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https://hdl.handle.net/10945/55508

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

PROOF-OF-CONCEPT PART-TASK TRAINER TO ENHANCE SITUATION AWARENESS FOR INSTRUMENT APPROACH PROCEDURES IN AVIATION DOMAIN

by

Nicholas L. Arthur

June 2017

Thesis Advisor:	Amela Sadagic
Co-Advisor:	Lee Sciarini

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<tr><td colspan="3" align="center">**REPORT DOCUMENTATION PAGE**</td><td>*Form Approved OMB No. 0704–0188*</td></tr>
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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704–0188*

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1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2017	**3. REPORT TYPE AND DATES COVERED** Master's thesis	
4. TITLE AND SUBTITLE PROOF-OF-CONCEPT PART-TASK TRAINER TO ENHANCE SITUATION AWARENESS FOR INSTRUMENT APPROACH PROCEDURES IN AVIATION DOMAIN			**5. FUNDING NUMBERS**
6. AUTHOR(S) Nicholas L. Arthur			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number NPS.2017.0029-IR-EP7-A.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The terminal environment in the aviation domain is referred to as the region within close proximity of airports. Performance in this environment leaves little room for error and requires that pilots are fully aware of their situation and surroundings. This is especially true when conducting an instrument approach (IA). Currently, United States Marine Corps (USMC) KC-130J units do an exceptional job of training their pilots in this environment. However, the emergence of new technologies affords the opportunity to address shortfalls of legacy training approaches. To this end, this thesis uses a quasi-instructional systems design approach to develop a prototype IA part-task trainer (PTT) using commercial off-the shelf (COTS) systems to enhance current training methods to allow for training opportunities that are not limited by schedules or location. After the development of the PTT, subject-matter experts evaluated the prototype training system. Their feedback suggests that the system reliably re-created necessary cues (cockpit displays, environmental conditions, communications, time, and space) to build on users' existing knowledge and support situation awareness training for IA. Ultimately, the proof-of-concept prototype created for this thesis is envisioned to be part of a family of solutions capable of addressing existing training gaps in a cost-effective manner.

14. SUBJECT TERMS part-task trainer, instrument approach procedures, situation awareness, aviation, knowledge	**15. NUMBER OF PAGES** 77
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540–01-280-5500

Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

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PROOF-OF-CONCEPT PART-TASK TRAINER TO ENHANCE SITUATION AWARENESS FOR INSTRUMENT APPROACH PROCEDURES IN AVIATION DOMAIN

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF SCIENCE IN
MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION**

from the

**NAVAL POSTGRADUATE SCHOOL
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LIST OF ACRONYMS AND ABBREVIATIONS

CBT	Computer Based Trainer
CMC	Commandant of the Marine Corps
DVTE	Deployed Virtual Training Environment
EP	Emergency Procedures
FRD	Fleet Replacement Detachment
HUD	Heads Up Display
IA	Instrument Approach
IAP	Instrument Approach Procedure
IP	Instructor Pilot
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAID	Navigational Aid
PF	Pilot Flying
PTT	Part-task Trainer
RP	Replacement Pilot
SA	Situation Awareness
SME	Subject Matter Expert
USMC	United States Marine Corps
VE	Virtual Environment
VR	Virtual Reality

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ACKNOWLEDGMENTS

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I. INTRODUCTION

A. RESEARCH DOMAIN

An instrument approach (IA) is one method used to successfully land an aircraft at an airport. When an IA is being flown, there are several basic procedures that the pilot flying (PF) must accomplish in order to successfully land that aircraft. These basic procedures typically follow a sequence that does not change from approach to approach, so the aviator becomes very good at accomplishing this sequence successfully. However, when an emergency situation occurs during the flight and an IA must be flown to land the aircraft, these basic procedures could become difficult to accomplish. These emergency situations often require heighten situation awareness (SA) so that the basic procedures can be accomplished while also successfully completing the procedures of the emergency. Having sound SA is crucial in these situations for one major reason: if all basic and emergency procedures are not successfully completed during the IA, a catastrophic event could occur.

United States Marine Corps (USMC) KC-130J replacement pilots (RP) receive initial IA training at a Fleet Replacement Detachment (FRD). At the FRD, a RP conducts ground school, which consists of self-paced computer-based training (CBT) and instructor-led discussions focused on studying the missions of the KC-130J. In addition, there is material within different publications that a RP needs to know. The instrument approach procedure (IAP) elements of ground school consist of generic IAP for all aviators and IAP specific to KC-130J aviators. The RP will then begin to fly IAs in the KC-130J simulator. Initially, these IAs consist of honing these basic procedures so that the RP could acquire a solid level of confidence while executing those procedures. In these early stages of training at the FRD, it is commonly accepted that it is more important that the RP polishes these basic procedures rather than successfully fly the simulator. Successful flight of the simulator will come with practice, and it will be enhanced with mastery of the basic IAPs.

B.   RESEARCH PROBLEM AND MOTIVATION

When emergency procedures (EP) are introduced to an IA, the aviators, especially RPs, could experience some difficulties. Repetition of basic procedures is extremely important to a RP; the repetitive training approach can build the required foundation of these procedures so that they become second nature. However, aviators cannot use the simulator and aircraft to groom and acquire these procedures at their leisure. The simulator and aircraft follow a very rigid schedule, and the aviator may only have access to the simulator and aircraft two times a week. Whereas the simulator and aircraft provide potentially better opportunity to properly practice the procedures, their availability does not allow for the consistent repetition that is necessary.

Another technique called chair flying is a non-computer based technique, and aviators use it to practice any procedure on their own; this is typically done without the supervision of instructors. This approach has modest demand on resources—chair flying does not require anything but a chair. Though, chair flying is only useful if the aviator is practicing all procedures properly. This is especially true of a RP because at that stage in their career and training the RP may not have the ability to recognize that he or she is practicing the procedure incorrectly. It is worth emphasizing that negative practice could transfer to negative execution of procedures within the simulator and aircraft.

The instructor-led discussions are the only portion of the classroom environment that is required of the student. The knowledge of the computer-based training and readings are upon the student. However, the RP is required to combine the knowledge from these different avenues and apply it mentally and physically within the simulator and aircraft. The act of combining the required mental knowledge with the required physical actions of operating the cockpit while flying the aircraft can be overwhelming to the RP.

Proper repetitive practice of any procedure is essential to the development of this procedure. Since simulators and aircraft are not readily available and chair flying does not ensure proper practice, the development of a PTT could address that gap. If such a PTT would use a COTS platform that is inexpensive and easy to acquire, such as a tablet,

the PTT would afford the aviator the cost-effective opportunity to practice procedures anywhere at any time. General Robert B. Neller (2016), the Commandant of the Marine Corps (CMC), has stated that the Marine Corps can be "enabled by technology, we will increase the amount of training each unit can accomplish—to 'increase the reps' in mentally and physically stressing environments for all elements of the MAGTF before they do so on the battlefield" (p. 8). With the guidance of the CMC, the development of such a PTT becomes imperative to the Marine Corps future training programs. This type of affordable yet highly capable devices has a great potential of bridging a gap that currently exists in the training pipeline of any community in the Marine Corps.

C.   RESEARCH QUESTIONS

The foundation of the thesis is based on the following research questions:

- What is the feasibility of developing a prototype virtual reality (VR) system that supports the training of instrument approach procedures and situation awareness?

- Are there training gaps identified in connection with procedures and situation awareness needed to conduct an instrument approach by the aviators?

- What cues (cockpit, environmental, CRM, ATC, haptic, etc.) should KC-130J FRD students attend to in support of maintaining situation awareness during instrument approaches?

D.   SCOPE

The scope of this thesis is to investigate current techniques used by Marine Corps KC-130J squadrons and the FRDs to train aviators for IAP. A PTT will be developed as a proof-of-concept prototype with a goal to become a supplemental tool to the current training that aviators receive. A significant portion of this work will address the aspects of SA and how SA relates to IAP. The study also includes gathering of informal feedback during demo sessions. A training effectiveness study is not part of this thesis, yet it is envisaged as elements of follow-up work.

E. APPROACH

The approach used in support of the thesis research has consisted of analyzing literature related to SA and how a PTT enhances SA so that the basic IAP are committed to memory and conducted without thought. In addition, a user survey is conducted to provide a better understanding of preferences, habits, and recommendations from the fleet. The research of SA and the survey results were then used to design and develop the PTT. A demo of the prototype system was given to fellow aviators, and their informal feedback was acquired to help understand the value of the developed PTT.

F. METHODOLOGY

1. Introduction

The basis for this thesis is the work presented in a past NPS thesis involving Marine aviation (Attig, 2016). This thesis is not continuation work of those results but rather an effort to apply the basic concepts presented there to a different domain of Marine aviation—IAPs—and provides a novel PTT that could become a valuable tool to the Marine Corps' future training environment. Initially, multiple missions of the KC-130J community were suggested, and after much deliberation, the IAPs were chosen because they are among the first missions that RPs must learn. The PTT that resulted from this thesis effort gives the aviator the ability to run the scenario and observe the proper procedures associated with an IAP as it is conducted in the KC-130J.

2. Design Process

To begin with, a literature review of situation awareness, knowledge types, and PTT was conducted. These issues are the basis of this thesis, and it is imperative to express how the information acquired about each topic applies to the idea of using technology to assist with future training aspirations of the Marine Corps. The task analysis for the PTT was developed from the KC-130J Super Hercules' Naval Air Training and Operating Procedures Standardization (NATOPS) documentation. Within the NATOPS, sections of chapters 7 and 16 were used to generate the elements of task analysis (Chapter 7 was focused on the in-range, approach, and before landing flows and

checklists material, and Chapter 16 addressed the standard callouts required while executing an IA) (Department of the Navy, 2014). In order to assist with the design of the PTT, two surveys were conducted to collect valuable information from current IPs and RPs. Not only would these answers provide valued information for this thesis' success but the information was also used to inform the thoughts for follow-on work. Prior to developing these surveys, subject matter experts were questioned to assist with the development of the survey questions from the current atmosphere across the KC-130J community.

G. THESIS STRUCTURE

The remainder of this thesis is structured as follows:

- Chapter II describes SA, COTS, and knowledge.

- Chapter III details task analysis focused on instrument approach.

- Chapter IV presents the results of the instructor pilot (IP) and RP surveys and describes the process of developing a prototype trainer.

- Chapter V describes the informal feedback from fellow aviators and includes a summary of conclusions and future works related to this study.

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II. BACKGROUND

A. INTRODUCTION

The terminal environment of aviation is very dynamic and requires an aviator to maintain an elevated level of SA. It could also be argued that aviators must maintain a higher level of SA than air traffic control and ground personnel in this environment. Even under the most ideal conditions, this environment can become overwhelming for even the most experienced aviators. A less than appropriate level of SA could lead to disastrous results for many of the individuals involved. SA is comprised of many factors, and one factor is often dependent upon another factor or factors.

