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Developing a Low-Cost, Portable Virtual Environment for Aircraft Carrier Launch Officers

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The primary purpose of a United States aircraft carrier is to transport its embarked air wing in order to project combat power through the launch and recovery of various aircraft. In order to get airborne, the air wing depends upon the skills of a small number of officers responsible for the safe and rapid launch of aircraft from the carrier deck. These officers, known as "shooters", receive initial classroom training on the systems they use then receive qualification to be launch officers through on-the-job training. Due to scheduling complexities the training to achieve qualification is disjointed and often requires trainees to go underway with different aircraft carriers to complete their training. The current approach results in burdens on the parent command, host commands, and the trainees. Of greater concern is the lack of consistency in the training of such a high risk activity. This paper describes the results of a job task analysis conducted to provide insights into the skills required to perform the duties of a launch officer. Further, the information from the job task analysis was examined and a representative finite state machine was developed and is presented. Finally, a portable, low-cost virtual environment created based on the work described above is discussed. It is proposed that the current virtual reality system used for this demonstration faithfully recreates the required attributes and scenarios to train launch officer tasks and that the prototype system, with proof of training transfer can reduce the burden on commands, trainees, and perhaps most importantly, provide consistent training.

INTRODUCTION

The primary weapons system on the aircraft carrier is the carrier air wing which consists of approximately 80 aircraft with varying capabilities. These aircraft and their crews cannot complete their missions while parked on the carrier. Aboard the aircraft carrier, the air department is responsible for ensuring that the aircraft of the air wing are fueled, positioned, launched, and recovered safely. Of the approximately 800 personnel composing the air department, only a small group of officers, roughly 10, are qualified to launch aircraft from the carrier. These officers are the Aircraft Launch and Recovery Officers (ALROs), known as "shooters", are a vital component to the success of the air wing and the carrier. Shooters complete an initial three-week training course which focuses on the catapult and arresting gear systems. Upon completion of this course the officers report to their assigned ship and the remainder of their training is conducted by following a standardized training and qualification program known as the Personnel Qualification Standard (PQS) (Naval Education Training Command (NETC), 2012) which relies on on-the-job training (OJT). To become fully qualified, launch and recovery officers must train on four different watch stations: Arresting Gear Officer (AGO), No-Load Operations Officer, Bow Launch Officer (BLO), and Waist Launch Officer (WLO).

In order to complete the training and become qualified, these officers must accomplish their training on a carrier which is underway and performing flight operations. Often, this training cannot be conducted on a prospective shooter's assigned carrier due to the carrier being in port or underway and not performing flight operations. This will force the trainee to receive the required training on another carrier. In these cases, opportunities to train will be subject to scheduling conflicts as the training requirements of the host carrier's personnel and aircrew will be prioritized in order to maximize their opportunities to certify for deployment. On the surface, the use of experiential learning via OJT can be viewed as consistent with creating well developed mental models and solidifying procedural knowledge of the trainees. However, a closer examination of the OJT approach reveals that this training does not provide experiences with emergency or other abnormal conditions. Consequently, a shooter experiencing an off-nominal event for the first time will likely be their first opportunity to recognize the situation and employ the necessary skills to perform the procedures required to maximize the safety of personnel and equipment.

Skill Acquisition.

Based on decades of refinement, the five-stage model of the mental activities involved in directed skill acquisition (Dreyfus & Dreyfus, 1980, 1984; Dreyfus, H., 1986; Dreyfus, S., 2004) proposes five skill levels based on four mental qualities that one must progress through when learning a new skill. These skill levels are: novice, advanced beginner, competence, proficiency, and expertise. Within each skill level, the model suggests that there are mental functions which are required to take place including: components, perspective, decision, and commitment. Components represent the elements of a situation a trainee is capable of perceiving. Perspective is described as the ability to choose which components are attended to. The decision making type is either the analytic or intuitive approach that is taken based on experience. Commitment is described as the trainees immersion in a situation in regards to understanding of a situation, the decisions made based on that understanding and the resulting impact of those decisions. Adapted from Dreyfus (2004) Table 1 provides a brief description of each skill level's components, perspective, and approach to decision making. Considering the experience of the training audience (accomplished naval aircrew) which the system described in this paper proposes to engage, commitment, as described by the five-stage model, is a factor that may not be applicable. This assumption is based on the fact that ALRO trainees possess intimate carrier-based aviation domain knowledge.

