REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
03/25/2016	Master's of Military Studies	SEP 2015 - APR 2016

4. TITLE AND SUBTITLE	
21st Century Digital Battlefields: MAGTF Simulation Effectiveness for Training Marines	**5a. CONTRACT NUMBER** N/A
	5b. GRANT NUMBER N/A
	5c. PROGRAM ELEMENT NUMBER N/A
6. AUTHOR(S) Vaught, Bryan, A, Major, USMC	**5d. PROJECT NUMBER** N/A
	5e. TASK NUMBER N/A
	5f. WORK UNIT NUMBER N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
USMC Command and Staff College Marine Corps University 2076 South Street Quantico, VA 22134-5068	N/A
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)** Office of Naval Research (ONR)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) N/A

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This paper addresses the current capability and future requirements of two specific Marine Corps simulation devices--the Supporting Arms Virtual Trainer (SAVT) and the Augmented Immersive Team Trainer (AITT)--in comparison to live fire ranges. The paper also provides a description and in-depth analysis of both systems to include operating costs, digital interoperability, capabilities/limitations, and future upgrades that enable Marines to accomplish additional training and readiness objectives via these simulators.

15. SUBJECT TERMS
simulation, training and readiness, supporting arms training, Joint Terminal Attack Control (JTAC) training, digital interoperability

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			USMC Command and Staff College
					19b. TELEPHONE NUMBER *(Include area code)*
Unclass	Unclass	Unclass	UU	38	(703) 784-3330 (Admin Office)

United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068

MASTER OF MILITARY STUDIES

TITLE:

21st Century Digital Battlefields: MAGTF Simulation Effectiveness for Training Marines
SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

AUTHOR:

Maj Bryan A. Vaught

AY 15-16

Mentor and Oral Defense Committee Member: Bruce I. Gudmundsson, D.Phil.
Approved: [signature]
Date: 24 March 2016

Oral Defense Committee Member: Gilbert D. Juarez LtCol/USMC
Approved: [signature]
Date: 24 MARCH 2016

J.W. Gordon
[signature]
24 March 16

Table of Contents

Page

DISCLAIMER

Illustrations

Page

Executive Summary

Title: 21st Century Digital Battlefields: MAGTF Simulation Effectiveness for Training Marines

Author: Major Bryan A. Vaught, United States Marine Corps

Thesis: As supplements to live fire training, the Supporting Arms Virtual Trainer (SAVT) and Augmented Immersive Team Trainer (AITT) provide Marines with valuable tools for creating tactical scenarios that are nearly impossible to replicate in live training.

Discussion: Simulation has become a proven method for replicating training in a realistic, cost-effective manner. Since 2010, the supporting arms community has frequently used the SAVT simulator facility to conduct Military Occupational Specialty (MOS) proficiency training. One-third of required Joint Terminal Attack Controller (JTAC) Training and Readiness (T&R) annual currency events can be accomplished in the SAVT. There are now six SAVT simulators serving the Marine Corps, but training time is hard to schedule and they are commonly booked more than 90 days in advance. Despite the difficulty in reserving a SAVT simulator for unit training, the scheduling of live aircraft is even more challenging and far more costly. Additionally, there are software limitations that currently prevent the SAVT from being approved to handle a greater percentage of T&R events.

The AITT is a new man-portable device that has not yet been fielded to Marine units. It uses an augmented reality headset and wearable computer to super-impose objects and fires effects over actual terrain. For the past five years, the AITT has undergone developmental and limited operational testing with Marines from the Infantry Officer's Course and at exercises such as Bold Quest in 2014. The AITT was transitioned from the Office of Naval Research (ONR) to Program Manager Training Systems (PMTRASYS) at Marine Corps Systems Command (MARCORSYSCOM) in December 2015. PMTRASYS's objective is to further mature and ruggedize AITT's technology in order to begin fielding the system to Marine units by late 2017.

Conclusion: The Marine Corps should increase funding for SAVT upgrades in order to allow the SAVT to be accredited for more Training and Readiness events. Hiring more instructor operators and increasing the number of SAVT simulators could also vastly enlarge the current training volume. Continued financial investment can enable the AITT to reach a higher Technology Readiness Level and be ready for full implementation by Marines as a fires-based effects tool. The AITT's promising augmented reality technology will likely bring a new level of realism to simulation at a cost that is far lower than traditional live fire training.

Preface

I have thoroughly enjoyed watching the advancement of video games and computer technology over the past 30 years. When I was six years old in 1986, I vividly remember how much fun I had playing Space Invaders on my neighbor's Atari. In 1988 when our family purchased a Nintendo Entertainment System, I was finally able to explore the world of gaming in my own home. As a teenager in 1993, I saved my allowance for months to buy a Super Nintendo, and I was able to play games such as Street Fighter II for hours on end with arcade-like graphics. When I bought my first computer before college in 1998, I specifically recall that it had a 10 GB hard drive and cost me over $2000. In 2011 when I bought my recent computer, it had more than 100 times the hard drive storage space of my 1998 computer hard drive and cost less than $1000. Today my iPhone 6 is more powerful and capable than even the best supercomputer of the 1990s. My iPhone can communicate with people around the world via real-time video calls, multi-player strategy games, and it holds a virtual library of hundreds of songs, e-mails, contacts, photos, video clips, and other files. To witness how much technology has advanced from the 4-bit Atari games on a home TV to portable, 128+ bit wireless games on a phone with hundreds of players from around the globe simultaneously interacting is astounding.

The Marine Corps has been using flight simulators since the late 1920s, and simulator technology has grown exponentially over the past 40 years, as computer processing has allowed for life-like graphical displays, the creation of complex training scenarios, and a multitude of digital environments. The topic of MAGTF simulation is particularly interesting to me as an Aviation Command and Control Officer. The Marine Air Control Group uses simulation and role players for training far more than live aircraft, since the volume and availability of live aircraft is seldom great enough to challenge our operators. Not only do I appreciate the value that simulation brings to the Marines using the simulator for training, but I also realize the tremendous savings in ammunition, fuel, maintenance, and logistical planning that simulation affords, ultimately allowing for more repetitions with reduced cost and planning time. In today's fiscally austere environment, the need for the Marine Corps to accomplish more training with fewer resources has become increasingly important. Therefore, simulation will likely play a larger role in Marine training, as simulators become more capable, immersive, and realistic.

I would like to thank a few of the people who helped make this paper a reality. First, Dr. Peter Squire from ONR who advertised this research topic, introduced me to the concept of augmented reality, and helped me begin the research process. Captain Michael Eady, Captain Nick Armendariz, David Dunfee, John Keppeler, Terry Bennington, Frederick Rott, Ken Potter, and Ken Knarr from Training and Education Command (TECOM) were also extremely valuable in providing background on both simulators and providing vital financial information and data on simulation usage. Next, I appreciate Master Sergeants Jeffery Correnti, Hiram LaChapelle, and Greg Szczepaniak (US Air Force, Retired) for allowing me to observe Marines conducting training in both the SAVT and at the BT-11 live fire range. I am also grateful for the time and information provided to me by Majors Dean Oltman and Mike McNeil from Expeditionary Warfare Training Group Atlantic (EWTGLANT) who both teach the JTAC Course, and Cory Shackleton who operates the Multi-Purpose Supporting Arms Trainer (MSAT). Finally, I must acknowledge the dedication and assistance of my MMS mentor—Dr. Bruce Gudmundsson who encouraged me to begin writing and made numerous course corrections throughout the creation process. This paper is dedicated to the warfighters who use the SAVT and AITT simulators, and I trust that their realistic training will ultimately save American lives.