B. SITUATION AWARENESS

Situation Awareness has been widely studied by researcher Mica Endsley; Endsley (1995) describes SA as having three separate levels. Her definition of SA is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (p. 36).

The first level of SA is the ability to perceive the pieces of information, objects, etc. Perception is related to an individual's knowledge and can be influenced by the design of the system that supports SA (Endsley, 1995, pp. 36–37). She notes that if an individual has the necessary knowledge and the system is designed to take advantage of human information processing, the likelihood that the salient cues will be perceived is high (pp. 36–37). Initially, an individual's knowledge needs to be at a level that is suitable to fly an IA within the terminal environment. An aviator's knowledge does not have to be at an expert level, but he or she needs to know all the vital information needed to safely and successfully perform an IA. This includes the declarative and procedural knowledge concerning where and how to read an approach, frequencies, navigational aids (NAVAID), approach course, altitude, course adjustments, etc. Additionally, an aviator needs to know the Federal Aviation Administration's guidelines to flying an IA such as clearance procedures and missed approach procedures. If a system is poorly designed, it

is likely that an aviator's knowledge alone will not be sufficient enough to achieve or maintain a high level of SA. Hence, a well-designed system that enables the perception of environmental cues combined with the requisite knowledge will support an individual in successfully achieving level 1 SA and have a foundation for the higher levels of SA.

Level 2 SA is the comprehension of the elements within the current situation. Comprehension signifies one's ability to take the perceived information from level 1 and piece that information together in order to create a complete mental picture of the world in context of the operating environment (Endsley, 1995, p. 37). Simply put, level 2 SA is the ability to understand the current state of the perceived elements in the environment. Being able to create this mental picture is a crucial aspect of developing and maintaining a high level of SA within any given situation.

What is considered the highest level of SA, level 3 SA, is one's ability to accurately simulate the future activities of the elements perceived within the context of the individual's level 2 SA of the world (Endsley, 1995, p. 37). Beyond perceiving and comprehending relevant information, Level 3 SA is the convergence of "comprehending the meaning of that information in an integrated form, comparing it with operator goals, and providing projected future states of the environment that are valuable for decision making" (p. 37).

Endsley and Garland (2000) state that the proposed levels of SA describe a model for acquiring information, processing it, and applying it accurately. They claimed an individual's goals are what determine what would be considered appropriate SA. The two reported that if goals change, what comprises appropriate SA might need to be adjusted just as well. If maximal performance is desired, an individual must strive to have the highest possible SA in order to support the optimal decisions making on the associated tasks, their study showed. However, desired outcome expectations can have an impact on these goals. An individual may want to perceive information in a different manner than is required because they were expecting something different according to Endsley and Garland. According to the authors, it is preferable to have appropriate expectations so that when anticipated information is perceived it can be processed effectively. However, it is more important to have the ability to recognize that the information is not as

expected and the ability to process it properly per their study. Complexity of a situation can be related to the goal. In Endsley's 1995 work, she states that if the goal is too difficult, the complexity of a situation could become overwhelming and detract from an individual's ability to maintain sound SA (Endsley, 1995, p. 53). This is especially relevant for situations in which an overall goal is comprised of numerous sub goals.

SA is the main precursor to decision-making. Yet, many factors occur between SA and good decision-making (Endsley & Garland, 2000, pp. 4–5). An individual may have a high SA, but their performance may be poor due to circumstances outside of their control such as a faulty user interface or lack of information from third parties. In addition, the information available to an individual as they developed their three levels of SA may be insufficient, and the individual's perception of the situation can become significantly subpar. The key takeaway is that "SA, decision-making performance can be seen for theoretical purposes to be distinct stages that can each affect the other in a circular ongoing cycle, yet which can be decoupled through various other factors" (p. 5).

The measurement of SA is meaningful because it "provides a useful index for evaluating system design and training techniques and for better understanding human cognition" (Endsley & Garland, 2000, p. 17). This notion is essential because if the goal is to achieve a high level of SA than it is crucial that the system design provides this opportunity. There is not a level of SA that is required for each situation but having an appropriate level of SA is valuable. The key though is that the information that is available needs to be assessed properly so that a solid foundation of SA can be developed. Additionally, maintaining SA is a dynamic function that is constantly changing, and this requires an individual to dynamically process the ever-changing information and process it to the best of their ability at that given time.

In addition to building SA, an operator's attention is another key topic within the SA realm. If an individual is being attentive, the SA of that individual will typically be higher (Endsley & Garland, 2000, p. 9). However, it is important to note that even if an individual is being attentive, they may be attending to the wrong cues and their SA could be faulty and ultimately result in the committing of errors.

According to Endsley and Garland (2000), working memory is an activated subset of long-term memory. They suggest, "information from the environment may be processed and stored in terms of the activated mental model or schema" (p. 10). The concept of a mental model is something that an individual develops in order to visualize the information and process it. This concept is believed to be how an individual builds SA. These mental models are used within long-term memory and working memory. It is this mental model that "is the underlying knowledge that is the basis of SA" (p. 12). Again, according to Endsley and Garland, the level of SA depends on how good a mental model an individual develops. Applying Endsley and Garland's three levels of SA can develop this mental model. If executed poorly, an individual can develop a poor mental model and the results of the situation could be drastic. Parasuranam, Sheridan, and Wickens (2008) state that SA is not a choice nor is it general knowledge of material. However, SA can be measured by the performance of an individual conducting a task or multiple tasks by assessing their choices, and it is these studies that have proven that SA is a quantifiable instrument in the construct of cognitive engineering according to the authors.

Stress and workload can be related when analyzing SA. Every person has a different capacity for stress, but a level of stress is necessary in order to perform at an acceptable level (Endsley, 1995, p. 52). In addition, individuals have different capacities for workload. If the workload becomes too much for that individual, the stress will increase, and an individual's SA will begin to decrease (pp. 52–53). This type of human factor can impact the SA of an individual, and it is that individual's capability that impacts how stress affects the situation.

An important aspect of Endsley's work is the concept of automaticity, which is defined as the automatic processing of information with minimal effort. In essence, an individual completes required procedures without using too much attention (Endsley, 1995, p. 45). This is a significant concept because it explains the goal of this prototype. For a USMC KC-130J aviator executing an IA, the basic procedures will never change, yet every IA is different.

A key element of the SA of a USMC KC-130J aviator is the use of the aircraft's automation within the cockpit. Over the past few decades, automation has increased dramatically. Parasuraman et al. stated that as automation has increased, the trust in the automation has increased, and this trust stems from the user's knowledge of the automation and proper manipulation of the automation. However, complacency can cause an individual to have too much trusted in the automation, which can have negative results. In addition, an individual with not as much knowledge as necessary can rely on the automation too much and have negative results as well according to Parasuraman et al. It is vital that aviators use the automation efficiently because "working with automation have been found to have a diminished ability to detect system errors and subsequently perform tasks manually in the face of automation failures as compared with manual performance on the same tasks" (Endsley, 1995, p. 53). Conversely, some research has found that automation can benefit SA because "automation that reduces unnecessary manual work and data integration required to achieve SA may provide benefits to both workload and SA" (p. 54). Trust in automation is widely dependent upon the individual and what their knowledge is of the necessary material and proper execution of the automation (Parasuraman et al., 2008, p. 151).

C. KNOWLEDGE

Within the aviation domain, there are key types of learning that occur: procedural and conceptual (Dattel, Durso, & Bédard 2009, p. 1964). Procedural "emphasizes the step-by-step actions and sequences required to complete a task" while "conceptual emphasizes the interrelationship of the system components" (pp. 1964–1965). In addition, Cooke, Salas, Cannon-Bowers, and Stout (2000) stated that declarative knowledge, which consists of facts, figures, rules, relations and concepts in a task domain, is another knowledge (p. 157). Before, conceptual and procedural knowledge is explained, declarative knowledge has an overarching impact on the other two types of knowledge because it is imperative that an aviator have that type of knowledge memorized before evening taking-off. In order to decipher between how conceptual and procedural knowledge work within aviation, the two techniques can be applied to different aspects of the aviation domain. For example, procedural is beneficial when a

typical procedure needs to be followed in order to successfully accomplish a task such as normal checklists, communication calls, and landings. If at any time during the situation it becomes atypical, conceptual knowledge becomes more beneficial than procedural because a "conceptual knowledge of the interrelationships of the system components may successfully" remedy the atypical situation (Dattel et al., 2009, p. 1967).

Dattel et al. (2009) conducted an experiment that involved separate groups of novice aviators learning aviation knowledge such as course rules and landing pattern traffic via conceptual and procedural knowledge. At the conclusion of the experiment, Dattel et al. determined that the conceptual knowledge technique is better for aviation skills. Particularly, Dattel et al. concluded that for non-complex "unfamiliar and atypical conditions" conceptual learning is better than procedural (p. 1967).

D.   PART-TASK TRAINING

Part-task training is an emerging phenomenon that is becoming a crucial supplemental resource in many training fields (Stanney, Mourant, and Kennedy 1998, p. 327). PTTs have offered a more convenient and way of accessing information and communication (John, Phillips, Cenydd, Coope, Carleton-Bland, Kamaly-Asl, and Gary, 2015, p. 156). For example, neurosurgeons in the United Kingdom have developed an application for the iPad in order to train neurosurgeon trainees with vital procedures of a particular brain surgery in order to reduce a patient's possible exposure to additional risk (p. 155). Initial results have demonstrated promise to the positive effect PTT can have in training neurosurgeon trainees with brain surgery procedures. These finding suggest that using a PTT as a supplemental resource can have a significant impact on future training within many fields.

Part-task training can provide the user with additional confidence, situation awareness, and knowledge to successfully execute important steps within a crucial procedure. The Marine Corps has recognized the idea of using modeling and simulation in order to maintain the skills of Marines in regards to their duties (Neller, USMC, 2016). In particular, the Training and Education Command of the Marine Corps has conducted research into Deployable Virtual Training Environment (DVTE) for the purpose of

sustaining Marines' readiness (Brannon & Villandre, 2002, p. 15). It is suggested here that the deliberate creation and use of a PTT for training will continue to meet the needs of the Marine Corps and could begin to turn the tide of their deployment and underutilization for training.

