REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
17-04-2020	Master of Military Studies (MMS) thesis	AY 2019-2020

4. TITLE AND SUBTITLE

Changing the Paradigm of Military Training with Modeling and Simulations: Developing a Fully Integrated Live and Synthetic Training Environment

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)
Burkhart, Shawn J., 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)
USMC Command and Staff College
Marine Corps University
2076 South Street
Quantico, VA 22134-5068

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSOR/MONITOR'S ACRONYM(S)
Dr. Christopher Stowe

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

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

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Current limitations in training resources, including availability of suitable areas and facilities, and budget and materiel constraints, make it difficult to create training scenarios that mimic the physical and cognitive complexities of dynamically evolving and challenging operational environments. The use of Modeling and Simulations to augment training offers a solution to this problem; however, current efforts within the Department of Defense (DoD) are not unified, and have limited interoperability between service and functional programs. A fully Integrated Live and Synthetic Training Environment provides the DoD with an effective way to achieve training objectives at every echelon, that is permanent, cost-effective, tailorable, scalable, and modular.

15. SUBJECT TERMS

Modeling and Simulation (M&S), Live Virtual Constructive (LVC), Simulation, Synthetic Training Environment (STE), Integrated Training, 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
Unclass	Unclass	Unclass	UU	47	19b. TELEPHONE NUMBER *(Include area code)* (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: Changing the Paradigm of Military Training with Modeling and Simulations: Developing a Fully Integrated Live and Synthetic Training Environment

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

AUTHOR:
Major Shawn J. Burkhart, USMC

AY 2019-20

Mentor and Oral Defense Committee Member: Christopher Stowe, Ph.D.

Approved: _____

Date: 20200417

Oral Defense Committee Member: Bradley Pennella, LtCol, USMC

Approved: _____

Date: 20200417

Executive Summary

Title: Changing the Paradigm of Military Training with Modeling and Simulations: Developing a Fully Integrated Live and Synthetic Training Environment

Author: Major Shawn Burkhart, United States Marine Corps

Thesis: Modeling and simulation (M&S) can be fully integrated to become a permanent and reliable instrument augmenting training at every echelon, and change the paradigm on how the military approaches training.

Discussion: The U.S. is shifting its National Defense Strategy (NDS) toward great power competition, and must train its military to contend with highly capable adversaries, in dynamically evolving and challenging environments. Current limitations in training resources, including availability of suitable areas and facilities, and budget and materiel constraints, make it difficult to create training scenarios that mimic the physical and cognitive complexities of this operational environment. The use of M&S to augment training offers a solution to this problem; however, current efforts within the Department of Defense (DoD) are not unified and have limited interoperability between service and functional programs. Unity of effort would support functional, service, and DoD training efforts, and reinforce national strategic goals. This can be achieved through the creation of a fully integrated live and synthetic training environment (ILSTE).

This research will propose a concept that frames and structures an ILSTE. It will identify the impetus for developing this concept by analyzing the current gaps in training, and inhibiting factors of M&S efforts within the DoD. The proposal will stratify functional components of the ILSTE into mutually supportive layers in order to describe the construct, with the intent of creating a viable option for flexible, evolving and sustained training.

Conclusion: An ILSTE provides the DoD with an effective way to achieve training objectives at every echelon, that is permanent, cost-effective, tailorable, scalable, and modular.

DISCLAIMER

Illustrations

Page

Table of Contents

Page

Preface

Commanders are responsible for establishing their unit's training philosophy, and developing a plan that is standards-based, mission-oriented, and in keeping with the principles of the *Systems Approach to Training.*[1] Marine Corps training plans must meet Training and Readiness (T&R)[2] requirements as well as Annual Training and Education Requirements (MCBUL 1500).[3] When coupled with a pre-deployment training program (PTP),[4] directed unit training, professional military education (PME),[5] and advanced training courses for individuals, the plan gets very crowded, very quickly. A commander's staff will construct a training, exercise, and employment plan (TEEP)[6] establishing the framework for resourcing time, material, and personnel to training at the battalion level and above, yet that frame changes constantly, and at a pace that can be difficult for Marines and Sailors maintain. Persistent personnel turnover, limited funding, and limited training-area availability can also challenge the progression, sustainability and continuity of a training plan. [7] There simply is not enough time, training space, and material to accomplish all requirements and goals. At least, not in the physical world in which we live.

Technology offers a solution to training shortfalls. Physical resources (i.e., training areas, weapons, ammunition, vehicles, equipment) that are necessary for live training can be synthetically constructed in a virtual environment. Using M&S, these entities can be manipulated to build practically any military unit type, size and function with great fidelity. Within this Synthetic Training Environment (STE), it is conceivable to create and simulate any environment and condition with limitless variables.[8] Traditionally, live, virtual, and constructive (LVC) simulations augment individual, small-unit, or staff training that is task-specific or support a combined arms scenario.[9] Live simulations are perhaps the most common option to support training, where individuals or units train in a live environment that is supported by a simulated

scenario or with simulated systems or entities.[10] Virtual reality (VR) and augmented reality (AR) offer individuals the opportunity to be more immersed in a synthetic environment and interact with virtual entities, while constructive simulations allow commanders and staffs an opportunity to exercise a holistic-mission approach to a scenario in a statistical, two-dimensional representation of the environment.[11] These simulations are typically used exclusively from one another, or have limited interaction. They also typically do not interact with proprietary Department of Defense (DoD) command-and-control (C2) programs without intermediary interoperability bridging programs, or contracted technical experts.[12] These simulators can be effective in developing tactics, techniques, and procedures (TTPs), but generally have a narrow scope of focus, or only support one element of a larger training goal.