Table 1. Five Stages of Skill Acquisition (adapted from Dreyfus, 2004)

Skill Level	Component	Perspective	Decision
Novice	Context free	None	Analytic
Advanced Beginner	Context free & situational	None	Analytic
Competent	Context free & situational	Chosen	Analytic
Proficient	Context free & situational	Experienced	Analytic
Expert	Context free & situational	Experienced	Intuitive

Following the five-stage model, it is essential to determine the skill level that the trainee has achieved in order to be effective. If the training program is not at the appropriate level the trainee will not progress to the next stage and may even regress to a previous level. For example, officers undergoing training who have already completed schoolhouse shooter training would be assessed as advanced beginners. These officers are able to recognize various situations and determine he correct actions to take, however they have no applied experience and will lack the rehearsed motor skills required to carry out a prescribed action and may not recognize unusual circumstances. According to the Dreyfus and Dreyfus model, this recognition will come with experience, practice, and exposure to varying situations.

Transfer of Training

Baldwin and Ford (1988) define training transfer is as "the degree to which trainees effectively apply the knowledge, skills, and attitudes gained in a training context to the job." In their review of the transfer of training research, the authors identified the principles of identical elements and stimulus variability as key contributors to the successful interaction between training inputs, training outputs and conditions of transfer. In context of computer generated training, Alexander, Brunyé, Sidman, & Weil (2005) propose that knowledge transfer can be increased by manipulating key concepts of an environment including fidelity, immersion, and presence.

Identical elements. The principle of identical elements consists of two aspects, physical fidelity and psychological fidelity. Succinctly defined by the Alexander, et al. in 2005, physical fidelity is "the degree to which the physical simulation looks, sounds, and feels like the operational environment in terms of the visual displays, controls, and audio as well as the physics models driving each of these variables" while psychological fidelity is defined as "the degree to which the simulation replicates the psychological factors (i.e., stress, fear) experienced in the real-world environment, engaging the trainee in the same manner as the actual equipment would in the real world."

Stimulus variability and fidelity. In 1961, Shore and Sechrest found that using a number of examples repeated a few times was a more effective training approach than using one example repeated many times. Several other early investigations (Shore & Sechrest, 1961; Underwood, 1969; Smith et al., 1974; Smith et al., 1974; Cormier, 1984) demonstrated that the highest levels of positive training transfer may not be based on fidelity, but rather the capacity of one part of the stimulus to cue the entire scenario. This means that the required fidelity can be subject to the level of training and that even low fidelity training can produce high quality training as long as there are strong and accurate cuing relationships between the scenario attributes.

Immersion and presence. Immersion is the degree to which an individual feels absorbed by or engrossed in a particular experience (Flexser & Tuluvung, 1978). Presence refers to the experience of actually existing within the virtual environment (Flexser & Tuluvung, 1978; Witmer &Singer, 1998). The difference between immersion and presence can be thought in terms of having a sense of physicality. For example, when an individual is immersed in an activity they remain aware of their physical location. When one has the sensation of presence in a virtual environment are experiencing a sensation in which they are physically located in that environment. In order to achieve appropriate immersion and presence, training system developers must consider how interactive virtual image displays, special processing techniques, and the use of non-visual modalities (i.e. auditory and haptic) can be used to convince users that they are immersed in a synthetic space Ellis (1994).

Simulating Training Tasks

A Government Accountability Office (GAO) briefing to the Senate and House Armed Services Committee in 2012 emphasized the use virtual environments for training when it stated that "if a skill or talent can be developed or refined, or if a proficiency can be effectively and efficiently maintained in a simulator, then these skills/talents/proficiencies should be developed/refined/maintained in a simulator" (United States Government Accountability Office, 2012). In order to understand the tasks that are to be simulated, an analysis of the job in question must be completed. The Naval Education and Training Command (NETC) developed a Job Duty Task Analysis (JDTA) Manual (NETC, 2011) which describes a process for analyzing the components which result in the accomplishment of an objective (Table 2).

