



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

AIR SUPPORT CONTROL OFFICER INDIVIDUAL POSITION TRAINING SIMULATION

by

Kathleen M. Haggard

June 2017

Thesis Advisor:
Co-Advisor:

Perry L. McDowell
Lee Sciarini

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REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE June 2017		3. REPORT TYPE AND DATES COVERED Master's thesis
4. TITLE AND SUBTITLE AIR SUPPORT CONTROL OFFICER INDIVIDUAL POSITION TRAINING SIMULATION			5. FUNDING NUMBERS	
6. AUTHOR(S) Kathleen M. Haggard				
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 <u>2017.0077-DD-N</u> .				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (maximum 200 words) The Direct Air Support Center (DASC) is one of the Marine Corps' primary air control agencies and is responsible for the procedural control of aircraft in support of combat operations. The primary controller in the DASC is the air support control officer (ASCO). Current ASCO training is costly, infrequent, and inadequate. This thesis addresses these gaps by using an instructional systems design approach to creating a prototype training environment for ASCO training. First, this thesis conducts a detailed analysis of the ASCO task and a review of current technical capabilities for similar domains. Based on these analyses, key technology features and ASCO tasks are identified and used to generate requirements for the development of the prototype system. Next, based on identified requirements, a prototype virtual-training environment utilizing a speech-to-text engine was designed and developed. Finally, an efficacy evaluation of the system by subject matter experts suggests that a training simulation such as the prototype developed in the course of this work could improve readiness of the DASC community.				
14. SUBJECT TERMS training simulation, air support, Direct Air Support Center, voice recognition			15. NUMBER OF PAGES 85	
			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. Z39-18

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**AIR SUPPORT CONTROL OFFICER INDIVIDUAL POSITION TRAINING
SIMULATION**

Kathleen M. Haggard
Captain, United States Marine Corps
B.S., Old Dominion University, 2011

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
June 2017**

Approved by: Perry L. McDowell
Thesis Advisor

LCDR Lee Sciarini
Co-Advisor

Peter Denning
Chair, Department of Computer Science

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ABSTRACT

The Direct Air Support Center (DASC) is one of the Marine Corps' primary air control agencies and is responsible for the procedural control of aircraft in support of combat operations. The primary controller in the DASC is the air support control officer (ASCO). Current ASCO training is costly, infrequent, and inadequate. This thesis addresses these gaps by using an instructional systems design approach to creating a prototype training environment for ASCO training. First, this thesis conducts a detailed analysis of the ASCO task and a review of current technical capabilities for similar domains. Based on these analyses, key technology features and ASCO tasks are identified and used to generate requirements for the development of the prototype system. Next, based on identified requirements, a prototype virtual-training environment utilizing a speech-to-text engine was designed and developed. Finally, an efficacy evaluation of the system by subject matter experts suggests that a training simulation such as the prototype developed in the course of this work could improve readiness of the DASC community.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACM	Airspace control measure
ADDIE	Analysis design development implementation evaluation
ASCO	Air support control officer
ASLT	Air support liaison team
ASNO	Air support net operator
ASCOC	Air support control officers course
ATC	Air traffic control
ATO	Air tasking order
CAS	Close air support
CC	Crew chief
FSCC	Fire Support Control Center
F/W	Fixed wing
DASC	Direct Air Support Center
DOD	Department of Defense
DoN	Department of the Navy
HD	Helicopter director
ISD	Instructional system design
LSTM	Long-short term memory
MACCS	Marine Air Command and Control System
MAGTF	Marine Air Ground Task Force
MASS	Marine Air Support Squadron
MCCES	Marine Corps Communication-Electronics School
RIO	Radio in /out
RTB	Return to base
R/W	Rotary wing
SAD	Senior air director
SME	Subject matter expert

TAD	Tactical air director
USMC	United States Marine Corps
WTI	Weapons and tactics instructor

ACKNOWLEDGEMENTS

I want to offer my thanks to Perry McDowell, Lee Sciarini, Peter Squire (ONR), David Reeves, John Merwin (Adacel), Philippe Roy (Adacel), Robert Fahey (Adacel), Steven Seder (Adacel), and the subject matter experts who supported this work.

In addition, I thank Christian Darken for teaching me to program.

Finally, I thank my husband and family who supported me throughout this process.

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I. INTRODUCTION

The United States Marine Corps has been making an effort to improve training with the use of simulation and virtual environments. The intent of this effort is to decrease the time, personnel and materiel resources required to conduct training; improve accessibility, and reduce complexity in order to increase training repetition and extend the types and complexities of scenarios that can be trained. In the January 2016, in the fragmentary order titled *Advance to Contact*, General Robert B. Neller, the 37th Commandant of the Marine Corps, outlined the need to “capitalize on emerging technologies and future opportunities ... to leverage a virtual and constructive training environment and tools” (Department of the Navy United States Marine Corps [DoN USMC], 2016a, p. 8) and “increase the amount of training each unit can accomplish to ‘increase the reps’ in mentally and physically stressing environment for all elements of the [Marine Air Ground Task Force (MAGTF)] before they do so on the battlefield.”(DoN USMC, 2016, p. 8). The September 2016 *Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century* reiterates this point by listing the need to “leverage increased computing power and more powerful simulation tools to increase the number of turns, repetitions, and scenarios in training” (DoN USMC, 2016b, Section 6.5.2).

One community that could benefit from the use of simulations for training is the Direct Air Support Center (DASC). The DASC is one of three primary air control agencies in the Marine Corp’s Marine Air Command and Control System (MACCS). Within the DASC, air support control officers (ASCs) are the crew members responsible for devising safe routing, communing routes, air hazards, mission information, and friendly and enemy disposition to pilots; logging routing and relevant mission data for each supported mission, and reporting requisite information to designated MACCS agencies. ASCs play an important part in facilitating the safe and successful conduct of air operations in DASC-controlled airspace. They are also critical in integrating air and ground missions in support of MAGTF operations. The focus of this

thesis is the analysis of the ASCO task, with the goal of developing an affordable prototype simulation capable of demonstrating the potential to be used as an ASCO training system.

A. PROBLEM STATEMENT

Current training for ASCO is inefficient, inadequate and costly. It does not take advantage of increased computing power and simulation tools. ASCO training events currently do not provide trainees with the opportunity to participate in multiple trials. Furthermore, in its current form, ASCO training occurs infrequently, resulting in the inability to maintain skills, increase automaticity, or develop expertise.

B. RESEARCH QUESTIONS

1. What is the feasibility of developing an automated training system to support individual position training of ASCO?
2. How would subject matter experts consider a training system to support individual position training of ASCOs in context of current training procedures?

C. SCOPE AND LIMITATIONS

This thesis focused on the development of a prototype training simulation for ASCO individual position training. This prototype was built using the principles and best practices from training simulations, games for training, the science of human learning, and cognitive load theory. It also investigated the utility of such a prototype simulation for ASCO training.

The first step was an investigation of extant literature and technologies. The literature review focused on the aforementioned areas, as well as current simulation platforms associated with related fields, current speech-to-text and text-to-speech technologies, and development environments.

The second was developing a prototype simulation to support ASCO individual position training. This step included a task analysis of ASCO positions to scope the prototype and guide development process.

The third step was conducting a subject matter expert (SME) review in order to determine if the incorporated technologies are effective and if the DASC community sees such a system as a potential solution to training gaps. The information gathered was also used to form suggestions for future systems developments.

D. BENEFITS OF THIS STUDY

It is proposed here that the addition of an ASCO individual position trainer would

- Increase the frequency of training for ASCOs.
- Decrease the time it takes for ASCOs to reach qualification.
- Increase the readiness of Marine Air Support Squadrons (MASS).
- Improve the quality of overall DASC operations.

E. THESIS ORGANIZATION

The next section of this thesis is the background section. The background section introduces DASC operations, qualification requirements, training, and training shortfalls. The literature review follows the background section and examines training transfer of simulations for training, the process of human skill acquisition and how it relates to ASCO training, instructional system design, synthetic voice production, and voice recognition. After the literature review is the methods section in which the methods used to complete this work are described. The final three sections are the results section, the conclusion, and future work.

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II. BACKGROUND

In order to understand the potential benefits and requirements of an ASCO individual position training simulation, one must first understand the mission of the DASC and how it fits in to the MAGTF, the unique way the DASC conducts operations, and the role the ASCO plays within the DASC crew.

The DASC's mission consists of four parts that provide the flexible air control and support necessary to offset the inherent complexity of war. The first part of the mission is to procedurally control all aircraft in DASC controlled airspace (Department of the Navy United States Marine Corps [DoN USMC], 2010). "Procedural control is a method of airspace control that relies on a combination of previously agreed upon and promulgated orders and procedures" (DoN USMC, 2010, p. 137). The DASC uses procedural control exclusively and has no organic electronic means of tracking aircraft. In turn, the DASC can deploy rapidly in austere environments with a relatively small footprint.

The second part of the mission is to process immediate air support requests (DoN USMC, 2010). This means that the DASC maintains communications with ground units throughout the battle space. If a ground unit requires unplanned air support, such as a casualty evacuation, it contacts the DASC to request immediate air support. The DASC then makes a decision or recommendation, depending on their authority during the operation, on how and if the request is supported by air. If the request is supported, the DASC tasks an aircraft with supporting the request and passes all relevant mission data to both the supporting aircraft and the supported ground unit.

The third part of the DASC mission is to integrate aircraft employment with other supporting arms (DoN USMC, 2010). To this end, the DASC either is collocated with the senior fire support coordination center (FSCC) or provides the FSCC with an air support liaison team (ASLT). This provides the DASC with nearly immediate knowledge of fire missions and helps them to facilitate timely fires integration while maintaining safety of flight for all aircraft. For instance, if a ground unit were in contact with enemy

troops and requested artillery fire in support of a maneuver, the DASC would clear the airspace along the line of fire between the maximum and minimum ordinate of the fire mission and then report that the airspace was clear to the FSCC so that firing could commence.

The fourth part of the DASC mission is to manage terminal control assets (DoN USMC, 2010). When aircraft are supporting ground operations, often a terminal controller is responsible for the direction of aircraft to deliver ordnance, passengers or cargo to a specific location. Terminal control often requires visual tracking of the aircraft and identification of targets or landing zones (DoN USMC, 2010). These operations take place in DASC controlled airspace. The DASC allocates the terminal controller a block of airspace and follows hand-over procedures to pass aircraft control to the terminal control. Depending on the type of terminal control, the DASC may allocate radio frequencies for the terminal controller to communicate with the aircraft. The DASC maintains communications with terminal controllers. This link improves coordination and provides the terminal controller, and thereby the supported ground unit, a means to communicate with the MACCS.

In order to accomplish its mission, several continuous and concurrent tasks must take place. These tasks are carried out and managed by a crew composed of both commissioned and non-commissioned Marines. The crew positions include (numbers in parenthesis indicate a DASC's normal complement):

1. Senior air director (SAD) (1);
2. Crew chief (CC) (1);
3. Air support control officers (ASCO) (2):
 - a. Tactical air director (TAD)
 - b. Helicopter director (HD)
4. Air support net operators (ASNO) (multiple);
5. Plotters (multiple) (Department of the Navy United States Marine Corps [DoN USMC], 2015).

The SAD and CC are the most qualified commissioned and non-commissioned watch-standers, respectively, and are responsible for overall operations as well as inter- and intra-agency coordination. Several ASNOs are responsible for communications with other command and control agencies, ground units, terminal controllers, and DASC extensions and liaisons. The plotters are responsible for maintaining DASC displays such as the map and the radio in and out (RIO) board—a table displaying the mission data of all of the aircraft controlled by the DASC. The ASCOs are commissioned officers whose responsibilities include

1. Providing safe routing, mission updates and threat briefs to fixed wing and rotary wing aircraft;
2. Maintaining status and mission information on aircraft under their control;
3. Coordinating with the other ASCO to ensure there is no routing conflicts;
4. Reviewing immediate requests and providing support recommendations to the SAD.