Advancements in computer processing, software, peripheral devices, and networking have now made it possible for simulations to interact seamlessly, creating innumerable training opportunities. The exponentially improving technology continues to make the use of M&S more user-friendly, with less cumbersome setup and coordination requirements. DoD weapons, systems, and personnel can be instrumented with sensors allowing live entities to broadcast their location and actions, which can be simultaneously reconstructed in a parallel synthetic environment. Conceptually, several simulation programs, each designed to train specific TTPs, could all network together under a host program where commanders and staffs, as well as individual warfighters, small units, and crews, could exercise their objectives as part of a combined-effort training evolution. Using military C2 systems interfaced with simulation programs, commanders and staffs could direct the actions of subordinate and adjacent units in both the synthetic and live training environments, at every echelon. Multiple simulations serving a myriad of functions from various units, across multiple installations, can be networked together

without geographic restrictions.[13] A complete Marine Air Ground Task Force (MAGTF) could theoretically execute a unified mission within a single synthetic environment in tandem with live training elements, happening at several different physical locations.

As the U.S. shifts its strategic outlook towards great power competition in an "increasingly complex security environment,"[14] it is imperative that the nation embraces every opportunity to prepare for the most complex and challenging missions with a formidable and capable adversary. It is unlikely that the U.S. and its allied and partnered nations will have the terrain, equipment, personnel, and funding to create a live scenario that fulfills these training requirements, making M&S a necessary tool. It is in the best interest of the U.S. to invest in developing software, hardware, networks, and peripherals that will create a realistic synthetic training environment that seamlessly interacts with live training and DoD C2 systems.

The motive for the Marine Corps to develop M&S capabilities is a directed task. The 38th Commandant of the Marine Corps (CMC) reiterated sentiment from the preceding two CMC Generals[15] in his 2019 *Planning Guidance,* maintaining that the organization must seize upon innovative and experimental opportunities to develop training, including M&S. General David Berger specified that "Training must include appropriate background reading, tactical decision games, modeling and simulations, and augmented reality," [16] providing the impetus, and opportunity for developing this capability. M&S can be fully integrated to become a permanent and reliable instrument augmenting training at every echelon, and change the paradigm on how the military approaches training. There is a substantial amount of technical structure that needs to be applied, much of which requires research and development, but nothing that cannot be achieved. Detailed analysis of specific technical and acquisition requirements is beyond the scope of this research, but are necessary for further development of this proposal. This research

will identify the critical gaps and limitations within the current training environment, as well as existing M&S efforts, then determine the elements that would standardize M&S as part of DoD training. It will present a concept that structures the feasibility of fully integrating the live training environment with the STE in order to create a viable option for flexible, evolving and sustained training at any echelon.

DEFINE THE TRAINING GAPS

The TEEP

The following vignette describes a fictitious Marine battalion developing a training plan as it happens in today's training environment:

When *The Six* took command this past summer, everything seemed to be in place to execute a training plan. The Commander's guidance for training was enthusiastically received by the battalion staff, and they immediately went to work developing a TEEP that would accomplish all core and directed METs before the battalion deployed in 12 months. As the staff worked through T&R, PTP, and MCBUL 1500 requirements, the incongruities began to pile up. New-joined Marines trickled in throughout the year, while primary and alternate staff, senior enlisted SMEs, and company commanders frequently rotated in and out of critical roles. Competition for training areas and ranges seemed almost cutthroat with other tenant and transient units, which were struggling with similar issues. The high operating tempo kept vehicles, weapons, and gear constantly in and out of the field, making it impossible for maintenance crews to preserve material readiness. Company commanders were frequently frustrated by having their training plans curtailed or canceled altogether to participate in battalion training, just as battalion staff were frustrated from having to support numerous regimental or division-level training evolutions.

On the rare occasion that the battalion had an opportunity for live training as a whole, there was always something missing; staff or small-units or leaders were untrained to function as part of a larger element, or half of the vehicles and radios were down for maintenance, or training areas were shallow and limited or shared with other units, or limited ammo allocations only provided a fraction of what was needed to meet T&R requirements. Usually it was a combination of all these factors. The training scenario seemed underdeveloped, unrealistic and mostly focused on small unit tactics, leaving battalion staff with little to do but troubleshoot communication issues and move the forward and main COC around the training area. The result was usually a painful exercise in figuring out how organize, mobilize, and C2 the unit, with minimal opportunities for quality proficiency training.

At the end of the workup, *The Six* asked the staff what they could have done better with

Prohibitive Training Environment

There are limitations to existing training opportunities that are prohibitive in producing battle ready Marines and Sailors, and units that are prepared to C2 complex and evolving missions against a capable adversary. Repetitive training builds reflexive skill, but requires the systems

and weapons that operators will use in combat, and a place to conduct the training. The physical requirement to sustain this over time can become exceedingly costly in terms of material consumption, and training areas may not be adequate enough to meet the unit's objectives, particularly as the scope and scale of the training increases.

Live Training Shortfalls

Skills are retained, and physical and cognitive ability is gained through practical application, which can consist of live training.[17] Individuals and units can exercise TTPs and achieve a high degree of reflexive muscle memory, but training to a full-scale mission with all elements of a combined arms task force can be difficult to coordinate and cumbersome to execute, requiring a great amount of training aides and safety restraints. Elements of the units training can also receive a disproportionate degree of realistic training. For example, while small-unit maneuver elements (platoons and companies) can usually coordinate live training that is realistic, and can be administered with relative ease, staff planners and C2 at higher levels (battalion and above) are usually left with little to do. This is because simulated scenarios are limited in what they can produce in the live environment. The most limiting factor is a simulated thinking and maneuvering adversary.

Force-on-force training is conducted at limited capacity, with a myriad of safety restrictions. Notwithstanding the requirement for safety, the primary limitation to force-on-force is the scale in which it can be executed, and the matched TTPs between adversaries.[18] Units do not typically engage one another beyond the battalion level and usually keep to exercising wide terrain maneuvers.[19] Squad to company-level force-on-force training utilizes simulated weapons effects (i.e., blank-fire, Special Effects Small Arms Marking System, Instrumented Tactical Engagement Simulation System (ITESS),[20] Multiple Integrated Laser Engagement System (MILES)) to

develop weapons engagement skills, but developing tactical skill against a unique adversary is limited because Marines fight against other Marines, trained to the same tactics, using the same weapons and systems. Live training for staff sections typically boil down to moving command posts from one location to another in keeping with maneuver elements, and rehearsing communications. Tracking and fighting a thinking adversary can lack realism because the adversary's operational approach is well understood and mirrored to the opposition.

