boss (simulator operator) will be working the ARBs from the tower and will cross check one another. Put the sim on freeze so that they will not have to recover aircraft, but leave the noise on. Recommend that they assign duties to the team. Obviously some of them will work the numbers, someone needs to answer the phone as it will likely be ringing off the hook…literally. Add to the confusion by calling the platform and interjecting info. Make sure they know how to answer the phone on the LSODs and remind them that they are on a hot mike and don't need to press the button. Instruct them to rotate after each one controls one barricade. Make each controlling LSO give the barricade brief to the pilot. The sim operator will play the role of the pilot about to barricade. Remind them that the **Deck**

status will remain foul during the barricade. Remind them to brief the pilot on the ability to influence the nose (nose down) if called in order to get the aircraft's nose below the upper loading strap of the barricade.

Conduct: Set the sim up with 60 **night** aircraft. This is because a barricade recovery will in all likelihood be off of a straight-in approach. Allow the team to wave a few normal landings and then put the sim on freeze. The 4 canned scenarios are listed in detail on the following pages. Have the aircraft emergencies page pulled up on the sim, and when the controlling LSO calls for "cut, cut, cut" engage the engine failure left and right. Do 4 complete barricade scenarios in a row. After the completion of the 4th and final barricade scenario, leave the barricade up and allow them to practice waving a barricade without doing ARBs or the barricade brief. On the remaining barricade practice, take control of a few of the aircraft and purposely put the aircraft outside of safe parameter for a successful barricade to test the wave-off criteria of the team.

E-2C—2003 TR E-2C drifted right on bolter and wingtip hit turning prop on a parked E-2C.

- DA 500', Wind Avail 34 kts, IAS at 46K=115 (answer: 44K max trap/Barricade setting)
- HTDP 154', H/E 15.0'

F/A-18F—Hook Slap

- DA 2,300', Wind Avail 35 kts (answer: 39K max trap/Barricade setting)
- HTDP 148', H/E 17.15'

E/A-18G—Nose gear and one main gear trailing (able to retract)

- DA 1,400', Wind Avail 35 kts (answer: 43K max trap/Barricade setting)
- HTDP 148', H/E 17.15

F/A-18C—Stub nose gear

- DA 1,512', Wind Avail 33 kts (answer: 33K max trap/Barricade setting, 25–30kts)
- HTDP 142', H/E 16.35'

Debrief: Give a short debrief in the simulator while it is fresh in your mind as well as theirs. Invite questions or discussions as needed. Make sure to cover the goods and others. At a minimum, discuss: Voice inflection, cadence of controlling and back-up, barricade brief to pilot, timeliness of power/line-up/cut calls, foul deck awareness, LSOD scan, etc. Stress the importance of an early wave-off from a barricade.

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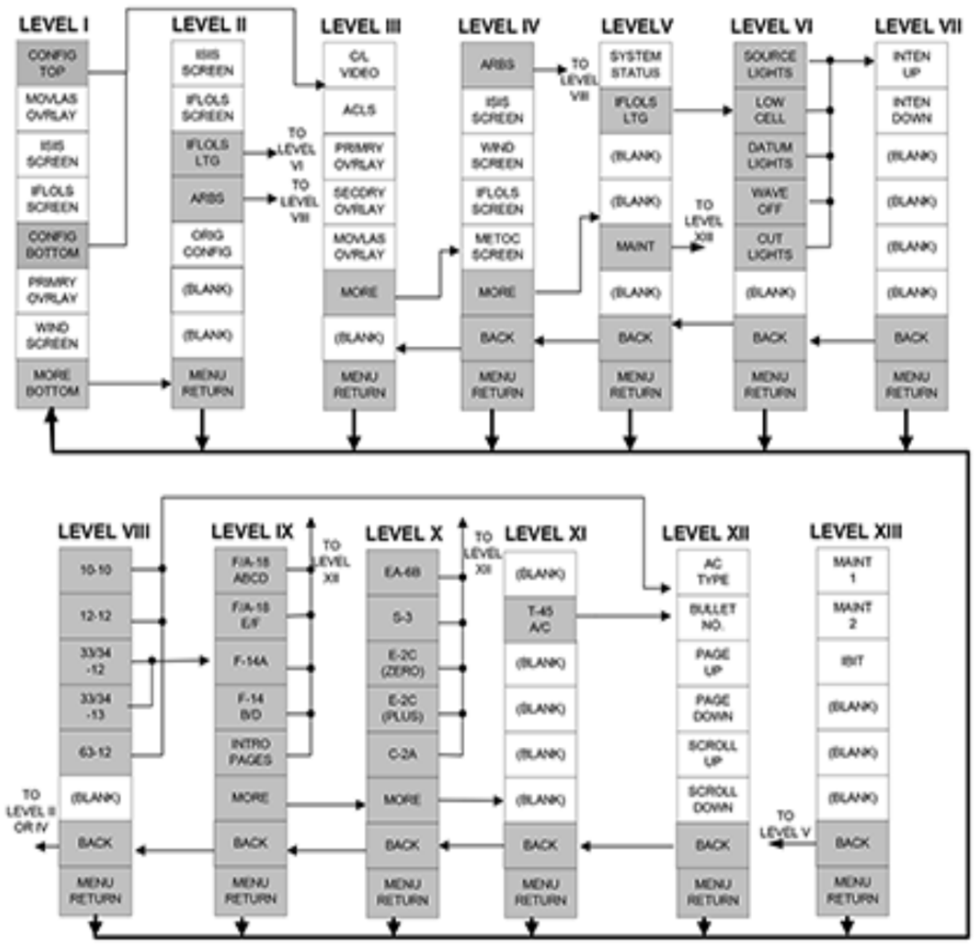
APPENDIX B. LSO DISPLAY SYSTEM BUTTON LOGIC



LEVEL 1 AND 2 LSODS BUTTON LOGIC

Level I – Operator Main Screen Select Menu

SWITCH LEGEND	ACTION
CONFIG TOP	Advance the switch legend to Level III. Any selections that the operator makes at Levels III, IV, or V will affect only the upper display.
MOVLAS OVRLAY	Show the MOVLAS Overlay Screen on the upper display with Centerline Recovery video.
ISIS SCREEN	Show the ISIS Screen on the upper display.
IFLOLS SCREEN	Show the IFLOLS Screen on the upper display.
CONFIG BOTTOM	Advance the switch legend to Level III. Any selections that the operator makes at Levels III, IV, or V will affect only the lower display.
PRIMRY OVRLAY	Show the Primary Overlay Screen on lower display with the Centerline video.
WIND SCREEN	Show the Wind Display Screen on the lower display.
MORE BOTTOM	Advance the switch legend to Level II.

Level II – Lower Display Screen Select Menu

SWITCH LEGEND	ACTION
ISIS SCREEN	Show the ISIS Screen on the lower display.
IFLOLS SCREEN	Show the IFLOLS Screen on the lower display.
IFLOLS LTG	Advance the switch legend to Level VI. Show the IFLOLS Lighting screen on the lower display.
ARBS	Advance the switch legend to Level VIII. Any selections that the operator makes at Level VIII will affect only the lower display.
ORIG CONFIG	Show Primary Overlay with centerline video on upper panel display. Show Secondary Overlay with ACLS on lower panel display. Remain at switch legend Level II.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
MENU RETURN	Revert to the switch legend Level I.

LEVEL 3 AND 4 LSODS BUTTON LOGIC

Level III – Configuration Menu 1

SWITCH LEGEND	ACTION
C / L VIDEO	Switch recovery video to Centerline on overlay screen.
ACLS	Switch recovery video to ACLS on overlay screen.
PRIMRY OVRLAY	Show the Primary Overlay Screen with the Centerline video.
SECDRY OVRLAY	Show the Secondary Overlay Screen with the ACLS video.
MOVLAS OVRLAY	Show the MOVLAS Overlay Screen with Centerline video.
MORE	Advance the switch legend to Level IV.
(BLANK)	No switch action or legend displayed.
MENU RETURN	Revert to the switch legend Level I.

Level IV – Configuration Menu 2

SWITCH LEGEND	ACTION
ARBS	Advance the switch legend to Level VIII.
ISIS SCREEN	Show ISIS Screen on the Level 1 selected upper or lower display.
WIND SCREEN	Show Wind Display Screen on the Level 1 selected upper or lower display.
IFLOLS SCREEN	Show IFLOLS Screen on the Level 1 selected upper or lower display.
METOC SCREEN	Show Meteorological Screen on the Level 1 selected upper or lower display.
MORE	Advance the switch legend to Level V.
BACK	Revert to the switch legend at Level III.
MENU RETURN	Revert to the switch legend at Level I

LEVEL 5 AND 6 LSODS BUTTON LOGIC

Level V – Configuration Menu 3

SWITCH LEGEND	ACTION
SYSTEM STATUS	Show System Status Screen on the Level 1 selected upper or lower display.
IFLOLS LTG	Advance the switch legend to Level VI. Show IFLOLS Lighting Screen on the Level 1 selected upper or lower display.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
MAINT	Advance the switch legend to Level XIII. Show Maintenance Screen 1.
(BLANK)	No switch action or legend displayed.
BACK	Revert to the switch legend at Level IV
MENU RETURN	Revert to the switch legend at Level I

Level VI – IFLOLS Light Select Menu

SWITCH LEGEND	ACTION
SOURCE LIGHTS	Highlight "SOURCE LIGHTS" text box on IFLOLS Lighting Screen. Advance the switch legend to Level VII to provide operator control of the selected lights.
LOW CELL	Highlight "LOW CELL" text box on IFLOLS Lighting Screen. Advance the switch legend to Level VII to provide operator control of the selected lights.
DATUM LIGHTS	Highlight "DATUM LIGHTS" text box on IFLOLS Lighting Screen. Advance the switch legend to Level VII to provide operator control of the selected lights.
WAVE OFF	Highlight "WAVE OFF" text box on IFLOLS Lighting Screen. Advance the switch legend to Level VII to provide operator control of the selected lights.
CUT LIGHTS	Highlight "CUT LIGHTS" text box on IFLOLS Lighting Screen. Advance the switch legend to Level VII to provide operator control of the selected lights.
(BLANK)	No switch action or legend displayed.
BACK	Revert to the switch legend at Level II or Level V, depending on the origin of the IFLOLS Lighting command and the previously shown recovery or data screen.
MENU RETURN	Revert to the switch legend at Level I and the previously shown recovery or data screen.

LEVEL 7 AND 8 LSODS BUTTON LOGIC

Level VII – IFLOLS Lighting Control Menu

SWITCH LEGEND	ACTION
INTEN UP	Increase the intensity of the selected IFLOLS lights by one increment. If the lights are at their maximum intensity, this button will be inactive.
INTEN DOWN	Decrease the intensity of the selected IFLOLS lights by one increment. If the lights are at their minimum intensity, this button will be inactive.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
BACK	Revert to the switch legend at Level VI
MENU RETURN	Revert to the switch legend at Level I and the previously shown recovery or data screen.

Level VIII – ARB Select Menu

SWITCH LEGEND	ACTION
10-10	Advance the switch legend to Level XII. Show ARB 10-10 on the display.
12-12	Advance the switch legend to Level XII. Show ARB 12-12 on the display.
33/34 -12	Advance the switch legend to Level IX
33/34 -13	Advance the switch legend to Level IX
63-12	Advance the switch legend to Level XII. Show ARB 63-12 on the display.
(BLANK)	No switch action or legend displayed.
BACK	Revert to the switch legend at Level II or at Level IV, depending on origin of ARB command.
MENU RETURN	Revert to the switch legend at Level I.

LEVEL 9 AND 10 LSODS BUTTON LOGIC

Level IX – ARB 29/33/34-12/13 Aircraft Type Select Menu 1

SWITCH LEGEND	ACTION
F-18 ABCD	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the F/A-18 A/B/C/D on the display.
F/A-18 E/F	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the F/A-18 E/F on the display.
F-14A	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the F-14A on the display.
F-14 B/D	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the F-14 B/D on the display.
INTRO PAGES	Advance the switch legend to Level XII. Show the Level VIII selected ARB Introductory /Cover pages on the display.
MORE	Advance the switch legend to Level X
BACK	Revert to the switch legend at Level VIII.
MENU RETURN	Revert to the switch legend at Level I.

Level X - ARB 29/33/34-12/13 Aircraft Type Select Menu 2

SWITCH LEGEND	ACTION
EA-6B	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the EA-6B on the display.
S-3	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the S-3 on the display.
E-2C (ZERO)	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the E-2C (ZERO) on the display.
E-2C (PLUS)	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the E-2C (PLUS) on the display.
C-2A	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the C-2A on the display.
MORE	Advance the switch legend to Level XI.
BACK	Revert to the switch legend at Level IX.
MENU RETURN	Revert to the switch legend at Level I.

LEVEL 11 AND 12 LSODS BUTTON LOGIC

Level XI - ARB 29/33/34-12/13 Aircraft Type Select Menu 3

SWITCH LEGEND	ACTION
(BLANK)	No switch action or legend displayed.
T-45 A/C	Advance the switch legend to Level XII. Show the Level VIII selected ARB ("33/34-12" or "33/34-13") for the T-45 A/C on the display.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
BACK	Revert to the switch legend at Level X.
MENU RETURN	Revert to the switch legend at Level I.

Level XII – ARB Page Control Menu

SWITCH LEGEND	ACTION
(Aircraft Type)	For ARBs 33/34-12 and 33/34-13 the switch legend will display the selected aircraft type.
(Bulletin Number)	The switch legend will display the bulletin number that is currently being displayed.
PAGE UP	Show the previous page of the recovery bulletin. If the first page of the document is being displayed and the "page up" button is depressed, display the last page of the recovery bulletin.
PAGE DOWN	Show the next page of the recovery bulletin. If the last page of the document is being displayed and the "page down" button is depressed, display the first page of the recovery bulletin.
SCROLL UP	Show the upper three-quarters of the ARB page.
SCROLL DOWN	Show the lower three-quarters of the ARB page.
BACK	Revert to the switch legend at Level VIII or Level XI, depending on origin, and the previously shown recovery or data screen.
MENU RETURN	Revert to the switch legend at Level I and the previously shown recovery or data screen.

LEVEL 13 LSODS BUTTON LOGIC

Level XIII – Maintainers Menu

SWITCH LEGEND	ACTION
MAINT 1	Show Maintenance Screen 1 on the Level 1 selected upper or lower display.
MAINT 2	Show Maintenance Screen 2 on the Level 1 selected upper or lower display.
IBIT	Initiate WPA IBIT.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
(BLANK)	No switch action or legend displayed.
BACK	Revert to the switch legend at Level V.
MENU RETURN	Revert to the switch legend at Level I.

APPENDIX C. SURVEY

1. What level of LSO designation have you achieved? *

Please select at most one answer

Please choose **all** that apply:

☐ Staff LSO or higher

☐ Training LSO

☐ Wing LSO

☐ Squadron LSO

☐ Field LSO

☐ No qualification achieved

Staff LSO	6
Training LSO	4
Wing LSO	6
Squadron LSO	7
Field LSO	9
No Qualification	3
Total	35

2. Have you attended IFGT and/or experienced the LSO Trainer (2H111)? *

Please choose **only one** of the following:

☐ Yes

☐ No

Qualification Level	Yes	No	Did not respond	Overall Total
Staff	6	0	0	
Training	4	0	0	
Wing	6	0	0	
Squadron	6	1	0	
Field	7	2	0	
No Qualification	0	3	0	
Total	29	6	0	35

* If subjects identified that they had not attended the LSO School for IFGT they would not be able to answer certain questions pertaining to the LSOT 2H111. Those questions will be marked with an asterisk below each question.