Introduction

Over the past 50 years, computers have become an integral part of American culture. As computer technology continues becoming more capable and less expensive, simulation usage for training within the US military has also become more widespread. Simulation has become a proven method for replicating training in a realistic, cost- effective manner. As supplements to live fire training, the SAVT and AITT provide Marines with valuable tools for creating tactical scenarios that are nearly impossible to replicate in live training.

The SAVT was developed for the Marine Corps in 2010 and it is largely based on the Navy's MSAT simulator. It is primarily used by the Supporting Arms Community, which consists of Forward Air Controllers (FACs), Artillery Forward Observers (FOs) or mortarmen, and Joint Tactical Air Controllers (JTACs). These Marines are generally members of a Tactical Air Control Party (TACP) or Fire Support Team (FiST) who use aircraft, artillery, or mortars to strike enemy targets. The SAVT is considered an augmented virtuality system, since it uses real objects in conjunction with the simulated background. The system has a dome shaped screen that gives the user a 240 degree panoramic view of the target area and can be loaded with a wide variety of training scenarios. In addition to the screen image, which is generated using a series of three high-definition projectors, there is also a portable laser range designator (PLDR), Vector 21 (laser range finder system), and Infrared (IR) pointer used for lasing targets. Marines use the SAVT's headset and radios to practice calling in airstrikes or other supporting arms fire missions on simulated enemy targets that appear on screen by communicating with one another and the control panel operator.

Figure 1: Reality – Virtuality Continuum

Source: Augmented Reality Objectives and State of Affairs Presentation by Ivan Martinez from Army Research Labs, 13 Nov 2015 (Slide 6)

The AITT is a new device that is currently under development by Lockheed Martin, the Office of Naval Research (ONR), and Marine Corps Systems Command (MARCORSYSCOM). The purpose of the AITT is to create a simulated training environment using actual terrain (such as a field or range) and system generated targets (enemy vehicles and personnel) to practice calling in airstrikes and fire missions. Unlike the SAVT, which takes place entirely indoors on the computer screen, the AITT is used outside in an open area where augmented targets appear on the terrain in a lifelike manner and fire effects are used to engage the enemy threats. The primary audience for the AITT is currently the infantry squad. However, there are also plans for the AITT to eventually be fielded to the Supporting Arms Community (FACs, FOs, and JTACs) too. The Marine wears a headset and visor attached to his helmet, which is connected to a lightweight computer system worn on the back. The computer-generated images are then sent to the Marine's visor where they appear as realistic targets in scale and motion. Fires-based effects and aircraft are displayed on-screen, and the impact of these weapons is simulated against enemy targets. High-definition graphics and surround sound provide the user with a convincing feel of the impact of the artillery round's impact or a bomb's explosive power.

Despite the increased realism and capabilities of contemporary simulators, there is still a continued need for live training with real aircraft, weapons, and ordinance. Training and Readiness (T&R) Manuals for all Marines in the Supporting Arms Community insist that live ranges occur regularly, and this training is beneficial to the controllers (FAC, FO, JTAC) as well as the pilots, artillery batteries, or mortar teams on the ground. In live training there is an authentic realism and level of friction that currently cannot be effectively duplicated through simulation. Although not a complete substitution for live training, there is an optimal portion of supporting arms training that should be completed via simulator.

Supporting Arms Virtual Trainer (SAVT)

The purpose of the SAVT is to simulate the operational environment required to train JTACs, FOs, and FACs to conduct Close Air Support (CAS) and call for fire (CFF) procedures while positioned at an observation point (OP). The SAVT's partial-dome screen display is comprised of three projectors, and it provides a view of the battlespace from the perspective of the OP, to include all terrain, buildings, and targets within that battlespace. The SAVT also supplies the Marine with all needed equipment, from maps to laser-target designators (LTDs) that are required to execute current tactics, techniques, and procedures (TTPs). Behind the simulated OP is an instructor operator station (IOS) where the SAVT operator manipulates the training scenario and targets within the battlespace. There is also space for a separate instructor (not the device operator) to observe training and participate or provide input to the user via the integrated communications headset.[1]

Figure 2: SAVT

Source: http://www.tecom.marines.mil/Units/Di rectorates/ TrainingandEducation CapabilitiesDivision.aspx

There are currently six SAVTs in use throughout the Marine Corps, and the simulation contract is divided between two contracts—TJ Incorporated and Droidan Incorporated. The locations of the SAVTs include Camp Lejeune, North Carolina; Camp Pendleton, California; Camp Hansen, Japan (Okinawa); Kaneohe Bay, Hawaii; Twenty-Nine Palms, California and Yuma, Arizona.[2] The SAVT in Yuma is funded separately by the Deputy Commandant for Aviation and is operated by 3rd Marine Aircraft Wing's Marine Aviation Training Systems Site. The other five SAVTs are funded by TECOM.[3] During an interview conducted with the instructor operator of the Camp Lejeune SAVT, Greg "Sixpack" Szczepaniak, he noted that the simulator is generally scheduled 60-90 days in advance. The SAVT is typically available for Marines to use 0800-1600 Monday through Friday. Nights and weekends are scheduled by exception, since there is only one operator instructor available.

The SAVT is a capable platform, and it provides training in a variety of supporting arms functions. However, the SAVT is currently limited as an approved device for only certain live training events. For T&R purposes, the SAVT was recently accredited in August 2015 as an approved device for the following five types of training activities:

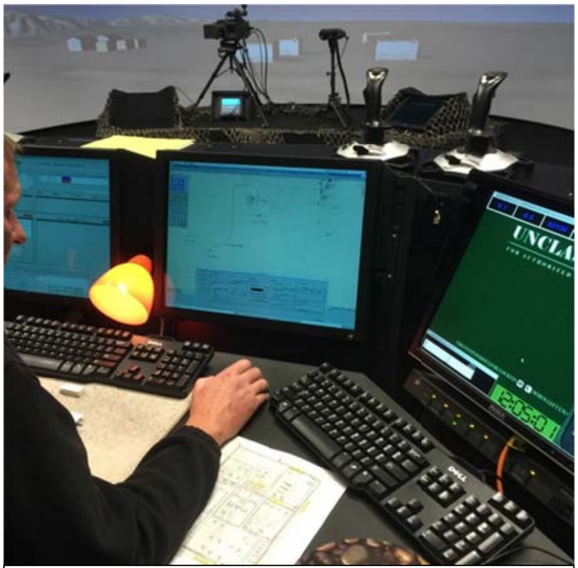
A. Type 1 terminal attack control (Rotary Wing (RW) aircraft only)
B. Type 2 and Type 3 terminal attack control
C. Use of a LTD to mark/designate a target for a CAS mission
D. Surface to surface fires integration
E. Air to surface fires integration[4]