There are some important human factor elements that need to be examined when developing a PTT. Stanney, Mourant, and Kennedy (1998) state that it is important to consider how to assess a VE in order to determine the impact on training that has occurred through the use of the device. The desire is to have the outcome of the training with the VE device be no less than the outcome of its predecessor's training according to the authors. In other words, "the use of a VE should improve task performance when transferred to the real-world" (p. 330). Furthermore, there is also the appeal to have the VE device easy to navigate and use (p. 329). In order to accomplish these goals, it is recommended that the user experience appropriate levels of immersion and presence when using a VE system according to Slate and Wilbur (1997). Presence is defined as a "psychological sense of being somewhere else than in one's immediate physical world" while "immersion is a degree to which the technical elements of VE solutions envelop the users" (Slater and Wilbur, 1997, pp. 606–607).

Stanney et al. (1998) suggests that a positive transfer of training can occur as long as original learning occurs. In VE, original learning can occur if the immersion and presence are representative of the task environment (p. 332). Key aspects of human performance that should be considered in the design of the VE device are the "abilities and limitations of human sensory and motor physiology" (p. 334). When referring to the learning aspect of VEs, "there are strong scientific reasons why the active engagement available in VE games rather than passive action of television watching can have better retention of learned skills" (p. 344).

E.   SUMMARY

This chapter described SA, aspects of SA that can impact situations, and how factors such as presence, immersion, usability, and performance assessment impact the acceptability of the use of VEs for military training. Additionally, the types of knowledge

(procedural, declarative, and conceptual) were addressed as well as their relation to aviation. Finally, a case is made on how PTT could be used as a viable tool for enhancing SA, and the type of learning that is required having a positive transfer of skills and knowledge into the intended environment.

III. TASK ANALYSIS

A. INTRODUCTION

An aviator should have a standard practice for setting-up and performing the necessary procedures of an IA. Regardless of what special situation or even emergency arises during any particular IA, the aviator with a standard practice for an IA has the potential to successfully handle these situations and fly the approach successfully. It is the repetition of a standard practice that has a power to permit aviators the ability to maintain a high level of SA throughout the approach according to Fowlkes, Dwyer, Oser, and Salas (1998).

The need to understand the tasks that are to be simulated requires an analysis of the job. Naval Education and Training Command's (NETC) Job Duty Task Analysis (JDTA) Manual (NETC, 2011) provides a framework in which the task analysis (TA) divides a task into separate steps and identifies important characteristics of each step. The initial step is to identify the components and sequence of steps of the task. Next, the conditions under which the task will be performed must be identified along with any triggers or cues that will keep the sequence progressing. Finally, a performance level must be administered with each task so that the individual executing the task can be evaluated.

The TA for KC-130J IAPs was conducted in context of SA, knowledge, and PTT described. The following section describes the approach and outcomes of the TA that was used to create the prototype system.

B. SITUATION AWARENESS, KNOWLEDGE, AND INSTRUMENT APPROACH PROCEDURES

The KC-130J community within the USMC has a common practice for their aviators. First, aviators are to request and receive the weather report at the necessary airfield (Department of the Navy, 2014). The weather report is their initial SA builder and should be retained throughout the approach. The next step is for the aviator to select the correct IA to fly, and an aviator's conceptual knowledge should assist in choosing the

best IA. The next several steps of conducting an IA have many similar aspects that require the aviator's procedural knowledge to be sound. For example, an aviator needs to set-up the cockpit instruments properly, have the correct decelerating airspeed, descending altitude, and the correct heading. These are just a few of the steps to flying an IA, and they often occur at the same time. Rogers, Maurer, Salas, and Fisk, (1997) state that it is theorized that tasks, or parts of tasks, can be trained to become habitual or automatized. When achieved, automaticity results in the performance of those tasks or subtasks with little cognitive effort. An aviator's automaticity can be developed if the same practice is used when conducting an IA and can become paramount in the ability of the aviator to maintain a sound SA.

Throughout the entire IA, an aviator will rely on what is referred to as the three separate levels of SA, (1) perception of the elements within the environment; (2) comprehension of the current situation; and (3) projection of future status, that Endsley discussed (Endsley, 1995, pp. 36–37). While the procedures of an IA should be constant for every approach, other elements such as crew relationships, weather, and airfield features are different, which project different future status. Successful landings, despite the potential problems presented by these variables, are built on a strong foundation of conceptual knowledge. These three levels tie into many sublevels such as time, space, and decision-making, and those are vital aspects of every IA.

The SA of an aviator while flying an approach can be impacted by many factors such as attention, perception, working memory, and long-term memory. Attention is needed in order to properly perceive the information and apply the appropriate memory (Endsley, 1995, pp. 40–41). As it is further clarified, working memory conducts the active processing of information whereas long-term memory uses stored information to counter any limitations of working memory.

For KC-130J aviators, the impact of automation plays an important role in their development and maintenance of SA. The aircraft is capable of complete autopilot, which consists of navigation, speed control, and altitude control. Endsley points out three crucial reasons as to how operators of automated systems may have slower reactions

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times to problems and longer recovery times (Endsley, 1995, p. 54). The three reasons are:

> a loss of vigilance and increase in complacency associated with the assumption of a monitoring role under automation, the difference between being an active processor of information in manual processing and a passive recipient of information under automation, and a loss of or change in the type of feedback provided to operators concerning the state of the system under automation (p. 54).

Considering these circumstances, one can argue that aviators utilize more cognitive resources to maintain the required level of SA during automation than when manually flying the aircraft because being actively engaged in the task can assist with keeping the attention and perception high.

C.   INSTRUMENT APPROACH PROCEDURES

This section will focus on the prototype questions and cues used as the basis for the prototype that was developed for this thesis. These questions and cues were derived from the high level TA for an IAP. Additionally, these are color coded to correspond to the TA (see Appendix B). For brevity, this section will focus on PF information since the PM information is nearly identical.

1.   Prototype Question TA

Prototype question TA is from the Department of the Navy's (2014) *Naval Air Training and Operating Procedures Standardization Flight Manual* selects sets of items that are part of NATOPS task description have been expressed in the prototype system via questions-and-answers as part of the user interface. These questions require the user to recognize the correct sequence of steps as presented on the corresponding instrument panels. Segments of NATOPS task description that are presented as question-and answer form of interface include:

Step 1. Review Pressurization Panel.

Step 2. Review Anti-Ice/De-Ice Panel.

Step 3. Review HUD.

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Step 4. Review CNBP Menu.

Step 5. Review AMU Menu.

Step 6. Review REF/MODE panel.

Step 7. Review CNI-MU.

Step 8. Fasten Belts/Harnesses.

Step 9. Complete Approach Brief at appropriate time.

2.   **Prototype Visual Cues TA**

Prototype visual cues TA is from the Department of the Navy's (2014) *Naval Air Training and Operating Procedures Standardization Flight Manual.* There are several visual cues that an aviator must recognize and act accordingly when flying an IA. The prototype presents several of those cues by mirroring the aircraft's layout of the heads up display (HUD) on the user interface. Visual cues address the following segments of NATOPS task description. These include:

Select the appropriate NAVAID when cleared by ATC.

Maintain awareness of the DME.

Maintain awareness of the altitude.

Maintain awareness of heading.

3.   **Prototype Audio Cues TA**

Prototype audio cues TA is from the Department of the Navy's (2014) *Naval Air Training and Operating Procedures Standardization Flight Manual.* Throughout an IA, radio calls are constant and provide valuable cues that an aviator needs to recognize. The scenario that has been presented in our prototype system has a number of common radio calls that an aviator should listen to and know what action is expected to happen and when to do it. The following list presents elements of NATOPS task description that were integrated as audio cues within the prototype.

Listen to the weather report to determine which IA to fly.

Execute an approach brief once the PM has completed flows.

Listen to ATC's clearance for the approach.

Listen for the mandatory call outs during the approach.

D.   SUMMARY

This chapter discussed the outcomes of the TA, which was conducted in context of SA and requisite knowledge for KC-130J IAs. This TA serves as the basis of the prototype and the scenario created to represent an IA for this thesis.

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IV. DESIGN AND DEVELOPMENT OF THE PROTOTYPE TRAINING SYSTEM

A. INTRODUCTION

Before a design and development of a prototype system was approached, a survey of KC-130J subject matter experts (SMEs) was conducted. The objective of this work was to capture information about possible gaps in training, the issues and trends they identified with performance of the aviators during FAM stage (with special emphasis on IAP), and their suggestions on how a new PTT could fit in and benefit the current training regimen. It is important to obtain the current pulse of the fleet while developing such a device because it provides a review of the most up-to-date insights and necessities as they are seen by the warfighters i.e., the actual users of current and future systems.

B. SURVEY OF A USER BASE

The use of human subjects in surveys that includes data collection from those individuals and analysis of the same data sets, dictates applying institutional review board (IRB) protocol and its adopted requirements and procedure. In the case of this thesis, it required permission to proceed with the study from an IRB Committee at NPS and within the U.S. Marine Corps; the latter required approval from the survey approval office and the human research protection office of the U.S. Marine Corps. (See Appendix C)

1. Subject Matter Expert Input

Two KC-130J SME were consulted regarding different issues in this domain – their insights and feedback helped us develop the entire survey that would be delivered to the target user base. The questions for the SMEs were rather generic and open-ended about training IAPs for the KC-130J; their responses allowed us to generate more precise questions for the official online survey. The full list of questions submitted to the SMEs is in Appendix A; only the most significant responses given by the SMEs are discussed in this section.

The SMEs reported that they observed RPs having problems with basic IAP. One SME commented that RPs rely too much on the automation of the KC-130J, which could lead to problems escalating before the RP even recognizes the existence of a problem. A common theme amongst the SME's responses was that repetitive exposure to the IAP via practice such as chair flying could be very beneficial. Another valuable point commented by a SME was that RPs struggle with complex approaches or busy airports. These statements were not acquired to validate the purpose of this thesis but rather to confirm potential value of repetitive chair flying. The SMEs' replies confirmed that a PTT could be used as a supplemental training tool, as it was outlined in this thesis. That type of training solutions can be seen as essential tools for enabling additional training opportunities that are needed to maintain SA at an appropriate level.

2.   Online Survey: Procedures and Results

The LimeSurvey system was used as an instrument that helped generate online surveys for RPs and IPs. This system allowed a link to a web-based application be sent to potential survey takers, thus eliminating the need for subjects to come to a laboratory and fill the physical questionnaire.

Participation in all surveys was voluntary basis. Unfortunately, only two IPs responded to our call, nevertheless valuable information was acquired even with a small number of participants. Questions for the RPs addressed several topics that included current studying (training) practices, subjects' perceptions about current IA practices, trends in students' performance, and desired capabilities that future PTT could provide. A full list of survey questions is in Appendix A and only the most significant replies of the IP survey are summarized in this section.