3. Have you ever instructed on LSO Trainer (LSOT 2H111)?

Please choose **only one** of the following:

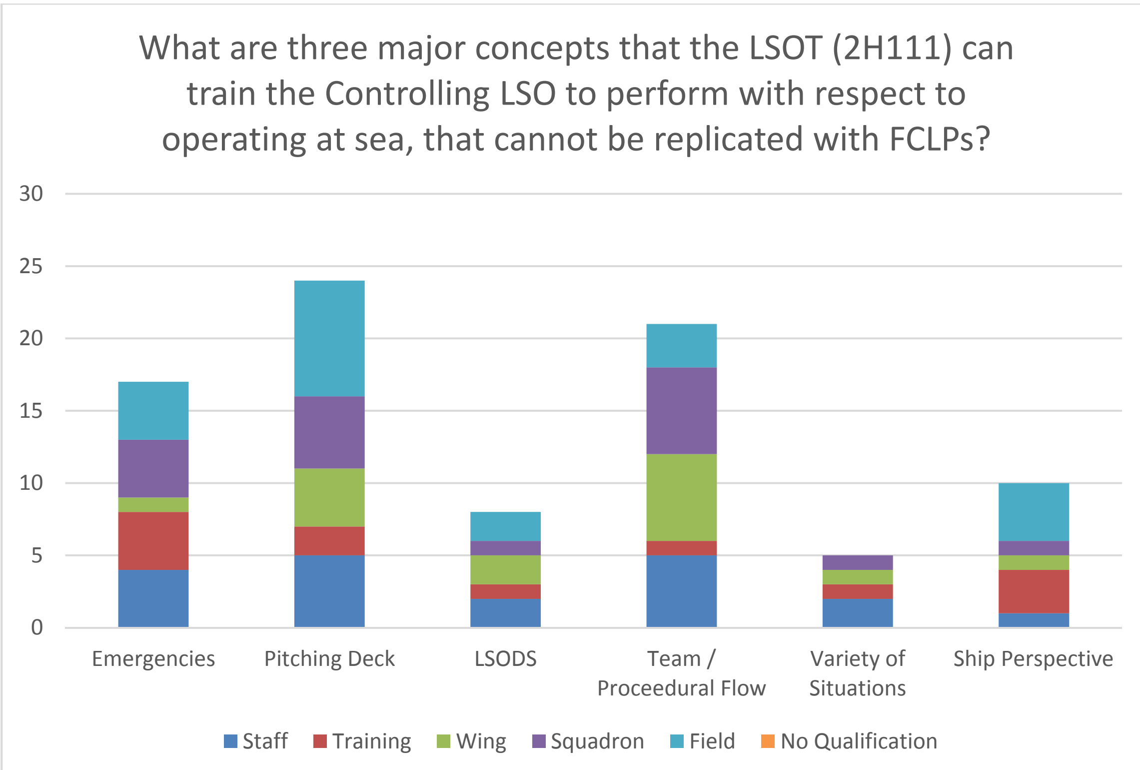
☐ Yes

☐ No

Qualification Level	Yes	No	Did not respond	Not able to answer	Overall Total
Staff	1	5	0	0	
Training	2	2	0	0	
Wing	1	5	0	0	
Squadron	0	6	0	1	
Field	0	7	0	2	
No Qualification	0	0	0	3	
Total	4	25	0	6	35

* Only subjects that identified that they had attended the LSO School for IFGT were allowed to answer this question.

4. What are three major concepts that the LSOT (2H111) can train the Controlling LSO to perform with respect to operating at sea, that cannot be replicated with FCLPs?



* Only subjects that identified that they had attended the LSO School for IFGT were allowed to answer this question. The following six LSOs were affected by this:

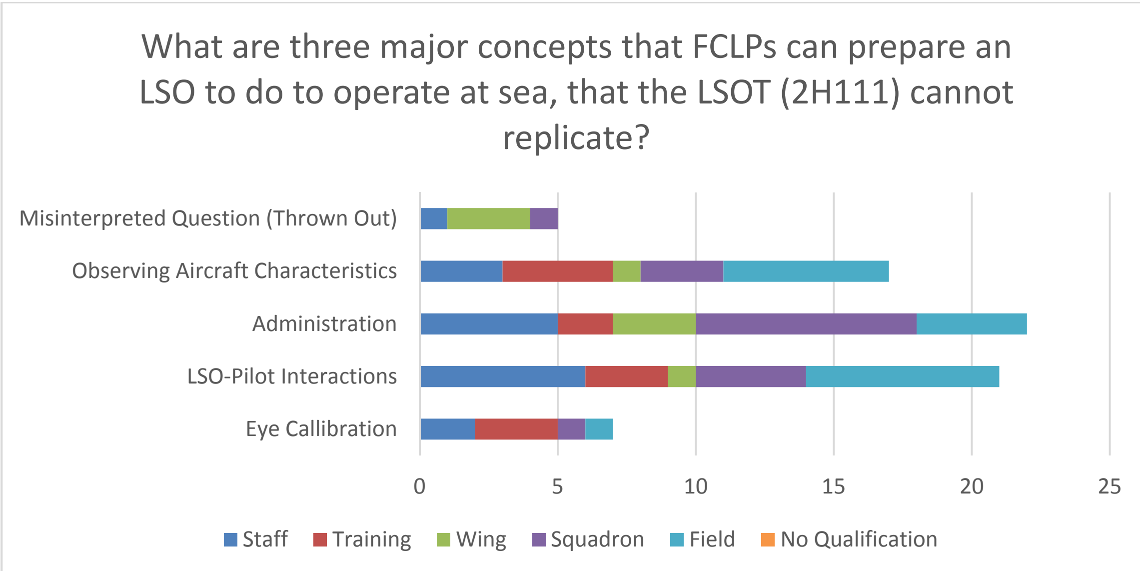
- One Squadron LSO
- Two Field LSOs
- Three No Qualification LSOs

Qualification Level	Emergencies	Pitching Deck	LSODS	Team / Procedural Flow	Variety	Ship Perspective
Staff	Aircraft Emergencies	Marginal wx/sea state conditions	CASE III/night recoveries with full LSODS	Standing the position while the rest of the positions are manned.	Dissimil ar Aircraft During Recoveri es	Ship sight picture
	Emergencies	Pitching deck	LSOD operation and Scan	Team Duties	Variable weather condition s day and night	
	Emergencies	Increasing difficulty of Sea State and Pitching Deck		Carrier atmosphere		
	Platform/Equipme nt Malfunctions	LSO Decision Making for MOVLAS VS IFLOS WRT conditions		Procedural flow on the platform		
		Carrier MOVLAS Operation with pitching deck		Going through all the phases of controlling a pass from a clear deck to calling and grading the pass.		
Qualification Level	**Emergencies**	**Pitching Deck**	**LSODS**	**Team / Procedural Flow**	**Variety**	**Ship Perspective**
Training	Abnormal configurations	Practice day and night MOVLAS mechanics	Overall LSOD operation	Seeing everything in context, i.e., seeing all flight deck personnel in their positions and how they interact with each other on an actual flight deck.	Identify gross glideslop e deviation s	Realistic perspective, i.e., seeing the glideslope from the same angle as you'd see at the boat.
	Abnormal approaches (extremely off parameters)	Pitching Deck				Deck Motion/Ship movement.

	Emergencies in a safe environment					Develop confidence in commanding wave offs
	Barricades					
Qualification Level	**Emergencies**	**Pitching Deck**	**LSODS**	**Team / Procedural Flow**	**Variety**	**Ship Perspective**
Wing	Shipboard emergencies	MOVLAS	A/C gear and weight settings	Deck going foul mid pass	Recognizing a mis configured aircraft.	It helps newer LSO become familiar with the sights and sounds on the platform.
		Weather!	LSODS displays	Working as a wave team		
		pitching deck		not landing an A/C on a foul deck		
		Deck movement and WX and environment		Teamwork		
				Learn how to judge the waveoff window for different situations.		
				It helps with foul deck waveoff procedures		
Qualification Level	**Emergencies**	**Pitching Deck**	**LSODS**	**Team / Procedural Flow**	**Variety**	**Ship Perspective**
Squadron	Emergency recoveries	Movlas and pitching deck practice in adverse weather	LSOD	Interaction with the deck/hook spotter, specifically with regards to foul deck waveoffs	Variety of Aircraft	Deck Motion
	Emergencies	MOVLAS utilization during adverse weather.		Working with a wave team vice as a single LSO at the field.		
	Barricade Procedures	Pitching Deck MOVLAS		Interaction with Backup		

				and CAG paddles		
	Barricade	Pitching Deck		LA incursions		
		Pitching Deck		The interaction between backup and controlling LSO during busy Case I operations.		
				Deck status lights monitoring.		
Qualification Level	**Emergencies**	**Pitching Deck**	**LSODS**	**Team / Procedural Flow**	**Variety**	**Ship Perspective**
Field	Barricade Ops	Pitching deck/Inclement weather Paddles talk down	Roll angle adjusted lens and HTDP	Working with a full LSO team		Hook to ramp sight picture.
	Abnormal aircraft configuration/Emergency scenarios	MOVLAS	Verifying gear and lens settings	Bad Weather Procedures		Pilot response
	Emergency Procedures / ARBs	Movlas		Ensuring a clear deck via deck status lights and team awareness		Watching aircraft all the way through a real approach turn. (East coast bubbas only)
	Barricade	MOVLAS with moving deck				The joy of watching someone bolter.
		Pitching deck				
		Pitching Deck				

5. What are three major concepts that FCLPs can prepare an LSO to do to operate at sea, that the LSOT (2H111) cannot replicate?



*Only subjects that identified that they had attended the LSO School for IFGT were allowed to answer this question. The following six LSOs were affected by this:

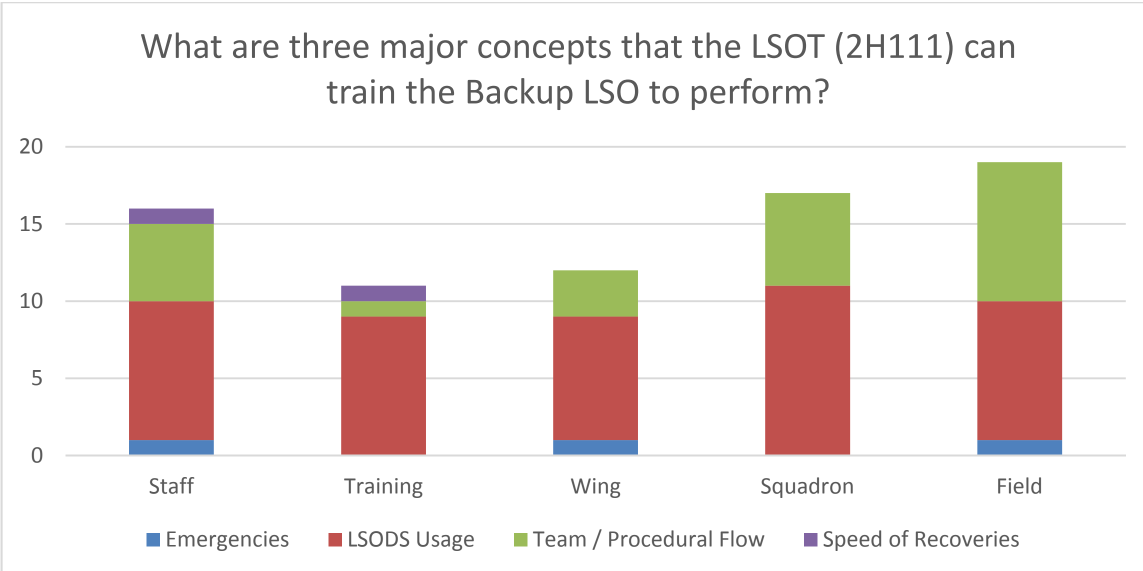
- One Squadron LSO
- Two Field LSOs
- Three No Qualification LSOs

Qualification	**Eye Calibration**	**LSO-Pilot Interactions**	**Administration**	**Aircraft Performance**	**Misinterpreted Question (Thrown Out)**
Staff	Eyeball cal.	Real-time LSO to pilot FCLP corrections while in the pattern.	Administrative aspect of carrier aviation	Aircraft performance	Aircraft Emergencies
	Visual Acuity for glideslope deviations	Real LSO to pilot debriefs.	Pattern Management	Learn to evaluate engine performance based on audible cueing	
		Pilot response	Pattern Management	Actual aircraft	
		Actual Waving and learning individual performance levels	knowing the pilot trends		
		Actual Pilot response to LSO calls	Pilot trends/performance		
		actual pilot responses to calls/inflection			

Qualification	Eye Calibration	LSO-Pilot Interactions	Administration	Aircraft Performance	Misinterpreted Question (Thrown Out)
Training	Calling passes accurately	Practice LSO talk downs with an actual pilot	Control a FCLP pattern	Control actual aircraft	
	Actual eye calibration	Seeing actual pilot response to LSO calls.	SA enhancing managing the pattern.	Aircraft audio cues / what engines sound like during power corrections.	
	True sight picture	Actual pilot performance		"Real World"-isms: an actual jet is flying	
				Actual sound of aircraft engines on approach	
Qualification	**Eye Calibration**	**LSO-Pilot Interactions**	**Administration**	**Aircraft Performance**	**Misinterpreted Question (Thrown Out)**
Wing		Talking to a student	The unknown	Controlling actual aircraft	A/C gear and weight settings
			Manage timing for FCLP players in following waves		pitching deck
			Managing FCLP players fuel states.		not landing an A/C on a foul deck
Qualification	**Eye Calibration**	**LSO-Pilot Interactions**	**Administration**	**Aircraft Performance**	**Misinterpreted Question (Thrown Out)**
Squadron	Verbal/Written Judgment of individual passes	Squadron pilot response to talk downs and LSO calls	Trend analysis	Actual aircraft control	Barricade utilization.
		Realistic pilot response	LSO Debrief	Aircraft sound recognition	
		Actual pilot responses	Observe squadron pilot trends	Realistic Aircraft Performance	
		Aircrew interaction	Ability to maintain global SA to all aircraft in the pattern, not just the guy about to roll in the groove.		
			Pilot trends		
			Pattern Management		
			Learning your own squadron's/Airwing's pilot tendencies		
			Real world platform environmentals and distractors		

Qualification	Eye Calibration	LSO-Pilot Interactions	Administration	Aircraft Performance	Misinterpreted Question (Thrown Out)
Field	Eyeball calibration for glideslope	Pilot/LSO Interaction	Task Saturation	Sound of the Aircraft	
		LSO Talkdown w/ Feedback	Briefing and Debriefing	Watching a listening to motors spool up/down	
		Paddles Talk Down	Managing the landing pattern	Realistic engine noise cues	
		Pilot response time	Visually pick out all players in the pattern	Real aircraft noise.	
		human to human communication, vice human to machine		Using engine pitch to assess aircraft energy state (engine pitch not loud enough or not accurately represented in LSOT)	
		human error		Aircraft make more appropriate glideslope corrections (LSOT aircraft tended to make extreme and unpredictable corrections, and manual controlling interface seemed to be difficult to use for instructors)	
		Realistic response to LSO's voice			

6. What are three major concepts that the LSOT (2H111) can train the Backup LSO to perform?



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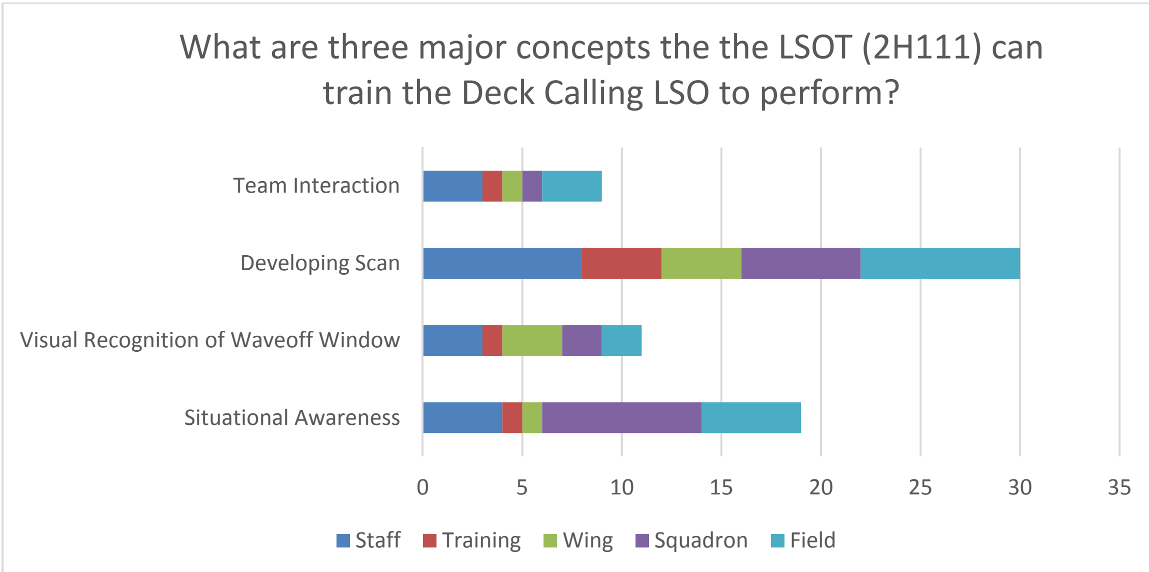
- One Squadron LSO
- Two Field LSOs
- Three No Qualification LSOs