Figure 3: Summary of Types of Control and Methods of Attack	
Type of Control	**JTAC/FAC(A) Requirement**
Type 1	JTAC/FAC(A) will visually acquire the target and the attacking aircraft during the terminal phase of an attack, prior to weapons release, and assess attack aircraft geometry while maintaining control of individual attacks.
Type 2	JTAC/FAC(A) will utilize other measures to mitigate risk while maintaining control of individual attacks.
Type 3	JTAC/FAC(A) will utilize other measures to mitigate risk and assesses that the measures in place will allow multiple attacks within the same engagement.
Method of Attack	**Requirement**
BOT	Aircraft/aircrew will acquire the target or intended aim point using the best method available.
BOC	Aircraft/aircrew will employ weapons on the specified coordinates given in the CAS brief.
BOT	bomb on target
BOC	bomb on coordinate
CAS	close air support
FAC(A)	forward air controller (airborne)
JTAC	joint terminal attack controller
Source: JP 3-09.3 Close Air Support, page III-47	

The five accredited training activities account for approximately one-third of the Marine Corps' five SAVT devices can currently support 10,000 hours of training each year spread throughout the five locations (2,000 hours per location). The current training capacity for the SAVT is insufficient to keep up with the required level of training for the community which is 36,451 hours. According to a recent Simulator Assessment Working Group (SAWG) conducted in May 2015, the SAVT demand was determined to be 364.5% greater than its current capacity.[5]

Additionally, if the instructor is unavailable due to illness or emergency reasons, another qualified instructor must be flown in from TJ Incorporated's corporate headquarters in Orlando or one of the other four SAVTs.[6] A replacement instructor can be sourced for periods such as known vacations and scheduled surgeries, but it is not feasible to find a qualified instructor operator to fill-in if there are unforeseen illnesses, accidents, or emergency situations. Therefore, the Marine Corps must find a solution to increase the capacity at its five current SAVT locations or possibly build additional simulation facilities.

Figure 4: SAVT Instructor Operator Station



Source: Photo provided by the author.

Augmented Immersive Team Trainer (AITT)

The AITT's purpose is to enhance Marine Force-On-Force (FOF) training during CFF and CAS. It is currently not possible for Marines to see simulated battlefield effects, such as exploding munitions and destruction of enemy targets, during FOF exercises. The Marine Corps considers this limitation to be a requirement gap, and the AITT addresses the gap by providing an augmented reality system. Augmented reality (AR) is a technology that combines virtual information with real-world backgrounds. One well-known example of AR is the yellow first-down line in a televised football game--although the line is not actually on the field, it is digitally overlaid into the live scene. [7]

Figure 5: AITT Helmet-Mounted Display

Source: "Augmented reality trainer transitions to MCSC Training Systems", 20 Oct 2015, (page 2)

The AITT program's goal is to enhance squad operational readiness and squad leader tactical decision-making skills. The AITT seeks to transition the science and technology of both the FOF program and the Squad Immersive Training Environment (SITE) program. Both programs contain a "toolkit" of live, virtual, and constructive (LVC) technologies to train Marines. Live training consists of classic maneuvers on a field with real equipment and a human adversary or mock targets. Virtual training is entirely synthetic, and responses to human interactions are generated electronically by a computer. Constructive training is the training of virtual people or equipment in a virtual world. ONR defines constructive training as, "simulated forces that respond to trainee actions. Typically, real human inputs are needed to fully operate these simulated forces which then carry out the resultant actions in a synthetic environment." [8]

The AITT combines realistic virtual elements such as weapons effects from mortars, artillery, or aircraft with targets (e.g., enemy personnel, tanks, or buildings), and superimposes those features on top of real-world scenery. The trainee's viewpoint is accurately determined by using advanced software algorithms and multiple sensors. A commercial off-the-shelf (COTS) head-worn display and other tactical equipment, such as binoculars or the Vector 21 consolidate the images into a single view. An enhanced instructor station (EIS) allows the instructor to select and control each of the trainee's tactical scenarios. The AITT currently interfaces with the Instrumented Tactical Engagement Simulation System (ITESS II), which is already a Marine Corps program of record, and is used to support direct FOF and force-on-target tactical engagement training.

Figure 6: Augmented Tanks at Camp Pendleton

Source: AITT Presentation by Dr. Peter Squire from ONR, 5 Nov 2015 (Slide 7)

The AITT project began in FY11, and subsequent demonstrations took place at Marine Corps Base Camp Pendleton in February 2013, Marine Corps Base Quantico in August 2013 and Orlando, Florida in February 2014. The focus of the work thus far has primarily been further development of the video see-through AR system, integration of the AR system with existing Marine Corps devices, initial prototypes of a tablet-based EIS, and building the training framework. There are two primary development contracts for the AITT. Lockheed Martin handles the software and lead integration, and SRI International manages the hardware and tracking functions.[9] A final demonstration took place in November 2015 and the AITT was transitioned from the ONR to the acquisition arm of the Marine Corps—the Program Manager Training Systems (PMTRASYS) division of MARCORSYSCOM in December 2015. [10]

Figure 7: AITT Marine-worn Computer

Source: AITT Presentation by Dr. Peter Squire from ONR, 5 Nov 2015 (Slide 6)

Future AITT developments will focus on integrating the optical see-through AR capability (eyeglasses perspective), and enhancing the realism of the computer-generated elements and EIS functions. PMTRASYS will also conduct assessments of the AITT's effectiveness to support squad training tasks and work with industry to "mature" AITT so it can eventually be fielded to Marines. According to the PMTRASYS Program Manage, Colonel Walter Yates, "Our task is to get the best value for the Marine Corps. That may mean [a system that is] smaller, lighter, has a longer battery life and is hardened to how Marines would use it in the field. And then we'll provide the life-cycle support for it."[11]

There are currently three prototype AITT systems that have been built. According to the AITT portfolio manager at Training and Education Command (TECOM), David Dunfee, the system is currently considered to be at a Technology Readiness Level Six (TRL-6). During the next two years, PMTRASYS will work to increase the AITT to TRL-9 which is fully fieldable. This will be done through further Research, Development, Testing, and Experimentation (RDT&E). One of the prototypes is scheduled to be sent to Okinawa for testing, and another prototype will be sent to the Infantry Officer's School in Quantico. The third prototype will likely be shipped to the PMTRASYS Office in Orlando. [12]

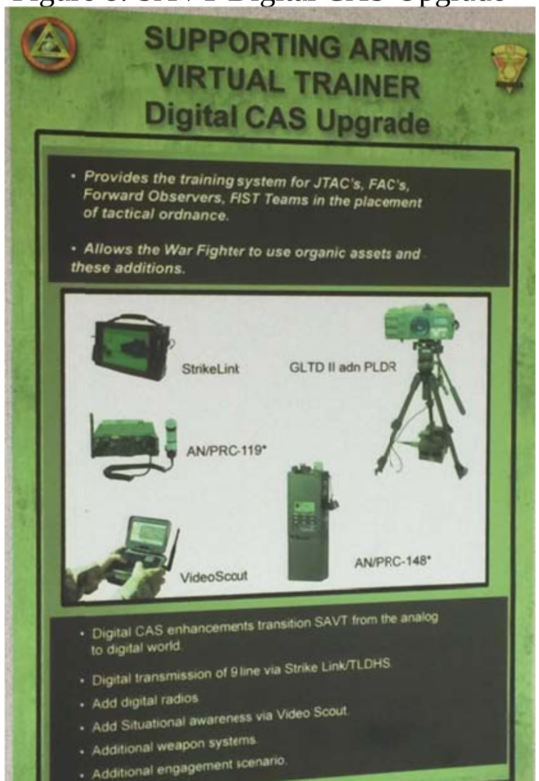
Although there is still a great deal of work to be done on the AITT during the next two years, the results have been promising so far. The PMTRASYS project officer for the SITE program, Koren Odermann remarked that "AITT is a win for the Marine Corps. So many science and technology projects never make it into the hands of Marines, but with AITT, we're able to see an S&T product that is transitioning to a fielded capability to train Marines."[13] Developers are optimistic that AITT will soon enable small unit leaders, forward observers, and mortarmen to more realistically participate in FOF training. The AITT will hopefully provide realistic training at a fraction of the cost of live training, and enable more elements of a Marine infantry battalion to operate together during training events. The AITT system also strives to improve instructor and trainee efficiency and effectiveness by allowing the instructor and student to share a common view of the training area and targets.