The two IP survey results collected in this study reported a common issue identified in procedural execution. Procedural execution is not a lack of procedural knowledge; in this content it refers to a lack of IAP experience such as performing the flows efficiently and accurately. RPs tend to take too much time performing these flows, which results in a RP getting well behind the approach's timeline. Additionally, the IP survey reveals that RPs tend to struggle with communications and maintaining SA. Both

responses address the importance of chair flying. The survey also addressed questions pertaining to features desired in a future PTT; that discussion will be addressed in Chapter V. As stated, the RPs' struggles with flow execution were used as guidance during the design phase of the prototype. For example, the in-range flows are one of the few items that are visually depicted within the prototype so that a RP can visualize their proper sequence.

C.   CONCEPTUAL FRAMEWORK

The overall conceptual framework for this PTT is very simple. The questions are called from a JavaScript Object Notation file, which allows the user to answer the questions presented in the scenario. At the end of the scenario execution, the IP can view the results of how the user answered the questions from a file once the scenario is complete. Figure 1 shows elements of the conceptual framework that has been adopted for this PTT.
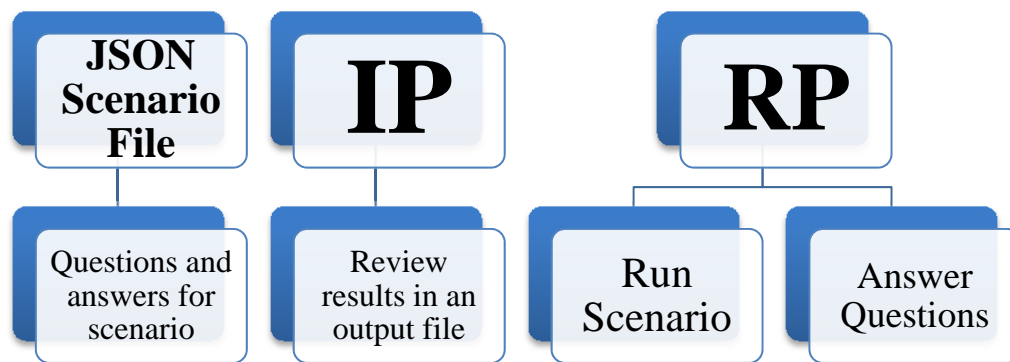

Figure 1.   Conceptual framework.

D.   PROGRAMMING AND DEVELOPMENT ENVIRONMENT

Since this is a prototype training system at a very basic level, many aspects of the coding were hard coded, which does not permit any of the scenario to be altered. The reasoning behind this concept is based on two primary reasons: 1) it is a proof-of-concept

2) the prototype addresses the basic IAP and radio calls a RP should know and expect to hear.

1.   Unity Game Engine and C#

The Unity game engine was used to develop the scenario since it has vast capabilities with the most important being that it is compatible with multiple operating systems. Unity was primarily developed to assist with the development of video games and simulations. In addition, Unity is free to download from the Internet, which makes it easily accessible. These characteristics make Unity a viable choice when selecting a program to use for an effort such as this thesis. Figure 2 shows a segment of the terrain used in the PTT as seen inside the Unity interface.
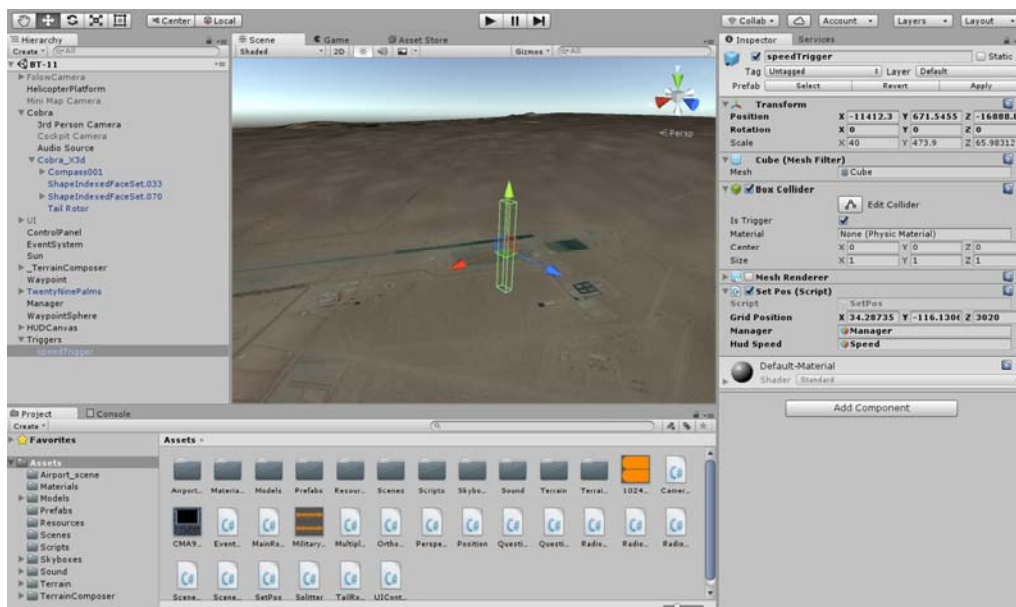
Figure 2.   Unity game engine.

2.   Images of the PTT Interface

Figures 3–7 depict different elements of the PTT interface that the user will experience during the scenario. The images display different aspects of the scenario ranging from the instrument panels with their questions to how the terrain looks at different altitudes.
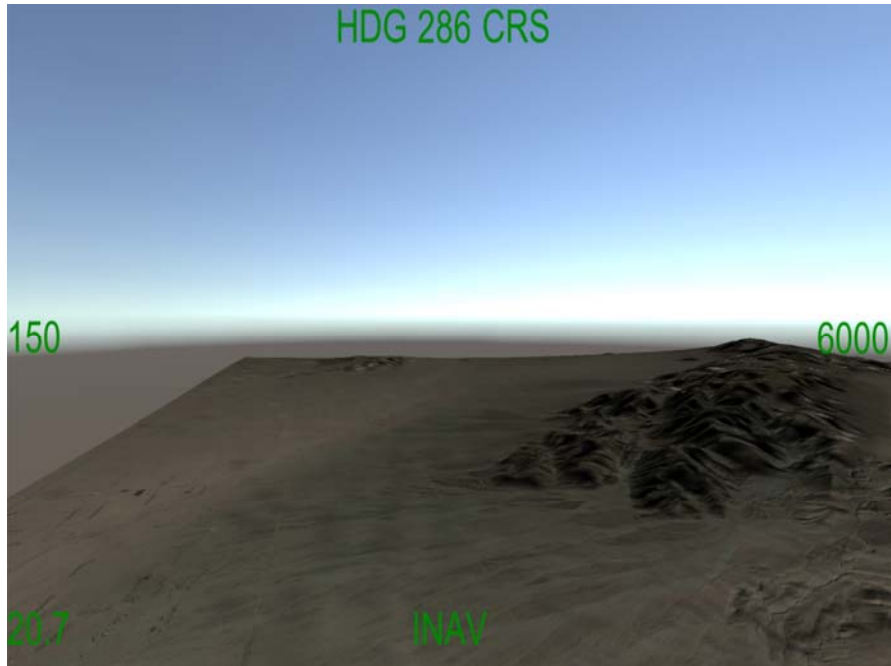
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Figure 3.   Screen shot at 6000 feet.

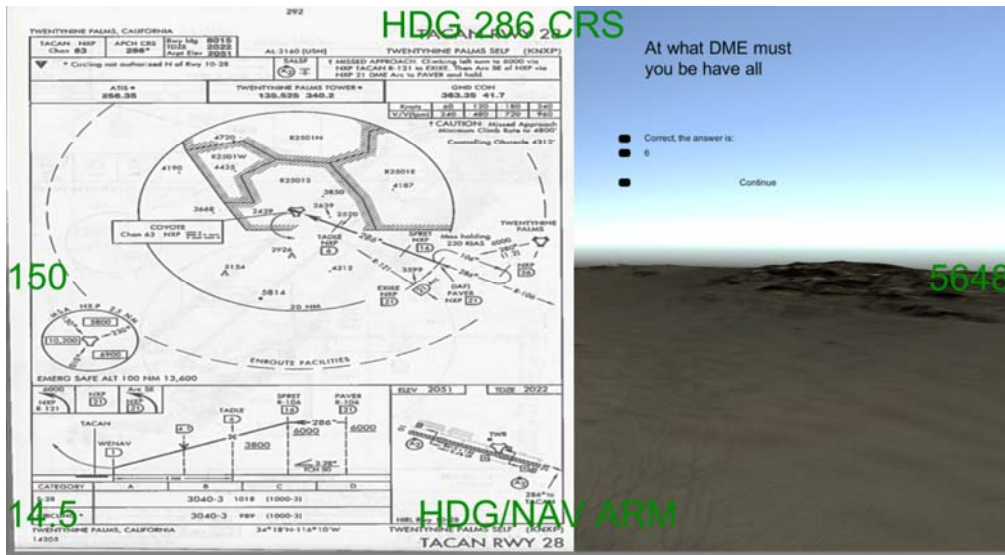Figure 4.   Screen shot of instrument panel and question.

Figure 5.   Screen shot of approach plate and question.
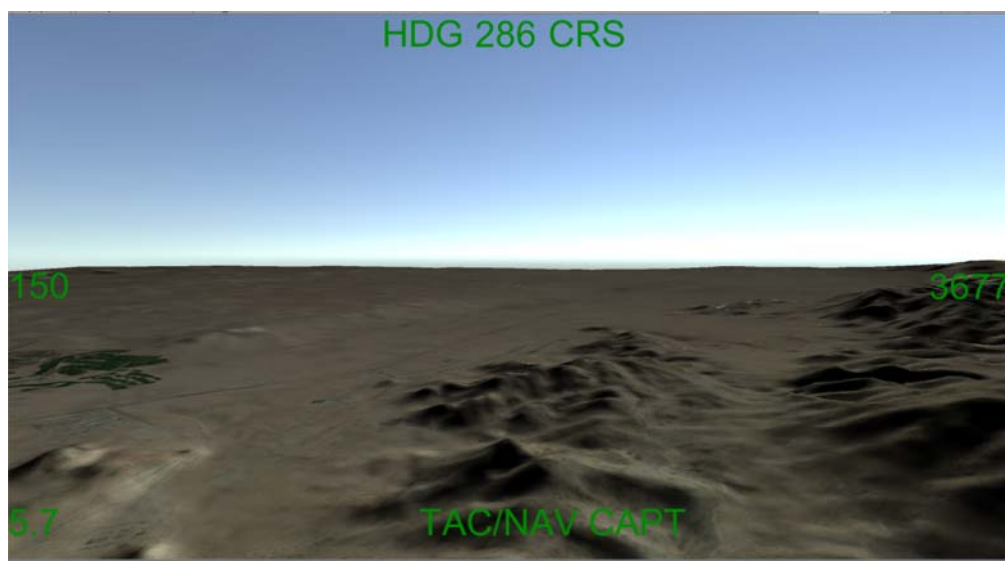