Qualification	Emergencies	LSODS Usage	Team / Procedural Flow	Speed of Recoveries
Staff	ADB drills	Lineup Management	Responding to the phone talker and hook spotter.	Task saturation for challenging conditions
		Crosschecks.	Interaction between controlling and backup	
		Visual scan and failure recognition	Basic Backup Procedures	
		System Radio Operation	Procedural flow on the platform	
		Abnormal gear/Lens settings i.e Cross check	Procedures	
		Line-up corrections.		
		Scan		
		LSODs scan/backup platform comms		
		Building the proper scan between glideslope and centerline		

Qualification	Emergencies	LSODS Usage	Team / Procedural Flow	Speed of Recoveries
Training		Practice line-up calls	All responsibilities on platform	Seeing how fast paced recovery operations can be as backup
		Recognize out of limit winds and density altitude corrections		
		Improve cross check and deck status scan		
		Practicing system scan (wind, lens & gear crosscheck, etc.).		
		Gross line up deviations		
		LSODs manipulation.		
		Gear setting over watch		
		Incorporating centerline camera into scan.		
Qualification	**Emergencies**	**LSODS Usage**	**Team / Procedural Flow**	**Speed of Recoveries**
Wing	Different malfunctions you will see as backup	Watching for lineup	Procedural practice	
		How the LSODS works	Interface with team on the platform	
		line-up corrections	Teamwork	
		Watching for out of limit winds	not landing an A/C on a foul deck	
		LSODS management		
		Improve the overall scan		
		Centerline control		
		A/C gear and weight settings		

Qualification	Emergencies	LSODS Usage	Team / Procedural Flow	Speed of Recoveries
Squadron		Lineup	Only environment outside of ship where Backup can interact with CAG paddles	
		Only environment outside of the ship where Backup can practice lineup calls	Working as a team to work a complicated ARB.	
		Monitoring wind changes and ensuring they remain in limits throughout a recovery.	Control of LSO Team	
		Deviation Recognition	Proper communications with enlisted spotter	
		Monitoring Lineup	Basics	
		Radio frequency management	Communications	
		Only environment outside of the ship where backup can practice checking gear and lens settings		
		Developing a useful scan to ensure the arresting gear and IFLOS are set to the proper settings.		
		Lineup/Glideslope Management		
		LSODs usage		
		Scan		
Qualification	**Emergencies**	**LSODS Usage**	**Team / Procedural Flow**	**Speed of Recoveries**
Field	Emergency Procedure/ARB	LSODS Scan	comms with gear spotter	
		actually having a line up camera	Focusing the team into each pass	
		Verifying gear/lens settings and required wind	Everything	
		Gear/Lens settings and appropriate procedures	Waveoff window training	
		Use of LSODS	Allow people to practice backing up before operating at the ship.	
		Controlling line up deviations	It's the only place besides the boat to do it	
		waving off ACLS repeater during low visibility	Talkdown Cadence	
		Verifying gear and lens settings	Back up responsibilities	
		lineup cues and when to make correction calls	Verifying clear deck status and backing up primary	

7. What are three major concepts the LSOT (2H111) can train the Deck Calling LSO to perform?



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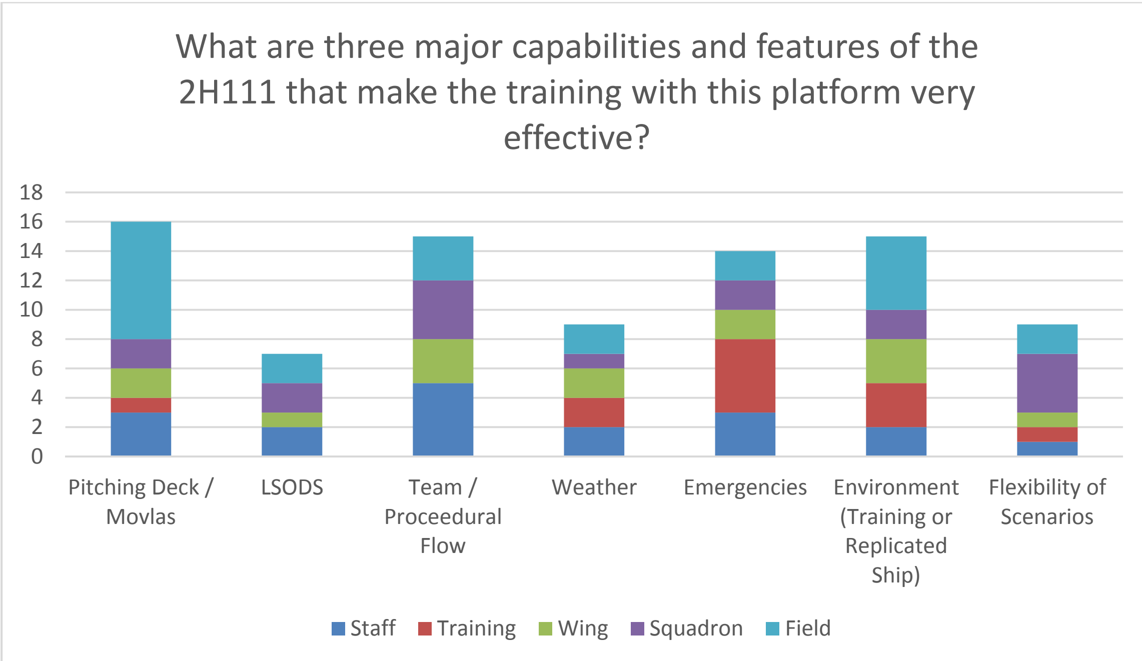
- Three No Qualification LSOs

Qualification	Situational Awareness	Visual Recognition of Waveoff Window	Developing Scan	Team Interaction
Staff	Responsibilities	100' vs 10' foot window recognition	scan	Proper voice inflection for time-critical deck status changes
	testing SA to foul decks	Calling 100/10 ft wave off window.	Actual scan of calling the deck.	inflection
	Mistakes when clear deck is called and it is not clear ie Jet in the LA	Proper positioning during 100' and 10' windows	Foul Line Management	Proper Voice projection
	keeping the deck clear during an emergency and not becoming sucked into the excitement on the platform.		Proper use of the Deck Status lights	
			Foul line scan	
			Calling deck foul	

			after a foul line incursion.	
			Proper Scan between foul line and deck status light.	
			Late foul decks	
Qualification	**Situational Awareness**	**Visual Recognition of Waveoff Window**	**Developing Scan**	**Team Interaction**
Training	Identifying a foul deck	Backing up controlling LSO with 100/10 windows	Practice scanning along the foul lines	Seeing everything in context, i.e., seeing all flight deck personnel in their positions and how they interact with each other on an actual flight deck.
			Practice appropriate scan pattern for a Deck Caller.	
			Quick changes to deck status	
			The trainer can simulate landing area incursions to test the deck caller scan.	
Qualification	**Situational Awareness**	**Visual Recognition of Waveoff Window**	**Developing Scan**	**Team Interaction**
Wing	Foul deck scenarios	Wave off window	Deck going foul mid pass	Make foul deck calls at appropriate times
		100 ft waveoff window	watching the foul lines	
		10 ft waveoff window	Learn the sight picture	
			Scan of the deck / watching AGO	
Qualification	**Situational Awareness**	**Visual Recognition of Waveoff Window**	**Developing Scan**	**Team Interaction**
Squadron	Pattern Awareness	Waveoff window	Only environment outside of the ship where the deck caller can incorporate other deck operators (AGO, etc) in making sure the deck isn't foul	Being directive with the controlling LSO when the deck goes foul.
	SA to people crossing the LA	Only environment	Ready Deck Signal	

		outside of the ship that the deck caller can practice calling 100 and 10 foot waveoff windows		
	WO VS FD		Proper scan	
	Unpredictability of the deck/deck personnel		Scan	
	Deck status		Only environment outside of the ship where Deck Caller can practice clearing the LA and foul lines	
	Foul Deck Awareness		Keeping an eye on both foul lines.	
	NOT watching the aircraft in the groove.			
	Gravity of the job			
Qualification	**Situational Awareness**	**Visual Recognition of Waveoff Window**	**Developing Scan**	**Team Interaction**
Field	Foul Deck Considerations	Its really just good for primary to see the different wave off windows	Landing Area Scan	AGO communications and wave off windows
	Foul deck procedures	differences in 10 foot and 100 foot waveoff windows	flight deck personnel fouling the LA	AGO hand signals
	recognize FD's	Standardize their 100' calls	Recognition of foul line incursions	Communicating Foul Deck with Controlling LSO
	LA incursions and proper reaction		Deck Calling procedures	
	Recognizing reasons deck is foul		Scan of the deck	
			deck status lights	
			Watching JBD's and wing spread on CAT II	
			Day/night scan when ensuring deck is clear	

8. What are three major capabilities and features of the 2H111 that make the training with this platform very effective?



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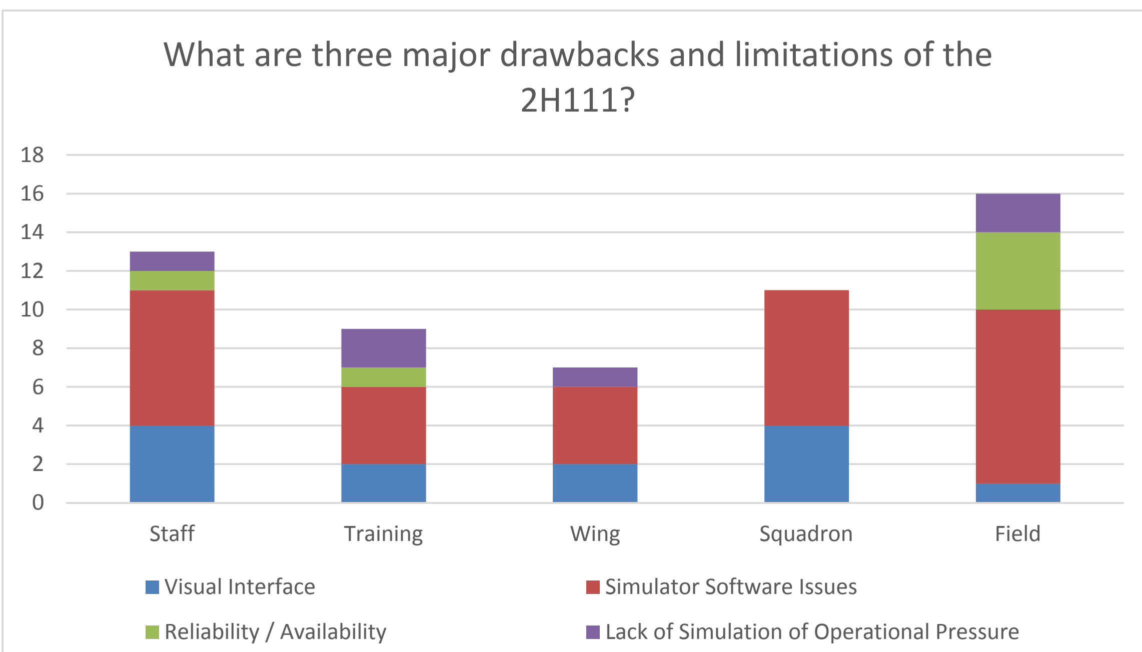
Qualification	Pitching Deck / MOVLAS	LSODS	Team / Procedural Flow	Weather	Emergencies	Environment (Training or Replicated Ship)	Flexibility of Scenarios
Staff	Can simulate pitching deck and MOVLAS.	LSODS training	Good simulation of the responsibilities of each station.	Simulated weather training.	Can simulate emergencies.	Visually, the opportunity to train in a replicated environment that is similar to the ship.	adaptability to unlimited conditions
	This is the only place you can wave pitching deck MOVLAS without the actual danger.	LSODs operation and scan	Talk Down procedures in simulated environment	Foul Weather task saturation in abnormal conditions	ARB drills in a time crunch	allows instructors to observe and teach in a controlled environment. You can learn from mistakes without endangering anyone (except pride!)	
	When to wave someone off vice keep them coming in Pitching Deck		Entire LSO Team integration		ARB procedures and seeing the outcome for the ARB		
			The trainer is invaluable for proper platform procedures				
			allows a team to train in a safe environment before operating at sea				
Qualification	**Pitching Deck / MOVLAS**	**LSODS**	**Team / Procedural Flow**	**Weather**	**Emergencies**	**Environment (Training or Replicated Ship)**	**Flexibility of Scenarios**
Training	Practice day/night MOVLAS			Practice poor visibility	Work through platform and A/C emergencies	Realistic perspective, i.e., seeing the glideslope	Seeing huge pilot errors without risk to

						from the same angle as you'd see at the boat.	pilots
				foul weather condition simulatio n.	Dealing with emergencies in an environment with no repercussions	Seeing everything in context, i.e., seeing all flight deck personnel in their positions and how they interact with each other on an actual flight deck.	
					barricade recoveries	Seeing dangerous passes with no repercussion s	
					Emergency Procedure		
					The ability to practice barricades		
Qualification	**Pitching Deck / MOVLAS**	**LSODS**	**Team / Procedural Flow**	**Weather**	**Emergencies**	**Environme nt (Training or Replicated Ship)**	**Flexibility of Scenarios**
Wing	Ability to do MOVLAS	LSODS	Working together as a wave team	Ability to do WX	malfunctions	It can simulate the boat without having to go to the boat	can change to any weather conditions
	can create pitching deck		It helps with procedural practice most of all	Environ ment and WX	can practice barricade drills		
			Teamwork				
Qualification	**Pitching Deck / MOVLAS**	**LSODS**	**Team / Procedural Flow**	**Weather**	**Emergencies**	**Environme nt (Training or Replicated Ship)**	**Flexibility of Scenarios**
Squadron	first intro to MOVLAS	Simulati ng minor malfunct	Excellent trainer for new LSOs to practice talk	Very good trainer for	Simulating Emergencies (Especially ones that	Seeing aircraft from the 180	See a lot of aircraft in a short time

		ions with arresting gear or IFLOS settings to teach backups the importance of a fluid scan.	downs and call passes.	adverse weather conditions and degraded landing aide capabilities	don’t actually happen very often but when they do they will be dangerous. Barricade for example.)		
	Pitching Deck Profiles	LSODs	Extremely good trainer for all positions on the LSO platform, teaches primary, backup and CAG paddles how to work together to make sure everyone gets aboard safely		Simulated emergencies		Variable scenario setting
			Training the LSO team interactions with unusual situations.				Versatility of scenarios
			Low risk intro to all positions				Multiple Aircraft Profiles
Qualification	**Pitching Deck / MOVLAS**	**LSODS**	**Team / Procedural Flow**	**Weather**	**Emergencies**	**Environment (Training or Replicated Ship)**	**Flexibility of Scenarios**
Field	MOVLAS training	Full LSODS display familiarization	Wave Team Responsibilities and Integration	Bad Weather	Training to emergencies	Opportunity to make mistakes in low risk environment	Multiple Scenarios
	Pitching Deck	Full working LSODS mock-up	Specific training at each position	Ability to simulate adverse weather	adverse aircraft configurations	Getting lots of reps in a short period of time.	It can show you passes no reasonable pilot would ever throw.
	Pitching Deck		Introduction to working with an LSO team and the			cyclic ops	

			different responsibilitie s				
	pitching deck					control of the aircraft, (when working)	
	Movlas control and pitching deck training					Full, panoramic, visual representatio n of an operating LA.	
	Waving with a high sea state						
	using MOVLAS						
	Ability to simulate adverse sea state						