Table 2. Components of Achieving an Objective (NETC, 2011)

Component	Definition
Occupation	A family of jobs that share a common set of skills.
Job	The duties, tasks, and steps performed by an individual.
Duty	A set of related tasks within a job.
Task	A single unit of a specific work behavior with clear beginning and ending points
Sub-Task	A major part of a task which is made up of one or more steps.
Step	The smallest component of a process.

Following the definitions above, "Aircraft Launch and Recovery Officer" can be understood as an occupation composed of various jobs which are outlined in the PQS. Following NETC's JDTA process, jobs can be decomposed into tasks and steps. In order to complete the various steps specific skills are required. These skills can be comprised of declarative knowledge, procedural knowledge, situation awareness, and psychomotor skills. Through an analysis of these elements, a determination can be made to inform which tasks are candidates for representation in a virtual training environment as discussed by Ellis (1994).

This effort demonstrated that a low-cost virtual environment to provide shooters with consistent training can be developed by using the five-stage model of skill acquisition as a framework, basing development on the level of the intended trainees (advanced beginners), considering the elements required to achieve positive transfer of training, and performing a systematic analysis of the Launch and Recovery Officer occupation.

METHOD

An Aircraft Launch and Recovery Officer subject matter expert (SME) participated in the development of a JDTA (NETC, 2011) for the ALRO occupation. Using the catapult launch system status as a reference, the identified candidate tasks from the JDTA were organized into a finite state machine (FSM) for the development of a virtual environment and creation of training scenarios.

Materials

Software. The Unity 4 game engine was used to create the virtual aircraft carrier flight deck environment. Unity is a cross-platform game development system which can be used by numerous platforms including Windows, OS X and Oculus Rift.

Autodesk 3DS Max 3D modeling software was used to create, modify and provide animation to the models used in the virtual environment.

Virtual reality head mounted display. The Oculus Rift Development Kit 2 (DK2) was used for this investigation. The Oculus is a lightweight, inexpensive head mounted display (HMD) device which can be used with a personal computer. The Oculus provides each eye with a 960x1080 resolution display, has a nominal field of view of 100 degrees, and has a refresh rate of 1000Hz

User input devices. Interaction with the virtual environment using was enabled with either a keyboard and mouse configuration or a Wii remote controller.

PROCEDURE

Job Task Analysis

A modified JDTA (NETC, 2011) process was followed to deconstruct the ALRO occupation and determine the relevant tasks. With the understanding that declarative knowledge is required for all jobs, an assessment to the SME assisted in determining which skills and sub-tasks were required for each task. In order to identify those shooter tasks with the greatest potential for training and in a virtual environment, each task was examined and assigned a level of difficulty, importance, and frequency which is used to rank the tasks.

Programming the Virtual Environment

Based on the evaluation of the enablers and detractors for developing a virtual environment for conducting shooter tasks, a top down programming approach was identified as being the most appropriate for creating the desired environment. Tasks identified in the job task analysis were evaluated to determine how best to represent and perform those tasks in a virtual environment. Once understood, the steps identified as parts of those tasks were further broken into corresponding programming elements and evaluated to determine the specifics of how to create these elements within a virtual environment. These elements were then used in to develop a FSM (Figure 1) based on the catapult launch system status which was used guide the development of the virtual environment and scenarios using object oriented methods.