DASC operations are fast-paced and complex. ASCOs require a broad range of knowledge and skills, most of which are highly perishable such as

1. Familiarity with both ground and aviation operations and terminology;
2. Knowledge of the capabilities and limitation of organic, joint, and multinational aircraft and aircraft ordinance;
3. The ability to communicate quickly and effectively via radio;
4. The ability to maintain a three dimensional mental picture of the airspace including aircraft locations;
5. The ability to maintain situational awareness of the rest of the DASC crew's actions;
6. The ability to multi task in order to maintain constant communication with aircraft, update logs, and report required information to the rest of the command and control system.

ASCOs are required to be qualified in two positions—the HD and TAD. In order to earn each qualification, ASCOs must meet several prerequisites. First, the ASCO must complete air support control officers course (ASCOC). Next, they must be observed

conducting the duties of an ASCO in a DASC at operational tempo levels one through three (Table 1). Then, they must be deemed proficient by a senior instructor while operating in a DASC at operational tempo levels one through five. Proficiency is defined as correct, efficient, and skillful execution of tasks without hesitation, requiring minimal input from the instructor and with minor errors corrected by the trainee. Finally, they must be deemed proficient by a weapons and tactic instructor (WTI) at operational tempo levels one through five (DoN USMC, 2013). This is an abbreviated description of the qualification requirements focusing on practical skills and does not include academics, environmental requirements and various prerequisites. A full description of requirements can be found in the *Direct Air Support Center Training and Readiness Manual [NAVMC 3500.120]*.

Table 1. Operational Tempo per Hour Requirements.
Adapted from DoN USMC (2013).

Level	Fixed Wing	Rotary Wing	Immediate Requests	Fire Missions
1	2	2	2	1
2	4	4	3	2
3	6	6	4	3
4	8	8	5	4
5	10	10	6	5

A. CURRENT TRAINING

ASCOs receive initial training at ASCOC at the Marine Corps Communication-Electronics School (MCCES) in Twentynine Palms, California. The instruction at ASCOC is comprised of a classroom-based lecture series that provides the foundational education required to understand the mission, tasks, coordination and terminology intrinsic to the DASC as well as practical application to train and test the skill required during DASC operations. ASCOC provides practical experience by conducting live simulations. A common format for live DASC simulations is to deploy and operate two DASCs. One DASC is simulation control and the personnel staffing it act as the pilots,

MACCS agencies, DASC extension, and ground unit with which the DASC coordinates. The second DASC is manned by the training audience. They assume the crew positions on which they are being trained or evaluated. At ASCOC, each session lasts twenty minutes and can only accommodate two ASCOs, one in the position of HD and one in the position of the TAD. The rest of the students conduct self and partner study while they wait between four and six hours for their turn. Self-study generally involves reviewing published coordination procedures, maps, airspace control measures (ACM) and the air tasking order (ATO). During partner study, two trainees take turns acting as a pilot and an ASCO. They reference a map depicting the airspace and practices routing the aircraft with the use of proper radio in/out (RIO) procedures.

Training at a MASS (a fleet DASC unit), is conducted in the same basic format as at ASCOC. Classroom instruction and self-study are the primary means of knowledge expansion and live DASC simulations and partner study are used to train skill. Outside of these simulations, there is little formal training, meaning that on the job training during live exercises and in support of military operations is a common occurrence.

B. TRAINING SHORTFALLS

There are several problems with these training methods. The on-the-job training provided by exercises rarely reaches an operational tempo that can count towards qualifications. Also, during exercises, the DASC is not the primary training audience, and many of the agencies with which the DASC doctrinally coordinates do not participate or are not focused on training that requires coordination with the DASC. Furthermore, the airspace available for the procedural control of aircraft is extremely limited and cannot support the volume of aircraft or complexity of airspace required to train an ASCO.

Live simulations are time and resources intensive. Coordinating activities associated with planning and scenario building, resources acquisition, and personnel and material availability combine to result in difficult and complex preparations. For this reason, training drills are infrequent, often taking place only once or twice a year, and only last for a couple of days. Their rarity and limited duration make it unlikely that all

personnel requiring training will be able to participate. Furthermore, due to the limited operational tempo reached during exercises, these drills are often used for qualification instead of training. This means that trainees are expected to be ready to be evaluated having received little to no simulation time beforehand.

Live simulations focus on not only individual training but also crew training since all of the crew positions interact. These interactions, paired with the inherently adaptable form of airspace control performed by the DASC, make live simulations complex. Live simulations generally start out with a script that the actors use to provide inputs. In a live DASC simulation, it is unlikely that the trainee will make decisions that align with the prepared script, which causes deviations and changes the scenario. It is up to a training confederate to track these deviations and respond accordingly for the duration of the simulation to maintain the realism of the training. If the confederates forget a change made by the ASCO and report an aircraft in the wrong position, it is not just a break from reality, but it corrupts the mental model of the ASCO.

Other problems exist upon completion of a training scenario. For example, after action playbacks are not available. This leaves instructors little choice but to conduct performance reviews and assessments that are largely subjective. There is no standardized means of evaluating performance. Usually, a senior Marine will observe and provide feedback, but most of the senior Marines are on the crew acting as the SAD or providing inputs to the training exercise. This limited amount of training and feedback is detrimental to the maintenance or improvement of the skills required of an ASCO. In summation, numerous critical training gaps exist which can impact the performance of ASCOs, the DASC, and ultimately, the combat effectiveness of the MAGTF.

III. LITERATURE REVIEW

It is not enough to say the military leadership has decided to use simulation for training so everybody start using simulation. There must be evidence that the addition of a training simulation will result in better trained personnel and a rigorous means of developing systems to meet specific training goals. This section reviews relevant literature associated with the transfer of training from simulation and virtual based training systems, skill acquisition, and instructional system design.

A. TRAINING TRANSFER

The main goal of any training is the transfer of targeted knowledge, skills, and attitudes to real world performance (Department of Defense [DOD], 2001). There is significant evidence that suggests using simulation and virtual environments for training can result in improved performance. For example, simulation-aided performance improvement was shown during the Royal Australian Air Forces live training event, Pitch Black (Francis, Best & Yildiz, 2016). Prior to Pitch Black, a group of trainees participated in a simulation supported training exercise called Black Skies. The intent behind Black Skies was to prepare trainees for the more expensive live training of the Pitch Black exercise. Results demonstrated a twenty percent average improvement in performance during Pitch Black by those teams that participated in Black Skies compared to those that did not (Francis et al., 2016). Another study evaluated the effectiveness of a virtual training system called the flooding control trainer (FCT). Conducted at Naval Recruit Training Command, the FCT experiment demonstrated a 50% reduction in decision-making errors, an 80% reduction in communication errors, and a 50% improvement in situational awareness and navigation skills during the training capstone evaluation called Battle Station 21 (Hussain et al., 2009). The proposed training system for the FCT study used a computer game design to keep learners engaged and drive home the consequence of their actions. In another study of medical residents' ability to perform a colonoscopy, researchers found that those who received training on a virtual reality simulator prior to the evaluation performed significantly better than those who received

only conventional training (Park et al. 2006). While just a sample, these studies come from different professions, incorporated different types of training systems, and trained different skills to different populations. However, each example, and numerous others, demonstrates that training with the aid of simulation and virtual environments can result in real world performance improvements.

B. SKILL ACQUISITION

As discussed in Chapter I, there are several reasons why the DOD and the Marine Corps are increasing investments in simulation and virtual training. These approaches to training have been shown to be less expensive than live training, able to allow more complex and dangerous mission training, and increase the opportunities for training. As a stated goal of this thesis, increasing the number of training events an individual ASCO can perform is needed to improve proficiency and readiness. The following section addresses why repetition is important and how the benefits of such an increase in training event could be advantageous to the Marine Corps.

The answer to why increased practice is advantageous is founded in several cognitive theories. The theory of human information processing, introduced by Atkinson and Shiffrin (1968), examines how humans take in information and process it into memory. Under this theory, stimuli activate the sensory register, and if attention is given to the stimulus, the information is transferred to a short-term store, or working memory, and the long-term store is scanned for existing relevant information. Upon rehearsal and association with prior existing knowledge, the information in the short-term register is transferred to the long-term register. Atkinson and Shiffrin (1968) suggest that the information held in the short-term store begins to decay after 15–30 seconds if not rehearsed and transferred to the long-term register, which they describe as relatively decay free.

Short-term memory is not only limited by duration but also by capacity. Miller (1956) proposed that people are only able to hold seven plus or minus two chunks of information in short-term memory. Even though the number of chunks is relatively static,

the size of the chunks is not. As a person becomes more familiar with the information he or she is handling, the person is able to group several chunks together. This group is then a single chunk, and the total amount of information that can be held in short-term memory is increased.

Clark, Nguyen, and Sweller (2006) liken these larger capacity chunks to schemas. Schema is one of many terms for knowledge that is stored in a relational network (Harper-Sciarini, 2010). According to Clark et al. (2006), expanding one's schemas is one way to reduce the impact extraneous load. Cognitive load theory finds its basis in the theory of human information processing. As discussed before, short-term memory is of limited capacity and duration. If you try to hold too many chunks in short-term memory, the process becomes overloaded and capacity is diminished. Eventually, continuous overload can result in a complete shutdown (Clark, Nguyen & Sweller, 2006).

Cognitive load comes in three different forms: intrinsic, which is load due to the nature of the task; germane, which is load due to the innate diversity of the task; and extraneous, which is load that is irrelevant to the task (Mayer, 2014). Of these, instructional designers want to increase germane load because "germane cognitive load that contributes to, rather than interferes with, learning" (Sweller, Van Merriënboer & Pass, 1998, p. 264).

As a simple example of these loads, consider an addition problem. The intrinsic load would increase if adding multiple figures (ex. $3+3+3$) was required, germane load would come from doing multiple examples (ex. $1+2+3$, $5+9+2$), and extraneous load would come from the fact that each number that is being added is on a different page so that the task requires flipping through a work book to find each number. Ultimately, our goal is to decrease the extraneous load so that limited mental resources can be spent dealing with intrinsic and germane load. Developing larger and more complex schemas through experience and practice (assuming the appropriate items were being rehearsed) will provide the means to relate more information into groups and ultimately increase the size of chunks and held in short-term memory and decrease the likelihood of cognitive overload.

Another way to manage extraneous load is to build automaticity. Clark et al. (2006) described automaticity as the rehearsal of skill so often they become automatic. This means that mental processes are no longer being spent thinking thorough how to accomplish a task. Instead, the task is accomplished automatically and mental processes are freed to deal emerging information.

The job of an ASCO is cognitively tasking. Not only do they continuously relay information back and forth with pilots, they communicate that information with the rest of the MACCS, maintain RIO logs, supervise the RIO board plotter, track updates to aircraft mission data, and maintain situational awareness of changes to the airspace. Furthermore, since the DASC does not have radar, they accomplish these tasks without live visual cues of aircraft flight information. This means ASCOs must create a three-dimensional model in their heads that incorporates the routing they assigned to each aircraft in the airspace. Increasing the availability of relevant practice could result in enhance schemas allowing them to deal with larger amounts of information and more complex scenarios and develop automaticity of certain skills thereby freeing more space in working (short-term) memory.

C. INSTRUCTIONAL SYSTEM DESIGN

Because the proposed prototype for this thesis is intended to be a training simulation, it is imperative to consider instructional system design (ISD). The approach discussed below offers a framework in which ISD can be accomplished.