Financial Considerations

When assessing simulations it is important to capture the entire lifecycle costs which includes the RDT&E expenses, procurement amount required to purchase the system, and the operation and maintenance costs needed to sustain the program. Costs for the SAVT are much easier to compute than the AITT, since it has been a program of record since 2010 and more financial information is known. Nevertheless, the AITT costs can be calculated based on what has been spent so far on RDT&E for the three prototypes that have already been acquired. Additionally, costs for live training are able to be closely estimated based on known factors such as: ammunition, fuel, aircraft maintenance hours, transportation, billeting, and range maintenance. Thus, a comparison can be drawn between costs for both simulators and compare these expenses to the amount required to conduct live training.

The program acquisition unit cost for a single SAVT is $4.172 million dollars, which includes the cost requirements for modular/temporary facilities and site preparation. The annual Operations and Maintenance Cost for the five TECOM-operated SAVTs is $950,740 or $190,148 per system. In addition to the costs to build and operate each facility, there is also the expense of upgrading the hardware and software systems at each location. In 2015, the tech refresh for five systems cost $3,583,214. There are also two technical refreshes scheduled for FY17 and FY18, which are estimated to cost $4.1 million each. [14]

Figure 8: SAVT Digital CAS Upgrade



Source: Photo provided by the author.

The AITT development costs required to achieve TRL-6, which have been funded by ONR thus far, are $10.14 million. The current procurement cost for each of the three AITT prototypes is $45, 186.[15] There is currently a plan to procure approximately 133 units at a total price of $6.4 million beginning in FY18. That price does not include additional maintenance costs or post-deployment software support.

When estimating the cost of live training, the most straightforward items to calculate are fuel, ammunition, and the cost of flight hours. While fuel prices fluctuate based on the international crude oil market price, ammunition is generally procured well in advance at contracted prices and must be forecasted at least 90 days in advance. The flight hours cost is based on a historical average for each type and model of aircraft. In certain situations, a contract with a civilian aircraft is more cost-effective, since the contracted aircraft are dedicated solely to supporting the training event and have less competing priorities. The table below shows a list of typical flight hour costs, derived from the TACP Course at EWTGLANT.

Figure 9: Cost per Flight Hour for CAS Training	
Organization Type/Model/Series	**Cost/flight hour**
USMC FA-18A+/C	$9,229.24
USMC FA-18D	$10,629.71
USMC AV-8B	$10,533.95
USMC H-1*	$4,116.00
US Air Alpha Jet**	$250,000.00
USN FA-18A+/C	$9,321.30
USN FA-18E/F	$9,189.60
*Average of UH-1N, UH-1Y, and AH-1W cost/flight hour	
**Firm-fixed price contract per live fire week (per TACP class)	

Source: Djuanaedi, Guerrant, & Stafford "Cost Benefit Analysis of EWTGLANT FAC/JTAC Training Options", Naval Postgraduate School, 13 Mar 2013, page 43.

During TACP Class 1-12, the training costs for using each of the various types of aircraft were calculated. These amounts were compiled over an entire week, in which 190 sorties were flown in support of all students in the class. TACP class sizes vary from 18-24 students. Using the maximum number of students (24) who could have been present during the training, the total cost per student for aircraft support was $81,609.94. Additionally, the average cost per sortie came out to $10,308.62. Overall, the flight time cost (for all aircraft types) was $304.09 for every minute of Time on Station (TOS) flown.

Figure 10: Flight Training Costs for TACP Class 1-12 at EWTGLANT

TACP Class	Organization Type/Model/Series	Base	Actual sortie	Actual TOS (hh:mm)	Transit time	Total flight time	Total (Hours)	Total Cost
1-12	USMC FA-18C	NBC	50	6:22	2:00	80:22:00	80.4	$742,030.90
1-12	USMC FA-18D	NBC	22	13:30	22:00	35:30:00	35.5	$377,354.71
1-12	USMC AV-8B	NKT	7	4:34	2:20	6:54:00	6.9	$72,684.26
1-12	USMC H-1	NCA	46	23:28	12:16	35:44:00	35.7	$146,941.20
1-12	USMC H-1	NKT	20	10:08	13:20	23:28:00	23.4	$96,314.40
1-12	US Air Alpha Jet	NKT	24	13:10	8:00	21:10:00	21.1	$250,000.00
1-12	USN FA-18C	NTU	2	1:14	1:40	2:54:00	2.9	$27,031.77
1-12	USN FA-18E/F	NTU	19	10:55	15:50	26:45:00	26.8	$246,281.28
Totals:			**190**	**107:21:00**	**125:26:00**	**232:47:00**	**232.7**	**$1,958,638.51**

Source: Djuanaedi, Guerrant, & Stafford "Cost Benefit Analysis of EWTGLANT FAC/JTAC Training Options", Naval Postgraduate School, 13 Mar 2013, page 45.

The cost of aviation and ground ordnance is another category of expenses that must be included in the overall cost of live training. The cost of shipping to, storing ammunition at, and transporting ammunition from the ammunition supply point (ASP) is also worth considering to determine a more realistic cost. However, for the purpose of simplicity, it is assumed that the overall cost of firing the ammunition is the basic cost of each round. The tables below detail the costs of aviation ordnance from 2011 and the costs of ground ammunition from 2014. These ammunition prices will be used to calculate training cost estimations later in this paper.

Figure 11: US Aviation Ordnance Costs FY 2011

NALC	NOMENCLATURE	cost per
A896	CTG, 20MM, LKD, TP PGU-27/B	$5.69
A978	CTG, 25MM PGU-23/U, TP	$14.00
F562	CTG, SIG, MK4	$4.13
H842	WHD, 2.75 INCH HE	$34.24
HA07	RKT MTR, 2.75 INCH MK66 MOD 4	$1,245.00
H663	WHD, 2.75 INCH PRAC	$17.89
MT95	CTG, IMP, CCU-107/B	$26.09
FW92	CCG, MAU-169A/B	$10,000.00
EB52	GUIDANCE SET, KMU-572A/B	$23,878.00
BWHC	ACCESSORY SET F/FMU-139 FUZE	$2,000.00
EB05	FUZE, BOMB, FMU-139B/B	$2,000.00
GW03	SWITCH, ARM SAFETY, MK122	$655.20
F289	BOMB, GP, MK82, LD 500LB	$1,046.00
F782	FIN ASSEMBLY, BOMB, BSU-33	$427.00
XW32	ARMING CABLE F/GBU-10/12-16	$490.00
F017	BOMB, PRAC, BDU-45/B, 500LB	$1,599.00
WF90	GM, SURFACE ATTACK, INERT	$43,128.00
PC91	GM, HELLFIRE, AGM-114B	$49,241.00
PU61	GM, TOW, TACT, BGM-71E-5B	$15,000.00
E973	BOMB, PRAC, MK76 W/SUSP LUG	$30.54
EB33	LGTR, BDU-59A/B	$2,000.00
A131	CTG, 7.62MM, LINKED, BALL	$0.85
A557	CTG, .50CAL, LINKED & TRACER	$2.71
YW33	RKT, SMOKEY SAM	$171.14
F470	CTG, SIG, MK3	$10.00

Source: Djuanaedi, Guerrant, & Stafford "Cost Benefit Analysis of EWTGLANT FAC/JTAC Training Options", Naval Postgraduate School, 13 Mar 2013, page 57.