Live training can also require a tremendous amount of logistical support. Wear and tear on gear and equipment can prevent units from progression or fulfilling training goals. The larger the scope and scale of an exercise, the larger the maintenance toll. Restrictive budget and limited maintenance capacity (including limited numbers of qualified personnel), prohibits the number and extent of a unit's training exercises. Commanders must balance their training goals against maintaining their unit's reportable defense equipment readiness[21].

Limitations to Live Training Areas

Physical training areas have limiting factors that may inhibit training objectives. Prohibitive factors include: physical limitation (size), limited availability (competition with other units), target and target-area limitations, and local range regulations and restrictions. The coveted force-on-force training usually takes place within a mock urban terrain (i.e., Marine Corps Air-Ground Combat Center, Range 220). While much effort has been contributed to the realistic design of these accommodations, their capacity does not facilitate training above the battalion level, and in most cases company level. They also generally require a tremendous amount of contracted or uniformed personnel to ensure safety parameters are enforced. Other live training areas are typically partitioned to serve a specific function (i.e., live-fire ranges, maneuver areas, aerial bombardment ranges, etc.). Many do not overlap, restricting or limiting the physical area

available for training. Priority of range and training area use is given to units training within the PTP, in keeping with the overarching Force Generation guidance.[22] Units participating in large-scale exercises (i.e., Integrated Training Exercise, Mountain Exercise, Talon Exercise) take first priority for reserving service-level training venues,[23] after which other units can reserve areas on a first-come, first-serve basis.[24]

Employing weapon systems in a live environment is critical to understanding their function and operation. Fire and maneuver is a common training practice, but is usually conducted against static targets, or mechanical moving or reactive targets following a set pattern or track. Live-fire ranges cannot be substituted; however, they can have limitations. Engaging targets in live training exercises the physical functions of employing weapons and systems, but can fall short of producing realistic effects as they would be applied in a combat scenario. Static targets do not maneuver or replicate adversary behavior. Building realism into training requires simulation of what the adversary is doing and the overall scenario, which is typically narrated or "painted" to training participants through a training coordinator.

In addition to training safety enforcement, every military installation hosting live-training ranges and facilities has its own unique regulations and/or restrictions. These rules must conform to civil and environmental stipulations of the host city, county, state, or nation.[25] Regulations vary by installation, but often have limiting effects on overall training goals.

Simulated Training Shortfalls

Simulation offers an alternative method to enhancing skill and proficiency that live training cannot produce. It allows for the creation of environments and conditions that would otherwise be difficult, if not impossible to create, except in combat. Computer-created virtual worlds, human-worn peripheral devices that augment reality with virtual environments and entities, and

fabricated weapons and systems that simulate form-fit-function (F3) capabilities allow the servicemember build skill in a STE. Notwithstanding the physical or functional limitations of simulation technology, to include resource acquisition, the primary limitation of a STE is the human imagination. The DoD acquisition process cannot be ignored when considering shortfalls to simulations, and the topic requires a detailed analysis beyond this research to identify methods for expediting the procurement of cutting-edge technology, and progressively incorporating it into training.

Most virtual and constructive simulations have a very narrow training function. Virtual simulations typically train individuals or small units to performance standards utilizing an interactive virtual environment, augmented with synthetic or F3 simulated weapons and systems. A long-standing example would be the Indoor Simulated Marksmanship Trainer (ISMT), which displays a virtual scenario projected onto a screen and allows individuals or small teams to engage targets with F3 weapons.[26] Virtual simulation function varies widely, ranging from laptop computers employing first-person virtual programs, to fully immersive facilities with 360-degree simulated environments. Entirely virtual simulations (i.e., Virtual Battlespace), can network multiple users to a host element, but are not developed to function above the platoon or company level.[27] Fidelity breaks down and lag increases with more users.

The most critical gap in virtual and constructive simulations is their incompatibility with each other. There are myriad simulations which are frequently used to develop individual skill, from marksmanship to piloting aircraft to battle tracking, but few of them share interoperability. Individuals or small teams may gain proficiency from simulations, but rarely if ever do so in a combined arms simulation. Training evolutions that are successful at networking multiple (different) simulations do so with complex work-arounds which typically require highly

specialized contracted technicians, and produce limited results (See Annex A). Virtual simulations have far less compatibility with constructive simulations due to their markedly different function. Furthermore, these simulation programs are typically not developed to interact with proprietary DoD C2 systems without similar work-around techniques, and an added security protocol. To clarify, the DoD M&S Management directs the development of M&S capabilities to be "common and cross-cutting," [28] but allows DoD Components to develop their own specific requirements for verification, validation and accreditation to meet common and general-use.[29]

SUPPLEMENTING TRAINING WITH MODELING AND SIMULATIONS

The New-Joins

The scenario now follows a Marine battalion progressing along a training plan where Modeling and Simulations has been fully incorporated into training at all echelons:

Checking in to a new unit is unnerving to say the least, and the untried, untested new-joins had precious little understanding of what life is really like before getting out to The Fleet. For the battalion staff it is more of a challenge to figure out how best to bring them up to speed. By the end of summer, the battalion had received its drop of new-joins with only three months left in their PTP. They had been assigned to their respective companies, and made up nearly a quarter of the battalion's T/O. Although they all left their MOS school with current rifle, PFT, and CFT scores, they all needed to complete their 2000-level T&R codes, MCBUL 1500 individual requirements, and the battalion was barely through half of the unit requirements. *The Six* was concerned that the new-joined Marines would not be ready for the upcoming battalion certification exercise happening at the end of the PTP, and he turned to the staff for viable solutions. The Battalion Operations Chief was happy to report that the process of training the new-joins was already underway.