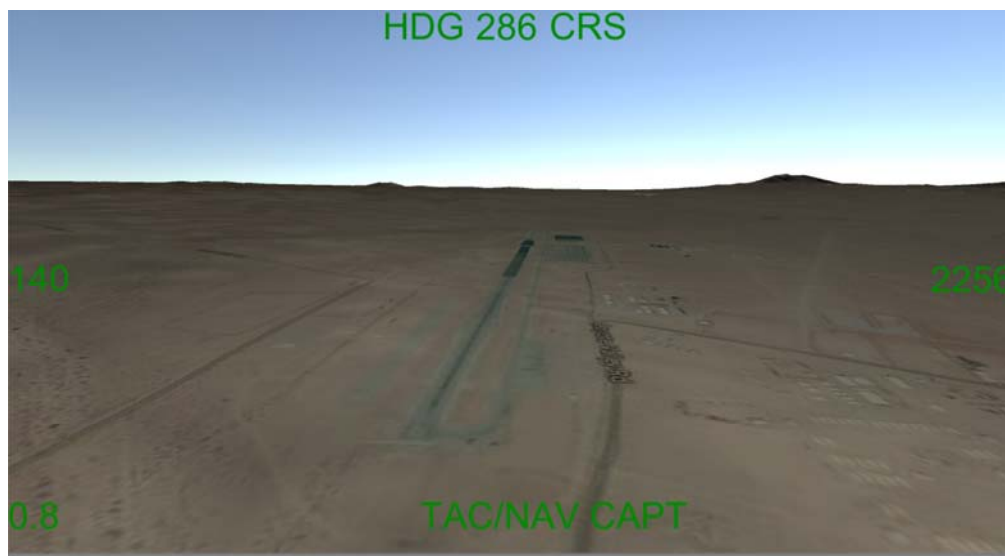Figure 6.   Screen shot at 3677 feet.

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Figure 7.   Screen shot of airfield at Twenty-nine Palms

3.   Auditory Cues

The Audacity application was used to record radio calls, which commonly occur during an IA. In order to increase realism within the environment, engine noise was added to the scenario. This audio sample was downloaded from a free sound library (freesound.com). The use of the Unity development environment allowed for the relatively easy addition of the required auditory cures; simple drag and drop action is all that is required to add this capability to the final user interface.

E.   DEVELOPMENT

The initial idea was that this prototype training system would replicate a very realistic ability to practice IAP, but through the tasks analysis and SME input, it became evident that a system of this complexity was not needed since the goal of this prototype was to create a supplemental tool to serve as a PTT. Hence, the scope of the prototype was narrowed down to address the procedures and situation awareness associated with IA. The user could practice the IA task as often as it was desired, allowing those skills to become second nature so that an appropriate level of SA could be maintained while executing IAPs.

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The prototype training system was designed to support the execution of a scenario from the beginning of an IA until just before the touchdown upon an airfield. A minimal user input is required except for answering a set of questions that test user's SA and knowledge. The prototype depicts the first person view, and it adds an additional visual layer that replicates a look and feel of the HUD of the KC-130J (Figure 6). The scenario used in the system addresses all the steps described in the NATOPS documentation; the same steps must occur for a normal IA along with the standard cockpit and radio calls.

F.   MODES OF USE

The prototype can be used in three modes or configurations: tablet, laptop, or large screen. All three modes of use offer different aspects that can enhance general capability of the prototype. The tablet's advantage is that an individual can practice IAP anywhere at any time. A laptop can be used amongst a small group. A large screen device can be used in an instructor-led classroom. Figures 8 - 10 depict the different modes.
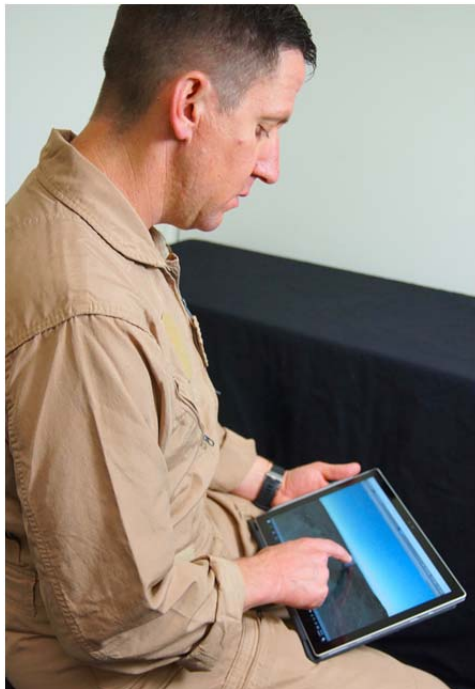

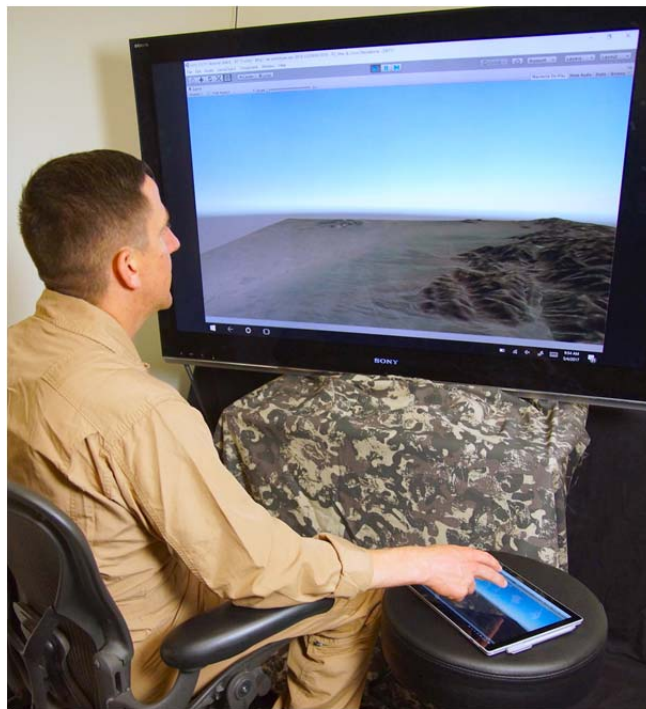Figure 8.   Tablet mode.

Figure 9.   Laptop mode.

Figure 10.   Large screen mode.

G. INFORMAL DEMONSTRATION

An informal demonstration of the prototype was conducted with the goal to acquire valuable feedback that could be applied to future work.

1. Study Design

The demonstration population consisted of aviators currently attending the Naval Postgraduate School (NPS). A request was submitted to the registrar's office to acquire a list of Navy and Marine aviators so that their presence could be requested for the demonstration. Of the thirty-five aviators contacted, eight participated in the demonstration.

For the demonstration, a brief explanation of the thesis and prototype was given. Upon completion of the brief, the scenario was shown to the aviators. The scenario lasted about eight-and-a-half minutes. At the conclusion of the demonstration, the participants handed in written answers to the questionnaire (see Appendix A), thanked for their participation, and departed the demonstration area.

2. Results

The insights gained during the demonstration coincide with recommendations from the IP LimeSurvey:

- **Ability to develop a scenario so that a RP can be evaluated for a particular portion of an IA.** Currently, the prototype executes an approach from start to finish, which does not allow the user to focus on a single section of the approach.

- **Provide feedback and a study guide.** A suggestion collected in the IP survey was that the PTT could provide guidance for the user and suggest elements that needed to be improved in order to develop the required IAP skills.

- **Ability to study approaches at any airfield.** A common comment from the demonstration was a desire to have the PTT execute and support IA at several airfields with multiple approaches.

- **Ability to select or alter switches/buttons.** Both the IP survey results and the demonstration expressed a desire to have the PTT provide the user the opportunity to select switches or buttons on the instrument panels. Some

of the buttons or switches might require a haptic feedback, yet this would only need to be a vibration sensation similar to a smart phone's vibration when a button is selected. This type of haptic feedback would permit the device to still be transportable. While including haptics could be advantageous for the overall learning process, it could also be more than what a PTT needs to perform. An analysis of how passive haptics would impact a PTT would need to be examined.

- **Voice recognition.** The radio calls are prerecorded in this prototype, yet many expressed a desire to have a support of voice recognition software so that the user could practice radio calls.

- **Moving Screen.** The orientation of the viewpoint, first person, in the PTT does not change, and a suggestion received from SMEs was to introduce the possibility of changing the orientation of the viewpoint independently so that a section of the cockpit with the instruments could be seen.

- **Impose time constraint to scenario.** For a more advanced PTT, a suggestion was to put the user in a time constraint scenario and emulate real situations.

- **Pop-up windows.** During dead space of the scenario, it has been suggested to have pop-up questions or comments to keep the user engaged.

H.   SUMMARY

This chapter discussed different aspects of the design and development of the prototype training system. This included a survey of the user base and its results, followed by a review of conceptual framework, the user interface that was developed, and finally a discussion of the informal demonstration and feedback gathering that was done with a help of local SMEs at NPS.

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V. DISCUSSIONS AND CONCLUSIONS

A. DISCUSSION

The increasing accessibility of low-cost, off the shelf technologies presents an opportunity to drastically impact how aviation training is accomplished. Recognizing this, the thesis presented here looked to answer an overarching research question and two additional research questions that support the main question. First, would it be feasible to develop a VR system to support training IAPs to improve situation awareness? Next, what if any, training gaps exist with the training of IAPs and SA for IAs? Lastly, and based on the former, what cues should be included in a PTT to support the practice of gaining and maintaining SA during IAs?

The first question was partially answered. Through a modified instructional systems design approach, this thesis demonstrates that a systematic approach to the development of a PTT for training IAs could be accomplished in a relatively short amount of time in a resource-constrained environment. Unfortunately, due to administrative delays, a training effectiveness evaluation was not conducted and the second part of our first research question cannot be definitively answered. However, post-demonstration SME feedback suggests that the prototype developed for this thesis shows promise for helping aviators in the KC-130J FRD develop knowledge about IAPs and improve their ability to rapidly perceive, assess, and plan their actions during IAs.

In support of the main question, the exploration of potential training gaps was a mandatory step to ensure that the effort of this thesis was warranted. Through this work, we discovered that gaps do exist in the form of available opportunities and the fidelity of training aides. Further, it is suggested here that a fundamental change in how training is considered may be overdue. While technology can be considered merely the vessel in which content is delivered, current and future generations of aviators may grow to expect particular technologies to be part of their experience. This is not to minimize the value of chair flying as a form of mission rehearsal but to offer that aviators using virtual

technologies in their everyday lives may have improved training experiences and outcomes if these technologies are available for their training.