The aim of ISD is to use the principles of learning to develop learning plans, resource material, activities and evaluation that results in efficient learning and measured outcomes (Hussain & Coleman, 2014). While there are several different models for ISD, the preferred approach for the DOD is the five phase analysis, design, development, implementation, and evaluation (ADDIE) model (DOD, 2001). The analysis phase focuses on what learners need to learn and who the learners are. This is often done by conducting a task analysis and identifying what tasks are not being trained by current methods. During the design phase, the outcomes of the analysis and appropriate learning

theories are used to create a plan to produce instruction that will result in successful learning. This can include decomposing complex tasks into separate lessons, including feedback to support learning, and developing pass / fail criteria. The development phase is closely linked with design and constitutes the actual production of prototypes and the final system and associated materials that support the system and training. Implementation is the actual delivery of the system to the learners. Evaluation is, in theory, continuous, and should exist at every level of the process. This thesis focused on the analysis, design, development, and evaluation stage of the ADDIE process.

D. SYNTHETIC VOICE PRODUCTION AND VOICE RECOGNITION

The full results of the ADDIE model are given in the results section, but one factor that emerged from it was the requirement for users to interact with the system via voice. In creating a simulation that relies on verbal communication, it is important to identify key areas that can be automated in order to reduce the need for instructors and operators to perform as training confederates (providing pilot communication for the trainees) instead of their primary responsibilities. For example, the procedural controls practiced in the DASC requires constant communication between pilots and the ASCO. Because of this persistent two-way communication, current training requires a role player, usually a senior ASCO, to play the part of pilots in the DASCs area of responsibility. Role players are also required for every other DASC crew position when conducting training. A minimum of six role players is needed to conduct training for a single DASC crew. In order to simulate these exchanges, some method of vocal interaction between the trainee and the system was necessary. For the verbal output from the system, there were two options: a prerecorded, scripted, solution, or dynamic, synthetic voice generation. For interpreting the trainee's speech, the system required some form of speech recognition.

1. Computer Produced Verbal Output

When creating a simulation that provides verbal stimuli to a trainee, the stimuli can be produced in two ways: it can be either prerecorded audio clips or synthetic voice

production. Prerecorded audio has humans read words and phrases designers anticipate the system will have to say to the user. Synthetic voice production is the manufacturing of human speech via electronic means.

Even though prerecorded inputs offer better quality, they tend to be more expensive and less adaptable. Training simulators that use prerecorded voices would only have access to those discrete inputs and could not verbalize any comment the designers had not anticipated. If there was a need to train for a scenario or in an environment not accounted for by the recording, new recordings would have to be commissioned and the system would have to be adapted to handle new inputs. This type of static solution would not support one of the key characteristics of DASC operations, adaptability. Since war is inherently chaotic and unpredictable, the Marine Corps operates under the philosophy of centralized command and decentralized control in order to maintain the flexibility to respond to dynamic environment. The DASC is no different. The ASCO controls the airspace using general guidelines but can ultimately do whatever is needed to ensure the safe transit of aircraft. A system that uses prerecorded audio would not be able account for every eventuality and could even provide negative training by artificially restricting ASCO actions.

There are two main approaches to speech synthesis, formant-based, also called text to speech by rule, and waveform, also called concatenative synthesis. The formant-based approach uses an electronic model to synthesize the “voice.” This method was used often for early text to speech technologies and focused on individual segments and their acoustic quality (Winters & Pisoni, 2003). Waveform, on the other hand, is a newer technology and uses a library of prerecorded sound units taken from real human speech. These sound units are concatenated together to create the generated “voice.” The focus on this method is on the transition between segments (Winters & Pisoni, 2003). The sound units in the waveform method are often diaphones, “the section of speech from the middle of one phone to the middle of the next phone” (Cunningham, 2011, p. 3), though any size of unit can be used.

Cunningham (2011) explains that early synthetic voice production focused on the intelligibility of individual words or segments, as is seen with formant-based synthesis, and, more recently, the focus has shifted to making synthetic voice sound more natural and encompassing the prosodic cues found in real human speech, such as tempo, rhythm, stress, and intonation. Waveform seeks to achieve this by providing smoother transitions. As technology has progressed, so too has the prosodic ability of waveform-based systems. Higher quality synthesizers and the use of natural language processors have improved prosody by adjusting pitch based on punctuation and the presence of homophones. Also common in higher quality synthesizers is the use of a large number of prerecorded sound units, including recordings with different pitch. This gives speech algorithms more samples to choose from, and ultimately, the ability to produce smoother transitions (Cunningham, 2011).

Another important area of research is the effect of noise on the intelligibility of synthetic speech. This is of particular interest in the case of a training simulation for ASCOs because the DASC is a noisy environment. Since any well-designed training system should be extensible (Zyda, 2001), allowing for the integration of other crew positions would result in the need to include additional noise and pose another challenge for a representative system. Pisoni and Koen (1982) found that there was an interaction between the use of synthetic voice and the addition of white noise. Additionally, as the sound-to-noise ratio increased, the intelligibility of synthetic segments degrades at a higher rate than natural voice (Winters & Pisoni, 2003). When investigating babble instead of white noise, Koul and Allen (1993) demonstrated that the addition of babble did not produce an interaction with synthetic voice, but instead degraded synthetic and natural voice evenly. They postulated that the difference, in addition to some specific degradation of the constant “h,” may arise from the tendency of babble to remain at a lower frequency while white noise is evenly spread across the spectrum.

As the understanding of the intelligibility of synthetic speech grew, so, too, did interest in the cognitive demands of working with synthetic speech. Since humans find it easier to understand human speech than synthetic speech, logic suggests that its

interpretation requires the use of more cognitive resources. In general, increasing cognitive load is not necessarily a bad thing. In fact, one of the goals of a training system is to increase the germane load in order to produce learning. Due to limited cognitive resources, however, learners can become overwhelmed, resulting in the disengagement from any useful learning. For this reason, it is important to reduce extraneous and even intrinsic load to the greatest extent possible. In doing so, more “space” is left for germane load and learning that is more efficient is possible.

In cases where the duration of a simulation training event is long (greater than one to two hours) or requires a large amount of adaptability, the use of synthetic voice generation may be more advantageous but presents the possible drawback of becoming extraneous cognitive load (Hussain & Coleman, 2015). Additional cognitive load is a specific concern when training ASCO because, as discussed above, the intrinsic load of the job is already restrictively high. Due to the high intrinsic load of the ASCO task, any training system should seek to reduce all extraneous loads to the greatest degree possible. These realities present a challenging problem. The use of synthetic voice generation in such a training simulation is more cost effective, and can provide more adaptive and relevant training, but may add to the extraneous load and potentially reduce the effectiveness of the training. However, multiple trials of dynamic training enabled by the use of synthetic speech generation may outweigh the potential impacts for both trainees and instructors.

Hussain and Coleman (2015) address the effect of synthetic speech on mental workload. They point out that the use of synthetic voice has several advantages and may be a good option for simulations. They emphasize that if used on a regular basis, trainees will have the advantage of the learning the effects associated with synthetic voice. Hussain and Coleman’s also pose an interesting question: could listening to synthetic voice improve overall listening skills by requiring the trainee to focus more on what is being said.

Bowers, Hussain and Procci (2014) sought to confirm the idea that using synthetic voice in a training simulation would require more focus and result in deeper learning. To

do so, they adapted a current Navy training system that used text as the primary communication medium to incorporate synthetic and natural voice. The participants, 119 U.S. Navy recruits, were divided into two groups with one group participating in the traditional, text-based training approach while the other used the modified approach. Upon completion of the training, participants in each group listened to an audio clip and were asked to extract important information. The audio clips were all natural voice, but one had white noise added, one was sped up, and one was the control. The intent of the difference in the audio clips was to simulate the distortion common to radio transmission. They found no evidence that using synthetic voice in the training improve the listener's ability to extract information during the evaluation, though the authors do suggest that a single exposure is unlikely to result learning.

These results point to the need for additional research in the area of transfer of learning effects. It is unclear if issues with fluency would necessarily apply to novices who are easily overwhelmed with information. However, the learning effect of synthetic voice may still prove to be useful if it can be shown to transfer to other difficult listening situations such as military radio transmissions. This is of particular interest for the training of ASCO since their communications are dependent on the use of radios transmitting over large distances in less than ideal environments.

2. Speech Recognition

Most modern speech recognition systems use a combination of computer learning, neural networks, and statistical reasoning to create accurate speech recognition systems (Chen et. al, 2006; Gales, 1997; Xiong et. al, 2016; Zhu, Stolcke, Chen, & Morgan, 2005). Recent breakthroughs have been made by a Microsoft research group using convolutional and recurrent neural networks, specifically, a Long-Short Term Memory (LSTM) model for both acoustic and language modeling. Xiong et.al (2016) used this combination of techniques to create their speech recognition. When tested, their system achieved better performance results than the human participants.

Like most speech recognitions systems, the goal of LSTM is to model natural speech including human utterances, self-corrections, and hesitations. A commonly used data set for testing these systems was created by the National Institute of Standards and Technology. The most difficult to understand of these data sets, i.e., the one resulting in the most incorrect interpretations by speech recognition systems, consisted of personal communication over the telephone (Cieri, Miller & Walker, 2004). These data sets are particularly difficult due to the poor sound propagation over telephones, resulting in less accurate acoustic evaluation, and the inconsistency in speech inherent to a natural conversation, resulting in less accurate linguistic evaluation.

Even with systems reaching human speech recognition, as demonstrated by Xiong et.al (2016), a system that focuses on natural language may not be an acceptable option for an ASCO individual position trainer. As stated above, most of these systems use statistical analysis to decide if what is being said fits what is expected from grammar or training sets of data. ASCOs, and most people operating on military communication systems, do not use normal grammar. Communications over these systems often use acronyms, sometimes spelled out and sometimes said as word (not necessarily an English word). This domain specific communication type often renders most systems useless due to accuracy issues. However, there are several systems that allow users to create a grammar specific to their needs. Several of these options were considered for inclusion in this work. The outcome of this consideration will be further explained in the methods section.

IV. METHODS

This section examines the steps taken in the development of the ASCO individual position training prototype simulation. The first step was to identify training requirements via task analysis. The next step was to identify constraints for the system by considering external requirements, such as usability, availability, and development time. Using this information, we built a conceptual model to guide product selection and prototype development. We considered several commercial-off-the-shelf products were, chose the best options and developed a prototype. The final step was to demonstrate the prototype to subject matter experts and get feedback on the prototype and the possible addition of such a system into ASCO training.

A. TASK ANALYSIS METHOD

The task analysis was conducted using a modified ADDIE model. The first step in the task analysis was to examine the DASC training and readiness manual and identify those tasks specific to ASCO individual position training. In order to scope the project, a single task was chosen and broken down into sub-tasks and associated skills. Out of these sub-tasks, we chose to focus on those that were not exclusive to specific equipment or environments. For example, a sub-task of “turn on the radio” may vary depending on the equipment setup being used. This type of variable task was not considered for inclusion in the simulation because it is costly to simulate, likely to become obsolete and require costly upgrades, and is not exclusive to ASCOs.

Further scoping was conducted by removing tasks related to document familiarization such as “extract information from the air tasking order.” Even though these types of tasks are important, ASCOs are often given time to conduct them prior to the start of an operation. In the case of tasks like “conduct airspace familiarization,” ASCOs have several days to study the airspace prior to operations. Because these tasks require a less perishable skill set and relatively large amounts of time are allotted for ASCOs to conduct these tasks, they are not included in the prototype simulation. It is

important to note that these types of tasks should be included in a more robust simulation, and it would likely be easy to add them with the creation of a scenario development tool.

B. PROGRAMMING APPROACH

One of our main goals when deciding on a programming approach was modularity. The initial intent was to create models of non-ASCO DASC crew positions to provide additional stimuli and flexibility to the system. It was unclear at the outset of this project if there would be enough time to create these models and logic to support interaction with the user. For this reason, we decided to modularize the models to support extensibility.