Figure 12: USMC Ground Ordnance Costs FY 2014

DODIC	Nom	Cost Per
AO59	5.56 Ball	$0.25
A064	5.56 Link 4/1	$0.56
A131	7.62 Link 4/1	$0.58
A576	.50 Cal Link 4/1	$2.27
A940	25mm TPDS -T	$50.89
B542	40mm HEDP	$54.12
B643	60mm HE	$524.37
BA21	40mm Practice Link	$32.52
C785	120mm TPCSDS-T	$1,211.34
C868	81mm HE M821	$627.78
C869	81mm HE M889	$504.50
C871	81mm Illum	$751.78
CA31	120mm TP-T	$3,030.21
D505	155 Illum	$1,402.74
DA12	Prop 155 MACS M231	$109.88
DA13	Prop 155 MACS M232	$179.93
DA54	155 HE	$1,208.13

Source: "Cost of Training Template" provided by CWO5 (Ret.) David Dunfee from TECOM on 13 Jan 2016

Using a common scenario that is encountered both in training and the real-world, suppose that an infantry squad came up against two enemy technical vehicles (a pick-up truck with a mounted machine gun in the bed). If the squad wanted to call for an artillery strike on the vehicles using two rounds from their battalion's organic 81 mm mortar platoon, the ammunition cost would be approximately $1,009 using 81mm HE M889 rounds. Likewise, if the same squad decided to engage the vehicles using an AV-8B Harrier (assuming only one flight hour) and two TOW missiles, the cost would be approximately $40,533.95. In this scenario, the engagement of the target using an aircraft is over 13 times more expensive than with mortars, and it would likely exceed the replacement cost of the equipment for the enemy. This scenario serves an important purpose, because it provides a general estimate of the training costs associated with using live ordnance.

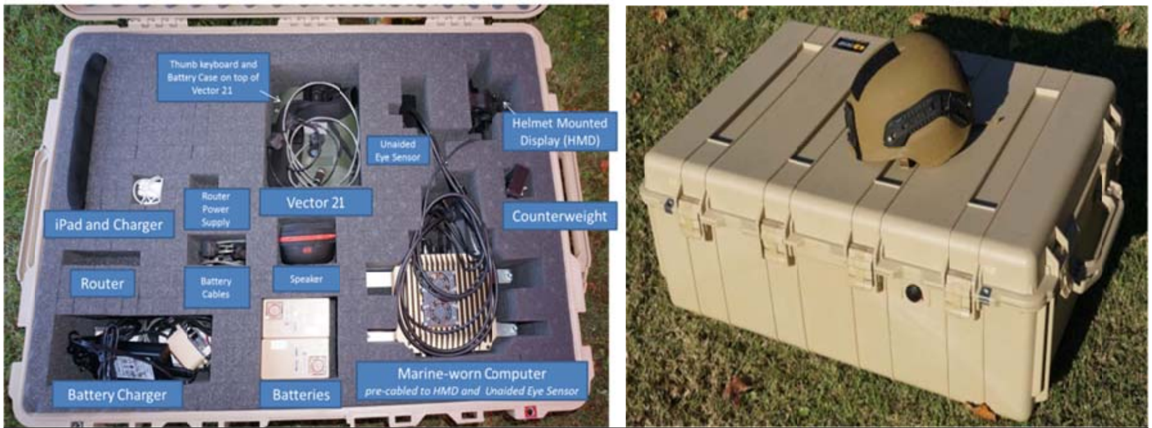
Figure 13: JTAC Training at BT-11 Range

Source: Photo provided by the author.

For the same tactical scenario described above to occur in a simulator, it would likely take 15 minutes from identification of the target until its confirmed destruction via either ground-based weapons or aircraft. Using the SAVT for this particular example, if the complete acquisition cost of a brand new SAVT system is $4,172,000, and the O&M cost for an entire year ($190,148) is added, the cost to operate the SAVT for the first year is $4,362,148. In reality, the life expectancy for the simulator would be far longer than one year and the acquisition cost would be spread out over the entire lifecycle, but one year is used for the sake of simplicity. For the first 2,000 hours of training, each hour costs $2,181.05. Therefore, the cost of conducting a 15 minute training scenario in the SAVT is $545.26, or about the price of one 81mm mortar.

Finally, there is the hypothetical cost of using the AITT for training. Since the AITT is still under development and not yet ready to be deployed, these costs are difficult to determine accurately. Nevertheless, the training cost can be computed based on assumed costs that are realistic and known costs that have been expended so far. Development costs to bring the AITT up to its current readiness level (TRL-6) are assessed at $10.14 million. Assuming that it will cost approximately the same amount to complete the RDT&E for the AITT to reach TRL-9 and become fielded, the overall RDT&E cost would be $20.28 million. The first lot of 133 units is anticipated to cost $6.4 million. Therefore, the total cost for acquiring the first 133 units (not including the three prototypes) is expected to cost $26.68 million or $200,601.50 each. If the average useful service life of an AITT system is 5,000 training hours (in reality it will likely be much higher), then the cost per hour of training is $40.12 per hour. Therefore, the cost to run a 15 minute training scenario on the AITT would be approximately $10.03.

Figure 14: AITT Deployed in a Single Pelican Case



Source: AITT Build 8 handout v2.0 by Dr. Peter Squire from ONR. Released on 30 October 2015 (Page 2)

<u>Digital Interoperability</u>

Today's Marine Corps often conducts training by employing a combined arms approach. Although individual units carry out stand-alone weapons training, multiple Marine units are typically integrated during training exercises. Moreover, the standard infantry battalion has a wide-range of different caliber machine guns, rockets, mortars, and missiles. Therefore to effectively train for combat, there must be a way to share targets, friendly and enemy unit locations and current statuses, and other key information between different Marine units.

Likewise, there is a requirement for Marine simulators to be able to share information with other systems. The concept of interoperability is "the ability of software, hardware, or components to operate together successfully with minimal effort by the end user. Interoperability can be further attributed with functional, behavioral, lifecycle, and architectural scopes and it can be delineated in terms of control, levels, types, or degrees. It is facilitated by common or standard interfaces."[16] There has been a heavy focus on ensuring that both the SAVT and AITT systems are digitally interoperable with other Marine Corps simulators and information systems.