Finally, and perhaps most importantly for the development of any training system, the identification and incorporation of the system and environmental cues needed to support training goals was accomplished. Mistakes at this stage could have disastrous results. Ensuring elements such as cockpit displays, environmental conditions, communications, time, and space are accurately represented is critical for avoiding negative transfer of training for aviators. We are confident that the thorough review of available publications, SME interviews, and SME evaluations conducted for this thesis enabled us to understand these cues and translate them into the KC-130J IA training prototype created. In sum, this thesis was able to achieve the goals as originally stated. However, as with many projects such as this, there is still work that must be accomplished before a prototype could be released to actually support training.

B.   FUTURE WORK

The general objective of this thesis was very broad, and future work in this domain could accomplish that goal. An entire range of PTTs can become valuable training solutions in the future and address a variety of training gaps. Scenarios for other missions could be developed; this would permit aviators the repetitive opportunities needed to master a plethora of skills required to safely and successfully operate within the KC-130J community. In that regard, a very similar concept of PTT could be used for other segments of aviation community. An additional line of future work could network these PTTs together so that separate communities could conduct joint mission rehearsals such as an aerial refueling mission.

1.   Knowledge

This thesis focused on SA; however, there is a significant amount of work needed to analyze the three types of knowledge that were introduced within chapter two. The work could focus on how each type is important to an IA and the IAP of the KC-130J in support of maintaining SA. The reference for this material within this thesis is a good

starting point for knowledge and general aviation, but a focus of knowledge and the KC-130J could be beneficial work for the community.

2. Eye Tracking

A thesis that could integrate eye tracking system and try to differentiate between a novice, junior level, and SME executing an IA. The study could be designed to acquire understanding of what each of those three separate groups is looking at during an IA and provide valuable feedback on what to do and what not to do during an IA. Eye tracking could also provide important insights as to the progression of a trainee through a curriculum. If a trainee's scan pattern repeatedly matches an expert model, it may be possible to advance them through a training program more rapidly. Conversely, it would also be possible to identify those who may need extra training opportunities or other interventions.

C. CONCLUSIONS

The importance of developing a PTT that can supplement current training of IAPs cannot be understated. The value that a PTT could be easily transported and used at the user's leisure is significant. A PTT can fulfill that gap of repetition and allow an individual to master procedural and demonstration knowledge with the ultimate goal of developing conceptual knowledge and maintaining sound SA.

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APPENDIX A. QUESTIONNAIRE AND SURVEYS

1.   SME QUESTIONS

1.   In your experience, what are the types of issues that pilots struggle the most with as they begin conducting instrument approach procedures in the actual aircraft? List three major issues that, in your view, fit this description.

2.   Given your experience with RPs, how well do you think that the majority of them perform instrument approach procedures?

   1 = it is well beyond minimal standards

   2 = it is beyond minimal standards

   3 = it is within minimal standard

   4 = it is below minimal standards

   5 = it is far bellow minimal standards

3.   In your estimate, what is the percentage of RPs that underperform and what is the percentage or RPs that excel in instrument approach procedures?

4.   What is your recommendation when you notice a RP is having problems with instrument approach procedures - what training approach do you recommend a RP take in terms of the skill remediation?

5.   Aside from the answers provided from the previous question, list any additional information or comments that relates to trends associated with instrument approach procedures.

6.   What supplemental instructional techniques (ones that are not directly required by the Training & Readiness (T&R) manual) are used in your squadron in order to better prepare RPs for instrument approach procedures?

7.   In your opinion, what is the most effective supplemental technique for preparing RPs for instrument approach procedures?

8.   What element of that supplemental technique do you think is very effective for preparing RPs for instrument approach procedures?

9.   In your opinion, how often should RPs ideally use that type of supplemental technique?

10.   In your opinion, is there any additional training solution that should be made available to the RPs to better prepare them for instrument approach procedures in the actual aircraft?

11.   What major learning and training objectives should that system support?

2.   CONSENT

◯ Yes   ◯ No

3.   IP

IP Survey

1. Does a training gap exist between the classroom/computer-based trainers and the simulator?
Choose one of the following answers

- ○ Yes
- ○ No

Please enter your comment here:

2. Does a training gap exist between the simulator and the aircraft during the familiarization (FAM) stage?
Choose one of the following answers

- ○ Yes
- ○ No

Please enter your comment here:

3. During the first flight event in the FAM stage, most replacement pilots (RPs) are able to conduct all procedures and communications of instrument approach (IA) at an acceptable standard per the grade sheet.
Choose one of the following answers

- ○ Strongly Agree
- ○ Agree
- ○ Somewhat Agree
- ○ Neither Agree nor Disagree
- ○ Somewhat Disagree
- ○ Disagree
- ○ Strongly Disagree

4. In your opinion, what are the top three difficulties the RPs have during FAM flights? (e.g. – Flows, Checklists, Getting behind the aircraft, comms, etc.)

1.
2.
3.

5. List any additional information or comment that relates to trends associated with the performance of RPs in FAM stage.

1.
2.
3.

6. Which of the following supplemental instructional techniques that are not directly required by the Training & Readiness (T&R) manual, are used in the squadron in order to better prepare RPs for the FAM stage? Check any that applies, and select frequency with which it is used.

	Daily	Weekly	Monthly	Rarely
Chair Flying	○	○	○	○
Formal quizzes/tests	○	○	○	○
Self study of supplemental readings	○	○	○	○

7. In your opinion, what is the effectiveness of each supplemental technique used to prepare RPs for FAM flights?

	Very Effective	Effective	Somewhat Effective	Neither Effective nor Ineffective	Somewhat Ineffective	Ineffective	Very Ineffective
Chair Flying	○	○	○	○	○	○	○
Formal Quizzes/tests	○	○	○	○	○	○	○
Self Study of Supplemental Readings	○	○	○	○	○	○	○

8. In your opinion, how often should RPs ideally participate in chair flying sessions while preparing for the FAM stage?
Choose one of the following answers

○ Daily
○ Weekly
○ Monthly
○ Other: [   ]

9. List three most significant reasons why you recommend using chair flying to RPs under your instruction:

1. [   ]
2. [   ]
3. [   ]

10. In your opinion, what are the limitations of chair flying?
Check any that apply

☐ Lack of IP availability to lead evolution.
☐ Lack of IP availability to create new scenarios/scripts.
☐ Time constraints for all participating aircrew (Crew Day, Crew Rest, etc).
☐ The inability to train large groups at one time.
☐ Other: [   ]

11. RPs who perform well on formal quizzes/tests more likely to perform well in the aircraft during FAM flights?
Choose one of the following answers

○ Strongly Agree
○ Agree
○ Somewhat Agree
○ Neither Agree nor Disagree
○ Somewhat Disagree
○ Disagree
○ Strongly Disagree

12. List the three most significant reasons why you think RPs should take formal quizzes/tests.

1. [_____]
2. [_____]
3. [_____]

13. Describe other supplemental instructional techniques that you use or think those could help RPs become better prepared to conduct their first IAPs. This may include things that RPs do on there own time without direct involvement of an IP.

1. [_____]
2. [_____]
3. [_____]

14. Imagine you are tasked with designing a new tool to help prepare RPs for their first flight involving IAPs in a flight simulator. The system could, for example, allow visualization of IAP and practicing of a specific skill set associated with instrument approach. What major training objectives should that system support?

1. [_____]
2. [_____]
3. [_____]

15. The features of that system may allow an IP to define details of some scenario and a set of popup questions that could be presented to a RP at various checkpoints or phases of the flight to quiz the RP's knowledge. What other system capabilities would you recommend that such training system could have?
Check any that apply

☐ Ability to question the knowledge about in-range and approach checklists
☐ Ability to have text or voice operated radio calls
☐ Ability to select from a set of prebuilt airfields with their approaches
☐ Other: [_____]

16. In order to test RP's situational awareness in the training system described in previous question, what element of RP's situational awareness would you test and how would you go about it in that training system?

1. [_____]
2. [_____]
3. [_____]

17. What would be the best hardware platform to support desired functionality of this training system?
Choose one of the following answers

○ Computer with wall size projection display
○ Computer with large monitor
○ Laptop Computer
○ Tablet with touch screen
○ Smart Phone

18. What instructor billets do you currently hold in the squadron?

1. [_____]
2. [_____]
3. [_____]
4. [_____]
5. [_____]

19. How many years of experience do you have as a flight instructor?
Only numbers may be entered in this field.

[_____]

4.   RP

RP Survey

1. Have you conducted your first flight event in the familiarization (FAM) stage of the Training and Readiness manual, and if you did, when did that occur? Please enter date in the comment box.
Choose one of the following answers

○ Yes

○ No

Please enter your comment here:

2. In your opinion, do you have enough opportunities to practice instrument approaches (IAPs) to stay proficient?

○ Yes   ○ No

3. During the first flight event in the FAM stage, I was able to conduct all IAP procedures and communications at an acceptable standard per the grade sheet.
Choose one of the following answers

○ Strongly Agree

○ Agree

○ Somewhat Agree

○ Neither Agree nor Disagree

○ Somewhat Disagree

○ Disagree

○ Strongly Disagree

4. In your opinion, what are the top three difficulties you had during these flights? (e.g. - Flows, Checklists, Getting behind the aircraft, comms, etc.)

1.

2.

3.

5. List any additional information or comments that relates to trends associated with your performance during FAM stage.

1.

2.

3.

6. Which of the following supplemental instructional techniques that are not directly required by the Training & Readiness (T&R) manual, are used in the squadron in order to better prepare you for the FAM stage? Check any that applies, and select frequency with which it is used.

	Daily	Weekly	Monthly
Chair Flying	○	○	○
Formal quizzes/tests	○	○	○
Self study of supplemental readings	○	○	○

7. In your opinion, what is the effectiveness of each supplemental technique used to prepare you for FAM flights?

	Very Effective	Effective	Somewhat Effective	Neither Effective nor Ineffective	Somewhat Ineffective	Ineffective	Very Ineffective
Chair Flying	○	○	○	○	○	○	○
Formal Quizzes/tests	○	○	○	○	○	○	○
Self Study of supplemental Readings	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

8. In your opinion, how often should you ideally participate in chair flying sessions while preparing for the FAM stage?
Choose one of the following answers

○ Daily
○ Weekly
○ Monthly
○ Other: [   ]

9. List the most significant reasons why you use chair flying.

1. [   ]
2. [   ]
3. [   ]

10. In your opinion, what are the limitations of chair flying? Check all that apply:
Check any that apply

☐ Lack of IP availability to lead evolution
☐ Lack of IP availability to create new scenarios/scripts
☐ Time constraints for all participating aircrew (Crew Day, Crew Rest, etc)
☐ The inability to train large groups at one time
☐ Other: [   ]

11. RPs who perform well on formal quizzes/tests more likely to perform well in the aircraft during FAM flights?
Choose one of the following answers

○ Strongly Agree
○ Agree
○ Somewhat Agree
○ Neither Agree nor Disagree
○ Somewhat Disagree
○ Disagree
○ Strongly Disagree

12. List three significant reasons why you think RPs should take formal quizzes/tests.

1. [   ]
2. [   ]
3. [   ]

13. Describe other supplemental instructional techniques that you use or think those could help RPs become better prepared to conduct their first IAPs. This may include things you do on your own time without direct involvement of an IP.