Even though the development of a user interface was not one of the main goals of this thesis we wanted to include some tools to support scenario modification. For this reason, enumerations of specific configuration options were included in some of the models as publically accessible drop down menus.

C. ANALYSIS OF ALTERNATIVES

An analysis of alternatives was conducted to identify available simulation and voice recognition / synthetic voice production software. It is important to research what options are available. Oftentimes conducting an analysis of alternatives introduces options that were not previously known, and identifies the best design options.

For this thesis, several alternatives were identified and their relative merits were considered. Aspects for consideration included suitability, usability, availability, interoperability and transferability. A suitable option meets required performance standards. A usable option requires minimal front end training. Available options do not require special permission or certification and are not restrictively expensive. Interoperable systems are able to integrate with other selected systems. A transferable system is one that can transition to military use or is already certified for military use.

D. SUBJECT MATTER EXPERT EVALUATION

The final step was to show the ASCO training system prototype to subject matter experts (SMEs) and elicit feedback on the system's perceived utility. Each SME was

provided with a questionnaire prior to a demonstration of the simulation. This first portion of the questionnaire focused on current ASCO individual position training. The second part of the questionnaire was distributed after the demonstration and focused on the possible effects such a simulation could have on training, what positives and negatives the system offers, and what additions would improve the utility of the simulation. The results of the project and the feedback from the demonstration are discussed in the results section of this thesis.

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V. RESULTS

This section describes the functionality achieved in the prototype simulation, the capabilities of the resultant grammar and the input provided by subject matter experts.

A. TASK ANALYSIS RESULTS

The overarching task identified for use was AIRS-1152: Perform as a Tactical Air Director. Figure 1 is an excerpt from the *DASC Training and Readiness Manual* outlining the subtasks associated with AIRS-1152. Highlighted are the subtask and mission sets that were further broken down and analyzed for inclusion in the prototype simulation. Outlined in blue are those tasks analyzed and included in the prototype simulation.

AIRS-1152 * B E G

Goal. Perform as a Tactical Air Director

Requirement. In a DASC, perform the following:

1. Parse the ATO to create accurate soft frags.
2. ~~Route aircraft in accordance with ATO.~~
3. De-conflict aircraft with surface to air threats, other aircraft, and combined arms fires.
4. Use proper terminology associated with procedural control.
5. Use the SALT brief to RIO F/W aircraft.
6. Accurately control common F/W missions:
 - a. CAS
 - b. XCAS
 - c. FAC(A)
 - d. Reconnaissance
 - e. Refueling
 - f. SCR
 - g. UAS
 - h. Downed A/C
7. Pass and receive air support requests to and from F/W aircraft.
8. Give a crew brief.

Performance Standard. Without the aid of reference, pass a test with a minimum score of 80% and apply knowledge gained in practical application using the DASC.

Reference.

1. MCWP 3-25.5
2. DASC Pocket Checklist

Figure 1. AIRS-1152 Extracted from *Training and Readiness Manual*.
Source DoN USMC (2013).

These sub-tasks were further decomposed into step-by-step processes. This helped us to identify how the simulation should run, the visual and auditory information should be presented to the ASCO, and what inputs the ASCO should be able to provide to the system. The following is a list of the displays, and inputs and outputs identified for inclusion.

Displays

- Airspace map (see Figure 2)
- Radio in/out board (see Figure 3)
- Chat window (see Figure 4)

Output

- Audio of pilot communication
- Visual representation of aircraft (to be used as scaffolding)
- Visual information describing airspace status

Input

- Verbal communication of instructions to pilots
- Type in dissemination of mission information

The fixed wing (F/W) mission type selected for inclusion was close air support (CAS). The following is a chronological list of events during an inbound CAS mission.

1. Aircraft check-in
2. Routing
3. Safety of flight brief
4. Air tasking order confirmation
5. Air defense warning condition weapons control status brief
6. Follow-on instructions
7. Handover to terminal controller

After a pilot switches to terminal control, they are no longer in communication with the DASC. Once the CAS mission is complete, the pilot contacts the DASC for

return-to-base routing. The following list is the chronological steps of the return-to-base at the conclusion of a CAS mission.

1. Aircraft check-in
2. Confirm fuel and ordnance status
3. Routing
4. Safety of flight brief.
5. In flight report
6. Air defense warning condition weapons control status brief
7. Follow-on instructions
8. Handover to air traffic control (ATC)

Once the task analysis was complete we began to consider what product would help to support the development of the system. To further guide the product decision we identified several constraints in the analysis of alternatives.

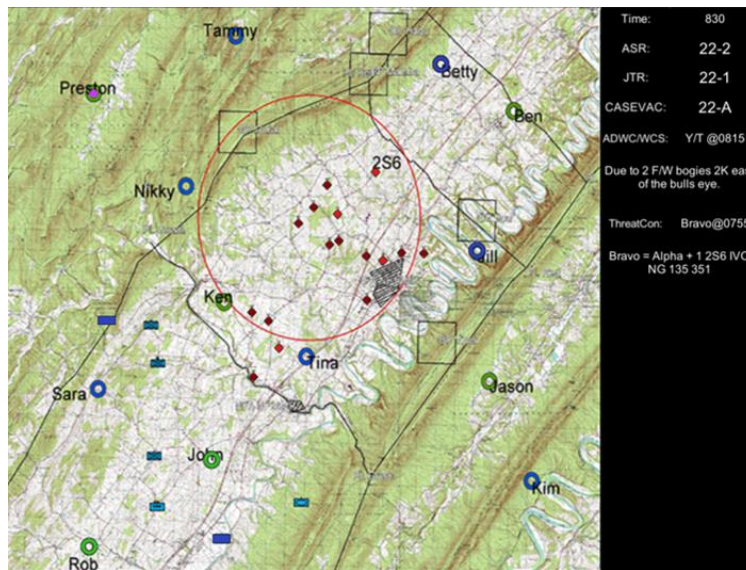


Figure 2. Map Screen Capture from Prototype Simulation

B. ANALYSIS OF ALTERNATIVES RESULTS

Using the information gathered during the task analysis, we identified the components of a DASC that the prototype simulation would encompass. Mockups were made of each of these components and the flow of information from one component to the next was identified.

1. Constraints

In order to improve the availability and reduce the cost of simulations, several constraints were applied. First, the prototype main hardware consists of a single laptop. This makes the system easy to transport and reduces the amount of space to house the system. Ultimately, this small footprint makes the system more affordable and accessible if adopted and fielded. The only requirement for the hardware was that it works with the selected software.

The requirements to access a military network are very stringent and take a considerable amount of time and effort to complete. In order to facilitate the possibility of testing the prototype at a MASS, we decided that the system should run without an Internet connection. The intent was to improve the ease of testing and make the system easier to deploy.

As previously mentioned, one of our main goals is to improve the availability of training for ASCO. One way to accomplish this is to reduce the personnel requirement associated with training. To this end, another requirement is for the prototype simulation to be operable by a single trainee.

2. Hardware

The selected hardware includes an Alienware laptop and a Plantronics vivox headset with incorporated microphone and adjustable volume control. The laptop includes an Intel i7 processor with a 2.80GHz CPU, 16 GB of RAM, a 64-bit operating system and Windows 8.1 Pro. The choice of the laptop was the result of a software quirk. The Lexix uses the computer's serial number to create a computer specific identification

number. The serial number on the original computer was masked so one of the school's computers was used instead.

The headset is not a requirement but improves the usability of the system in a noisy environment and is similar to the headsets worn by ASCOs. It would be advantageous to procure a headset that had an incorporated push to talk button. The current system requires the user to use a mouse to select the push to talk button on the Lexix user interface. By doing this, the user is deselecting the simulation to select the voice recognition system. To use the simulation's keyboard interactions, the user has to reselect the simulation using the mouse. This is a slight inconvenience during the demonstration of a prototype but would significantly affect the usability of a real simulation.

3. Simulation Software

Several products were considered to be used as the backbone of the prototype simulation including Sculpt, Flames, and the Unity game engine. The advantage of Sculpt and Flames is that they are designed to work with the common aviation command and control system (CAC2S) by generating data link information as an output. The CAC2S is the command and control system used by the MACCS.

Sculpt is a proprietary scenario generating system developed by Raytheon Solipsys. It uses graphical user interfaces to simplify the task of creating scenarios. Operators are able to preplan routes for aircraft and instantly update them during playback. It also gives the operator the ability to dynamically introduce new objects in order to change or increase the complexity of the scenario on the fly (Raytheon, n.d.). Because Sculpt is a closed system, we would be restricted to interacting with the simulation in limited ways. This would preclude the use of voice interaction without addition of a human interpreter. Since voice communication is a key skill for ASCO, Sculpt was not used for the prototype.

FLAMES is a simulation training solution, produced by the Ternion Corporation. Unlike Sculpt, FLAMES is not a single purpose simulation, but a framework for

developing simulations. This gives FLAMES an inherent flexibility but also implies a certain level of programming overhead (Ternion, n.d.). To use FLAMES, we would have to learn how to program within that framework. We would be able to incorporate voice communication using FLAMES, but there is no integrated voice recognition system. We would have to build a bridge to get FLAMES to work with whichever voice recognition system we chose. For these reasons, FLAMES was not used for the prototype .

The Unity game engine is a freely available game engine. Like FLAMES, it is flexible in that we can program it to do almost anything we require. Furthermore, several voice recognition packages have Unity plugins. In addition to these positives, there are several Unity experts in the MOVES Institute available for consultation and students receive an introduction to Unity as a part of the curriculum. For these reasons Unity was chosen as the backbone to the prototype.

4. Voice Recognition Software

During the conduct of the task analysis it became obvious that two-way voice communication is a key aspect of ASCO tasks. As mentioned before, all current training solutions achieve this with the use of role-players. As outlined in the constraints, it was our intent to create a system that a single trainee could use without such external support. The use of voice recognition and synthetic voice production was identified as the best option to produce a system that met that requirement.

Several voice recognition systems were considered for inclusion in the prototype training simulation, but the majority had difficulty meeting our requirements. Most commercial off-the-shelf (COTS) speech recognition systems are made to identify normal speech patterns, i.e., full sentences using common words spoken at the usual speed of speech. The type of communications passed over the radio between the DASC and pilots does not constitute normal speech patterns. For example, “Are you up as fraggged?” is a common phrase used to confirm that there has been no change to an aircraft’s configuration since the publication of its mission data. The word “fraggged” is not part of normal English but is a common military term. In addition to not recognizing military

radio speech, the speed of speech used during radio communication overwhelmed most systems. Asking an ASCO to slow down their rate of speech so that a COTS system could properly parse the utterances would likely produce negative training. ASCOs are often talking to several different aircraft, are required to speak in ten second bursts for emission control, and often have pass as much information as possible between static bouts of static interference. It was necessary to find a system able to handle rapid speech using a specialized lexicon. Table 2 outlines the voice recognition systems considered for inclusion.

Table 2. Voice Recognition Systems

System name	Unity plug-in	Supports programmable grammar	Apparent accuracy	Requires Internet connection
Watson (streaming)	Yes	No	Poor	Yes
Watson (non-streaming)	Yes	No	Fair	No
Wit.ai	Yes	No	Fair	No
Nuance Dragon Speech	No	Yes	Good	No
Windows Dictation	Yes	Yes	Poor*	No
Adacel Lexix	Yes	Yes	Good	No

*Without programming grammar

Of all the candidate systems, Adacel's Lexix was the only software that delivered the required capabilities. Adacel specializes in ATC simulations. Even though the DASC controls airspace in a very different way than the ATC, the voice recognition requirements are similar, such as the rate of speech and some of the base grammar. Much of the DASC specific communication had to be added but, Lexix handled the quick speech of controllers and pilots. Adacel provided programmers with access to the dictionaries used to support the voice recognition software, which enabled us to create

words and word combinations not found in normal language, allowing us to add the required components of the DASCs grammar. In addition to providing voice recognition, Lexix also provides synthetic voice production, which was used in our prototype simulation.