9. What are three major drawbacks and limitations of the 2H111?



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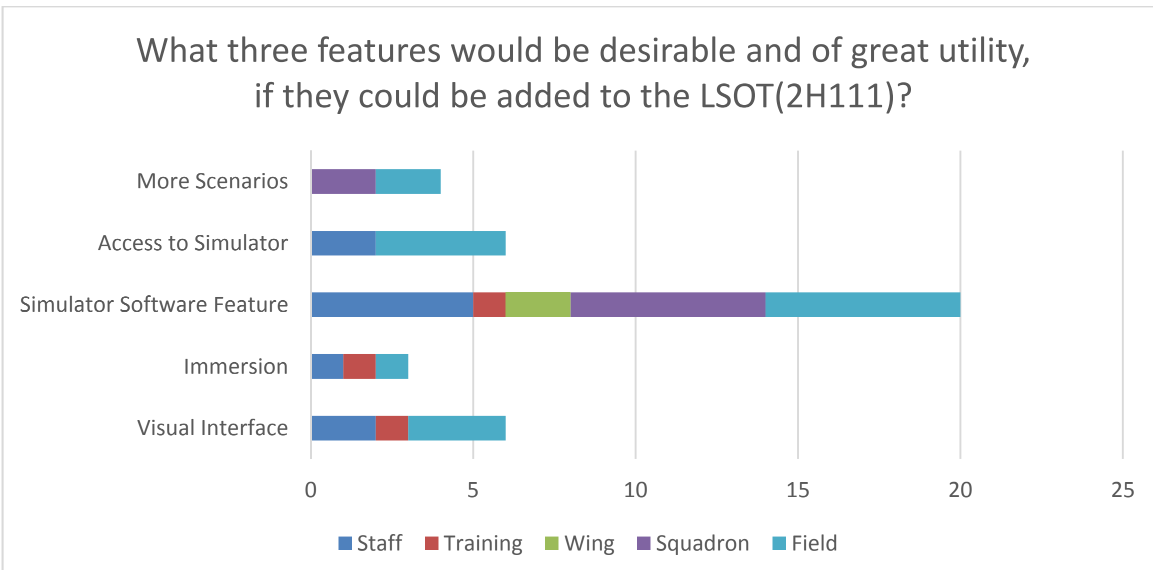
Qualification	Visual Interface	Simulator Software Issues	Reliability / Availability	Lack of Simulation of Operational Pressures
Staff	Not a real good simulation to build your eye.	Pilot response is not tied to LSO calls	system is crash-prone	Don't have the pressure of actual recoveries
	Visual acuity of Jet Position IC-AR-HD camera on entire sim could help with the visual acuity	Aircraft don't exactly respond as timely as most pilots do.		
	Visuals	Voice Recognition		
	Visuals are not great	jumpy graphics		
		Engine performance and Audio Recognition		
		Software response limitations WRT Talk Downs		
		Inflexibility for responses in some emergency scenarios		
Qualification	**Visual Interface**	**Simulator Software Issues**	**Reliability / Availability**	**Lack of Simulation of Operational Pressures**
Training	Overall visuals are obviously computer generated	A/C cannot accurately simulate pilot response to LSO calls	Not available/staffed 24/7.	Doesn't simulate the physical aspects of being on the platform, i.e., rain, wind, heat/cold, etc.
	Screen to screen discrepancies make it hard to duplicate actual aircraft performance	LSO to pilot interaction is too instantaneous during MOVLAS, e.g., LSO makes a call and the reaction from the pilot is artificially fast.		Nothing like the real thing
		Sounds are not completely accurate		
Qualification	**Visual Interface**	**Simulator Software Issues**	**Reliability / Availability**	**Lack of Simulation of Operational Pressures**
Wing	Clarity	The jets don't respond realistically to MOVLAS		Artificial
	Visuals: You should be able to tell what	the graphics aren't the best		

	model of aircraft is at the Abeam position in Case I pattern.			
		it shows some pretty bad unrealistic passes		
		The AGO directly across from the platform signals a clear deck AFTER the light turns green, opposite of real life.		
Qualification	**Visual Interface**	**Simulator Software Issues**	**Reliability / Availability**	**Lack of Simulation of Operational Pressures**
Squadron	It is good for procedures but finding glideslope is learned with experience.	Deck image fidelity	Availability (east coast only)	
	Limited to only seeing aircraft at the abeam	Some pilot responses are laggy or unrealistic	Equipment crashes	
	Sight picture is not entirely accurate	Sounds simulations are difficult to program accurately to the LSO platform.	Frequently breaks down	
	Flickering Projectors	Pilot response is unrealistic		
		Aircraft response		
		Graphics		
		Pilot/LSO interaction		
Qualification	**Visual Interface**	**Simulator Software Issues**	**Reliability / Availability**	**Lack of Simulation of Operational Pressures**
Field	Projection resolution too low to see small objects in LA and often makes realistic deck calling difficult.	MOVLAS Fidelity Limitation	Occasional non-responsive jets leading to crashes	Pressure of actual flight ops
		"sim-ism" moments	Time spent in trainer	
		Visuals	software breaks, or not loaded properly often	
		Fidelity	It will usually crash towards the end of the sim	
		flight characteristics robotic		
		Sometimes unrealistic response to MOVLAS or voice calls		
		Night graphics are somewhat		

		unrealistic		
		Aircraft often make unrealistically cataclysmic power corrections resulting in student tendency to expect wave-off scenario on most passes. Manual interface for instructor to control aircraft helps, but seems difficult to use precisely.		
		Sound effects are unbalanced (helos can be heard over jet noise) and engine pitch sound for aircraft on approach is inaccurate or too faint to use for training.		

10. What three features would be desirable and of great utility, if they could be added to the LSOT (2H111)?



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Qualification	Visual Interface	Immersion	Simulator Software Feature	Access to Simulator	More Scenarios
Staff	Higher definition video inputs	rain from the ceiling with a full motion floor!	More integrated features that allow for real-time feedback of LSO calls	A simulator in Lemoore for Airwing Training	
	Visual Upgrades to the camera		better graphics		
			more realistic in-flight depiction		
			Better Visuals		
			Voice Recognition		
Qualification	**Visual Interface**	**Immersion**	**Simulator Software Feature**	**Access to Simulator**	**More Scenarios**
Training	More seamless transitions from screen to screen	Maybe some cold weather and rain? :-)	Better visuals, more life like		More seamless transitions from screen to screen
Qualification	**Visual Interface**	**Immersion**	**Simulator Software Feature**	**Access to Simulator**	**More Scenarios**
Wing			I-MOVLAS		
			Gear spotter messing up A/C type		
Qualification	**Visual Interface**	**Immersion**	**Simulator Software Feature**	**Access to Simulator**	**More Scenarios**
Squadron			E2-D software		More foul line incursions
			more realistic sim pilot response to LSO calls		More foul line incursions
			Bad lineup corrections		
			More realistic pilot response		
			Better carrier graphics		
			Software upgrade		
Qualification	**Visual Interface**	**Immersion**	**Simulator Software Feature**	**Access to Simulator**	**More Scenarios**
Field	Higher fidelity visual display	motion	Better Visuals	Having one on the West Coast!!!	More Scenarios
	Better fidelity, the principals are sound but things like calling the deck are worthless because you cant see anything.		Better response to LSO's	reliability	More scenarios

	Increased screen resolution.		It would be great to see someones motors spool up and get louder with a power call or tell when someone is EGTL.	not available on the west coast	
			More realistic engine noise to correspond with aircraft power changes	More reliable software	
			More realistic sounds better balanced to match actual CV environment.		
			More stable aircraft approach modeling or more user-friendly manual instructor controls for approaching aircraft.		

11. What positions on the platform did you experience before attending IFGT?

	Yes	No	Did Not Respond	Not able to Answer	Total	Percentage of LSOs who experienced position prior to LSO School IFGT.
Backup LSO	16	13	0	6	35	55%
Controlling LSO	28	1	0	6	35	97%
Deck Calling LSO	29	0	0	6	35	100%
Book Writing LSO	29	0	0	6	35	100%
Timing LSO	29	0	0	6	35	100%

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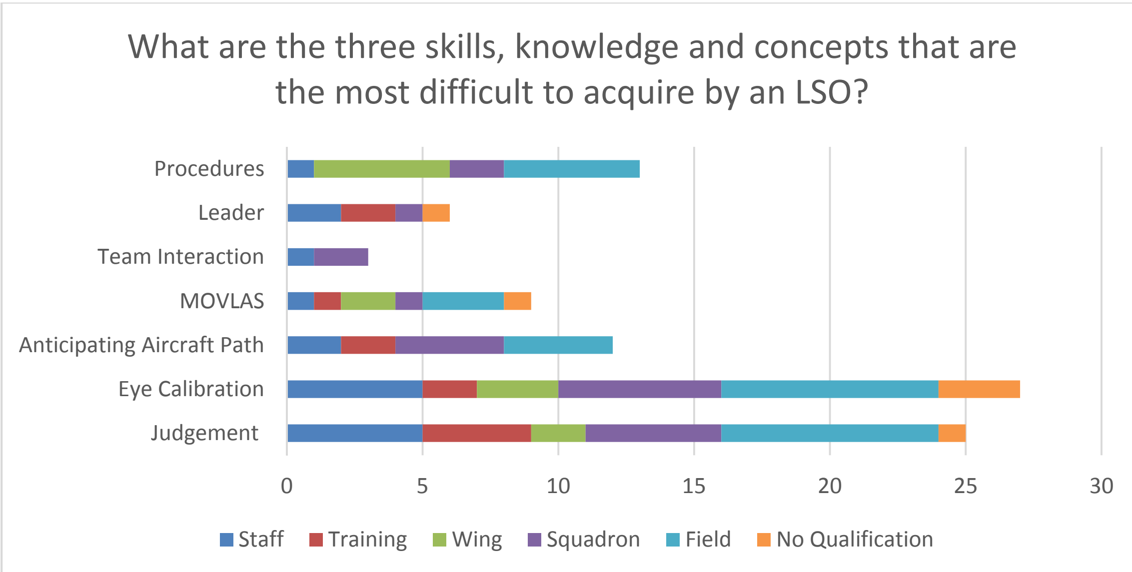
12. What are the three skills, knowledge and concepts that are the most difficult to acquire by an LSO?



Qualification	Judgment	Eye Calibration	Anticipating Aircraft Path	MOVLAS	Team Interaction	Leader	Procedures
Staff	Appropriate a timely power calls or WO.	Eye.	Recognition of aircraft energy state	Pitching deck concepts of MOVLAS (too many hornets in combat = hardly any movlas for anyone)	Platform/Team management	coaching a struggling pilot	Proper Backup scan
	judgment	Eyeball Calibration when shifting glideslope	Low Energy state aircraft			leading the ready room to be successful behind the boat	
	when not to talk	**Calling passes accurately and succinctly**					
	confidence	Calling and grading a pass.					
	The absolute right time to wave an aircraft off.	accuracy					
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Leader**	**Procedures**
Training	Confidence in giving appropriate LSO calls	Eye calibration	Getting ahead of the aircraft, knowing what's	MOVLAS		Platform training and leadership	

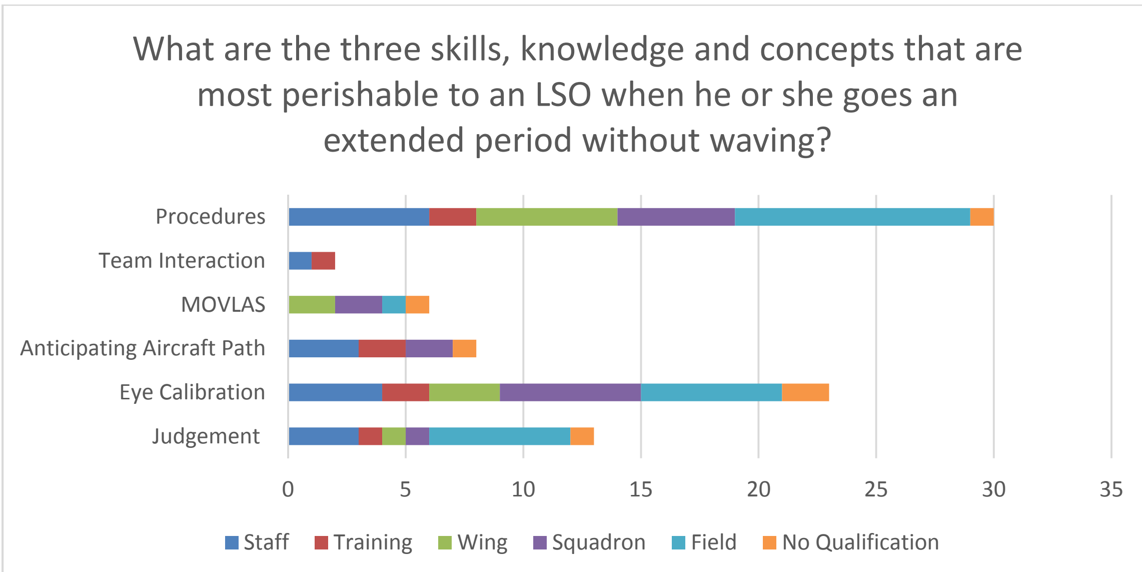
			getting ready to happen before it's too late.				
	Appropriate communication: timely, concise, clear, and in cadence with what else is happening.	The "eye"	Response to quick deviations			Effective debriefing of superiors, peers, and subordinates	
	Separating what is and is not important and any particular point in time						
	Knowing when to wave someone off or keep them coming						

Qualification	Judgment	Eye Calibration	Anticipating Aircraft Path	MOVLAS	Team Interaction	Leader	Procedures
Wing	Experience/time at sea	Eyeball Cal		MOVLAS			Talk downs
	Confidence	Glideslope perception		MOVLAS			Properly do ARB's
		Sight picture					Backup LSO lineup / power calls
							Backup Scan
							Waveoff windows
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Leader**	**Procedures**
Squadron	Ability to understand the power setting of the jet in the groove	Glideslope recognition	Pattern SA	MOVLAS	Emergency management	Trust of Aircrew	Night Primary
	Noticing trends	Eyeball calibration for glideslope	Understanding aircraft energy state.		Platform Presence		Barricade Procedures
	When to talk and when to let the pilot fix it and where that line is.	Eyeball Cal	Ability to know and react to pilot trends				
	Understanding how to very priority when an aircraft has an emergency.	Eyeball Cal	Evaluating Power States				
	Calling a pass in a timely manner	Accurate glideslope					

	with confidence	sight picture					
		Lens Geometry					
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Leader**	**Procedures**
Field	Allowable deviations	Eyeball	Platform SA	MOVLAS			ARBs
	Understanding Effective Glideslope/basic angle with regards to deviations from the norm	Calling an accurate pass	Projecting an aircraft's path to keep them safe	MOVLAS			Waving during pitching deck
	Knowing how late you can take someone before a 100' waveoff or 10'waveoff	Glideslope	Accurately assessing aircraft energy state as it approaches in-close position	MOVLAS			Speed and accuracy of running an ARB drill
	When to give a power/lineup call and when to let a guy fix it by himself	glide slope eye	sa for energy state				Talk-down during pitching deck and recognition when deck movement precludes safe landing
	experience, seeing a variety of possible senarios	Eyeball calibration for glideslope					Emergency Coordination
	Voice inflection for calls	eye					
	When certain LSO calls are required/helpful	Complete and accurate pass recall					
	Knowing when to reach out and grab someone from CATCC	Eyeball Calibration					
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Leader**	**Procedures**
No Qualification	multi-tasking	eyeball cal		MOVLAS recoveries along with pitching deck recoveries.		Tact	
		A good eye for when aircraft need power, attitude, or line-up calls					

		to keep them safe at the ship.					
		Getting an eye for aircraft that the LSO does not actually fly.					

13. What are the three skills, knowledge and concepts that are most perishable to an LSO when he or she goes an extended period without waving?