True to form, the Master Sergeant told his Commander that "…paragraph 1006, entitled T&R Event Composition, subparagraph 20, Suitability of Simulation/Simulators/DL products, outlines the requirements for the use of simulations to meet the standards. Since the T&R re-write, the majority of the 2000-level codes allow simulations to qualify Marines, so I think we're good-to-go, Sir. It's probably because the sims are so dang realistic now that you can hardly tell the difference between them and reality. Not only that, the new-joins are familiar with sims because all the schoolhouses now use them, so there's no learning curve." He went on to explain that the in-house Deployable Virtual Training Environment suite came loaded with programs to train to nearly every MOS skill in the battalion. The suite had more than enough computers, VR/AR sets and networking equipment to wirelessly build a training environment right in the CP. And finally, he told the boss that since all the other battalions on base received the same suite form TECOM, competition for ranges and the battle simulation center on base had been drastically reduced, allowing the battalion to schedule ranges and training areas to meet all live T&R requirements. They could even network to other battalions if they wanted to do some combined simulated training. The battalion would be ready for CERTEX four weeks before they took to the field. *The Six* breathed easily, allowed his Ops Chief a genuine smile, and gave him the thumbs up.

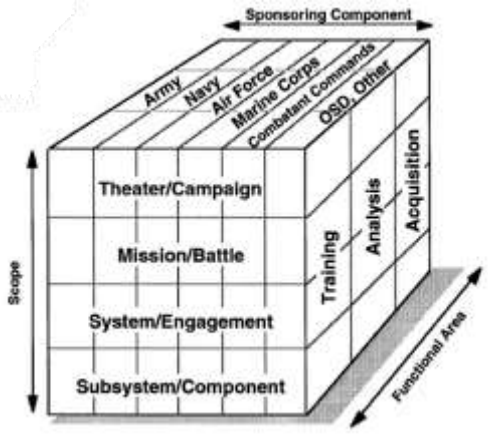
Current Modeling and Simulations Efforts

The concept of integrating simulations is presently being pursued by each of the Armed Forces services in its own respective way. Each has made significant headway in simulation

training, networking, simulation interoperability, organization and support, and improving the fidelity of peripheral devices (i.e., F3 simulators, immersive simulations, and VR/AR). While the efforts to improve M&S use in training have advanced, its overall application remains narrow focused and lacks overarching direction. An up-to-date, comprehensive and authoritative directive that stipulates the necessity for inter-service M&S compatibility is necessary to bring the DoD vision to fruition.[30]

Department of Defense Efforts

The Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) is identified as the chief authority, directed to "Establish and maintain the DoD management and administrative structure for M&S."[31] The USD(AT&L) Directive 5134.01 delineates overarching responsibilities and functions, authorities, individual component roles, but perhaps deliberately, uses language that is general, or unspecific. [32] This is likely to allow subordinate components to develop programs in keeping with their own function or purpose. USD(AT&L) is also responsible for maintaining the DoD Modeling and Simulation Master Plan. This policy outlines the vision and strategy for implementing M&S technology across the DoD. While the plan has not been updated since 1995, the vision does capture essence of compatibility between systems (Figure 1), stating that all types of M&S should embrace "interaction between the scope of the simulation, sponsoring component objectives and functional area requirements (e.g., education, training and military operations; analysis; research and development; test and evaluation; production and logistics)."[33] The Master Plan, supplemented by the DoD M&S Management Directive identifies lines of effort for components to pursue, but (like the senior USD(AT&L) directive), leaves much room for interpretation.[34]



In 1994, the Master Plan recognized inefficiencies that simulations were "narrowly focused, stove-piped developments for each user community," did not "meet active, reserve or joint needs," take too long and cost too much to build and operate, struggle with verification, validation and accreditation, "are not easily maintainable or extensible," and most egregiously, "are not interoperable with other M&S assets." Its first objective was to Develop a common

Figure 1: Range of M&S Embraced by the DoD M&S Vision.

technical framework for M&S.[35] Despite efforts by the Defense Standardization Program (DSP) to evolve interoperability standards all the way to the NATO level, including technical architecture and data interchange standards,[36] DoD components still struggle with inter and intra-system compatibility. While the DoD does have a functional, authoritative agency in the Defense Modeling and Simulation Coordination Office, it has not updated the Master Plan, or released standardization guidance in over five years.[37] Notwithstanding any forthcoming directives, M&S efforts at the DoD level seem to be a low priority.

US Air Force Efforts

The Air Force Agency for Modeling and Simulation (AFAMS) is organized into three divisions to manage support programs: Foundations, Operations, and Mission Support. These divisions provide overall guidance and support to major commands across the Air Force, developing standards for common access and interoperability for LVC programs.[38] AFAMS describes the functional organizations that support training with M&S collectively as the Training Systems Product Group (TSPG), which is divided into two primary divisions, the Warfighter Readiness Research Division and Simulators Division. These organizations employ several subordinate programs using various LVC simulators to develop skills from the individual through staff-level.[39]

The Air Force views M&S as a vital tool for preparing Airmen for increasingly complex technical applications and decision-making requirements. The vision for M&S during the 21st century is to hone in on what that capability can support, and develop a foundation and infrastructure that will link M&S programs to provide cutting edge training and support tools.[40] To realize the vision, the Air Force intends to follow a progressive plan which would identify the gaps in current M&S capabilities,

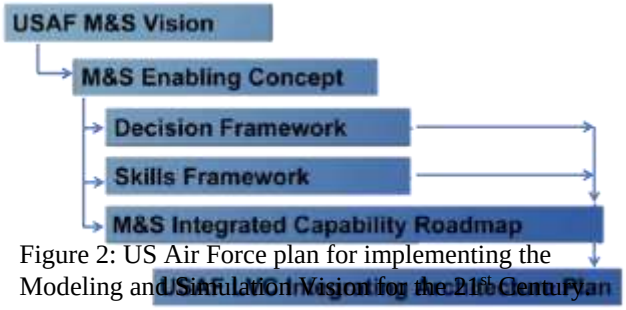


Figure 2: US Air Force plan for implementing the Modeling and Simulation Vision for the 21st Century

determine an enabling concept, and develop a roadmap that covers the integration framework, which would yield a plan for creating an integrated LVC architecture (Figure 2). This vision is now nearly a decade in development, and while TSPG continues to produce and support individual programs, there is limited information suggesting an integrated system.