C. PROTOTYPE DEVELOPMENT

1. Simulation Development

Development of the main simulation began with the creation of mockups of the three main DASC displays. The main components of each display and the required functionality identified during the task analysis were used to create the mockups. These mockups were imported into Unity and served as a guide to build the simulated displays. Since all DASC displays are two-dimensional, we decided to use two-dimensional displays in the simulation. This also reduced development time and saved on the amount of processing power required to run the simulation.

After the displays were created, models of representative aircraft were developed. Aircraft were given attributes to represent flight information, mission information, and configuration information. For example, an aircraft can be an F-18 on a CAS mission scheduled for 0830. It will initialize at 10,000 feet, at a given control point, and be armed with two AIM-9s. To facilitate voice communications, certain attributes were given nomenclature and one to three spoken names. The AIM-9, for example, has the given nomenclature AIM-9, the spoken name “aim nine,” and the spoken name “Sidewinder.” Instantiated aircraft are capable of moving around the airspace and interacting with certain objects via collision detection. For example, an aircraft will recognize when it is flown into a threat ring.

Certain aspects, such as an ordinance list, were included as an enumeration. This allowed us to create drop down menus to easily adjust attributes of our models. Certain attributes allow for the input of a string element, which can be used by the synthetic voice production system to provide spoken information to the user. An example of this is exceptions. If an aircraft is airborne with a different configuration that is published prior

to the mission, they are considered to be “up with exceptions.” It is the responsibility of the ASCO to confirm the aircraft is configured as published. If it is not, the ASCO asks the pilot to “state exceptions” and the pilot reports all of the exceptions, i.e., “I am a flight of one vice two due to maintenance.”

A mediator class was created to handle the information flowing between all of the displays, models, and voice recognition system. This class keeps all of the main components separate and unaware of each other. This approach provides modularization to improve extensibility.

The final step was to connect the voice recognition and synthetic voice production and program the mission logic into the system. Before we could do this we had to adapt the Lexix grammar to handle DASC communications.

2. Grammar Development

Creating the grammar for the DASC prototype simulation was the most time consuming step in the development process. Lexix follows the W3C speech recognition grammar specifications version 1.0. The language is constructed on several levels. The base dictionary contains every allowed word and its phonetic pronunciation. As mentioned above, Adacel provided access to the base dictionary, which enabled the addition of uncommon words; however, we did not have to add any words to the base dictionary.

The next level parameterizes commonly used words and word combinations. This section is largely made up of numbers and the phonetic alphabet. One of the main additions at this stage was time combinations and the military grid reference system. It was necessary to account for the fact that there might be multiple acceptable ways to say the same thing and the system needed to be able to recognize all of them. For example, it is common in the military for some to refer to a time as “zero five thirty,” or “oh six hundred,” or “zero seven one five.” By programming the grammar to recognize time as a parameter, we can now tell the system to recognize a sentence such as “the time is now \$time” (where “\$time” is any acceptable way to state a time as defined by the grammar).

The next level deals with dynamic grammar parameters. These parameters are specific to a simulation or a scenario. They are used to connect part of the ASCO's utterance to a specific object in the simulation. For example, one of the aircraft in our simulation has the call sign "Combat 22." The dynamic grammar allows you to input key value pairs to be recognized as a parameter. "Combat 22" is recognized as a call sign and the key CT22 is returned when the call sign is spoken in a recognized sentence such as "go ahead \$Callsign." The simulation uses the key to determine how to handle the results of parsing the utterance. In this case, if the ASCO says, "Go ahead Combat22.," the simulation passes the message ("Go ahead") to the object with the key CT22, and that object creates and delivers a response to the message.

The next level identifies available parameters to the system and enables increased complexity through the combination and concatenation of parameters. An example of this is building a route from a series of control points. The control points are added on the previous level as a set of dynamic grammar parameters. This set consists of individual control points described with key value pairs— for example, SH = Sarah, KM = Kim, EY = Emily. On this new level you can create more complex parameters by specifying varying combinations of different or similar parameters. Our simulation allows for the concatenation of up to five control point to define a route. If a user says "Proceed Sarah, Emily, Kim" or "Proceed, Kim, Tina, Sarah, Heather," the system will recognize it and return an appropriate key (SHEYKM or KMTASHHR). The key is parsed and used to build a route for an aircraft, which, in turn, is used to guide the aircraft's movements.

The next level is the instruction level. At this level all of the parameters that will be used in a given command are identified. For example, when passing a safety of flight brief for a firing artillery battery several parameters are required, such as the point of origin, the point of impact, the maximum ordinate, and the time of the fire mission. The instruction lists all of these parameters. It is also possible create an instruction with no parameters, for instance, "break" is a common radio phrase that means you are breaking the connection for a second but still have more information to pass. No parameters are required for this type of transmission.

The final level is the command level. Commands are the actual phrases the system will recognize. This include the parameters and all connecting words. Using the W3C speech recognition grammar specifications version 1.0 a single line can be used to construct several phrases. Optional words are set off by square brackets, e.g., [and], while places where multiple words might work are set off by parentheses and separated within the parentheses by a vertical line, e.g., (a | an). For example, if the required sentence is- “[be advised] (there is | you have) an \$Aircraft” and \$Aircraft is defined in the dynamic parameters as “F/A-18” or “AH-1W,” all of the following are acceptable phrases.

- “Be advised there is an F/A-18”
- “Be advised you have an F/A-18”
- “There is an F/A-18”
- “You have an F/A-18”
- “Be advised there is an AH-1W”
- “Be advised you have an AH-1W”
- “There is an AH-1W”
- “You have an AH-1W”

Lexix is configured to recognize up to four commands in a single transmission. Because of this limitation, it is important to consider how parameters and instructions are constructed. The communication of routes is an excellent example of this. As mentioned above, we created a parameter that concatenates several control points into a single route. This approach, versus allowing each control point to constitute a single command, allowed us to account for complex communication string without over-whelming the system. For example, the phrase “climb to 5000 feet (1st command), proceed Kim (2nd command), Emily (3rd command), Sarah (4th command)” would utilize all available system resources for a single transmission. This approach would cause an error unless the user included a transmission break. Based on the task analysis, it was clear that communication like this would not be natural for ASCO operations and would introduce the potential for negative training. For the mission set to be appropriately represented in

our prototype simulation, we developed parameters capable of mitigating this problem. This solution, however, does not cover all potential problems. Other mission sets, such as the passing of a “nine line” for casualty evacuation, which has nine pieces of information to pass could prove a difficult problem.

Because there is no standardized phrase book governing DASC communications, grammar was developed hand-in-hand with the mission logic revealed in the task analysis. After we completed one step of the mission we went on to the next. The grammar for the new mission step was diagramed and programmed and then the simulation was updated to recognize and respond to the new command. As the system was tested common phrases that are not specific to mission sets, such as “stand by” and “say again” were identified and added.

Lexix is able to recognize only the specific commands that it has been programmed to recognize. This improves accuracy by reducing search space. Initially we did not remove any of the pre-programmed ATC specific grammar. As the size of the DASC grammar increased, the accuracy began to decrease. In order to improve accuracy of the system we removed all of the ATC specific grammar. This had the desired effect and did improve accuracy.

Another problem we ran in to was the confusion of similar words. In our case, this was isolated to the control points – specifically Kim, Ken, and Ben. We resolved this by removing similar sounding control point. It is important to note that the use of similar sounding control points is bad practice for airspace design as they can easily be confused over the radio during actual operations, so this is not a limitation of the system.

3. The Final Product

The prototype system that resulted from this work is capable of simulating the basic tasks of an ASCO controlling a CAS mission. Pilot – ASCO interactions are conducted via voice communication. The system responds to ASCO commands in accordance with provided mission logic. For example if the ASCO says “climb to 10,000 feet and proceed to Sarah, contact this station Sarah” the aircraft model climbs at a

designated rate until it reaches 10,000 feet and moves at a designated speed to control point Sarah. Once the aircraft model reaches control point Sarah it reports that it is “established Sarah.” Each of the mission steps identified during the task analysis have been included in the mission logic and models behave as expected for each step.

The map (Figure 2) provides visual feedback to the ASCO. It acts as a visual representation of the airspace. The map is updatable, but currently the only portion that updates automatically is the clock and the visual representation of the aircraft as it traverses the airspace. In addition to the airspace, pertinent airspace information is depicted on the right hand side of the map and is updatable. This provides the ASCO the ability to visually reference changeable airspace information to incorporate in to air space briefs.

The RIO board (Figure 3) exhibits the desired behavior. Upon initiation, the simulation instantiates all aircraft missions. The relevant information is gathered from the aircraft models and populates the “upcoming missions” section of the RIO board. Once the aircraft checks in with the ASCO the mission is moved to the “airborne” section. Throughout the mission the RIO board updates automatically with the aircraft’s location and altitude information. After an aircraft has been turned over to ATC, the associated mission block is moved to the “completed mission section.

The chat windows (Figure 4) provide the opportunity to practice passing mission information to internal and external agencies. Currently, the ability to input information is the only function used in the simulation. However, the ability to automatically update the chat windows is available and would be used to provide information to ASCOs from internal and external agencies.

The voice recognition system accurately recognizes relevant ASCO commands and most commonly used phrases. Thirty-one commands resulting in 347 supported phrases have been programmed in to the system. The commands include:

- Acknowledge
- Altitude
- ATO confirmation
- Barometer

- Break
- Call sign (initiate contact)
- Climb to altitude
- Climb to flight level
- Air defense warning
condition weapons
control status explanation
- Descend to altitude
- Descend to flight level
- Flight level change
- Follow on instructions
- Control point reporting
- Fuel and ordinance status
- How copy
- In flight report
- State palmate call sign
- State present position and
altitude
- Proceed on control point
route
- Roger up
- Enemy safety of flight
- Say again
- State exceptions
- Artillery safety of flight
- Friendly traffic safety of
flight
- Stand by
- Stand by for grid
- Switch to terminal control
- Report time
- Warning condition

These commands are sufficient to support a CAS mission from beginning to end. The grammar will have to be expanded to support further mission sets but, due to the overlapping requirements of most mission sets, much of the grammar developed to support our prototype simulation would support other missions.

D. SUBJECT MATTER EXPERT RESULTS

To gage the efficacy of the prototype simulation SMEs were asked to complete a questionnaire. The first half of the questionnaire focused on current effectiveness and frequency of current ASCO individual position training. Table 3 shows the questions asked and relevant extracts from their answers. Some modifications have been made to improve readability. The complete questionnaire and answers can be found in appendix A and C.