Qualification	Judgment	Eye Calibration	Anticipating Aircraft Path	MOVLAS	Team Interaction	Procedures
	The absolute right time to wave an aircraft off.	Eye.	General SA		team responsibilities	LSO Talkdowns
	Calling and grading a pass.	Eyeball Cal	Overall SA of what is going on around the ship / pattern			Rhythm of operations
Staff	Appropriate a timely power calls or WO.	his eye	overall platform SA			SA WRT Platform Operations and Air Wing Standardization
		glide slope eye				backup scan / calls
						attention to detail
						The proper scan between the LSODs and glideslope

Qualification	Judgment	Eye Calibration	Anticipating Aircraft Path	MOVLAS	Team Interaction	Procedures
Training	Response to quick deviations	Eye calibration	Reaction time to pilot deviations		Making quick decisions with regards to controlling and backup	Knowledge of ARB's/performance numbers
		The "eye"	Ability to take in all the cues the LSO is sensing, process those cues, and translate the cues into timely, useful direction to the pilot.			ARB recollection.
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Procedures**
Squadron	Proper calling of passes (ie. HCDX \IM)	Glideslope recognition	Pattern SA	Waving MOVLAS		Emergency management
		glideslope eyeball calibration	Picking up on minute energy state changes.	MOVLAS		Dealing with the "fast pace" during CV recoveries.
		Eyeball Calibration				Proper Comms
		Accurate glideslope sight picture				Min RHW for T/M/S
		Eyeball Cal				ARB Drill Knowledge
		Eyeball Cal				
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Procedures**
Field	Timely and accurate advisory/imperative calls	Eyeball		MOVLAS		Overall knowledge
	The ability to call and project a pass	eye calibration				The responsibilities of each station
	Accurate pass recall	Eyeball calibration				procedural flow
	energy management of jets	glideslope perception				waving a variety of different aircraft
	Consistency/credibility for all passes	Overall eyeball cal				General knowledge such as gear and lens settings and required winds
	Credibility and Experience	Eyeball Calibration				Scan for backup LSO such as glideslope,

						centerline, and gear settings/deck status
						Backup scan of deck status and aircraft lineup
						Emergency Coordination
						keeping eyes on the next jet while calling the previous pass
						ARB procedures if not practiced periodically
Qualification	**Judgment**	**Eye Calibration**	**Anticipating Aircraft Path**	**MOVLAS**	**Team Interaction**	**Procedures**
No Qualification	confidence	eyeball cal	total SA	MOVLAS recoveries along with pitching deck recoveries.		Overall knowledge of complicated emergency aircraft handling.
		A good eye for when aircraft need power, attitude, or line-up calls to keep them safe at the ship.				

The following were not grouped into any category:

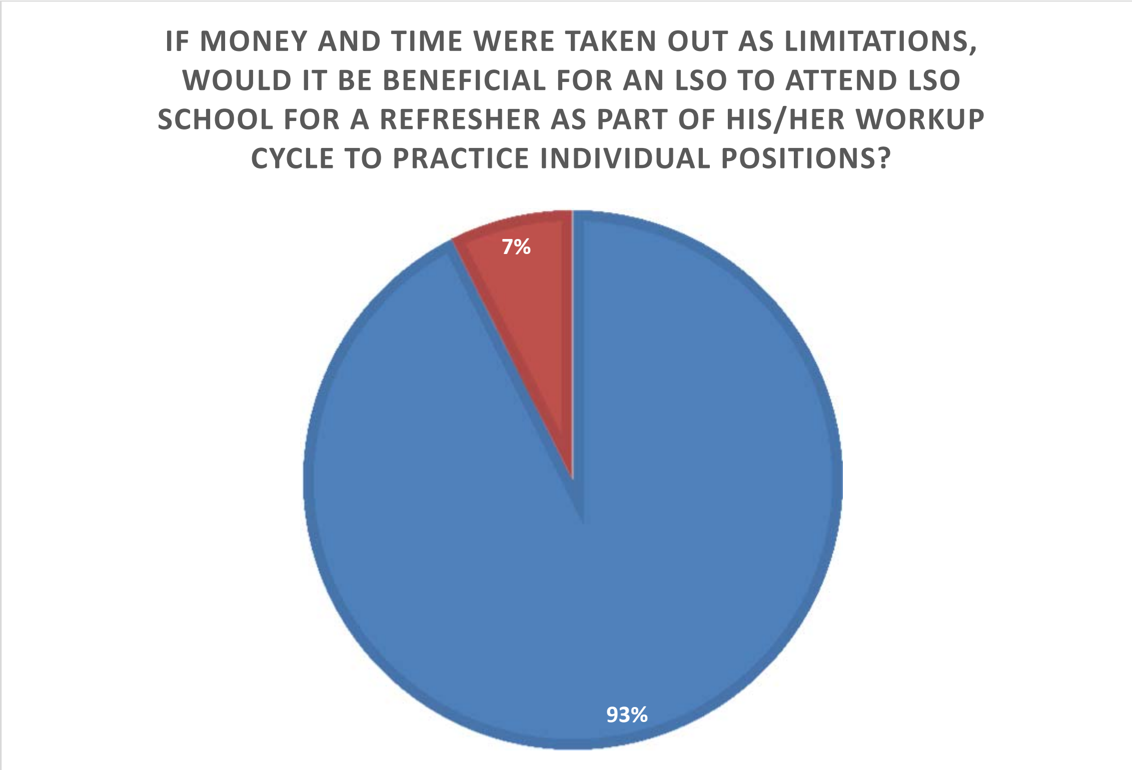
- Staff LSO—"Mid-level LSO's do not get quals as they have no training"
- Training LSO—"Field waving"
- Field LSO—"Not sure. 95% of my waving has been done since the start of workups and been fairly consistent"

14. If money and time were taken out as limitations, would it be beneficial for an LSO to attend LSO School for a refresher as part of his/her workup cycle to practice individual positions?

Please choose **only one** of the following:

☐ Yes

☐ No



Qualification Level	Yes	No	Did not respond	Not permitted to answer	Total
Staff	6	0	0	0	6
Training	3	0	1	0	4
Wing	5	1	0	0	6
Squadron	6	0	0	1	7
Field	5	1	1	2	9
No Qualification	0	0	0	3	3
Total	25	2	2	6	35

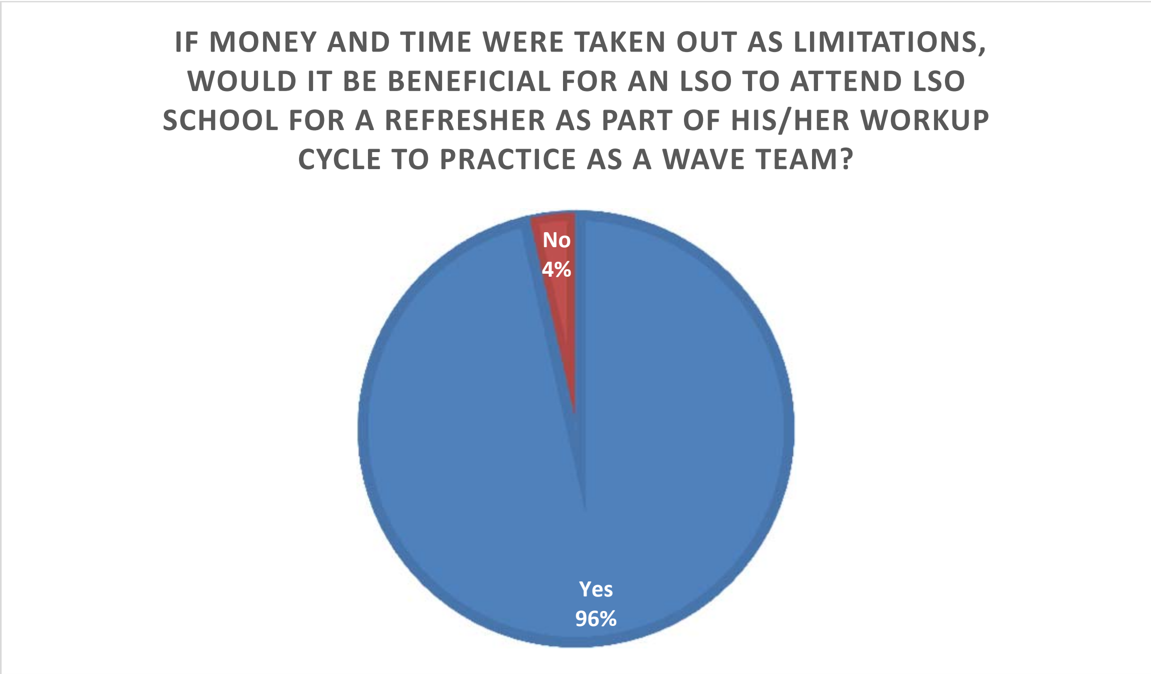
*Only subjects that identified that they had attended the LSO School for IFGT were allowed to answer this question.

15. If money and time were taken out as limitations, would it be beneficial for an LSO to attend LSO School for a refresher as part of his/her workup cycle to practice as a wave team?

Please choose **only one** of the following:

☐ Yes

☐ No



Qualification Level	Yes	No	Did not respond	Not permitted to answer	Total
Staff	6	0	0	0	6
Training	3	0	1	0	4
Wing	6	0	0	0	6
Squadron	6	0	0	1	8
Field	6	1	0	2	9
No Qualification	0	0	0	3	3
Total	27	1	1	6	35

* Only subjects that identified that they had attended the LSO School for IFGT were allowed to answer this question.

16. What types of scenarios would be beneficial to have as a routine practice in a simulator for any of the following positions?

Deck Caller
Controlling LSO
Backup LSO

Qualification	Deck Calling LSO	Controlling LSO	Backup LSO	Procedures	Broad Response
Staff	Wire not set—Broken Risers (we have had a ton on our current deployment and a few were not seen until very late or at all.)	LSO talkdowns where the pilot is responding to LSO calls could be a fantastic addition. As it is currently, the operator must have a high level of experience with the console in order to make this happen.		Cyclic ops. CVW-9 took 6 brand new LSOs to the LSO school for this reason exactly. Paid huge dividends when we went to the boat because the new how to stand the administrative positions which freed up what few experienced LSOs we had to control and back-up.	
	Jet exhaust in LA for the fat kids when boss doesn't catch it	10-15' Pitching Deck Day/Night with MOVLAS		ARB training	
	Deck caller- Foul line walker, deck fouls after clear	A/C Talkdowns for all control—loss of power to source or emergency A/C		Platform management and executing the correct procedures	
		Controlling- non-standard recoveries, high wind, excessive stbd wind, etc...			
		Pitching Deck MOVLAS			

Qualification	Deck Calling LSO	Controlling LSO	Backup LSO	Procedures	Broad Response
Training	Simulate the Deck Status Light is stuck Red, and have the simulated AGO giving the manual hand signals with the wand/signs that the deck is clear or foul.	Controlling	Back-up LSO	Barricade practice	
	Foul deck after clear with aircraft in close.	Talk downs	Drift left/right in close-at ramp.	Foul weather	
		Aircraft not responding to calls.	Aircraft not responding to calls.	Standard day with emergencies	
		Pitching deck which starts with aircraft in the			

		middle.			
		MOVLAS (the correct way).			
		Aircraft dragging in a low ball.			
		Aircraft announcing something abnormal on ball call (1st time LSO learns of something abnormal for that aircraft).			
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
Wing	random people running through the LA	unresponsive pilots	incorrect weight settings		Day, Night, pitching deck, bad weather, talk downs, MOVLAS, ARBs
					Everything, would be good to review the types of malfunctions with LSODS, aircraft, weather, foul deck, etc.
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
Squadron	Deck caller: Scenario where subtle things make the Deck go foul that no one else catches.	MOVLAS	Backup LSO: situation where gear and lens settings are incorrect or winds are out of limits.	normal operations	For all: ARB scenarios, Pitching deck, MOVLAS, tight interval, lack of pilot response, fouled LA
	Scenarios where maintainers run out into the LA	Controlling LSO: Waving in adverse weather conditions. i.e., no horizon/pitching deck. Practice MOVLAS	Malfunctions with the display system.		really all senarios, foul deck, gear not rigged, winds out of limits, adverse deck conditions and weather
	Foul line crossings.	MOVLAS	Arresting Gear Malfunctions.		
	Deck going foul with an aircraft in the middle.	Pitching Deck	Wind limits being exceeded.		
	People entering the foul lines during random intervals and deck light	Barricade	Barricade Execution.		

	turning red.				
	Foul Deck w/ aircraft in close	Paddles Talk Downs in good and bad WX			
		Controlling LSO is the most perishable skill.			
		Controlling LSO Day/Night			
		Degraded Pilots/Aircraft (Hypoxia, Fatigue, Battle Damage)			
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
Field	tight intervals for case I and foul line incursions during clear deck	Pitching deck movlas	Improper gear settings, tight intervals, lineup control problems		Tight intervals
	Landing area incursions during all phases of a pass	Standard Procedures and MOVLAS	Standard Procedures		bolter traffic cutting out breaking traffic
	clear/foul deck calls as appropriate.		checking wind limits, appropriate gear/lens settings		
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
No Qualification	Deck going foul due to people or objects in the LA with aircraft IM-IC and a 10 foot waveoff window already established.	Calling passes with large glideslope extremes, including aircraft without sufficient ramp clearance requiring waveoffs.	Large drift		

17. If you were the senior paddles for your squadron, what types of scenarios would be beneficial to expose junior paddles to in a simulator for any of the following positions?

Deck Caller
Controlling LSO
Backup LSO

Qualification	Deck Calling LSO	Controlling LSO	Backup LSO	Procedures	Broad Response
Staff	Green Deck that is actually foul	Low visibility (taxi lights only until IC-AR)	Loss of x-check	Emergency procedures during cyclic operations.	Dealing with emergencies, pitching deck LSO talk-downs, and MOVLAS.
		IFLOS and ACLS not matching IE glideslope vs instrument issues.	Not enough wind for DA calculation	Gusty winds	Extreme wind/wx conditions, LSODS malfunctions / ISIS / Primary or secondary displays / SATCC
		Pitching Deck MOVLAS		ARB execution on the platform	Everything! This trainer is the one Navy training aid that can not be used too much. Every paddles and wave team can benefit from repeated trips to the training. this needs to be a must as we move into an environment with less boat experienced JOs and more junior paddles with little examples to learn from.
				High task loading day recoveries	Dealing with emergencies, pitching deck LSO talk-downs, and MOVLAS.
				ADB Drills for different situations	
				ARB training	
				Platform management and executing the correct procedures	
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
Training	Quick foul deck scenarios			Foul weather	Night, foul weather, pitching deck, aircraft malfunctions, ship malfunctions, all good stuff.
				ARB drills	
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
Wing					All of them. I think the sim is an extremely valuable tool that can expose junior paddles to any and all types of scenarios/malfunctions/emergencies.
					I wish there was one out of the West Coast that I could bring my junior guys to.
					Day, Night, pitching deck, bad weather, talk downs, MOVLAS, ARBs
					As much as possible

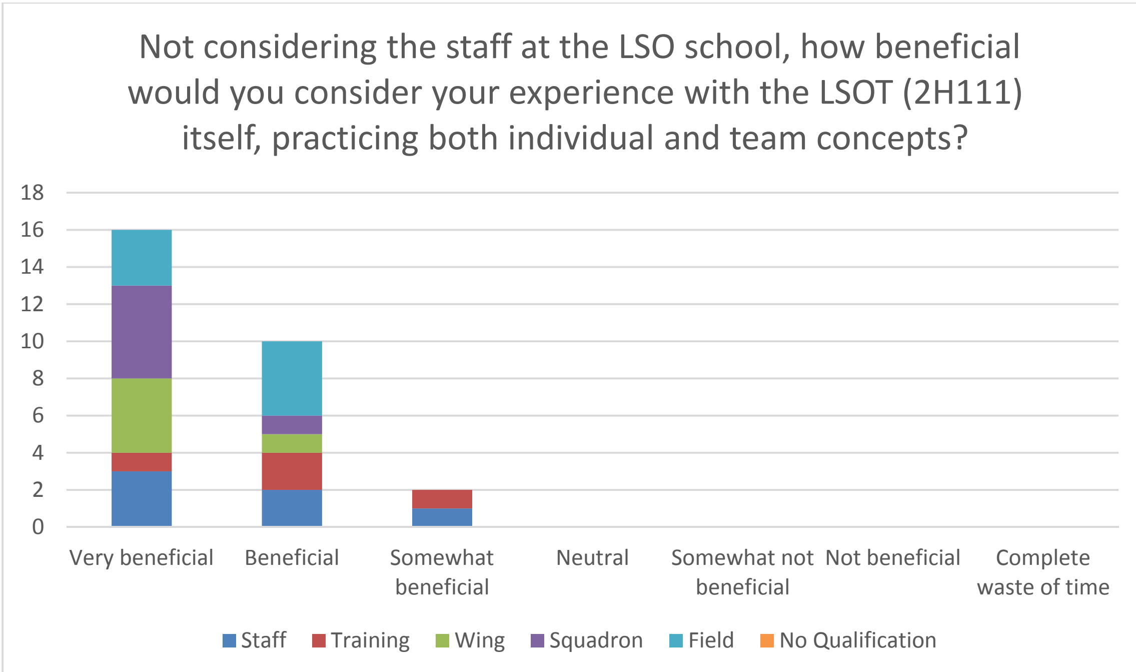
Qualification	Deck Calling LSO	Controlling LSO	Backup LSO	Procedures	Broad Response
Squadron	Short intervals.	Busy case I situations.	Backup LSO— The same things above for routine practice would be good to expose junior LSOs to help them understand the big picture.	As the trainer progressed it would be helpful to throw in aircraft emergencies that required the three LSOs to look through ARBs.	Barricade and emergency recoveries, ARBs, MOVLAS, etc...
	Deck status changing during a pass.	Aircraft rolling in the groove calling emergencies on the ball that have not been briefed.			
	Foul deck scenarios	Aircraft not responding to power calls and when the decision to wave them off occurs			
	LA Incursions	Unpredictable pilot responses			
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
Field	fouled LA	Pitching Deck	ARBs	Foul weather, pitching deck, MOVLAS, emergencies that don't require barricading because lets be honest we don't do that.	
		MOVLAS	Bad Weather	Starting out, I would show them what the "perfect pass" looks like so they can judge every pass off that glideslope.	
		Pitching deck	ARB	All scenarios	

			scenarios	are helpful to practice.	
		MOVLAS	procedural practice		
		Lack of pilot response			
		Tight interval			
Qualification	**Deck Calling LSO**	**Controlling LSO**	**Backup LSO**	**Procedures**	**Broad Response**
No Qualification	Deck going foul due to people or objects in the LA with aircraft IM-IC and a 10 foot waveoff window already established.	Calling passes with large glideslope extremes, including aircraft without sufficient ramp clearance requiring waveoffs.	Large Drift		everything, but mainly the ability to spit out the pass as quickly as possible—simply put: lots of iterations

18. Not considering the staff at the LSO school, how beneficial would you consider your experience with the LSOT (2H111) itself, practicing both individual and team concepts?