US Army Efforts

The US Army's Program Executive Officer Simulation, Training and Instrumentation (PEO STRI) employs the Project Manager Integrated Training Environment (PM ITE) with a mission to "Provide relevant integrated modeling and simulation capabilities to achieve Army readiness." It provides direction for several simulation programs including aviation, close combat (armor, mechanized infantry, cavalry, infantry and reconnaissance), and battle staff trainers. Each of these programs are operated from various training facilities across the United States, employing several contracted civilian agencies.[41]

There is an attempt through several PEO STRI programs to provide the comprehensive interoperability between LVC simulations. Specifically, the Live, Virtual, Constructive – Integrating Architecture (LVC-IA) program is attempting to establish network-centric data exchange between interdependent programs to enable "the live, virtual, constructive training audience to see the common operating picture and to communicate using organizational command and control equipment."[42] The Army is also developing standards for static and moving computer-generated entities, and common development tools for Training Aids, Devices, Simulators, and Simulations (TADSS) for LVC systems under its Synthetic Environment Core program.[43] In addition to these organizations, PEO STRI employs a myriad of training organizations with subordinate Project or Product Management organizations with varying

training simulations covering the range of functional areas, with fluctuating degrees of interdependence.

With over 70 individual programs supported by PEO STRI (Figure 3), many in various stages of development or change, it can be difficult to comprehend its overall focus of effort. An emerging initiative within the PM ITE may offer a unifying solution to system integration. The Synthetic Training Environment project aims to combine LVC programs into a single organization, coordinating and supporting existing and developing simulations. The concept would allow LVC simulations to interact with live training through various network-enabled systems including government and commercial off-the-shelf products.[44] There are limited details available regarding this program, as it is in the pre-material development decision phase.

Figure 3: US Army Program Executive Officer – Simulation, Training and Instrumentation (PEO STRI) Organization.

US Navy Efforts

The US Navy Modeling and Simulation Office (NMSO) provides analysis, training and acquisition through M&S under the direction of the Deputy Assistant Secretary of the Navy Research, Development, Test and Evaluation (DASN(RDT&E)). Its governance is divided into four functional areas: support the US Marine Corps, training, analysis, and research, development and acquisition. Within the training functional area, the Navy uses M&S to support US Fleet Forces Command training efforts from individual skills building through strike group staff.[45]

The NMSO has struggled to keep pace with the complexity of evolving threat environments and constricting budgets. As a result, M&S training programs tend to be outpaced by rapidly advancing technology rendering training and evaluation tools quickly outmoded, with little or no compatibility with other programs. Their aim is to create a M&S infrastructure that will fuse collaborative immersive virtual environments within an integrated and interoperable architecture (Figure 4). This common development environment will host LVC simulations along a digital continuum, and be partnered with civilian industries as well as work horizontally with other DoD services.[46] This program however, has not released (unclassified) status of production since 2016.

Figure 4: Navy Modeling and Simulation Office proposed synthetic environment structure.

While the NMSO does not host as robust a M&S structure as PEO STRI, it does work collaboratively with the US Marine Corps, at least at the director-level. The Navy also sponsors

the DoD's premier education program for M&S with Modeling Virtual Environments and Simulation (MOVES) Institute at the Naval Postgraduate School. MOVES offers Certificate, Master of Science, and Doctor of Philosophy programs to board-selected Marine and Navy officers. Marines and Sailors who complete the course then typically continue their service coordinating or directing M&S-related programs within their respective branches.[47]

US Marine Corps Efforts

The Operations Analysis Directorate within Combat Development and Integration (CD&I) is the formal office for Marine Corps M&S. CD&I's annually published *Marine Corps Concepts & Programs* strategic guidance offers direction for M&S development under Focus Area 2: Training and Simulation.[48] While this year's guidance for programs has yet to be finalized in the wake of recent planning guidance from the CMC, Focus Area 2 traditionally offers direction on developing individual, collective, and range training systems, including LVC simulations.

The 2018 *Concepts & Programs* offered insight into an emerging program that could expedite and reinforce inter-compatibility of M&S programs. The Live, Virtual, Constructive Training Environment (LVC-TE) concept would "provide the integrating architecture, common correlated authoritative data, standards and protocols, exercise design and control as well as the governance needed for existing and future training systems to seamlessly integrate and interoperate across the live virtual and constructive simulation domains."[49] The LVC-TE would, in effect become a synthetic training enterprise capable of hosting and supporting distributed simulations that support mission essential tasks for individuals, operational

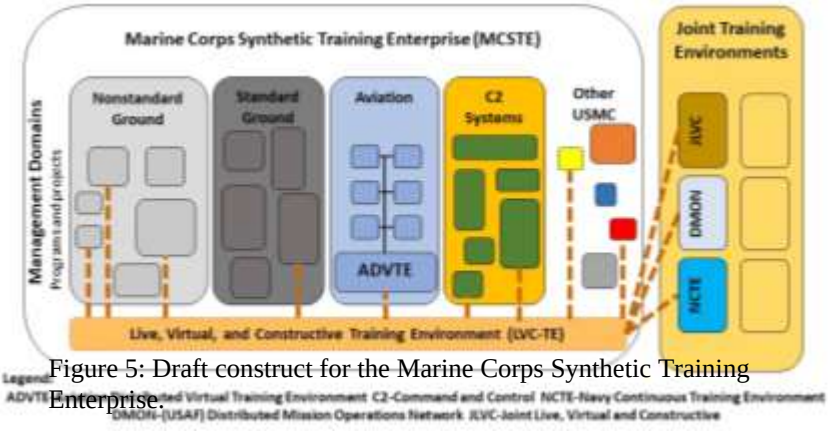


Figure 5: Draft construct for the Marine Corps Synthetic Training Enterprise.

units, and staffs (Figure 5). The program has succeeded through the Material Development Decision phase, and currently has a draft campaign plan outlining the lines of effort: Establish and Maintain Governance, Develop Science and technology, Integrate Training Capabilities, and Acquire and Support Training Systems.[50] If the program realizes its potential, it would make the Marine Corps ideally situated to fully integrate synthetic and live training environments.