Table 3. SME Questions and Response Pre-Demonstration

Question	SME 1	SME 2
1. Dose a gap exists for air support control officer's individual position training? If so describe the gap.	“Once out of MOS schools, ‘Individual’ position training does not truly exist. A significant number 2000 level T&R events (individual training events), actually require a crew and a white cell to execute. Because ... many of the 2000 level training events require a crew and a white cell to execute, training opportunities ... arise when DASC Drills are scheduled not based on the individual’s training requirement for progression. This limits the number of reps that an individual can get in a given year, limiting their proficiency as a result.”	“Yes, right now the only individual training occurs at MOS school. There is very minimal training that focuses on an individual controller. The most individual training a controller gets is practicing Radio in and out (RIO) with other officers. “
2. What, if any, individual position training is conducted prior to a DASC drills?	“There are very few T&R events that are conducted prior to DASC Drills. This is partly due to the factors mentioned above, but also [due] to the high op tempo of the Squadrons. DASC Drills are typically crammed in between exercises that squadron is supporting, and because most 2000 and 3000 T&R events inherently require a crew, a whitecell, and a qualified evaluator it rarely occurs”	“Like I stated above, the only individual position training is practicing RIOs with another officer (most of the time this is limited).”
3. What, if any, individual position training is conducted prior to live exercises or operations?	“Prior to combat operations, the squadrons do a pretty good job of running DASC drills using a scenario that mimics the theater of operations. But this is rarely “individual” for the reasons mentioned above.”	“Very minimal, if there is time a more senior officer might practice and mentor a junior officer. Most of the time more senior officers are busy planning and prepping for exercises or operations, so very little time if any is spent on individual training. Most of the training is conducted at the crew level, making sure the crew is ready to operate as a whole. “

Question	SME 1	SME 2
4. a. How often (in months) does this training occur?	“We tried to do a DASC drill once a quarter but this was driven by the squadron’s op tempo.”	“Every 4 months... at best!”
4. b. How is this training evaluated (sat/unsat, grades, etc.)?	“Performance evaluation is captured on a MACCS training form, 0–4 scale with zero being unsat and 4 representing mastery. A student must score at least a 3 (proficient) in order to receive credit for the T&R event. However, this is purely a qualitative evaluation by evaluator. Rarely are an actually metrics included in the performance evaluation. “	“None”
4. c. List the types feedback which is provided to the trainee (real-time, after action review, none, etc.)?	“After every crew executes the drill, there is a quick hot wash by the evaluators. This is purely qualitative. No actual metrics are collected and used to measure performance. Additionally, each evaluator is supposed to debrief the individual they were evaluating on their performance in greater detail providing areas for improvement.”	“None”
4. d. Are records of this training maintained?	“Yes on the MACCS Training Forms”	“No”
4. e. How are these records used to inform future training of individual ASCO	“WTTP is supposed to look at what training events an individual has completed and what training events they need to complete in order to get qualified, and then build drills to meet the requirements. As I mentioned previously, very few WTTP officers have the mental agility to make this happen. Typically a scenario is built, individuals sit position on a crew,	“N/A”

Question	SME 1	SME 2
	and evaluators must create the training in real time in order for the individual to get the X.”	
4. f. How are these records used to inform the squadron training plan?	“The WTTP officer was tasked with identifying who needed to get which qualification in order to make all of our crews qualified. Once that was accomplished, he had to identify what training requirements each individual needed in order to receive position qualification. Based on the requirements of the individuals, WTTP was tasked with coming up with individualized training plans and a squadron training plan that supported satisfaction of each individual’s requirement. This was too much work for my first WTTP officer and his fitrep reflected. My second WTTP officer knocked it out of the park”	“N/A”
5. What skills should an ASCO train on a regular basis?	“RIOs, typing, GARS/CGRS, threat system capabilities, friendly aircraft & ordnance capabilities”	“Radio in and out procedures to include routing, safety of flight, and other possible unique situations that an officer might encounter at an ITX or WTI”

Table 4 shows the SME's responses to questions were they were asked to rate DASC training on a five point Likert scale, with "1" representing worst and "5" representing best.

Table 4. SME Likert Responses Pre-Demonstration

Question	SME 1	SME 2
g. How adequate is this training in supporting skill <u>acquisition</u> of ASCO?	3	1
h. How adequate is this training in supporting skill <u>maintenance</u> of ASCO?	2	1
6. How would increasing the amount of individual position training improve the ability of ASCO to achieve and maintain qualification?	5	5

Each SME was given a demonstration of the prototype simulation produced during this thesis. After the demonstration they were asked to complete a second questionnaire regarding the demonstration. Table 5 shows the questions asked and relevant extracts from their answers. The complete and answers questionnaire can be found in the appendix B and D.

Table 5. SME Questions and Response Post-Demonstration

Question	SME 1	SME 2
5. For the purpose of generating feedback reports, what metrics should the system capture? i.e., duration of transmission, failure to brief safety of flight, unsafe routine, etc.?	-Speech speed (words per minute) -Transmission duration -Response delay (how long does it take the for the controller to respond) -Improper routing -Improper safety of flight -Improper tactics -It should be able to track an individual's metrics over time in order to show performance history and improvement/degradation."	"Failure to brief safety of flight, co-altitudeing aircraft, routing around EN threats and/or gun target lines"
6. What negative training could a training simulation provide?	"Not all aircraft ... should have ... simulated tracks so that that system better replicates reality. Currently, some TMS don't have Link 16 (such as CH-53s.). There is negative training value if all aircraft have simulated tracks since they won't have tracks in reality. This could cause a false reliance on tracks for current position"	"The experience of controlling with live thinking humans. The flexibility of a simulator might hinder a controller's ability to reroute or pull certain information from an aircraft."
7. Which attributes of the prototype training simulation were most useful?	"Its ability to recognize/comprehend speech and take appropriate action based on programming"	"The most useful attributes were the time accuracy of the flights and missions, the ability to hear different voices for different pilots, changes of operational tempo if the controller is doing well or poor, and the ability to integrate chat windows."

Question	SME 1	SME 2
8. Which attributes of the prototype training simulation were least useful?	<i>Did not provide an answer</i>	“The least useful attributes included the one screen view. A controller would have to click through to see the RIO board or the chat windows.”
9. What additional capabilities should a prototype training system include in order to increase the effectiveness or usability of an ASCO IPT?	“-The ability to split screen ATO, Chat, and map. -Computer generated chat messages and responses. This will provide more realism and a more realistic and dynamic training scenario. -It should be able to track an individual’s metrics over time (think individual profile) in order to show performance history and improvement/degradation. -It should have a gui for scenario building that makes it easy and efficient to build out a scenario. -It should have the ability to award points to a controller if there are multiple correct statements...think ‘state present position and altitude’ and ‘go’ at the beginning of a check-in”	“Either multiple displays or the ability to split screen so that a simulator felt like you were in a DASC. A controller learns a lot by sitting in a DASC and seeing the displays set up in a realistic manner. The controller can learn the system scanning patterns that work best for them.”
10. What capabilities should a prototype training system exclude?	“Currently, some TMS don’t have Link 16 (such as CH-53s,). There is negative training value if all aircraft have simulated tracks since they won’t have tracks in reality. This could create a false reliance on tracks for current position determination by controllers.”	“The capabilities in the simulator ... [were] very relevant!”

Table 4 shows the SME's responses to questions where they were asked to rate the potential effectiveness of a raining simulation for ASCO training on a five-point Likert scale, with '1' representing worst and '5' representing best.

Table 6. SME Likert Responses Post-Demonstration

Question	SME 1	SME 2
1. Would a training simulation be effective at improving ASCO skills?	4	5
2. Would a training simulation be effective at maintaining ASCO skills?	4	5
3. Could a training simulation be used to supplement ASCO training?	4	5
4. Could a training system be used to replace a portion of current T&R required training events?	5	4

Based on this input, it seems that there are shortfalls in ASCO individual position training. Further, the addition of a training simulation could significantly improve training. To improve the effectiveness and reduce the possibility of negative training the SME suggested that the system be able to incorporate multiple screens so the ASCO would not have to flip back and forth between displays using the key board and the ASCO could practice using a scan pattern similar to what would be used in a real DASC. Also, since the DASC is a procedural control agency, the system should be able to toggle off the visual representation of the aircraft. Because flexible airspace control is an important capability of the DASC, efforts should be made to improve the flexibility of control represented by the system. For example, a user should be able to direct a pilot to remain two kilometers north of a given control point or area.

VI. CONCLUSIONS

This work began because we felt that DASC training barely met the needs of the Marine Corps. Our investigations confirmed this impression and made it clear that current DASC training is insufficient to support skill acquisition and maintenance. This was not due to the problems with DASC personnel or leadership, but because the personnel and time requirements to support current training are too high to make regular training feasible and airspace limitations diminish the effectiveness of live exercises. In short, DASCs were too busy supporting other units' training requirements to spend enough time on their own.

We found that one of the major causes of this was the fact that there were no training aids available to help DASC Marines create, prepare, and execute their own training events. The amount of effort to train two ASCOs was enormous, generally requiring significant outlays of effort by several Marines from the unit to train those two. Our research concluded that the position of ASCO could benefit from a training simulation which did not currently exist. We found that this limitation was primarily due to the inherent complexity of DASC operations had precluded building a cheap and readily available training system previously. However, we felt that recent advances in technology, primarily speech recognition and modeling and simulation tools for application creation, had advanced in recent years to the point where it was possible to create a training device that would allow ASCOs to conduct worthwhile training without numbers of personnel spending substantial time and effort to plan and execute. We decided to attempt to build a prototypical simulation to provide training to an ASCO without involvement of others.

In the course of this thesis, we built such a prototype for some common events that ASCOs routinely perform. Trainees use the same voice commands to control simulated aircraft that they would use in the control of actual aircraft and can operate the system and conduct training without the intervention of anyone else. As the system currently stands, this would provide no feedback to the trainee on performance, but even

if training required a peer or senior Marine to observe the trainee's performance and provide feedback, this is still considerably less man-hours than previously required. Additionally, the capability of intelligent tutoring systems is rapidly expanding and integrating one into the system to allow training without any other Marine's intervention is definitely within the state of the art.

To validate our beliefs in the efficacy of this trainer, we interviewed Marines with DASC experience and asked them to comment on whether they felt such a training simulator would improve the ability to train ASCOs. They concurred that this system, once expanded to cover a larger percentage of DASC watch standers' duties and equipped with other capabilities, such as the intelligent tutoring system, scenario generation tools, etc., would greatly improve the ability to train DASC personnel. This confirmed our belief that a useful training application could be built and distributed relatively cheaply using available technology.

VII. FUTURE WORK

Future work for this project falls into two main areas – expanding the capabilities of the prototype and verifying its training effectiveness.

A. EXPANDED CAPABILITIES

The current prototype supports only a small subset of the missions controlled by a DASC. The system should be expanded to handle all of the different mission types, such as:

- Airborne alert (XCAS)
- Forward air controller (airborne) (FAC [A])
- Reconnaissance
- Refueling
- Strike coordination and reconnaissance (SCAR)
- Unmanned aerial systems (UAS)
- Downed aircraft
- Casualty evacuation (CASEVAC)
- Assault support coordination (airborne) (ASC [A])
- Very important person (VIP) transport
- Troop insert
- Logistics
- Tactical recovery of aircraft and personnel (TRAP)
- Pass and receive air support request for F/W and R/W aircraft

It should also be expanded to include models of other DASC crew positions and the external agencies with which ASCOs interact with regularly. This would provide the ASCO with realistic stimuli that could transfer to live DASC operations. These models

should remain as modular as possible to support the eventual extension of the simulation to include other crew positions.

Another important aspect that must be added is error tracking and feedback. One of the shortfalls of current training identified by the SMEs was the lack of metrics used to track progress and the qualitative and subjective nature of feedback given to trainees. Also, in order for a training system to be useful, there has to be some means to provide corrective guidance based on their performance. Feedback can be provided in a number of different ways and it may be worthwhile to incorporate several different methods.

The first method would be to provide immediate feedback. This method would be most useful for new controllers. Providing them immediate feedback will allow them to make immediate corrections, prevent them from making a habit of bad practices, and allow them to deal with a problem while the experience is fresh in their mind.

The next method would be to give feedback at the end of a training session. This would be better for more experienced controllers. Providing immediate feedback would break their focus and impede the learning process and they are more likely to be aware of mistakes they are making and remember specifics about the training session to which the feedback is related.

The final method would be to provide consequences to the users' actions. For example, directing a pilot to fly through a threat area would result in a downed aircraft situation. This method can generate an emotional response which can be particularly effective if applied properly. It is important that the user understand the link between their actions and the consequences. If not, the lesson is ineffective. Also, it is important that the event not be so traumatic that it damages the confidence of the user. This could result in the user being too timid to make decisions or to causes to act quickly when necessary and ultimately provide negative training.