Figure 15: AV-8B Harrier Simulator

Source: http://www.navair.navy.mil/img/uploads/AV_8B_cockpit_sim_12_9_10.jpg

The SAVT has successfully connected to the AV-8B Harrier simulator at the Marine Aviation Training System Site (MATSS) at Marine Corps Air Station (MCAS) Yuma. [17] Additionally, the SAVT has connected to other Command and Control (C2) systems and simulators in order to provide real-time data to the Marine Expeditionary Brigade (MEB) Battle Staff during Large Scale Exercise 2014 (LSE-14). During LSE-14, multiple tests were conducted to determine the interoperability between various Marine Corps simulations to determine the feasibility of sharing large amounts of data via military networks across multiple sites. Overall, the test results were successful, since they demonstrated that communication between various systems was possible with the right planning and network requests. However, the testing also highlighted a number of connectivity issues that still require resolution. LtCol Walter Yates from PMTRASYS provided the following comments regarding LSE-14:

> One thing that had always seemed to be a huge hurdle was how do you federate or make interoperable distinct training systems and simulations that come from a variety of vendors and government off-the-shelf origins and make them work together as if they were designed that way? What we found was that while it was not trivial, it was not as difficult as we had feared and not the most difficult challenge that we faced. We could make our systems communicate and interoperate together. The bigger challenge was getting the right network access with the quality of service to connect bases hundreds of miles away from each other in real time. We have the networks to do that. It's a question of how do we request and go through the approval process to use existing network bandwidth for training exercises in a distributed environment. [18]

Figure 16: AITT with the OneTESS/I-TESS System

Source: AITT Build 8 handout v2.0 by Dr. Peter Squire from ONR. Released on 30 October 2015 (Page 2)

Unlike the SAVT which was initially built as a stand-alone trainer, the AITT was designed from the beginning to operate with two other systems—the I-TESS and One Tactical Engagement Simulation System (OneTESS). According to Cubic, the primary developer for the I-TESS system, the I-TESS was designed as "a fully integrated ground combat training system, based on Cubic's latest laser-based wireless instrumentation products. The I-TESS II system provides force-on-force training capable of direct fire and indirect fire engagements between Marine units and similarly equipped opposing forces employing simulated minefields and simulated nuclear, biological, and chemical (NBC) agents. Vehicles, watercraft, bridges, and buildings can also be outfitted with I-TESS II equipment. It [I-TESS II] allows Marines to fully integrate live, virtual, and computer-based constructive elements into their training mix."[19] One-TESS is essentially the mortar simulation component of the I-TESS II System.

Figure 17: The OneTess System

Source: http://www.peostri.army.mil/PRODUCTS/ONETESS/

AITT will display the impacts of mortars (both 60 mm and 81 mm varieties), 155mm artillery shells, 500 lb bombs, and colored smoke on the helmet-mounted display. Rather than simply showing the impact on a computer screen of where the round lands relative to the target, the user will see and hear the impact as though it were live ordnance. Although there are currently no plans to make the AITT integrate with additional systems besides the I-TESS or OneTess, it is conceivable that the AITT may also interface with both flight simulators, and Command and Control programs, as the SAVT has previously demonstrated.

Storage Capability for Conducting After-Action Reviews (AARs)

Both the SAVT and AITT have the capacity to record data about the training scenario as it is occurring. This capability allows instructors to review the timeline of actions that occur during training and provide the student with specific, useful feedback afterwards regarding his or her decisions. The SAVT has an entire classroom dedicated to conducting pre-briefing before the exercise and de-briefing afterwards. For the SAVT, "Upon conclusion of the training event, the evaluator can conduct After Action Review with the Student JTAC(s) either in the Primary Display or the AAR room. AAR will include aural, 3-D and 2-D visual cues and text log to document the student's actions and present a performance grade. AAR is a complete set of playback tools with each event being time stamped to allow the Instructor to easily select any event to begin the debrief."[20]

Figure 18: Marines Wearing the ITESS-II

Source: http://archive.marinecorpstimes.com/article/20131116/NEWS04/311160002/Realism-new-Marine-Corps-simulation-systems-sparks-quantum-leap-training

For the AITT, the I-TESS includes the capability to capture events for up to 2,000 meters and 100 entities using a hardened laptop. This capability is expanded much further to a range of 12,000 meters and up to 1,000 entities when the mobile C2 trailer is used. The I-TESS II data is able to be quickly compiled and referenced by instructors during AARs following completion of the training scenarios.

Way-Ahead

The SAVT has already proven itself as a capable simulation system so far, since the "SAVT has been certified by the Joint Close Air Support Executive Steering Committee to replace 33% of live fire training controls required for JTAC annual currency training." [21] A straightforward goal for the SAVT would be to re-design the software to enable more T&R objectives to be accomplished, and thus a lower percentage of training would need to be accomplished via live fire. One of the common critiques of the current SAVT system is that the aircraft flight profiles are unrealistic. For example, the helicopters fly directly overhead when attacking a ground target. A software upgrade was recently performed at the Navy MSAT in Fallon, Nevada that has corrected many of the aircraft issues. [22]

Another proposal for maximizing the efficiency of the existing SAVT simulators is the hiring of an additional instructor operator to run the simulator. If each location had two instructors, this would permit the simulator to operate for 12-16 hours per day instead of only eight. With each simulator operating for 60-80 hours per week instead of 40, the volume of students that are able to use the SAVT would increase by 50-100% almost overnight. This will also permit instructors to take personal time for leave, medical reasons, or other emergencies that may be unforeseen without affecting training.

The AITT is still under development, and funding has already been budgeted for its continued enhancement. Therefore, it is inevitable that current capabilities and realism will improve. However, one of the most apparent areas where the AITT may need work is with the enemy formations and behavior. It is doubtful that Marines will ever face an enemy that does not maneuver or fight back when being attacked. So far, there is no indication that AITT enemy personnel or vehicles offer any sort of resistance when being engaged. It is strongly recommend that software developers look for ways to increase the enemy personnel and vehicle realism, so that Marines don't develop bad training habits, a false sense of security, or over-confidence in their ability to effectively engage enemy targets.

Figure 19: AITT Video

Source: https://www.youtube.com/watch?v=ZZzspVSxcj4
Screen capture at the 2:43 mark depicting enemy infantry dying in unison.

The ability to tie both the SAVT and the AITT to flight simulators, especially with the F-35B II Lightning aircraft, should be a top priority. Although the F-35 has reached its initial operating capability in the Marine Corps, certain portions of the F-35 system are still being refined. Lockheed Martin who is the primary developer for both the F-35 and the AITT, promotes digital interoperability as one of the F-35's major advantages. According to Lockheed Martin, "When the first F-35 squadron becomes operational, those aircraft can and will support other aircraft with electronic attack and situational awareness through information sharing. Advanced avionics give the pilot real-time access to battle space information with spherical coverage and an unparalleled ability to dominate the tactical environment. Data collected by F-35 sensors will be immediately shared with commanders at sea, in the air or on the ground, providing an instantaneous, high-fidelity view of ongoing operations — making the F-35 a formidable force multiplier while enhancing coalition operations."[23] If real-time flight data and target information from the F-35 simulator could be shared with the AITT and SAVT systems, this would greatly increase situational awareness for Marines on the ground. Ultimately, there may be a method for sharing information directly from an actual F-35 with both of the AITT and SAVT simulators, but in the interim, the possibility of tying in the F-35 flight simulator seems more feasible, and would likely provide all Marines involved with the same training value.