Joint Efforts

Interoperability is the critical shortfall to collaborative M&S programs. Without it, these programs continue to serve narrow lines of effort along many individual requirements, with little opportunity for mutual support or combined training. Capstone M&S policy directs interoperability at the service-level, using specific language to the point,[51] yet there is little evidence to support collaboration across services. Furthermore, M&S doctrine tends to be infrequently updated; some have not changed since the mid-1990s. Without keeping pace with technological advances, doctrine can quickly become obsolete and even ignored as M&S programs emerge.

Despite the inconsistent direction within each of the service programs, there is an ongoing joint effort to develop innovative simulation solutions. Team Orlando is a collaborative organization that focuses on developing simulation programs and systems for US military services. Each branch of service contributes a team that provides direction (service requirements), for analysis, research and development, engineering, acquisition, and life cycle management (Figure 6). Team Orlando provides

Figure 6: Team Orlando contributing members.

programs and tools to the end-user throughout the DoD.

BUILDING A FULLY INTEGRATED LIVE AND SYNTHETIC TRAINING ENVIRONMENT

The Staff Rotation

The scenario now follows the battalion one month before the pre-deployment plan certification exercise:

Before the Ops Chief departed for Senior Enlisted PME, he reported to *The Six* that company-level Core and Directed METs were 90% complete, but that 7000-level T&R codes had not been touched. It was now four weeks before the battalion's certification exercise. He normally received his training report from the OpsO, but the major had just checked in to the unit two days ago. He was one of several key staff members with less than a month's time with the battalion. The Adjutant, Communications Officer, Maintenance Management Officer, and Intel Chief were also new to the unit, and three senior enlisted Marines, including the Ops Chief, were at SEPME. Companies seemed to be firing on all cylinders, but the battalion staff was untrained to operate as a cohesive organization. The whole staff would be on deck by the end of next week leaving just two weeks to come together. During the in-call with his new OpsO, *The Six* presented this dilemma to him and asked what his solution was.

Not knowing the battalion staff, the major asked his Commander if he felt they needed time in the field exercising the functional operations of running a COC, or needed to gain proficiency in commanding and controlling a battalion. The response was affirmative to both. The OpsO, anticipating this suggested that he divide the battalion staff into two parts. The NCOs from each staff section would organize and conduct command post exercises, running setup, teardown, movement and communication drills with all the operators, drivers and communicators. Meanwhile, the primary and alternate staff, to include their chiefs, would conduct a week-long simulation training exercise at the CP. The staff can gain reps and sets running through a different scenario every day, challenging them in various virtual environments at varying degrees of complexity. The Battle Simulation Center on base maintains a myriad of virtual environments and scenarios with tailorable adversary capabilities. The battalion's DVTE suite is equipped with all the necessary computers and communications equipment to build a mock COC in a relatively small space. The staff could exercise battalion SOPs and TTPs with high fidelity, and real-time feedback. At the conclusion of the training the staff would marry up with their respective sections to be ready for field training, all with minimal, if any cost to maintenance. *The Six* had a feeling his new OpsO would be a good addition to the

Proposed Concept of Employment

The potential use for M&S in training is limited only by one's imagination. That is not to say there are technical limitations such as computer hardware and networking; however, constructing a virtual world in a synthetic environment is boundless. The utility to military application is equally boundless. The key to successful application is defining the synthetic environment and organizing its functions.

The ideal synthetic environment would exist on a perpetual, dedicated training network with a series of hubs at each major military installation. Virtual and constructive simulation programs would be compatible with each other, regardless of their primary function. This would require incorporating the compatibility feature during development of each simulation program. These simulations would also be designed to function with proprietary DoD C2 systems, allowing users to train to actual system standards. The synthetic environment would have the option to overlay live-training environments, reconstituting instrumentized live entities. This would allow individual, and small-unit live actions to merge into a larger virtual scenario. Commanders and staffs would monitor and C2 virtual and live entities within the mission parameters that transcend physical boundaries. It would also allow training to be tracked in real time for after-action evaluation. Simulation scenarios would be scalable in function and scope, allowing all echelons to be trained from the individual executing specific MOS skills, to the joint and combined task force, executing a mission in multiple domains.

The organization of M&S training is critical to ensuring it is realistic, repeatable, sustainable, and accessible. The ideal organization would be run by uniformed service members, augmented by contracted support. Operational and dedicated training commands would each maintain an M&S element. Operational units would each have a dedicated simulations suite, with foundational hardware and software, but tailored to meet their functional role. Training

commands would maintain much more specifically tailored simulation equipment developed to focus training to serve the school's function. Each major military installation would host a simulations center with contracted specialists that would act as the primary hub within a broad training network, and serve as the technical support center for simulation programs. The functional organization would allow for modular and task-oriented simulation to be available at every echelon.

Defining the Integrated Live–Synthetic Training Environment (ILSTE)

The purpose of fully integrating live and synthetic training environments is to support the accomplishment of training objectives, from individual through joint levels. An ILSTE provides the DoD with a cost-effective, tailorable, scalable, modular option for conducting training. In order to achieve a functional and sustainable training environment, there must be paradigm shift in the approach to training, and several technical aspects must be realized. The shift in how the DoD conducts training would need to not only embrace the use of technology, but also account for the exponential advancement of that technology and infuse this philosophy at the foundational training doctrine. The philosophical discussion concerning the military training paradigm likely requires an in-depth analysis and is beyond the scope of this research; however, were the technological aides to be fully embraced as an essential element to training, then the following application becomes feasible.

The concept of an ILSTE must consider the technical aspects required to be able to use it as an effective training option. These technical aspects, while essential in their own right, are not mutually exclusive. They can be categorized by their functional purpose and delineated into layers. Each layer is a module in the ILSTE concept (Figure 7). The functional areas include simulation programs (LVC simulations), proprietary DoD programs, DoD systems, communication networks, and people (coordinators and operators). When categorized by function and purpose into layers they can be stratified as: 1) integrated simulation programs, 2) instrumentized DoD systems, 3) integrated C2 systems, 4) integrated synthetic and live environments, 5) dedicated STE network, 6) support structure. Stratifying each functional area within a layered construct allows this concept to be visualized holistically. Each layer will be examined within its own right, but the overall concept requires interdependence between them.