To improve the usefulness of the performance tracking system, it may be worthwhile to incorporate a records keeping function. This would allow a user to track their progression over time and identify areas where they could use improvement of

review do to inactivity. If there was a means to aggregate this information it could be used to guide the development of a squadron training plan and provide leadership with an effective vision of the command's readiness.

It may also be useful to include an instructor's interface. This would allow the instructor to easily view the progress of the trainees and prescribe training. Depending on the robustness of this tool, it could allow an instructor to review recorded training sessions or even listen in during training sessions. Further, it could provide the instructor with the ability to make on-the-fly changes to an active raining session.

It may be useful to take this a step further and incorporate an intelligent tutoring system. Like an instructor, such a system would prescribe training based on past performance. It may even be able to make dynamic adjustments to in progress training sessions. For example, if a user was performing particularly well the system would automatically increase the difficulty until the user was challenged. On the other hand, if a user was struggling, the system would automatically decrease the difficulty to prevent the user from becoming overwhelmed.

The simulation should also be expanded to include a scenario generation tool. Ideally the tool would operate in several modes. The first mode would allow the user to input every aspect of the simulation. This would be useful as a mission rehearsal tool prior to the conduct of live exercises or military operations. The ASCO would be able to practice controlling in the airspace in its actual configuration and become familiar with the participating units and their call signs.

The second mode would allow the user to input a portion of the scenario and randomly generate the next. This would be useful if a user needed to practice certain aspects of controlling, such as downed aircraft procedures, but other specific information, such as radio frequency code words, was unimportant. This would allow for focused training without the overhead of building an entire scenario. The third mode would create a completely random scenario and require no user input. His mode would be useful to support day to day training and would prevent ASCO from becoming too familiar with a given scenario. The scenario generation tool should have a user interface to facilitate ease of use.

B. TRAINING EFFECTIVENESS EVALUATION

The system should be tested on several levels. A usability study should be conducted to see if users find interacting with the system cumbersome. If the system is too difficult to use, is too error prone, or does not meet the user's expectations in some other way, it will not be used.

A transfer of training study should be conducted. It is important that the use of the system actually result in improved performance. If not, then it is just a waste of resources and another administrative burden for the unit. Transfer of training studies should be conducted at several different levels, examining whether the system provides benefits to users across the experience spectrum. Novices need to perform different tasks to become advanced beginners than proficient operators need to perform to become experts. Understanding how the system should be used to maximize improvements for learners at different levels could provide valuable information on how to structure both a training and acquisition program for such a system.

At a higher level, analysis should examine how the addition of such a system effects on ASCO training progression and how it affects the readiness of a squadron. If the addition of a training simulation improves skill acquisition and maintenance, the time required for an ASCO to achieve qualifications could be reduced resulting in more qualified ASCOs and improving the readiness of the squadrons. Likewise, if the time and effort to produce training events is reduced, it may be possible to require operators to perform more of them, resulting in a better trained group.

Finally, it is important to make sure that we are investing the right system. The prototype training simulation produce during this thesis represent only a single configuration. One of the next steps would be to conduct an analysis of alternatives at the system level. It may be that a system that does not use voice recognition, but allows a facilitator to manually update routes and provides the facilitator with responses to read to the user, is a more suitable option.

APPENDIX A. SME 1 PRE-DEMONSTRATION QUESTIONNAIRE

Questions for SME on ASCO IPT

The scope of the questions below is restricted to the individual position training of air support control officers. It is not focused on other DASC positions individual position training except as possible extensions for future work. It does not focus on crew training except in respect to the improvements that may accrue as a result of improved individual performance.

As a DASC SME, please respond to the following questions in context of DASC operations and training:

1. Dose a gap exists for air support control officer's individual position training? If so describe the gap.

Yes, we do not have a procedural control publication in the Marine Corps. Instead we have an individual position training handbook maintained by the Air Support Training Section at Marine Corps Communications Electronic School. While the IPT handbook does support general procedural control techniques, it is not authoritative, since it is not a MCRP. Additionally, because it is locally maintained, it is at risk of being changed to align to the personal experiences of whomever maintains it.

Once out of MOS schools, "Individual" position training does not truly exist. A significant number 2000 level T&R events (individual training events), actually require a crew and a white cell to execute. Because the many of the 2000 level training events require a crew and a white cell to execute, training opportunities are arise when DASC Drills are scheduled not based on the individual's training requirement for progression. This limits the number of reps that an individual can get in a given year, limiting their proficiency as a result.

Additionally, there is not standardization among the MASS units for how each of these events is designed. In my mind, ever officer sitting a ctrl 2000 event should be able to run through the same scenario or set of scenarios for a given T&R event. Instead, for each DASC drill mentioned above, a half bit scenario is developed and executed, usually without regard to what the individual is required to do in order to accomplish the T&R event.

2. What, if any, individual position training is conducted prior to a DASC drills? There are very few T&R events that are conducted prior to DASC Drills. This is partly due to the factors mentioned above, but also do to the high op tempo of the Squadrons. DASC Drills are typically crammed in between exercises that squadron is supporting, and because most 2000 and 3000 T&R events inherently require a crew, a whitecell, and a qualified evaluator it rarely occurs.

3. What, if any, individual position training is conducted prior to live exercises or operations? Prior to combat operations, the squadrons do a pretty good job of running DASC drills using a scenario that mimics the theater of operations. But this is rarely "individual" for the reasons mentioned above.

4. What, if any, individual position training is conducted between these periods for the purpose of skill maintenance? For each type, if any, please identify the following:

a. How often (in months) does this training occur? We tried to do a DASC drill once a quarter but this was driven by the squadron's op tempo.

b. How is this training evaluated (sat/unsat, grades, etc.)? Performance evaluation is captured on a MACCS training form, 0-4 scale with zero being unsat and 4 representing mastery. A student must score at least a 3 (proficient) in order to receive credit for the T&R event. However, this is purely a qualitative evaluation by evaluator. Rarely are an actually metrics included in the performance evaluation.

c. List the types feedback which is provided to the trainee (real-time, after action review, none, etc.)? After every crew executes the drill, there is a quick hot wash by the evaluators. This is purely qualitative. No actual metrics are collected and used to measure performance. Additionally each evaluator is supposed to debrief the individual they were evaluating on their performance in greater detail providing areas for improvement.

Questions for SME on ASCO IPT

d. Are records of this training maintained? Yes on the MACCS Training Forms

e. How are these records used to inform future training of individual ASCO? WTPP is supposed to look at what training events an individual has completed and what training events they need to complete in order to get qualified, and then build drills to meet the requirements. As I mentioned previously, very few WTPP officers have the mental agility to make this happen. Typically a scenario is built, individuals sit position on a crew, and evaluators must create the training in real time in order for the individual to get the X.

f. How are these records used to inform the Squadron training plan? I was fortunate that my last WTPP officer who understood my vision. It's quite simple. We must have a certain amount of individuals qualified in certain positions per the T&R manual for DRRS reporting. The WTPP officer was tasked with identifying who needed to get which qualification in order to make all of our crews qualified. Once that was accomplished, he had to identify what training requirements each individual needed in order to receive position qualification. Based on the requirements of the individuals, WTPP was tasked with coming up with individualized training plans and a squadron training plan that supported satisfaction of each individual's requirement. This was too much work for my first WTPP officer and his fitrep reflected. My second WTPP officer knocked it out of the park.

g. How adequate is this training in supporting skill acquisition of ASCO?

Not at all adequate		Adequate for acquiring <i>some</i> skills		Complete skill acquisition
1	2	3	4	5

H. How adequate is this training in supporting skill maintenance of ASCO?

Not at all adequate		Adequate for maintaining <i>some</i> skills		Complete skill maintenance
1	2	3	4	5

5. What skills should an ASCO train on a regular basis? RIOs, typing, GARS/CGRS, threat system capabilities, friendly aircraft & ordnance capabilities

6. How would increasing the amount of individual position training improve the ability of ASCO to achieve and maintain qualification?

No Improvement		Neither improve nor detract		Complete Improvement
1	2	3	4	5

***Reps without feedback are just reps. You can get really good at doing the wrong thing this way. Reps need to have feedback based on pre-determined qualitative and quantitative standards for performance. ***

APPENDIX B. SME 1 POST-DEMONSTRATION QUESTIONNAIRE

Questions for SME on ASCO IPT

The scope of the questions below is restricted to the individual position training of air support control officers. It is not focused on other DASC positions individual position training except as possible extensions for future work. It does not focus on crew training except in respect to the improvements that may accrue as a result of improved individual performance.

Considering the DASC simulation demonstration that you just received, as a DASC SME, answer the following questions in relation to DASC training:

1. Would a training simulation be effective at improving ASCO skills?

No Improvement		Neither improve nor detract		Completely Sufficient
1	2	3	4	5

2. Would a training simulation be effective at maintaining ASCO skills?

Not effective		Neither improve nor detract		Extremely Effective
1	2	3	4	5

3. Could a training simulation be used to supplement ASCO training?

Not possible		Likely		Definitely
1	2	3	4	5

4. Could a training system be used to replace a portion of current T&R required training events?

Not possible		Likely		Definitely
1	2	3	4	5

5. For the purpose of generating feedback reports what metrics should the system capture? i.e. duration of transmission, failure to brief safety of flight, unsafe routine, etc.

- Speech speed (words per minute)
- Transmission duration
- Response delay (how long does it take the for the controller to respond)
- Improper routing
- Improper safety of flight
- Improper tactics

-It should be able to track an individual's metrics over time in order to show performance history and improvement/degradation.

Questions for SME on ASCO IPT

6. What negative training could a training simulation provide? Not all aircraft for should have a simulated tracks so that that system better replicates reality. Currently, some TMS don't have Link 16 (such as CH-53s,). There is negative training value if all aircraft have simulated tracks since they won't have tracks in reality. This could cause a false reliance on tracks for current position.

7. Which attributes of the prototype training simulation were most useful?

Its ability to recognize/comprehend speech and take appropriate action based on programming.

8. Which attributes of the prototype training simulation were least useful?

9. What additional capabilities would should a prototype training system include in order to increase the effectiveness or usability of an ASCO IPT?

-The ability to split screen ATO, Chat, and map.

-Computer generated chat messages and responses. This will provide more realism and a more realistic and dynamic training scenario.

--It should be able to track an individual's metrics over time (think individual profile) in order to show performance history and improvement/degradation.

-It should have a gui for scenario building that makes it easy and efficient to build out a scenario.

-It should have the ability to award points to a controller if there are multiple correct statements...think "state present position and altitude" and "go" at the beginning of a check-in.

10. What capabilities should a prototype training system exclude? Not all aircraft for should have a simulated tracks so that that system better replicates reality. Currently, some TMS don't have Link 16 (such as CH-53s,). There is negative training value if all aircraft have simulated tracks since they won't have tracks in reality. This could create a false reliance on tracks for current position determination by controllers.

APPENDIX C. SME 2 PRE-DEMONSTRATION QUESTIONNAIRE

Questions for SME on ASCO IPT

The scope of the questions below is restricted to the individual position training of air support control officers. It is not focused on other DASC positions individual position training except as possible extensions for future work. It does not focus on crew training except in respect to the improvements that may accrue as a result of improved individual performance.

As a DASC SME, please respond to the following questions in context of DASC operations and training:

1. Does a gap exist for air support control officer's individual position training? If so describe the gap.

Yes, right now the only individual training occurs at MOS school. There is very minimal training that focuses on an individual controller. The most individual training a controller gets is practicing Radio in and out (RIO) with other officers.