Please choose the appropriate response for each item:

Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time
○	○	○	○	○	○	○



Qualification	Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time	No response
Staff	3	2	1	0	0	0	0	0
Training	1	2	1	0	0	0	0	0
Wing	4	1	0	0	0	0	0	1
Squadron	5	1	0	0	0	0	0	0
Field	3	4	0	0	0	0	0	0
No Qualification	0	0	0	0	0	0	0	0
Total—35 (29 + 6)	16	10	2	0	0	0	0	1

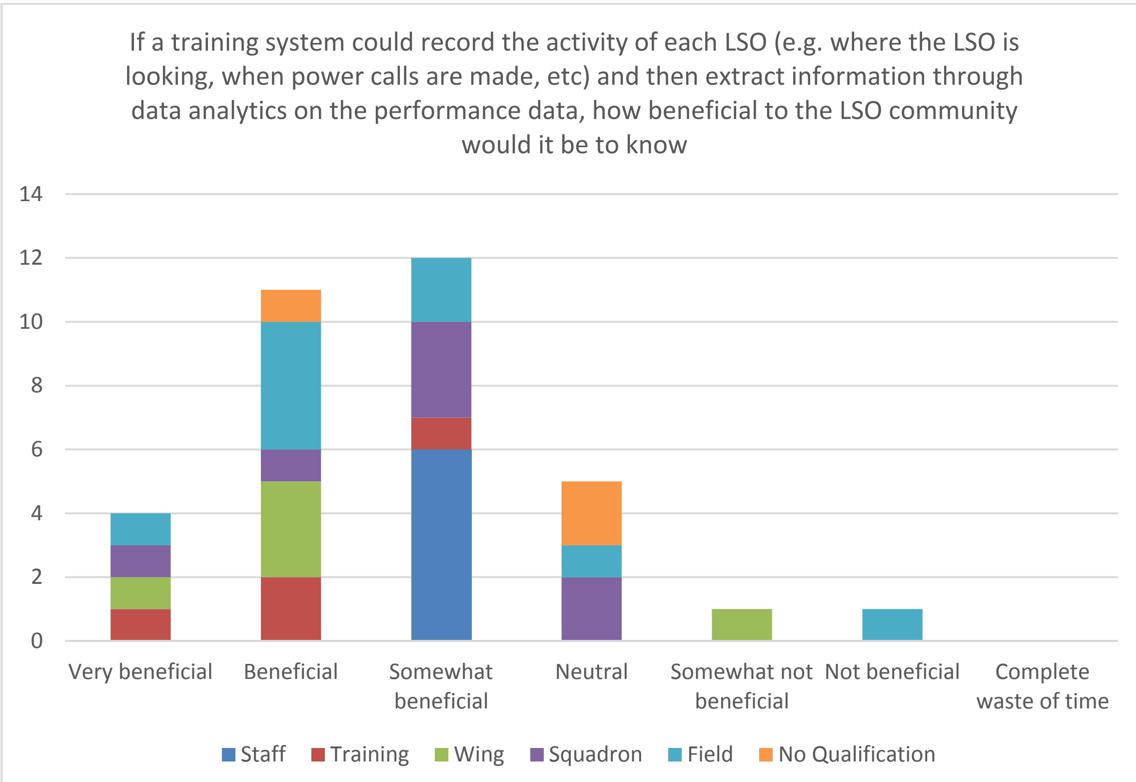
* Only subjects that identified that they had attended the LSO School for IFGT were allowed to answer this question. The following six LSOs were affected by this:

- One Squadron LSO
- Two Field LSOs
- Three No Qualification LSOs

19. If a training system could record the activity of each LSO (e.g., where the LSO is looking, when power calls are made, etc.) and then extract information through data analytics on the performance data, how beneficial to the LSO community would it be to know the performance trends of LSOs?

Please choose the appropriate response for each item:

Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time
◯	◯	◯	◯	◯	◯	◯

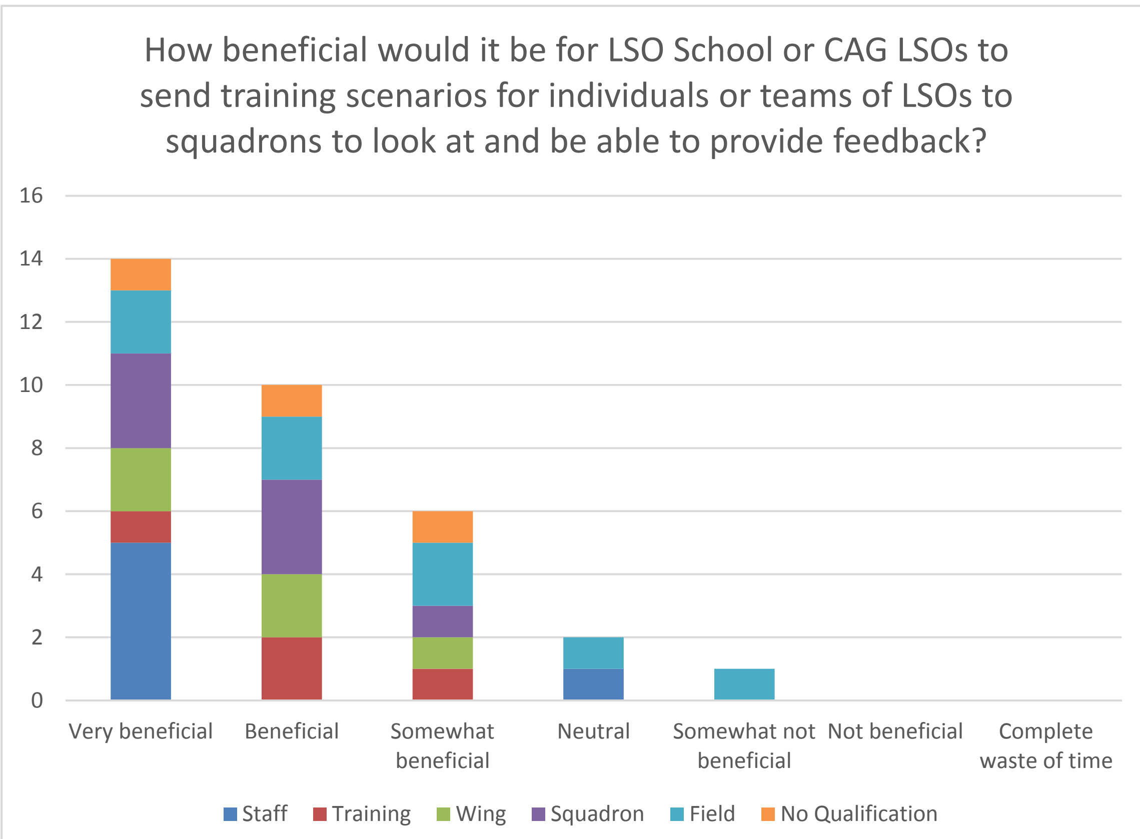


Qualification	Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time	No response
Staff	0	0	6	0	0	0	0	0
Training	1	2	1	0	0	0	0	1
Wing	1	3	0	0	1	0	0	0
Squadron	1	1	3	2	0	0	0	0
Field	1	4	2	1	0	1	0	0
No Qualification	0	1	0	2	0	0	0	0
Total—35	4	11	12	5	1	1	0	1

20. How beneficial would it be for LSO School or CAG LSOs to send training scenarios for individuals or teams of LSOs to squadrons to look at and be able to provide feedback?

Please choose the appropriate response for each item:

Very beneficial	**Beneficial**	**Somewhat beneficial**	**Neutral**	**Somewhat not beneficial**	**Not beneficial**	**Complete waste of time**
○	○	○	○	○	○	○

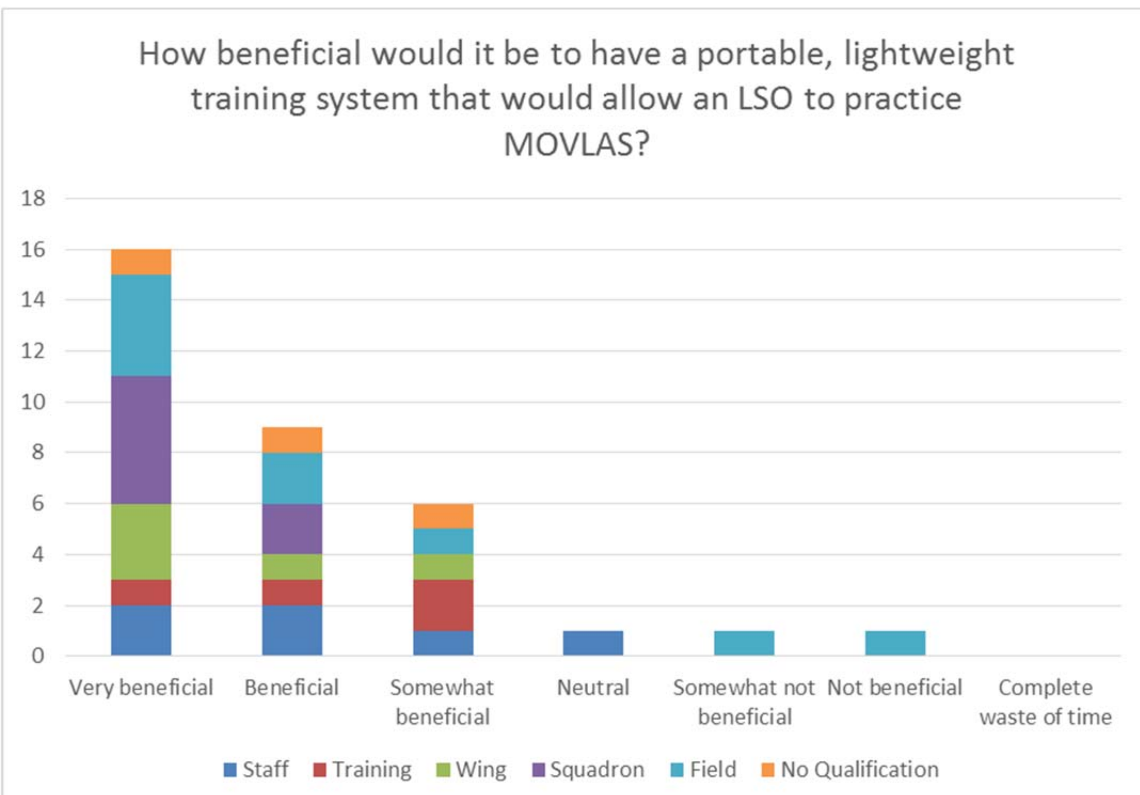


Qualification	Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time	No response
Staff	5	0	0	1	0	0	0	0
Training	1	2	1	0	0	0	0	0
Wing	2	2	1	0	0	0	0	1
Squadron	3	3	1	0	0	0	0	0
Field	2	2	2	1	1	0	0	1
No Qualification	1	1	1	0	0	0	0	0
Total—35	14	10	6	2	1	0	0	2

21. How beneficial would it be to have a portable, light-weight training system that would allow an LSO to practice MOVLAS?

Please choose the appropriate response for each item:

Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time
○	○	○	○	○	○	○



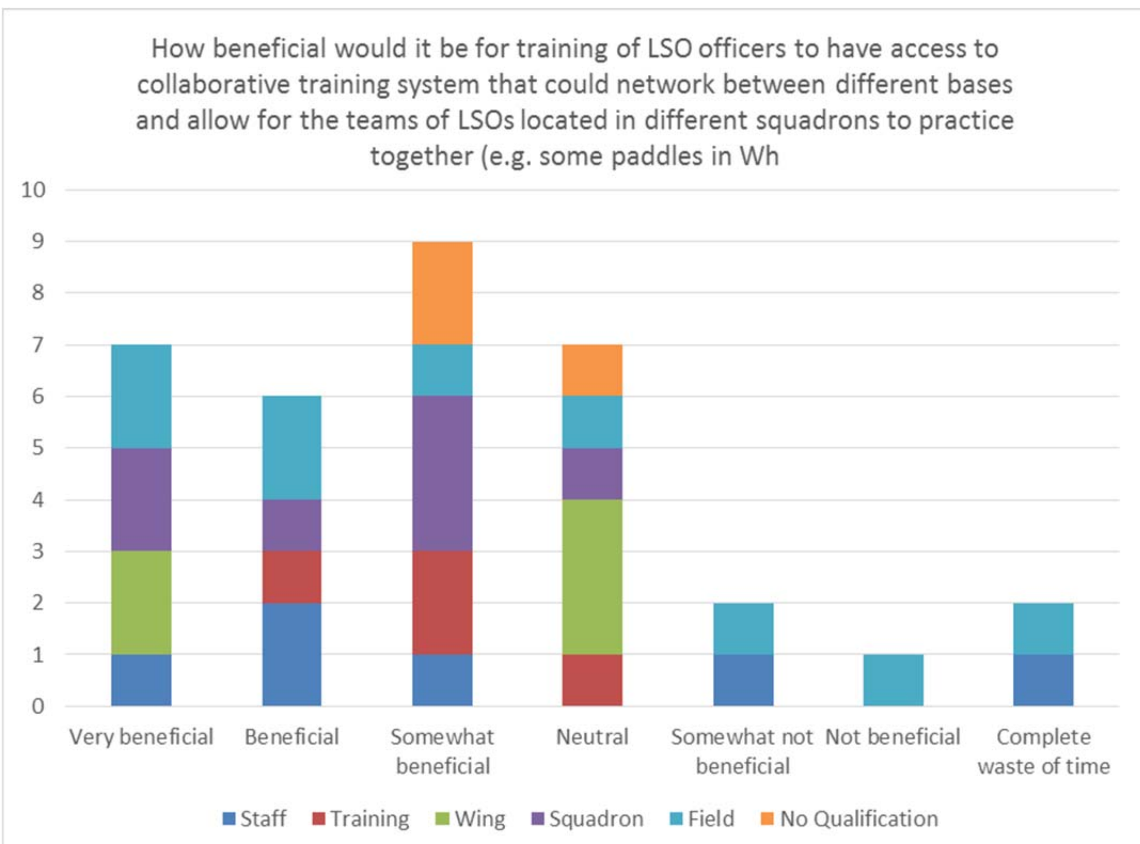
Qualification	Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not	Not beneficial	Complete waste of time

					beneficial		
Staff	2	2	1	1	0	0	0
Training	1	1	2	0	0	0	0
Wing	3	1	1	0	0	0	0
Squadron	5	2	0	0	0	0	0
Field	4	2	1	0	1	1	0
No Qualification	1	1	1	0	0	0	0

22. How beneficial would it be for training of LSO officers to have access to collaborative training system that could network between different bases and allow for the teams of LSOs located in different squadrons to practice together (e.g., some paddles in Whidbey and some in Lemoore)?