1. [   ]
2. [   ]
3. [   ]

14. Imagine you are tasked with designing a new tool to help prepare RPs for their first flight involving IAPs in a flight simulator. The system could, for example, allow visualization of IAP and practicing of a specific skill set associated with instrument approach. What major training objectives should that system support?

1. [   ]
2. [   ]
3. [   ]

15. The system may allow one to define details of some scenario and a set of popup questions that could be presented to a RP at various checkpoints or phases of the fight to quiz the RP's knowledge. What other system capabilities would you recommend that such training system could have?
Check any that apply

☐ Ability to question the knowledge about in-range and approach checklists
☐ Ability to have text or voice operated radio calls
☐ Ability to select from a set of prebuilt airfields with their approaches
☐ Other: [   ]

5.   DEMONSTRATION QUESTIONS

What functionality is currently missing from the prototype?
Which functionality of demoed prototype worked?
Which functionality of demoed prototype did not work? What was missing?
Which functionality of demoed prototype should be refined (corrected)?

APPENDIX B: TASK ANALYSIS

1.   NATOPS TASK DECOMPOSITION

TA is from the Department of the Navy's (2014) *Naval Air Training and Operating Procedures Standardization Flight Manual.*

a.   *PF In-Range Flows*
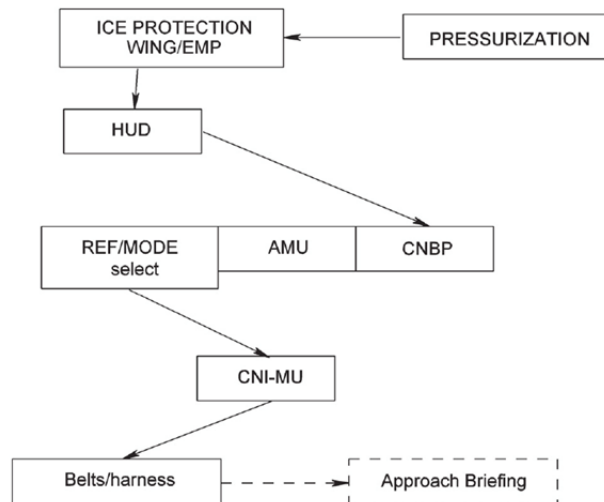
Figure 11.   PF In-Range Flows

1. PRESSURIZATION — Set.
       a. Pressure Mode Select — Set.
       b. Rate Selector — Set.
       c. LND/CONST — Set.
       d. PM states the settings of the pressure mode select switch, rate selector knob and
              LDG/CONST altitude.

2. Anti-Ice/De-Ice — As required.
       a. WING/EMP switch ON, ANTI-ICE (as required, if icing is anticipated).

CAUTION

The wing/empennage anti-ice/de-ice system should not be operated in the anti-icing mode except during approach and landing. Operation below -30 degrees Celsius at power settings above 2,500 HP, or above 20,000 feet pressure altitude at any power setting may degrade engine life.

45

Note
- Engine anti-ice should be ON if SAT is less than or equal to 10 degrees Celsius with visible moisture.

- Wing/empennage anti-icing in anti-ice mode should be turned on in sufficient time prior to landing to ensure the vertical stabilizer is completely anti-iced. This may take as long as 2.5 minutes. Failure to do so will cause the X-WIND LIMITED ACAWS message to be displayed when the landing gear are lowered, and the side slip warning system will limit crosswind landing capability if icing is detected.

- Failure to turn on wing/empennage anti-icing in anti-ice mode prior to lowering the landing gear when icing is detected causes the WING/EMP A/I NOT ON ACAWS message to be displayed.

3. HUD — Set as necessary for the approach.

4. CNBP — Set.
    a. NAVAIDs.
        (1) Set for required approach NAVAID guidance — (as required).
        (2) NAVAIDs — Set as required.

Note
- Ensure that NAVAIDs are tuned, identified and selected and that the instruments and radar are set for the approach.
- The standard NAVAID Tuning procedure is to use the station identification letters. After tuning the station, verify the frequency.

5. AMU — Set.
    a. HDDs — Set to desired approach configuration.
    b. NAV SELECT.
        (1) CDI SOURCE — Select the approach NAVAID.
        (2) PNTR 1/PNTR 2 — Set as required.
        (3) COURSE knob — Set.
        (4) CDI SOURCE — Set.

Note
- Set the planned final approach course if able.
- If the autopilot is engaged on the INAV controlling solution side and the
- CDI source is changed to set up for the approach, the NAV mode will disengage. Once the course is set for the VOR or TACAN approach, the CDI source can be returned to the INAV solution. Ensure NAV mode is reengaged or heading mode is selected if INAV is reselected as the CDI source.
- If changing CDI source in order to set the course for an approach, ensure the CDI source is reset to INAV and the flight director is reengaged if applicable.

    c. NAV RADAR — Select overlays.
    d. Digital Map Display — As required.
    e. EMS EVENT RECORD — Press.

Note

EMS EVENT RECORD can be pressed anytime level flight and constant airspeed can be maintained for 30 seconds. EMS EVENT RECORD only needs to be pressed once per flight to record propeller balance data.

6. REF/MODE panel — Set.
    a. RAD ALT — Set.
        (1) Precision Approach — 50 feet below HAT.
        (2) Non-Precision Approach — 250 feet.
        (3) Circling/Visual Approach — 300 feet.
        (4) VFR Pattern/Tactical — Set (As required).
    b. FPA — Set.
    c. MINS — Set.
        (1) IFR Approach — Set published minimums.
        (2) VFR Approach — Set (As required).
    d. BARO SET — Set.

7. CNI-MU — Set.
    a. ROUTE/LEGS

WARNING

Terminal area waypoints and fixes shall be identified by reference to the appropriate navigational aid as published in the approved approach procedure.

Note

Approach construction in the CNI should be considered as a secondary priority to the accurate programming of flow elements that precede it. If time permits, construct the approach in the CNI-MU to represent the approach as closely as possible.

    b. TOLD INIT.
        (1) TOLD INIT entries.
        (2) Check Landing Speeds.
        (3) Check Landing Distances.

CAUTION

Ensure the cargo weight used by the CNI-MU for landing data is current. If an airdrop has been performed or cargo jettisoned, input the new weight so that the system can calculate accurate landing data.

Note

If landing data is manually calculated, new landing data will be required for aircraft

weight change greater than 5,000 pounds, pressure altitude change greater than 1,000 feet or outside air temperature change greater than 5 degrees Celsius.

          c. MC INDEX.
                (1) V SPEEDS.
                (2) TACTICAL PLOT.
          d. INDEX.

8. Belts/Harnesses — Fastened.

9. Approach Briefing — Complete.
          a. Reference Chapter 16 for the arrival-briefing guide.

2.   Approach Brief Example

"We will fly radar vectors to the ILS RWY 17 at Navy Fort Worth. The weather is 800 with 2 miles visibility, the required weather is 200 and 3/4. The field elevation is 650, 650 is set in the pressurization panel. The NAVAIDs are set with I-NFW in the VORs and NFW in the TACANs. I will fly the approach with VOR1 and the CDI course is set to 174. DH is 836, 840 is set in MINS. RAD ALT is set 150. Speeds for a 100% flap landing are 135, 125, 118. There is an LZ in the CNI. Stable approach gate is 1650. I will fly automated with autothrottles. There is no significant terrain, but there are numerous towers along the approach corridor. The published missed approach instructions are climb heading 174 to 3000, intercept the FUZ 218 radial to MOLKE and hold."

3.   IN-RANGE CHECKLIST

Trigger: At the completion of the Crew Briefing the PF should call for the checklist.

1. Altimeters: "Set _____" (CP).
               "Set _____ twice" (P).

WARNING

Altimeters will be set to station pressure (QNH/QFE) if available when transiting the transition level. Altimeters may be set when above, but cleared through, the transition level. The In-Range Checklist shall not be called complete until the QNH/QFE has been set.

Note

The standby altimeter shall be set separately.

2. Pressurization: "Set, ___, ___, ___" (PM).
          a. PM states the settings of the pressure mode select switch, rate selector knob and
               LDG/CONST altitude.

3. ANTI-ICE/DE-ICE switch: "_____" (PM).
          a. PM states the setting.

4. ACAWS: "Checked" (PM).
5. Lights: "Set" (PM).

Note

Consideration should be given to using wing tip taxi lights, formation lights and pod illumination lights when descending into high-density traffic areas.

6. TCAS: "_____, _____" (PM).
       a. TA/RA — As required.
       b. ABV/Below/Normal — Check.
       c. PM states TCAS mode setting.

7. Belts/Harnesses: "Fastened" (PM).

8. Passengers and Cargo: "Secured" (LM/CC/CM).

9. In-Range Checklist: "Complete" (PM).

4.   APPROACH CHECKLIST

Trigger: When the final approach navaid is set in the CDI source of the AMU NAV SELECT   page.

Note

The APPROACH CHECKLIST should only be used when:
- NAVAIDs have been tuned and identified, if applicable, and
- Below TA/TL, and
- Entering the terminal environment.

1. Altimeters: "Set _____" (CP).
               "Set _____ twice" (P).
       a. Whenever the altimeters are reset, both pilots state the new setting.

2. NAVAIDs: "Set _____" (PM).
       a. The PM states the primary approach NAVAID Frequency.

3. CDI Source: "____, ____" (PM, PF).
       a. CDI source set for approach NAVAID.
       b. Course Select Knob — Set.
       c. Both pilots state the CDI source selected and CDI course.

4. Rad Alt: "_____Set" (PM).
       a. The PM states the radar altimeter set in the REF/SET Mode Select panel.

5. Minimums: "_____Set" (PM).
   a. The PM states the approach minimums set in the REF/SET Mode Select panel.
6. FUEL MANAGEMENT panel: "_____" (PM/ACM).
   a. The PM or the ACM turns the SPR DRAIN switch ON, if required, and verifies the fuel panel configuration.
   b. Fuel quantity — Check.
   c. Distribution — Check.
   d. State the fuel quantity, sink rate limit, and SPR drained.