Figure 20: F-35 Dropping Ordnance

Source: http://australianaviation.com.au/wp-content/uploads/2013/10/GBU_12-crop.jpg

Similar to their extensive usage by the aviation community, as the AITT and SAVT become more capable simulators and their realism improves, these systems will provide a greater proportion of training for Marine Ground Combat Element. On this topic, Lieutenant Colonel Walter Yates from PMTRASYS remarked:

> One important distinction – and where the aviation community remains ahead of the ground community –is that aviation simulators are outstanding because the aviation community considers them essential and imperative. They have to do this training using simulations because the budgets and the maintenance dollars just aren't there to do it all in the live environment. On the ground side, we're in the process of validating and accrediting our portfolio of training systems. We want it to be based on rigorous validation that they are indeed effective and imparting the skills that they're supposed to. Once we've done that validation, it needs to become prescriptive in the context of the training and readiness manuals the same way that it is on the aviation side for flight simulators. When it becomes the way that we train for the gamut of our tasks then, not only the fidelity, but the funding to acquire increased fidelity will become a higher priority.[24]

Conclusion

It is clearly evident that simulation is an effective tool for training. There is still a great deal of work to be done before both the AITT and SAVT system can realistically replicate live training. However, there has always been a trade-off between realism and cost that the Marine Corps is willing to accept. During most modern live training ranges, targets are steel mock-ups, pop-up infantry "Ivans," or older US military equipment that has been retired and would otherwise be rusting away in a scrapyard. Without FOF engagements, such as with the use of the I-TESS system, there is currently no effective way to conduct live training against a thinking enemy that moves or operates like a real human. Therefore, in many respects, simulators are perhaps more realistic than live training in terms of enemy reactions.

Figure 21: USMC Live Training Targets

Steel targets at BT-11 bombing range near Cherry Point, NC. Photo provided by the author.

Source: http://www.letargets.com/content/3-d-t-full-ivan-plastic-target-green.asp

General Robert Neller, current Commandant of the Marine Corps (CMC), recently published FRAGO 01/2016 in which he highlighted modernization and technology as one of his top five priorities. The CMC stated that "We will continue striving to do what we do today better, but also be willing to consider how these same tasks might be done differently. We will continue to develop and evolve the MAGTF, ensuring it is able to operate in all five domains. We will invigorate experimentation of new concepts and capabilities during scheduled training events in order to test, fail, adjust, learn, and advance our capabilities." [25] Few areas could be closer to keeping in synch with the CMC's guidance than increasing the financial investment in simulation technologies. With the JTAC training alone, where aviation support costs for a single TACP class are approximately $2 million dollars, the investment will quickly pay dividends as a higher percentage of simulated T&R events are accredited, and less live flights are required.

As the AV-8B Harrier and F/A-18 Hornet aircraft systems approach their planned sundown in 2026 and 2030 respectively, the need for more accredited JTAC events via SAVT or other simulators becomes even greater. [26] F-35 pilots are expected to spend a greater percentage of their time flying simulators and less time in a real cockpit. When the SAVT was recently accredited in 2015, this point was highlighted as a significant issue. The report clearly warned that " F-35 aircrew will rely more heavily on simulator flight hours then legacy platform aircrew have in the past; consequently fewer actual live fly flight hours will be available for CAS missions to support JTAC training. The ability for JTACs to train with CAS aircrew is essential to both parties and must be maintained. To mitigate current and future CAS sortie shortfalls, interoperability between aviation and JTAC simulation systems must be a requirement."[27] With the inevitable loss of the Harrier and Hornet aircraft and limited availability for the F-35 to support JTAC training, the Marine Corps should begin to set aside funding early for more software upgrades for both the SAVT and AITT, so that JTACs can accomplish a greater percentage of their required training through simulation.

Figure 22: Marine JTACs in Afghanistan

Source: https://geographicalimaginations.files.wordpress .com/2013/12/close-air-support-afghanistan-2010.jpg

In conclusion, MAGTF simulation is an important tool that has already begun to provide the Marine Corps with a return on investment for the money it saves in aircraft flight hours, fuel, and ordnance. If the Marine Corps desires to be serious about training the way that it fights, then it requires the most realistic simulations and training devices that it can afford. This will enable Marines leaders to achieve the required repetitions necessary to sharpen their combat skills in training and help to ensure that the mission is accomplished with a minimal price in Marine blood and American tax-payer's treasure.

---

[1] LtCol Scott Harris, USMC Aviation Liaison, "SAVT Systematic Team Assessment of Readiness Training." Orlando, FL: (Naval Air Warfare Center Training Systems Division, 2013), 1.

[2] Col Walter Yates, Program Manager Training Systems, Marine Corps Systems Command, "Training and Simulation Industry Symposium Brief." Orlando, FL: (PMTRASYS, 2015), 14.

[3] Capt Michael Eady, TECOM, personal e-mail to the author on October 19, 2015.

[4] GS-14 Joseph L. Sullivan, Joint Staff J-6 DD C5I JCAS Section, "Simulation System Accreditation for the USMC for JTAC Training." Washington, D.C.: (Joint Staff J-6 DD C5I JCAS Section, 2015), 2.

[5] CIV Ken Potter, TECOM "Simulator Assessment Working Group Program Objective Memorandum 18 Proposed Inputs Brief." Quantico, VA:(TECOM, 2015) , 4.

[6] Greg "Sixpack" Szczepaniak, (instructor operator for Camp Lejeune, SAVT), interview with Maj Bryan Vaught, November 4, 2015.

[7] John Bilbruck, SAVT Project Officer for PMTRASYS, "SAVT Trifold." Orlando, FL: (PMTRASYS, 2016), http://www.tjinc-eng.com/SAVT_TRIFOLD.pdf.

[8] Dr. Amy Bolton, ONR, "ONR BAA Announcement # 11-005." Arlington, VA: (ONR, 2011), 2, http://www.onr.navy.mil/~/media/Files/Funding-Announcements/BAA/2011/11-005.ashx.

[9] Dr. Peter Squire, ONR, "AITT Brief at Augmented Reality Conference" Arlington, VA: (ONR, 2015), 4.

[10] Monique Randolph, "Augmented Reality Trainer Transitions to MCSC Training Systems." Quantico, VA: (MARCORSYSCOM, October 20, 2015), http://www.marcorsyscom.marines.mil/news/PressReleaseArticleDisplay/tabid/8007/Article/624958/augmented-reality-trainer-transitions-to-mcsc-training-systems.aspx, 2-3.

[11] Ibid

[12] David Dunfee and John Keppeler, (Training and Education Capabilities Division (TECD), TECOM), interview with Maj Bryan Vaught, January 6, 2016.

[13] Monique Randolph, "Augmented Reality Trainer Transitions to MCSC Training Systems." Quantico, VA: (MARCORSYSCOM, October 20, 2015), http://www.marcorsyscom.marines.mil/news/PressReleaseArticleDisplay/tabid/8007/Article/624958/augmented-reality-trainer-transitions-to-mcsc-training-systems.aspx, 2-3.