2. What, if any, individual position training is conducted prior to a DASC drills?

Like I stated above, the only individual position training is practicing RIOs with another officer (most of the time this is limited).

3. What, if any, individual position training is conducted prior to live exercises or operations?

Very minimal, if there is time a more senior officer might practice and mentor a junior officer. Most of the time more senior officers are busy planning and prepping for exercises or operations, so very little time if any is spent on individual training. Most of the training is conducted at the crew level, making sure the crew is ready to operate as a whole.

4. What, if any, individual position training is conducted between these periods for the purpose of skill maintenance? For each type, if any, please identify the following:

a. How often (in months) does this training occur?

Every 4 months... at best!

b. How is this training evaluated (sat/unsat, grades, etc.)?

None

c. List the types feedback which is provided to the trainee (real-time, after action review, none, etc.)?

None

d. Are records of this training maintained?

No

e. How are these records used to inform future training of individual ASCO?

N/A

f. How are these records used to inform the Squadron training plan?

N/A

Questions for SME on ASCO IPT

g. How adequate is this training in supporting skill acquisition of ASCO?

Not at all adequate		Adequate for acquiring <i>some</i> skills		Complete skill acquisition
1	2	3	4	5

H. How adequate is this training in supporting skill maintenance of ASCO?

Not at all adequate		Adequate for maintaining <i>some</i> skills		Complete skill maintenance
1	2	3	4	5

5. What skills should an ASCO train on a regular basis?

Radio in and out procedures to include routing, safety of flight, and other possible unique situations that an officer might encounter at an ITX or WT1.

6. How would increasing the amount of individual position training improve the ability of ASCO to achieve and maintain qualification?

No Improvement		Neither improve nor detract		Complete Improvement
1	2	3	4	5

APPENDIX D. SME 2 POST-DEMONSTRATION QUESTIONNAIRE

Questions for SME on ASCO IPT

The scope of the questions below is restricted to the individual position training of air support control officers. It is not focused on other DASC positions individual position training except as possible extensions for future work. It does not focus on crew training except in respect to the improvements that may accrue as a result of improved individual performance.

Considering the DASC simulation demonstration that you just received, as a DASC SME, answer the following questions in relation to DASC training:

1. Would a training simulation be effective at improving ASCO skills?

No Improvement		Neither improve nor detract		Completely Sufficient
1	2	3	4	5

2. Would a training simulation be effective at maintaining ASCO skills?

Not effective		Neither improve nor detract		Extremely Effective
1	2	3	4	5

3. Could a training simulation be used to supplement ASCO training?

Not possible		Likely		Definitely
1	2	3	4	5

4. Could a training system be used to replace a portion of current T&R required training events?

Not possible		Likely		Definitely
1	2	3	4	5

5. For the purpose of generating feedback reports what metrics should the system capture? i.e. duration of transmission, failure to brief safety of flight, unsafe routine, etc.

Failure to brief safety of flight, co-altitudeing aircraft, routing around EN threats and/or gun target lines

6. What negative training could a training simulation provide?

The experience of controlling with live thinking humans. The flexibility of a simulator might hinder a controllers ability to reroute or pull certain information from an aircraft.

7. Which attributes of the prototype training simulation were most useful?

The most useful attributes were the time accuracy of the flights and missions, the ability to hear different voices for different pilots, changes of operational tempo if the controller is doing well or poor, and the ability to integrate chat windows.

8. Which attributes of the prototype training simulation were least useful?

The least useful attributes included the one screen view. A controller would have to click through to see the RIO board or the chat windows.

9. What additional capabilities would should a prototype training system include in order to increase the effectiveness or usability of an ASCO IPT?

Either multiple displays or the ability to split screen so that a simulator felt like you were in a DASC. A controller learns a lot by sitting in a DASC and seeing the displays set up in a realistic manner. The controller can learn the system scanning patterns that work best for them.

10. What capabilities should a prototype training system exclude?

The capabilities in the simulator was very relevant!

APPENDIX E. IRB DETERMINATION

NPS 2017.077- DD-N

NPS IRB
HSR Determination Checklist
last updated: 2-28-17

Instructions: This form is to be completed by the IRB Chair or Vice-Chair when providing an official IRB determination on whether a proposed activity meets the federal definition of research with human subjects according to 32 CFR 219. After completing the form provide to the IRB Administrator. The IRB Administrator will notify the investigators and file electronically.

Title of the Activity: SME Evaluation of DASC Training Simulation Prototype

Department: OR/MOVES

Principal Investigator: Lee Sciarini

Co-Investigators: Perry McDowell

Student Researchers: Kathleen Haggard

Determination Criteria

1. Is the activity research? For the activity to be research both (a) and (b) must be answered in the affirmative. Yes No

(a) Is the activity a systematic investigation? ☒ ☐

(b) Is the activity designed to develop or contribute to generalizable knowledge? ☐ ☒

2. Does the activity involve the use of human subjects? For the activity to involve human subjects (a) and (b) or (c) must be answered in the affirmative. Yes No

(a) Is the activity designed to collect information about a living individual? ☐ ☐

(b) Does the activity involve interaction with a person or persons? ☐ ☐

(c) Does the activity involve the use of pre-collected information that is both private and personally identifiable? ☐ ☐

IRB Determination

The attached activity involves human subjects and requires IRB review and NPS President approval. Yes No ☐ ☒

IRB Chair/Vice Chair: 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: 2017.04.25 09:43:17 -07'00'

Date: _____

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LIST OF REFERENCES

- Atkinson, R.C., & Shiffrin R.M. (1968). *Human memory: A proposed system and its control processes*. Retrieved from <http://cogs.indiana.edu/FestschriftForRichShiffrin/pubs/1968%20Human%20Memory.%20Atkinson,%20Shiffrin.pdf>
- Bowers, C., Hussain, T., & Procci, K. (2014). Assessing and improving listening skills: a test of two theories. *International Journal of Serious Games*, 1(4), 61–73. doi: 10.17083
- Chen, S.F., Kingsbury, B., Mangu, L., Povey, D., Saon, G., Soltau, G., ... Zweig, G. (2006). Advances in speech transcription at IBM under the DARPA EARS program. *IEEE Transaction on Audio, Speech, and Language Processing*, 14(5), 1596–1608. Retrieved from <https://pdfs.semanticscholar.org/e338/3014825fee865bd6e4950397db5b024e0328.pdf>
- Cieri, C., Miller, D., & Walker, K. (2004). The Fisher Corpus: a resource for the next generations of speech-to-text. *Proceedings of the 4th International Conference on Language Resources and Evaluation, USA*, 4, 69–71. doi:10.1.1.61.8327
- R.C. Clark, F. Nguyen, & J. Sweller. (2006). *Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load*. San Francisco, CA: John Wiley and Sons.
- Cunningham, T. R. (2011) *Understanding synthetic speech and language processing of students with and without a reading disability*. (Doctoral dissertation). Retrieved from https://tspace.library.utoronto.ca/bitstream/1807/31728/6/Cunningham_Todd_R_201111_PhD_Thesis.pdf
- Department of Defense (2001) *Instructional system development/systems approach to training and education: part 2 of 5 parts* (MIL-HDBK_29612-2A). Washington, DC: Department of Defense
- Department of the Navy United States Marine Corps. (2010). *Air support control officer's course / Air support operations operator course annex a student handouts*. Twentynine Palms, California: United States Marine Corps.
- Department of the Navy United States Marine Corps. (2013). *Direct air support center training and readiness manual* (NAVMC 3500.120). Washington, DC: Department of the Navy.

- Department of the Navy United States Marine Corps. (2015). *Direct air support center handbook (MCWP 3–25.5)*. Washington, DC: Department of the Navy.
- Department of the Navy United States Marine Corps (2016, Jan. 19). *Advance to contact* (FRAGO 01/2016) Washington, DC: General Robert B. Neller 37th Commandant of the Marine Corps
- Department of the Navy United States Marine Corps (2016) *Marine Corps operating concept: How an expeditionary force operates in the 21st century*. Washington, D.C.: Department of the Navy
- Francis, C., Best, C., & Yildiz, J. (2016). *Improving air force operator performance through synthetic mission rehearsal*. Proceedings of the Simulation Interoperability Standards Organization, Simulation Innovation Workshop.
- Gales, M.J.F. (1997). *Maximum likelihood linear transformations for HMM-based speech recognition*. Retrieved from ftp://svr-ftp.eng.cam.ac.uk/pub/reports/auto-pdf/gales_tr291.pdf
- Haper-Sciarini, M.E. (2010). Investigating the reliability and validity of knowledge structure evaluations: *The influence of rater error and rater limitations* (Doctoral dissertation). Retrieved from http://etd.fcla.edu/CF/CFE0002973/Harper_Michelle_E_2010_05_PhD.pdf
- Hussain, T. S., & Coleman, S. L. (2015). *Design and development of training games*. New York, NY: Cambridge University Press.
- Hussain, T.S., Roberts, B., Bowers, C., Cannon-Bowers, J.A., Menaker, E., Coleman, S. ... Lee, J. (2009). *Designing and developing effective training games for the U.S. Navy Interservice/Industry Training, Simulation, and Education Conference* paper No. 9477 Retrieved from https://www.researchgate.net/publication/228651182_Designing_and_Developing_Effective_Training_Games_for_the_US_Navy
- Koul, R.K., & Allen, G.D., (1993). Segmental intelligibility and speech interference thresholds of high-quality synthetic speech in presence of noise. *Journal of Speech and Hearing Research*, 36(4), 709–798.
- Mayer, R. E. (2014). *Computer games for learning: An evidence-based approach*. Cambridge, MA. MIT Press.
- Miller, G.A. (1956). The magical number seven, plus or minus two some limits on our capacity for processing information. *Psychological Review*, 63(2), 81–97. Retrieved from <http://cogprints.org/730/1/miller.html>

- Park, J., MacRae, H., Musselman, L.J., Rossos, P., Hamstra, S.J., Wolman, S., & Reznick, R.K. (2007). Randomized controlled trial of virtual reality simulator training: transfer to live patients. *The American journal of surgery* 194, 205–211. doi: 10.1016/j.amjsurg.2006.11.032
- Pisoni, B. D., & Koen, E. (1982). Some comparisons of intelligibility of synthetic and natural speech at different speech-to-noise ratios. *The Journal of the Acoustical Society of America*, 71, 94. doi: 10.1121/1.2019648
- Raytheon. (n.d.). SCULPT product information. Retrieved June 15, 2017, from <http://www.raytheon.com/capabilities/products/sculpt/>
- Sweller, J., van Merriënboer, J.J.G., & Pass, F.G.W.C. (1998) Cognitive Architecture and Instructional Design. *Educational Psychology Review* 10(3), 251–296. doi: 10.1023/a:1022193728205
- Ternion. (n.d.). FLAMES automated simulation trainer (FAST). Retrieved August 15, 2016, from <http://www.ternion.com/flames-automated-simulation-trainer-fast/>
- Winters, S. J., & Pisoni D. B. (2003) Perception and comprehension of synthetic speech. [Status Report]. Retrieved from <http://www.cs.toronto.edu/~gpenn/csc2518/winters-pisoni04.pdf>
- Xiong, W., Droppo, J., Huang, X., Seide, F., Seltzer, M., Stolcke, D. ... Zwig, G. (2016). *Achieving human parity in conversational speech recognition* (MSR-TR-2016-17). Retrieved from arxiv.org/abs/1610.05256
- Zhu, Q., Stolcke, A., Chen, B.Y., Morgan, N. (2005). *Using MLP features in SRI's conversational speech recognition system*. Retrieved from <http://http.icsi.berkeley.edu/ftp/global/global/pub/speech/papers/p2304.pdf>
- Zyda, M. (2001, November). *The future of modeling, virtual environments & simulation*. Naval Postgraduate School, Monterey, CA.

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