Please choose the appropriate response for each item:

Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time
○	○	○	○	○	○	○



Qualification	Very beneficial	Beneficial	Somewhat beneficial	Neutral	Somewhat not beneficial	Not beneficial	Complete waste of time
Staff	1	2	1	0	1	0	1
Training	0	1	2	1	0	0	0
Wing	2	0	0	3	0	0	0
Squadron	2	1	3	1	0	0	0
Field	2	2	1	1	1	1	1
No Qualification	0	0	2	1	0	0	0

23. Please put the following features that could be implemented in the trainer in order, based on perceived value in training**.**

All your answers must be different.

Please number each box in order of preference from 1 to 8

☐ Different aircraft platforms

☐ Emergencies and Malfunctions

☐ LSO Talkdowns

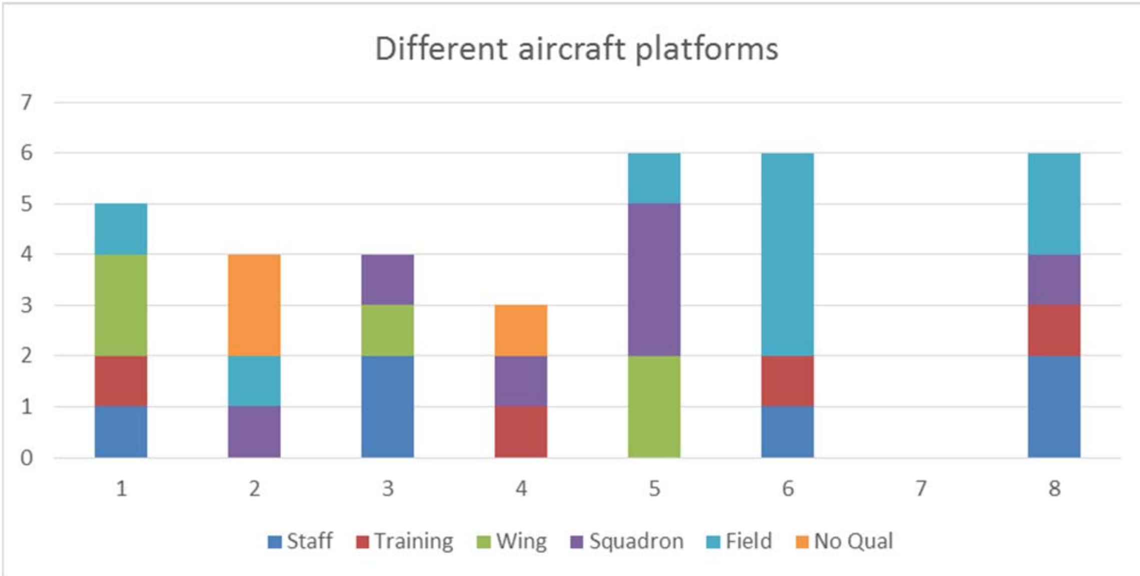
☐ Playback (being able to save and replay a pass, or run the same pass again)

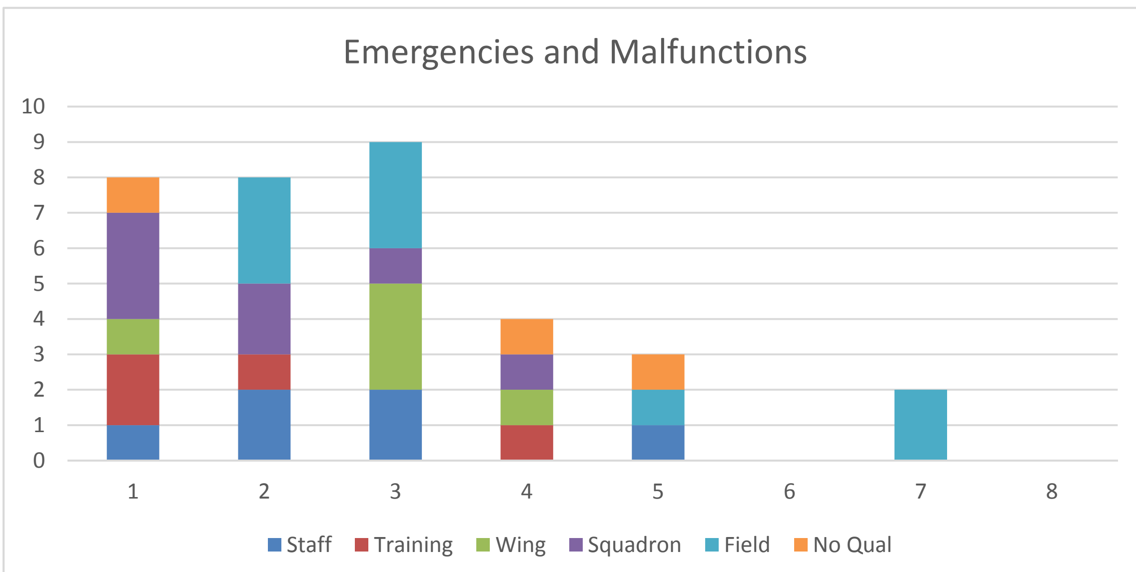
☐ Pause (Pause the simulation in the middle of a pass)

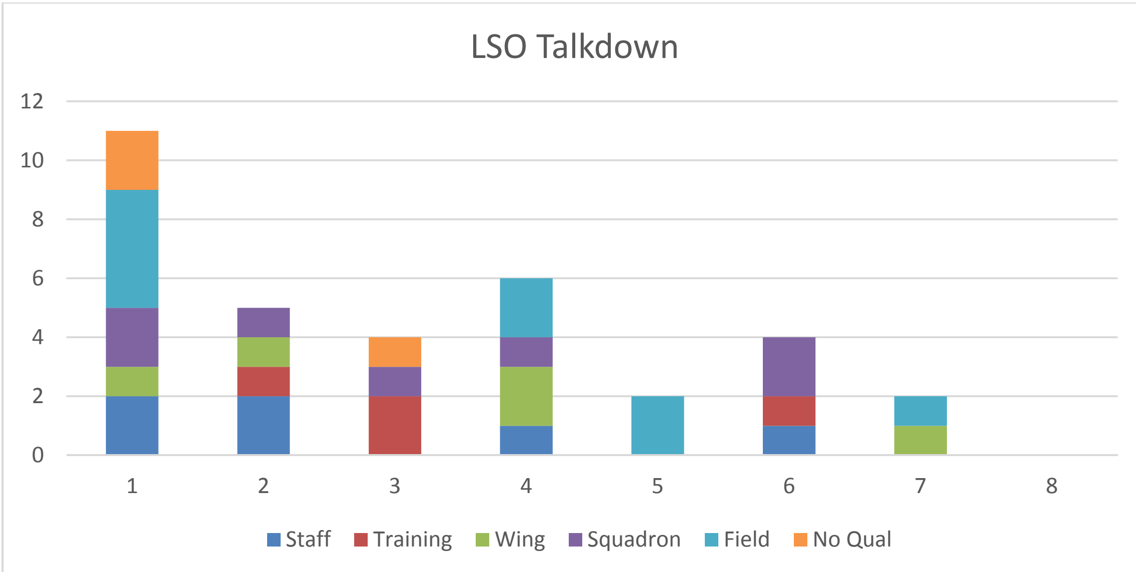
☐ Slow / Fast (Being able to manually adjust the speed of the pass)

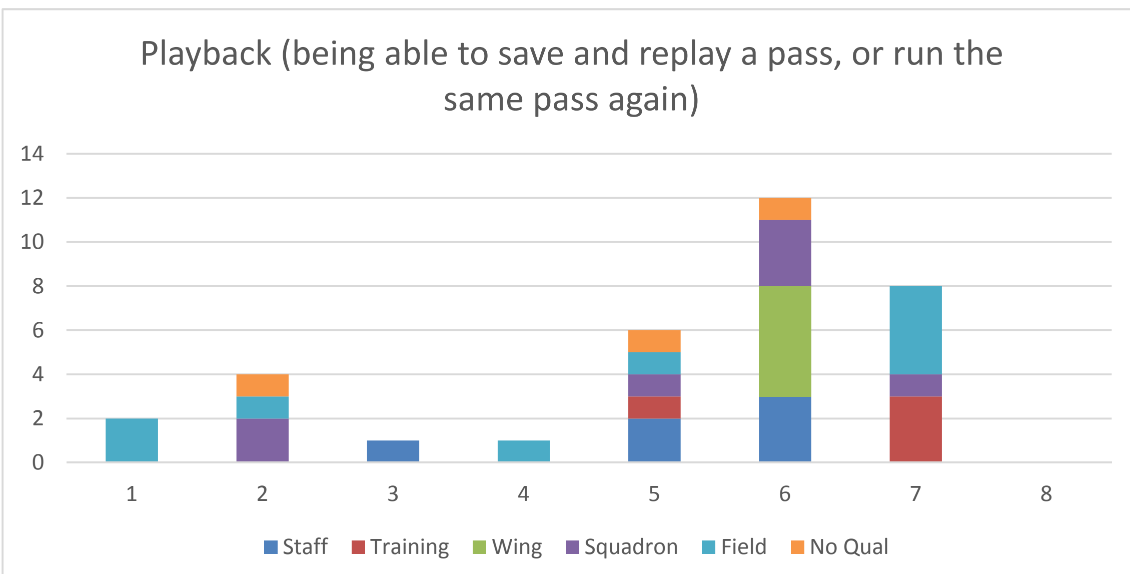
☐ Sound (Changing the pitch of the engine based on how the aircraft is performing)

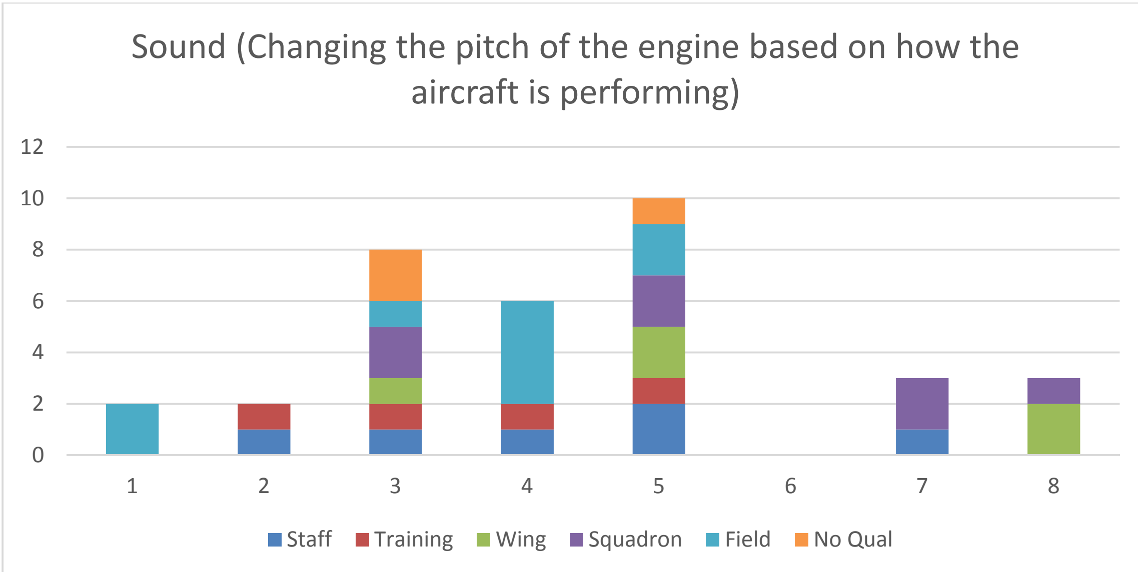
☐ Challenging weather conditions (e.g., limited visibility)

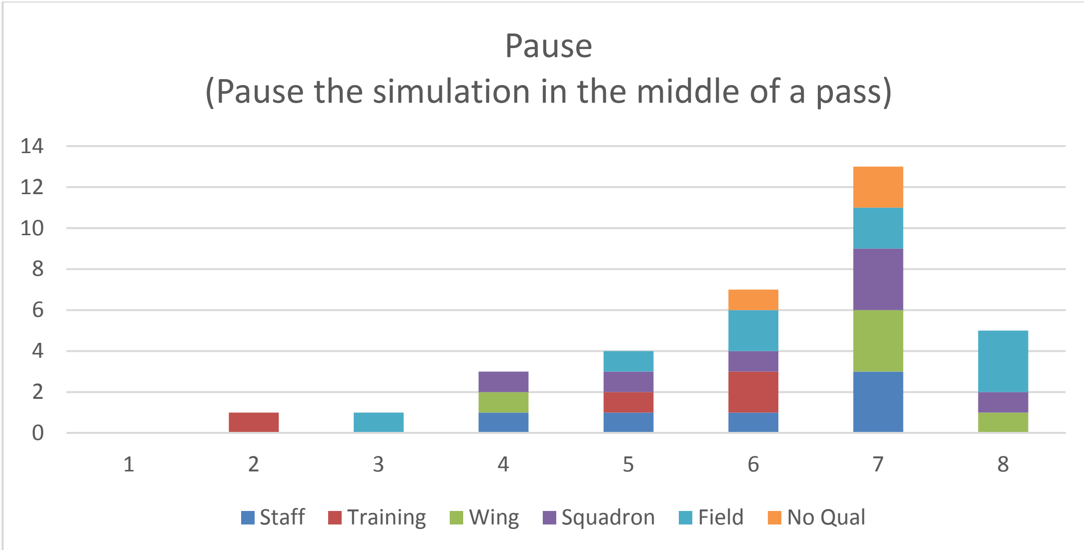

Different aircraft platforms
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual

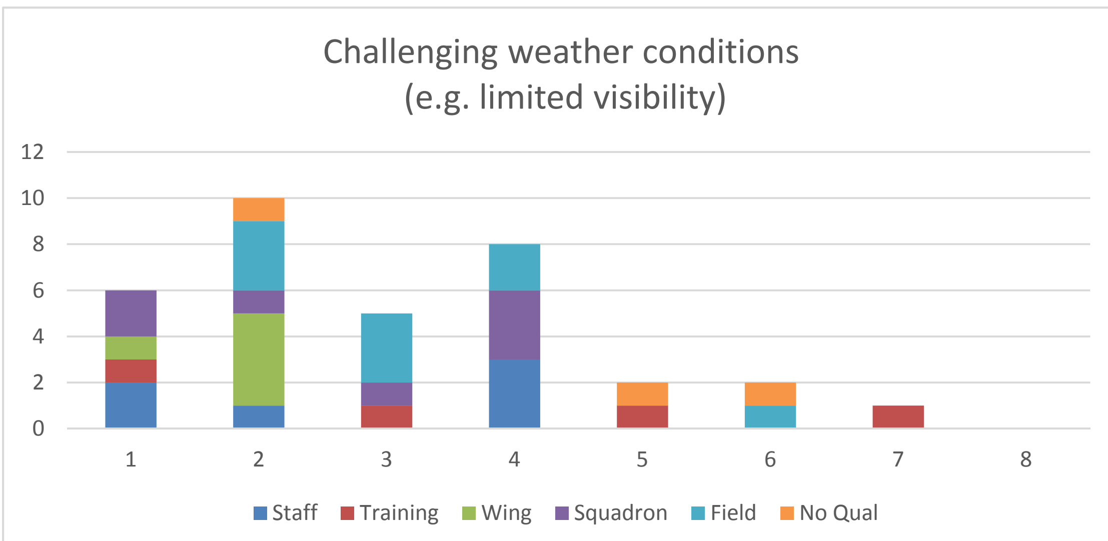

Emergencies and Malfunctions
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual

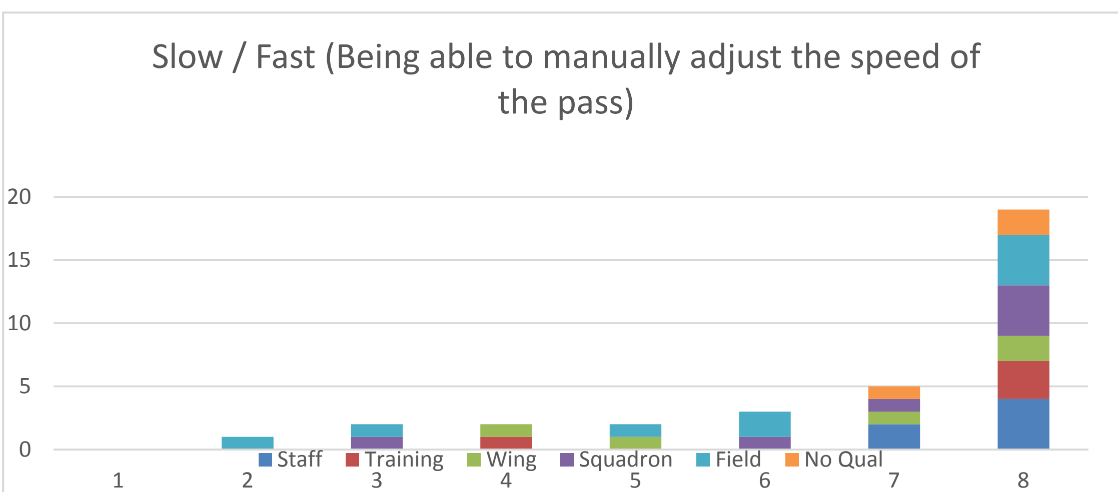

LSO Talkdown
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual


Playback (being able to save and replay a pass, or run the same pass again)
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual


Sound (Changing the pitch of the engine based on how the aircraft is performing)
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual


Pause
(Pause the simulation in the middle of a pass)
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual


Challenging weather conditions
(e.g. limited visibility)
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual


Slow / Fast (Being able to manually adjust the speed of the pass)
20
15
10
5
0
1
2
3
4
5
6
7
8
Staff
Training
Wing
Squadron
Field
No Qual

Staff LSOs Qualification Preferences—6 Individuals

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice	7th Choice	8th Choice
LSO Talkdowns	2	2	0	1	0	1	0	0
Emergencies and Malfunctions	1	2	2	0	1	0	0	0
Playback	0	0	1	0	2	3	0	0
Challenging weather conditions	2	1	0	3	0	0	0	0
Sound	0	1	1	1	2	0	1	0
Pause	0	0	0	1	1	1	3	0
Slow / Fast	0	0	0	0	0	0	2	4
Different aircraft platforms	1	0	2	0	0	1	0	2

Training LSOs Qualification Preferences—4 Individuals

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice	7th Choic e	8th Choice
LSO Talkdowns	0	1	2	0	0	1	0	0
Emergencies and Malfunctions	2	1	0	1	0	0	0	0
Playback	0	0	0	0	1	0	3	0
Challenging weather conditions	1	0	1	0	1	0	1	0
Sound	0	1	1	1	1	0	0	0
Pause	0	1	0	0	1	2	0	0
Slow / Fast	0	0	0	1	0	0	0	3
Different aircraft platforms	1	0	0	1	0	1	0	1

Wing LSOs Qualification Preferences—5 Individuals

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice	7th Choice	8th Choice
LSO Talkdowns	1	1	0	2	0	0	1	0
Emergencies and Malfunctions	1	0	3	1	0	0	0	0
Playback	0	0	0	0	0	5	0	0
Challenging weather conditions	1	4	0	0	0	0	0	0
Sound	0	0	1	0	2	0	0	2
Pause	0	0	0	1	0	0	3	1
Slow / Fast	0	0	0	1	1	0	1	2
Different aircraft platforms	2	0	1	0	2	0	0	0

Squadron LSOs Qualification Preferences—7 Individuals

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice	7th Choice	8th Choice
LSO Talkdowns	2	1	1	1	0	2	0	0
Emergencies and Malfunctions	3	2	1	1	0	0	0	0
Playback	0	2	0	0	1	3	1	0
Challenging weather conditions	2	1	1	3	0	0	0	0
Sound	0	0	2	0	2	0	2	1
Pause	0	0	0	1	1	1	3	1
Slow / Fast	0	0	1	0	0	1	1	4
Different aircraft platforms	0	1	1	1	3	0	0	1

Field LSOs Qualification Preferences—9 Individuals

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice	7th Choice	8th Choice
LSO Talkdowns	4	0	0	2	2	0	1	0
Emergencies and Malfunctions	0	3	3	0	1	0	2	0
Playback	2	1	0	1	1	0	4	0
Challenging weather conditions	0	3	3	2	0	1	0	0
Sound	2	0	1	4	2	0	0	0
Pause	0	0	1	0	1	2	2	3
Slow / Fast	0	1	1	0	1	2	0	4
Different aircraft platforms	1	1	0	0	1	4	0	2

No Qualifications LSOs Qualification Preferences—3 Individuals

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice	7th Choice	8th Choice
LSO Talkdowns	2	0	1	0	0	0	0	0
Emergencies and Malfunctions	1	0	0	1	1	0	0	0
Playback	0	1	0	0	1	1	0	0
Challenging weather conditions	0	0	0	1	0	1	0	1
Sound	0	0	2	0	1	0	0	0
Pause	0	0	0	0	0	1	2	0
Slow / Fast	0	0	0	0	0	0	1	2
Different aircraft platforms	0	2	0	1	0	0	0	0

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APPENDIX D. MISHAP STATISTICS

DEPARTMENT OF THE NAVY
NAVAL SAFETY CENTER
375 A STREET
NORFOLK, VIRGINIA 23511-4399

5720
Ser 023/F0172
July 23, 2015

LT Larry C. Greunke, USN
[redacted]

Dear Lieutenant Greunke:

SUBJ: YOUR FREEDOM OF INFORMATION ACT CASE 2015-NSC-195; DON-NAVY-2015-007332

This is in response to your July 7, 2015 Freedom of Information Act (FOIA) request asking for generic numbers regarding the total number of aircraft carrier landing mishaps involving Navy and Marine Corps fixed wing aircraft since 2005 and the involvement of Landing Signal Officers in those mishaps. Additionally, you asked for the number of aircraft carrier landing mishaps involving MOVLAS and IFLOLS.

A search of our database produced 108 landing-related mishaps on aircraft carriers since 2005. Of those, 99 involved the LSO in some manner, 41 events reported damage to property, and 2 reported injuries to personnel. Although we do not have a database field to specifically code the involvement of MOVLAS and IFLOLS systems in mishaps, 5 of the 108 events referenced MOVLAS and 2 of the 108 events referenced IFLOLS in the narratives. We do not believe the MOVLAS/IFLOLS numbers are accurate since they are not consistently captured.

Your request was treated as an "all others request" as defined by Secretary of the Navy Instruction 5720.42F dated 6 January 1999, Subject: DEPARTMENT OF THE NAVY FREEDOM OF INFORMATION ACT (FOIA) PROGRAM. There are no fees associated with the processing of your request in this instance.

If you have any questions, you may contact Mr. James Webb at (757) 444-3520 Ext. 7096 or via e-mail at safe-foia@navy.mil. Please refer to case number 2015-NSC-195 when inquiring about your request.

Sincerely,

N. B. Jones
Staff Attorney
By direction of the Commander

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LIST OF REFERENCES

Allen, G. L., Siegel, A. W., & Rosinski, R. R. (1978). The role of perceptual context in structuring spatial knowledge. *Journal of Experimental Psychology: Human Learning and Memory*, *4*(6), 617–630.

Australian Navy. *The Angled Flight Deck*. (n.d.). Retrieved from Australian Navy: http://www.navy.gov.au/history/angled-flight-deck

Bennett, A., Coxon, M., & Mania, K. (2010). The effect of stereo and context on memory and awareness states in immersive virtual environments. *Applied Perception in Graphics and Visualization* (pp. 135–140). New York, NY: Association for Computing Machinery.

Berbaum, K., & Kennedy, R. (1985). *Plan for evaluation of the training potential of helmet mounted display and computer-generated synthetic imagery*. Orlando, FL: Essex Corporation.

Binstock, A. (2015, May 15). Powering the rift. [Blog post]. Retrieved from https://www.oculus.com/en-us/blog/powering-the-rift/

Borden, G. J. (1969). *The Landing Signal Officer: A problem analysis*. Goleta, CA: Human Factors Research.

Bossard, C., Kermarrec, G., Buche, C., & Tisseau, J. (2008). Transfer of learning in virtual environments: A new challenge. *Virtual Reality*, 151–161.

Brictson, C. A., & Breindenbach, S. T. (1981). *Conceptual Development of a Premilinary LSO Carrier Training Aid*. Naval Training Equipment Center: Orlando, FL.

Brooks, F. P. (1998, April 21). Is There Any Real Virtue In Virtual Reality [PowerPoint]. Retrieved from University of North Carolina, Chapel Hill: http://www.cs.unc.edu/~brooks/RealVirtue.pdf

Brooks, F. P. (1999). What's Real About Virtual Reality. *IEEE Computer Graphics and Applications*, 16–27.

Burdea, G. C., & Coiffet, P. (2003). *Virtual Reality Technology*. Hoboken, NJ: John Wiley & Sons.

Cavagnaro, C. (2015, August 7). *150807-N-IP531-965*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/150807-N-IP531-965.JPG

Constine, J. (2014, July 21). Facebook's $2 Billion Acquisition Of Oculus Closes, Now Official. *Tech Crunch*. Retrieved from http://techcrunch.com

Dalgarno, B., & Lee, M. (2010). What are the Learning Affordances of 3-D Virtual Environments? *British Journal of Educational Technology*, *41*(1), 10–32.

de Vries, S. C., Bos, J. E., van Emmerik, M. L., & Groen, E. L. (2007). Internal and External Field of View: Computer Games and Cybersickness. *Visually Induced Motion Sickness, Fatigue, Photosentive Epileptic Seizures (VIMS)*, (pp. 89–95). Hong Kong.

Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science*, *323*(5910), 66–69.

Eddowes, E., & Waag, W. (1980). *The Use of Simulators for Training In-Flight and Emergency Procedures.* Neuilly sur Seine, France: Agard.

Elis, S. R. (1994). What are Virtual Environments? *Computer Graphics and Applications 14*(1), 17–22.

Fenaroli, S. (2014, April 9). *140409-N-HD510-006*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/140409-N-HD510-006.JPG

Hendrix, C. (2015, May 1). *150501-N-YO638-131*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/150501-N-YO638-131.JPG

Hettinger, L. J., Berbaum, K. S., Kennedy, R. S., Dunlap, W. P., & Nolan, M. D. (1990). Vection and Simulator Sickness. *Military Psychology*, *2*(3), 171–181.

Hilkowski, A. (2013, November 9). *131109-N-ZZ999-176*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/131109-N-ZZ999-176.JPG

Hof, R. (2015, June 11). VC Investments Pour Into Virtual Reality Startups, But Payoff Looks Distant. *Forbes.* Retrieved from http://www.forbes.com

Interrante, V., Anderson, L., & Ries, B. (2006). Distance Perception in Immersive Virtual Environments, Revisted. *Virtual Reality Conference* (pp. 3–10). Alexandria, VA: IEEE.

Jacko, J. A., Scott, I. U., Sainfort, F., Moloney, K. P., Kongnakorn, T., Zorich, B. S., & Emery, K. V. (2002). Effects of Multimodal Feedback on the Performance of Older Adults with Normal and Impaired Vision. *Proceedings of the User Interfaces for all* (pp. 3–22). Berlin, Germany: Springer.

Jones, N. B. (2015, July 23). Your Freedom of Information Act Case 2015-NSC-195; DON-NAVY-2015-007332. Norfolk, Virginia: Naval Safety Center.

Kelly, J. W., Hammel, W. W., Siegel, Z. D., & Sjolund, L. A. (2014). Recalibration of Perceived Distance in Virtual Environments Occurs Rapidly and Transfers Asymmetrically Across Scale. *Transactions on Visualization and Computer Graphics, 20*(4), pp. 588–596.

Kirwan, B., & Ainsworth, L. K. (2003). *A Guide to task analysis.* London; Washington, D.C.: CRC Press.

LaVoila, J. J. (2000). A Discussion of Cybersickness in Virtual Environments. *SIGCHI Bulletin, 32(I)*, 47–56.

MacMillan, J., Entin, E., Morley, R., & Bennett, W. (2013). Measuring Team Performance in Complex and Dynamic Military Environments: The SPOTLITE Method. *Military Psychology*, *25*(3), 266–279.

McCauley, M. E., Cotton, J. C., & Hooks, J. T. (1982). *Automated Instructor Models for LSO Training Systems.* Orlando, FL: Naval Training Equipment Center.

McLearnon, R. (2013, May 17). *130517-N-GC639-063*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/130517-N-GC639-063.jpg

Mestre, J. (2002). *Transfer of Learning: Issues and Research Agenda.* Washington, D.C.: National Science Foundation.

Naval Air Systems Command. *Landing Signal Officer NATOPS Manual (NAVAIR 00–80T-104).* (15 September 2013). Paxtuxent River, MD: COMNAVAIRSYSCOM.

Nerd's Best Advice. (2013, June 16). C# Programming | Speech Recognition & Text to Speech!! [Video File]. Retrieved from https://www.youtube.com/watch?v=KR0-UYUGYgA

Office of Naval Research (2015). *Naval S&T Strategy: Innovations for the Future Force.* Arlington, VA: Office of Naval Research.

Pittman, S. M. (2012, September 8). *120908-N-FI736-056.* Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/120908-N-FI736-056.jpg

Popp, M. M., Platzer, E., Eichner, M., & Schade, M. (2004). Walking with and Without Walking: Perception of Distance in Large-Scale Urban Areas in Reality and in Virtual Reality. *Presence, Vol 13, No. 1*, 61–76.

Salas, E., Rosen, M., Held, J., & Weissmuller, J. (2009). Performance Measurement in Simulation-Based Training. *Simulation and Gaming*, *40*(3), 328–376.

Stanney, K. M., & Mourant, R. R. (1998). Human Factors Issues in Virtual Environments: A Review of the Literature. *Presence*, *7*(4), 327–351.

Tate, J. R. (1978). We Rode the Covered Wagon. *United States Naval Institute Proceedings.*

The Verge. (2015*).* Oculus Rift DK2 [Fact Sheet]. Retrieved from The Verge: http://www.theverge.com/products/oculus-rift-dk2/7646

Thompson, W. B., Willemsen, P., Gooch, A., Creem-Regehr, S. H., Loomis, J. M., & Beall, A. C. (2004, October). Does the Quality of the Computer Graphics Matter when Judging Distances in Visually Immersive Environments? *Presence: Volume 13, Number 5*, pp. 560–571.

U.S. Army. (2014, May 19). *Virtual Battlespace 3.* Retrieved from United States Army: http://www.army.mil/standto/archive_2014-05-19

U.S. Navy. (2011, July 2). *110702-N-ZZ999-457*. Retrieved from Navy: http://www.navy.mil/management/photodb/photos/110702-N-ZZ999-457.jpg

U.S. Navy (2005). *Navy & Marine Corps Mishap and Safety Investigation, Reporting, and Record Keeping Manual.* Washington, DC: Office of the Chief of Naval Operations.

U.S. Navy. *The Landing Signal Officer* (1963). [Motion Picture]. Retrieved July 12, 2015, from https://www.youtube.com/watch?v=GtOI9NHmrOI

Unity. *Build Once Deploy Anywhere*. (2015). Retrieved from https://unity3d.com/unity/multiplatform

Wagner, J. (2014, October 16). *141016-N-TP834-500*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/141016-N-TP834-500.JPG

Wiekhorst, L., & Dixon, K. (1987). *F-16 Partial Field-of-View Visual Simulator Training Effectiveness Evaluation.* Williams AFB, AZ: Tactical Air Command.

Wilson, C. (2008). *Avatars, Virtual Reality Technology, and the U.S. Military: Emerging Policy Issues.* Washington, DC: Congressional Research Service.

Witmer, B. G., & Singer, M. J. (1995). Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence*, 225–240.

Wolfe, A. (2014, November 4). *141104-N-ZZ999-017*. Retrieved from U.S. Navy: http://www.navy.mil/management/photodb/photos/141104-N-ZZ999-017.JPG

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