[14] CIV Fred Rott (SAVT Portfolio Manager for TECOM), personal e-mail to the author on December 10, 2015.
[15] CWO5(Ret.) David Dunfee (AITT Portfolio Manager for TECOM), personal e-mail to the author on January 4, 2016.
[16] LTC Stuart Hatfield, US Army Training and Doctrine Command, "Initial Capabilities Document for Unmanned Systems." Fort Monroe, VA: (US Army TRADOC, 2010), 7.
[17] Col A.H. Nerad, (Director, TECD, TECOM), "Transfer of Authority for SAVT Located at MCAS Yuma, Arizona from TECD to HQMC Department of Aviation, Aviation Manpower and Support Branch." Quantico, VA: (TECOM, 2012), 1-2.
[18] Inter-service/Industry Training, Simulation and Education Conference (I/ITSEC) 2014, "LVC Integration is Future of Marine Corps Training." Arlington, VA: (National Training and Simulation Association, 2014), 6.
[19] Cubic, Inc. "I-TESS II Brochure." San Diego, CA: (Cubic, Inc., 2013), http://www.cubic.com /Portals/0/11741_014%20I-TESS%20II%20br_reader.pdf, 2-3.
[20] John Bilbruck, SAVT Project Officer for PMTRASYS, "SAVT Trifold." Orlando, FL: (PMTRASYS, 2016), http://www.tjinc-eng.com/SAVT_TRIFOLD.pdf.
[21] Ibid
[22] Cory Shackleton, MSAT Instructor Operator at EWTGLANT, interview with Maj Bryan Vaught, December 21, 2015.
[23] F-35 Interoperability, *F35.com*, accessed January 15, 2016, https://www.f35.com/about/capabilities/ interoperability.
[24] Inter-service/Industry Training, Simulation and Education Conference (I/ITSEC) 2014, "LVC Integration is Future of Marine Corps Training." Arlington, VA: (National Training and Simulation Association, 2014), 6.
[25] Commandant of the Marine Corps, *FRAGO 01/2016*, January 19, 2016, 11, http://www.hqmc.marines.mil/Portals/142/Docs/CMC%20FRAGO%2001%2019JAN16.pdf
[26] HQMC, "U.S. Marine Corps Moves Forward with the F-35 Transition." *Marines.mil*, August 12, 2015, http://www.marines.mil/News/NewsDisplay/tabid/3258/Article/613385/us-marine-corps-moves-forward-with-f-35-transition.aspx.
[27] GS-14 Joseph L. Sullivan, Joint Staff J-6 DD C5I JCAS Section, "Simulation System Accreditation for the USMC for JTAC Training." Washington, D.C.: (Joint Staff J-6 DD C5I JCAS Section, 2015), 2.

Bibliography

Armendariz, Captain Nicholas, Kenneth Potter, and Kenneth Knarr (MAGTF Training & Education Standards Division, TECOM), interview by Major Bryan Vaught on September 30, 2015.

Bilbruck, John, SAVT Project Officer for PMTRASYS, “SAVT Trifold.” Orlando, FL: PMTRASYS, 2016, http://www.tjinc-eng.com/SAVT_TRIFOLD.pdf.

Bolton, Dr. Amy (ONR), “ONR BAA Announcement # 11-005.” Arlington, VA: ONR, 2011 http://www.onr.navy.mil/~/media/Files/Funding-Announcements/BAA/2011/11-005.ash.

Cohn, Joseph, Denise Nicholson, and Dylan Schmorrow. *The PSI Handbook of Virtual Environments for Training and Education Volume 3,* Westport, CT: Praeger Security International, 2009.

Commandant of the Marine Corps, *FRAGO 01/2016*, January 19, 2016, 11, http://www.hqmc.m marines.mil/ Portals/142/Docs/CMC%20FRAGO%2001% 2019JAN16.pdf.

Correnti, Master Sergeant Jeffery (JTAC Manager for 2nd Marine Division) and Master Sergeant Hiram LaChapelle (Fires Chief for 1st Battalion/10th Marines), interview by Major Bryan Vaught on November 4, 2015.

Cubic, Inc. “I-TESS II Brochure.” San Diego, CA: Cubic, Inc., 2013, http://www.cubic.com /Portals/0/11741_014%20I-TESS%20II%20br_reader.pdf.

Dunfee, CWO5(Ret.) David, (AITT Portfolio Manager for TECOM), personal e-mail to the author on January 4, 2016.

Dunfee, David and John Keppeler, (Training and Education Capabilities Division (TECD), TECOM), interview with Maj Bryan Vaught on January 6, 2016.

Eady, Captain Michael, (Modeling & Simulation Officer for TECOM), interview by Major Bryan Vaught on October 22, 2015.

Harris, Lieutenant Colonel Scott, USMC Aviation Liaison, “SAVT Systematic Team Assessment of Readiness Training.” Orlando, FL: Naval Air Warfare Center Training Systems Division, 2013.

Hatfield, Lieutenant Colonel Stuart, US Army Training and Doctrine Command, “Initial Capabilities Document for Unmanned Systems.” Fort Monroe, VA: TRADOC, 2010.

Headquarters United States Marine Corps, “U.S. Marine Corps Moves Forward with the F-35 Transition.” *Marines.mil*, August 12, 2015, http://www.marines.mil/News/ NewsDisplay/ tabid/3258/Article/613385/us-marine-corps-moves-forward-with-f-35-transition.aspx.

Inter-service/Industry Training, Simulation and Education Conference 2014, “LVC Integration is Future of Marine Corps Training.” Arlington, VA: National Training and Simulation Association, 2014.

Nerad, Colonel A.H. (Director, TECD, TECOM), “Transfer of Authority for SAVT Located at MCAS Yuma, Arizona from TECD to HQMC Department of Aviation, Aviation Manpower and Support Branch.” Quantico, VA: TECOM, 2012.

Oltman, Major Dean and Major Mike McNeil (JTAC Instructors from EWTGLANT), interview by Major Bryan Vaught on December 21, 2015.

Potter, CIV Ken (TECOM), “Simulator Assessment Working Group Program Objective Memorandum 18 Proposed Inputs Brief.” Quantico, VA: TECOM, 2015.

Randolph, Monique, “Augmented reality trainer transitions to MCSC Training Systems,” *MARCORSYSCOM.marines.mil*, October 20, 2015, http://www.marcorsyscom.marines.mil/News/PressReleaseArticleDisplay/tabid/8007/Article/624958/augmented-reality-trainer-transitions-to-mcsc-training-systems.aspx.

Rott, CIV Fred (SAVT Portfolio Manager for TECOM), personal e-mail to the author on December 10, 2015.

Szczepaniak, Greg, (SAVT Operator/Instructor with TJ, Inc.), interview by Major Bryan Vaught on November 4, 2015.

Shackelton, Corey, (MSAT Instructor Operator at EWTGLANT), interview with Major Bryan Vaught on December 21, 2015.

Squire, Dr. Peter (ONR Code 30), “Augmented Immersive Team Training Fact Sheet,” http://www.onr.navy.mil/Media-Center/Fact-Sheets/AITT.aspx.

Squire, Dr. Peter, “AITT Brief at Augmented Reality Conference” Arlington, VA: ONR, November 13, 2015.

Sullivan, GS-14 Joseph L. (Joint Staff J-6 DD C5I JCAS Section), “Simulation System Accreditation for the USMC for JTAC Training.” Washington, D.C.: Joint Staff J-6 DD C5I JCAS Section, 2015.

Trumble, Hank, (Schedule Coordinator at Training Support Branch, Marine Corps Base Camp Lejeune) interview by Major Bryan Vaught on November 4, 2015.

Yates, Colonel Walter “Q&A Emphasizing Modular Open Architecture and Standards,” *Military Training Technology*, September 2015.

Yates, Colonel Walter “Training and Simulation Industry Symposium Brief.” Program Manager Training Systems, Marine Corps Systems Command, Quantico, VA, June 15, 2015.