RESULTS

Job Duty Task Analysis

Presented in Table 3, select results of the modified JDTA are combined with the evaluation of suitability for representation for simulation for the WLO and BLO watch stations. (for brevity, sub-tasks are not included). The most important task identified in the JDTA was the scan for both the BLO (front carrier catapults) and WLO (mid carrier catapults) positions. While the scan patterns for bow and waist launches differ slightly, both scans consist of the same steps with the primary difference being the location of items to be observed in

Table 3. Select results of the modified JDTA combined with the evaluation of suitability for representation for simulation

Task	Simulation Requirements	Enablers	Detractors	DIF	Suitability for Sim Training
Bow and Waist Scans	Center Deck / CSV, Bow Light, Beacon, Shuttle, Topside Petty Officer (TSPO), Weight Board, Jet Blast Deflector, Final Checkers, Aircraft with Pilot, Deck Edge lights and PO,	Most to gain by simulating this Most time lost during the launch officer qualification phase. Currently requires underway with aircraft. Can simulate launch emergencies currently not trainable	Persistence: Scan involves moving head around rapidly and looking at many different areas Registration: Due to head movement. Many Models required. Difficult to build environment	D: (5/6) I: (6) F: (7)	Yes
Aircraft hookup/alignment	TSPO, Aircraft with detailed nose wheel, Shuttle	Easier to simulate than a full launch. Part of the launch sequence, so scalable. Minimal head movement	Normally first noticed by TSPO. Better simulated as part of the launch	D: (2) I: (5) F: (6)	Yes, but should be incorporated into a full launch scenario
Aircraft Configuration (wing locks, flaps settings, external stores, etc.)	Shuttle, TSPO, Final Checkers, Aircraft with different configurations (Flaps/Struts/WPNS)	Get to recognize configurations prior to real world. Minimal head movement	Configurations could be shown as pictures instead of in simulation. Better simulated as part of a full launch scenario	D: (2) I: (4) F: (6)	Yes, but should be incorporated into a full launch scenario

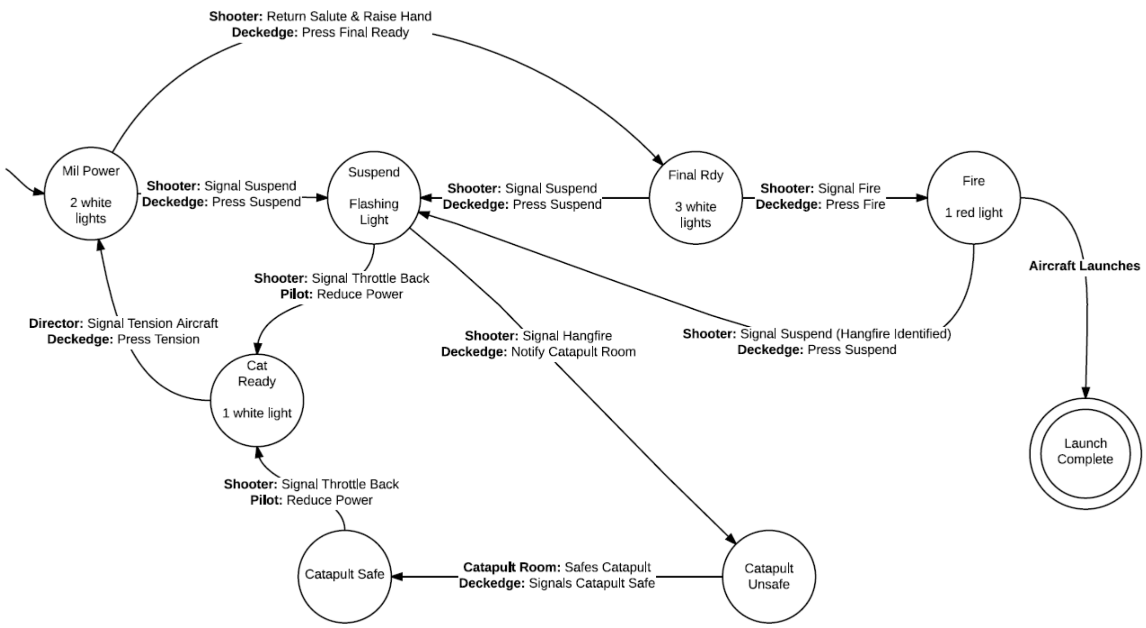

Figure 1. FSM based on shooter tasks in context of the catapult launch system

relation to the shooter. Based on the task analysis and available technology, the BLO watch station was determined to be position best suited for representation in the virtual environment. Additional shooter tasks such as aircraft configuration, aircraft hookup, and aircraft alignment were selected to increase the fidelity of each scenario.