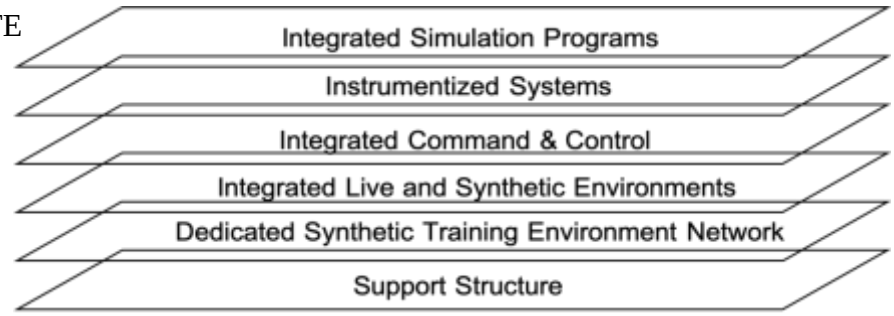


Figure 7: Functional layers of the Integrated Live-Synthetic Training Environment.

Integrated Simulation Programs

In keeping with the discussion on the limitations to simulated training, programs need to be compatible with each other. This is primarily a function of the software language used in simulations. At the conceptual level, a computer simulation program produces an entity (person, weapon, system, or object) with associated function and behavioral characteristics that interact with the synthetic environment in which it exists.[52] The software language used for computer DoD simulations is typically unique to each program, albeit based on a standardized language

used for acquisition, planning, evaluation and training.[53] Simulations with a similar purpose can produce similar entities, yet they can be written in a markedly different software language. Simulations with widely different purposes and functions (i.e., virtual versus constructive simulations), do not typically produce similar entities.[54] For example, a human entity within a virtual simulation typically has multiple physical and functional characteristics, while a human entity in a constructive simulation typically represents a numeric or statistical function. Using cross-functional interoperability software, simulations can map characteristics, functions, and positions of entities, seamlessly reproducing them between programs.[55]

Integrated Simulation Programs requires a DoD directive that ensures software interoperability. This can be accomplished in one of two ways: 1) All DoD simulation software is engineered using a standardized language. 2) DoD creates, maintains, and enforces a standardized interoperability program, and all DoD simulation software is engineered so that it is compatible with the bridging program. The first option would create the most reliable synthetic environment, as all entities and physical characteristics of the simulations would be produced using the same program architecture. This option may, however, stymie or restrict the creative process during simulation development. There would also necessarily have to be a standard interoperability framework between virtual and constructive simulations. The second option resolves these limitations; however, it adds the requirement to continuously map evolving entities and environmentals through the bridging program. Either option provides a viable solution for entity reproduction in the synthetic environment, which will allow simulations with varying functions to seamlessly interface with each other. This enables servicemembers with varying occupations and purposes to operate to their individual training standards while

interacting with others operating to their standards, simultaneously allowing for larger echelon training.

Instrumentized DoD Systems

Most DoD systems are (or can be) equipped with position locators and functional indicators. This information can be broadcast and received by C2 systems, giving unit commands functional information about elements on the battlefield. This same principle of instrumentizing systems can be applied to weapons, vehicles, and personnel, as well. Elements of instrumentization are currently used in some training environments (i.e., ITESS, MILES); however, their use is limited in scope and function (see Limitations to Live Training).

Instrumentized DoD Systems requires all weapons, personnel, vehicles, and systems participating in training be equipped with sensors and position locators, and a communications network capable of managing data flow. All elements would need position locators to accurately track movements of all variables within the training environment. Weapons would need to track munition consumption, and—depending on the scope and purpose of the exercise—direction of fire. Crew-served weapons could also be equipped with functional sensors. Personnel would need to be equipped with emitted energy (infrared, laser) sensors, allowing the simulated effects of munitions to be "felt" by individuals. Vehicles would need orientation, functional, and emitted energy sensors, tailored to each vehicle depending on its purpose and relevance to training objectives. Systems would require the most comprehensive instrumentization, depending on their function. Weapon systems (for example, howitzers and tanks) would need orientation sensors as well as vehicle function indicators and primary weapon sensors (similar to those previously stated). Sensors can be equipped during manufacturing (similar to how aircraft are manufactured), or attached as peripheral devices.

The most critical element of a training environment fielding instrumentized systems is the communications network. It would need to be robust enough to manage data flow from multiple, moving entities, sending and receiving varying amounts of data. The data network would need to be designed to function comparable to that of a cellular network. This would likely need broadband antenna throughout the live training environment. There are physical, mechanical and monetary costs associated with constructing and maintaining such a network, that would vary depending on the size and overall purpose of the training area.

Integrated Synthetic and Live Environments

The foundation of the ILSTE concept is integrating and synchronizing live training with simulated training. Both elements are achievable, and several programs have been initiated, making their way through the development and acquisitions process (e.g., LVC-IA, LVC-TE). Live training has been the method for gaining practical experience throughout the evolution of military organization, while simulation programs can interface with each other with interoperability software. With instrumentization comes another opportunity. Personnel, vehicles, weapons and systems can be instrumentized and broadcast their location and functions, to be received and reproduced in a parallel synthetic environment. This would allow computer simulation users to interface with live simulation participants.

Integrated Synthetic and Live Environments requires live entity reproduction within the STE, simulated entity projection within the live environment, and a host STE. In order to reproduce live entities in the STE, live elements would need to be instrumentized. The information about each entity would then be bridged into the STE. Simulated entities produced from the STE that have bearing on the training objective can have elements of their behavior projected into the live training environment, or (to a limited degree) reproduced virtually. Simulated behaviors that can

be projected into the live environment are entity-position locations, communications (voice and data), and simulated environmental effects in the form of data (i.e., live entities receiving indication they were within the effective casualty radius of a simulated munition). Personnel equipped with virtual or augmented reality devices could view reproduced simulated entities within the live training environment.[56]

The critical element tying the synthetic and live environments together is the host STE. The host would serve as the ground truth of the training evolution, synchronizing the elements and events as the training unfolds. The host STE would need to be able to produce and track all participating entities, translate all communications, and produce a geographic replica of any live training areas. It would also be responsible for producing and controlling artificial intelligence (AI) controlled non-player characters (NPC). The host STE would essentially serve as the central information hub for the training evolution.