Note
- Do not transfer fuel from tank to tank during landings or touch and go landings.
- Refer to Fuel Management, Approach and Landing procedures for allowable fuel system configuration.

7. Briefing: "Complete" (PF).

Note
Refer to Chapter 16 for the Arrival Briefing.

8. Approach Checklist: "Complete" (PM).

5.   BEFORE LANDING FLOW

The pilot may direct lowering of the flaps and gear before calling for the BEFORE LANDING Checklist.

Note
- Wing/empennage anti-icing in anti-ice mode should be turned on in sufficient time prior to landing to ensure the vertical stabilizer is completely anti-iced. This may take as long as 2.5 minutes. Failure to do so will cause the X-WIND LIMITED ACAWS message to be displayed when the landing gear are lowered, and the side slip warning system will limit crosswind landing capability if icing is detected.
- Failure to turn on wing/empennage anti-icing in anti-ice mode prior to lowering the landing gear when icing is detected causes the WING/EMP A/I NOT ON ACAWS message to be displayed.

1. FLAPS: "FLAPS 50" (PF).

CAUTION
Changing the direction of flaps travel while the flaps are moving may damage the flaps motor.

   a. The PM selects the flap handle to 50% and reports when the flaps are at 50%. "Flaps are 50" (PM).

Normal landing configuration is with 100 percent flaps and may be selected after the gear is reported down and prior to crossing the threshold.

2. Gear: "Gear Down Before Landing Checklist" (PF).

3. Lights: Extended and On (PM).
        a. Landing lights — Extended and On (As required).
        b. TAXI LIGHTS switch — ON.
        c. WINGTIP TAXI LIGHTS switch — As required.

CAUTION

Extending landing lights while illuminated may induce pilot vertigo when in IMC conditions.

Note

The Pilot Monitoring should operate the gear handle.

6.   BEFORE LANDING CHECKLIST

1. FLAPS: "FLAPS 50" (PM).

2. GEAR: "3 Down" (PM).
            "3 Down, Centered" (PF).

CAUTION

Check the nosewheel steering indicator to ensure the nosewheel is centered.

Note

Ensure anti-skid on and no anti-skid ACAWS messages displayed.

3. Lights: "_____" (PM).
        a. PM states whether the landing lights are extended or retracted and On or Off.

4. Before Landing Checklist: "Complete" (PM).

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APPENDIX C: RESEARCH APPROVALS

1. NPS IRB

Naval Postgraduate School
Human Research Protection Program

From: President, Naval Postgraduate School (NPS)
To: Dr. Amela Sadagic, Modeling, Virtual Environments and
       Simulation Institute (MOVES)
       LCDR Lee Sciarini, USN
       Capt Nicholas Arthur, USMC
Via: Vice Chair, Institutional Review Board (IRB)

Subj: PROOF-OF-CONCEPT PART-TASK TRAINER TO ENHANCE SITUATIONAL
       AWARENESS FOR INSTRUMENT APPROACH PROCEDURES IN AVIATION
       DOMAIN

Encl: (1) Approved IRB Protocol Amendment

1. The NPS IRB is pleased to inform you that the NPS President
has approved your protocol amendment (NPS IRB# NPS.2017.0029-
AM01-EP7-A). The approved IRB Protocol is found in enclosure
(1). Completion of the CITI Research Ethics Training has been
confirmed.

2. This approval expires on 5 March 2018. If additional time
is required to complete the research, a continuing review report
must be approved by the IRB and NPS President prior to the
expiration of approval. At expiration all research (subject
recruitment, data collection, analysis of data containing PII)
must cease.

3. You are required to obtain consent according to the
procedure provided in the approved protocol.

4. You are required to report to the IRB any unanticipated
problems or serious adverse events to the NPS IRB within 24
hours of the occurrence.

5. Any proposed changes in IRB approved research must be
reviewed and approved by the NPS IRB and NPS President prior to
implementation except where necessary to eliminate apparent
immediate hazards to research participants and subjects.

6. As the Principal Investigator (PI) it is your responsibility
to ensure that the research and the actions of all project
personnel involved in conducting this study will conform with
the IRB approved protocol and IRB requirements/policies.

7. At completion of the research, no later than expiration of approval, the PI will close the protocol by submitting an End of Experiment Report.

K. J. Euske
Digitally signed by K. J. Euske
DN: cn=K. J. Euske, o=NPS,
ou=GSBPP,
email=kjeuske@nps.edu, c=US
Date: 2017.03.23 14:00:16 -07'00'

Kenneth J. Euske, PhD
Vice Chair
Institutional Review Board

Ronald A. Route
Vice Admiral, U.S. Navy (Ret.)
President, Naval Postgraduate School

Date: ___MAR 3 0 2017___
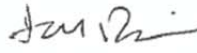
2. DEPUTY COMMANDANT OF AVIATION

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
3000 MARINE CORPS PENTAGON
WASHINGTON, DC 20350-3000

IN REPLY REFER TO
3970
AVN
6 Apr 17

From: Deputy Commandant for Aviation
To: Captain Nicholas L. Arthur 1285751540/7557 USMC

Subj: RESEARCH SPONSORSHIP FOR CAPTAIN NICHOLAS L. ARTHUR
      1285751540/7557 USMC

1. I support the research proposed by Captain Nicholas Arthur regarding the "Proof-of-concept Part-task Trainer to Enhance Situational Awareness for Instrument Approach Procedures in Aviation Domain" within the broader research area of Modeling and Simulations.

2. The part-task trainer can be used as a bridge between basic chair flying and actually flying approaches in a full-motion simulator or even the aircraft. This proof of concept will increase the likelihood that the pilot will be capable of successfully flying the approach while conducting additional tasks that often occur.

3. The research will focus on the following questions:

    a. What is the feasibility of developing a prototype virtual reality (VR) system that supports the training of instrument approach procedures and situational awareness?

    b. Are there training gaps identified in connection with procedures and situational awareness needed for conducting an instrument approach by the pilots?

    c. On what cues (cockpit, environmental, CRM, ATC, haptic, etc.) should KC-130J FRD students focus in support of maintaining situational awareness during instrument approaches?

4. This research will support the use of modeling and simulations for the Aviation community and provide cost effective training enhancements for pilots.

5. Colonel Todd Lyons, Associate Dean of Research at the Naval Postgraduate School, can address research specific topics at 831-884-8317 or twlyons@nps.edu.

J. M. DAVIS

3. USMC HUMAN RESEARCH PROTECTION

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
3300 RUSSELL ROAD
QUANTICO, VA 22134-5001

<div align="right">

3900
C 4623
7 Apr 17

</div>

From: Human Research Protection Official, U.S. Marine Corps (Attention: Ms Leah Watson), 1019 Elliot Rd, Quantico, VA 22134

To: Dr. Amelia Sadagic, Modeling, Virtual Environments and Simulation Institute (MOVES), Faculty Advisor
Lieutenant Commander Lee Sciarini, USN, Faculty Advisor, Naval Post Graduate School, Monterey, CA
Captain Nicholas Arthur, USMC, Student Investigator, Naval Post Graduate School, Monterey, CA

Subj: HUMAN RESEARCH PROTECTION PROGRAM U.S. MARINE CORPS ADMINISTRATIVE 17 REVIEW OF PROPOSED STUDY: "PROOF-OF-CONCEPT PART-TASK TRAINER TO ENHANCE STITUATIONAL AWARENESS FOR INSTRUMENT APPROACH PROCEDURES IN AVIATION DOMAIN"

Ref: (a) DoDI 3216.02
       (b) SECNAVINST 3900.16D
       (c) MCO 3900.18
       (d) U.S. Marine Corps Human Research Protection Program (HRPP) Policy and Procedures (27 Sep 16)
       (e) DOD N-40042 Naval Postgraduate School DOD-Navy Assurance
       (f) MCO 5300.18 Marine Corps Survey Program

Encl: (1) NPS.2017.0029-IR-EP7-A
       (2) NPS.2017.0029-AM01-EP7-A
       (3) DC Aviation ltr 3970 AVN of 6 Apr 7

1. Per references (a) through (d), I have performed an Administrative Review, on behalf of the Marine Corps, of the research titled "Proof-of-Concept Part-Task Trainer to Enhance Situational Awareness for Instrument Approach Procedures in Aviation Domain." The objective of this research is to explore the feasibility of developing a prototype virtual reality (VR) system that supports the training of instrument approach procedures and situational awareness. This research is being conducted as partial fulfillment of academic requirements for Captain Arthur as a student at the Naval Postgraduate School (NPS).

2. The research plan at enclosure (1) and the first amendment at enclosure (2), as submitted to the NPS IRB, has been reviewed by this office to ensure compliance with requirements the U.S. Marine Corps Human Research Protection Program.

3. As outlined in the research plan at enclosure (1), the research will involve voluntary subject participation in an online survey about their understanding of current instrument approach procedure training techniques. The results will be used by the researcher in determining the prototype interface design. Enclosure (1) also includes the Commanding Officer approval for solicitation of subjects, from the Commanding Officers of VMGR-152, VMGR-252, and VMGR-352. Enclosure (3), from the Deputy Commandant for Aviation, provides the General Officer level support required for research being conducted by institutions other than the Marine Corps.

4. Reference (e) is the DOD Institutional Assurance for Naval Postgraduate School which expires 30 November 2019. As reflected at enclosures (1), the

NPS IRB reviewed and approved your research proposal as meeting criteria for Expedited Review under Categories 7 and approved waiver of the requirement for documentation of informed consent under 32 CFR 219.117((2).

5. Review by the NPS IRB and the DC Aviation approval satisfy Marine Corps review requirements for this study. Approval by the NPS IRB assures that the members of the research team have completed the required research ethics training. You are required to inform this office, as well as your approving IRB, if there are any changes or amendments to your protocol. No further review or approval from this office is required. It is noted that the NPS IRB approval for this research expires 5 March 2018. A copy of the NPS IRB's approval of any continuing review for this research beyond the current expiration date must be submitted to this office.

6. Per reference (f) review and approval by the USMC Survey Office is required prior to execution of this survey.

7. If you have any questions or require further information, please don't hesitate to contact me at (703) 432–2566, email leah.watson@usmc.mil. I wish you success with your study and appreciate your patience in complying with our review and approval process.

                    L. B. WATSON
                    Chair, Institutional Review Board

Copy to:
USMC Survey Office

4.   USMC SURVEY OFFICE

On Apr 17, 2017, at 11:47 AM, Hogan Maj Kerry A
<kerry.hogan@usmc.mil> wrote:

Good Afternoon,

The DC, M&RA has approved your survey. Your SCN is: USMC-SR-
17008.

You are cleared to launch the survey.

R/S
Maj Hogan

LIST OF REFERENCES

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