Virtual Shooter Environment

The main elements identified for programming the shooter environment were: inputs (predefined scenarios, instructor injects, user input), actions (computations, timing events, variable manipulation), and outputs (environment display, reports, timing results). The resultant virtual environment is an interactive flight deck which immerses the user in the environment between the carrier's two bow catapults (Figure 2) and allows them to take actions as if they were on the flight deck conducting launch operations.

Figure 2. User view in the Virtual Launch Officer Environment (VLOE)

The system currently allows for a pre-planned and repeatable training scenario. Stimulus variability can be provided through the selection of the type and quantity of launch events desired. This is accomplished via a simple file requiring three fields for each scenario: type of launch (Table 4), headwinds, and crosswind.

Table 4. VLOE supported launch types

Type	Definition
Regular	Normal launch with no unusual circumstances.
Suspend	Launch that will be suspended by the airboss.
Hangfire	Launch that will end with a hangfire.
Badcheck	Launch that will be suspended by the final checker
Pitching	Launch with a pitching deck

Additional flexibility can be provided through the ability to inject or modify the scenario elements shown in Table 5.

Table 5. Available scenario injections and modifications

Injects	Modifications
Airboss suspend	Color of the bow safety light to red.
Final checker suspend	Headwinds
Pilot suspend	Crosswinds
Hangfire	Deck pitch (on or off only

Performance Measurement

The task of bow launch scan is measured in this virtual environment by roughly recording the amount of time the various elements identified are observed by the user. This observation determination is made by sphere-casting, which is projecting an invisible sphere of radius 0.9 from the user's center of vision forward until it intersects a collision box around the an object in the VLOE. Starting and ending values of both the headwind and crosswind are also recorded for each launch scenario. This information is presented to the user on screen (Figure 3) upon completion of a scenario and saved to file for debriefing, record keeping, and trend analysis.

CONCLUSIONS

The use of virtual environments to achieve training transfer which results in the progression through the levels of skill acquisition presents a complex combination of factors. Analysis of the desired tasks to be trained and skills to be learned are

Figure 3. Virtual Launch Officer Environment completion report

essential to identifying the right balance of these factors in the development of any training environment. The hardware which generates the environment will also impact the virtual environment based on the methods of its presentation. When determining which device should be used, practicalities such as cost and development time must be considered and can have a considerable impact on selection of the device selected for use

The work presented here created a lightweight, low-cost environment for launch officers. By using the five level skill acquisition model as a framework, considering the elements required to achieve positive transfer of training, and conducting a systematic analysis of the ALRO occupation we were able to demonstrate a VLOE. Further, the system discussed in this paper is capable of providing scenarios required to practice the skills used in launching aircraft from an aircraft carrier that are considered to be abnormal events and has the potential to fill identified gaps in the current on-the-job training used to qualify launch officers.

Future Work

This effort is a first step towards realizing a carrier deployable simulation environment for flight deck personnel. In order to realize an operational end state, additional research must be conducted.

Human-subjects testing. The VLOE provides the elements necessary to perform the tasks required of the launch officer. An empirical investigation on training effectiveness was not conducted. Future work should develop a testing plan to measure the training effectiveness with a group of unqualified shooters preparing for their qualification boards. Further, the VLOE could be tested with qualified shooters in various stages during the inter-deployment timeline to evaluate the effectiveness of this environment on maintaining proficiency. Additionally, an investigation is needed to determine if the presentation type (desktop display vs. HMD) has an impact on the transfer of training on the launch officer tasks.

Technological trends. At the time of this development, augmented reality (AR) technologies were not adequate to build an AR environment for training launch operations on an actual flight deck. With future advancements of commercially available AR systems, future work could build and compare the differences in effectiveness of an AR VLOE system to the one developed for this effort.

DISCLAIMER

The views expressed in this paper are solely those of the authors and not necessarily those of the Naval Postgraduate School, United States Navy or the Department of Defense.

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