Integrated Command and Control Systems

Not unlike simulation programs, C2 systems need to interface with each other in order to effectively convey the varying and dynamic unit functions on the battlefield. An effective way to train command elements in the functionality of C2 systems is to interface with simulations. Incorporating C2 systems into the ILSTE allows commanders and staffs the opportunity for practical application of critical capabilities, with real-time feedback, in a realistic and dynamic environment, operating against a thinking adversary with unique capabilities and strategies.

Integrated Command and Control Systems requires proprietary DoD C2 programs to interface with each other, and with simulation programs. Ideally, the C2 programs used in training would be the same used in actual operations. Interoperability and mapping tools or programs would be necessary to seamlessly reproduce simulation entity positions, functions and

status within C2 programs. The concept of mediation between the two types of programs is similar to the interoperability between simulation programs, however, DoD C2 systems would need to account for security protocol to prevent sensitive technology from interfacing with open source simulation programs. It logically follows that bridging software would need to be engineered to account for security protocol. Another approach would be to disable or remove specific security-sensitive functions or features of C2 systems for training, or substitute proprietary systems with simulators that have similar capabilities. To maintain fidelity with the training scenario, and mitigate against incongruent feedback from various live and virtual entities, C2 systems would be directly linked to the host STE.

Dedicated Synthetic Training Network

A training evolution is likely to have several localized participating elements, varying in scope and scale, at various locations, and with unique functions that serve the overarching training scenario. Each element would need its own network to allow for the integration of live and virtual entities, programs and systems, and those networks would need to be linked to each other to facilitate a combined exercise, and for the ILSTE to realize its full potential. Considering the physical separation between training areas, coupled with the functional separation of each network, the ILSTE frame would need to have a permanent dedicated network that all others could tie in to.

The *Dedicated Synthetic Training Network* would serve as a permanent and protected line of communication, devoted specifically to the flow of data between elements of the ILSTE. It would provide the communication framework for all subscribing elements (localized networks or individual simulations and programs), allowing them to interface with each other. The dedicated network would serve as the primary conduit of the ILSTE infrastructure, determining the

necessary bandwidth, processing power, and security, while coordinating host/client relationships of each participating training facility. The greatest challenge to establishing this network would be to identify lines of communication at training facilities that could serve as the uninterrupted, dedicated network. The ILSTE network could either isolate lines within existing communications networks, or establish new ones. These channels would need to be robust enough to handle the volume of data exchanged between inter-connected networks and programs.

Support Structure

The ILSTE should be designed to be scalable and modular, meaning that units could design, develop, and execute training exercises from the simple to complex, with limitless options for variables. Given the rapidly advancing nature of technology and wide variety of training objectives, the ILSTE would need an element capable of managing the demand.

The *Support Structure* requires a dedicated organization focused on maintaining and coordinating the STE, instrumentization of personnel and systems, program integration and interoperability, and network protocols. It would also serve as a dedicated repository of information, simulation programs, scenario solutions, and after-action reports. This organization would need to be authoritative enough to direct subordinate training elements, and enforce unified standards. It should consist of both military personnel to direct overall efforts in keeping with service objectives, and contracted technical support personnel to preserve continuity and maintain M&S technological developments. The most effective construct of this organization would be to stand up a new command, subordinate to the overarching service command that directs training. For example, the Marine Corps could create an ILSTE command, subordinate to TECOM. Most military installations have existing simulation training facilities that could be

integrated into the support structure. Apportioning the responsibility and authority to a dedicated organization would ensure the ILSTE could be permanently functioning and accessible.

CONCLUSION

The Integrated Live-Synthetic Training Exercise

The scenario concludes with the battalion conducting its certification exercise, participating as part of a larger MAGTF exercise happening in synchronized synthetic and live environments:

The Six joined the commanders of other MSEs from around the MAGTF in the manufactured COC at Battle Simulation Center on EWTGPAC. It seemed like a unit from every major installation was there; ACE units from Cherry Point and Miramar, LCE units from Barstow, GCE units from Twentynine Palms and Camp Pendleton, and a CE out of Okinawa. The synthetic OA was already up and running with intel collecting on the virtual enemy's activity. Red Cell contractors had built an adversary with near-peer capabilities and allowed the program's AI to run its course. Running parallel to the synthetic OA, all communications with subordinate live units at each installation were functioning with minimal friction. Everything was staged and ready to begin with shaping operations.

Squadrons from Miramar ran sorties against targets at the Chocolate Mountain Aerial Bombardment Range outside of Yuma, while fixed-wing aircraft from the East Coast did the same attacking targets at the G-10 range at Camp Lejune. Naval Surface Fire Support ships unleashed salvos at targets on San Clemente Island while UAS reported their spotting. The targets were identified and prosecuted by live observers wearing AR gear, locating virtual enemy systems matched to elements in the synthetic environment. The overall simulated effects from each of the live shaping events were reproduced in the synthetic environment, which was being monitored and displayed for commanders and their staffs in the COC.

The Six briefly marveled at the seamlessness of it all. He saw clear communications, hi-fidelity graphic representations of the enemy and the terrain, and remarkably few civilian-contracted technicians running the simulation. He nostalgically recalled how cumbersome simulations seemed just a few short years ago, and how resistant so many were to change. He could not quite put his finger on what the catalyst was that ushered in such a rapid transition to this fully integrated live and synthetic training exercise, but he was confident that the outcome would be a battle-ready, mentally and physically agile group of Marines and Sailors. The thought had passed as quickly as it materialized when his Ops Chief approached him.

"Sir, we're online with the battalion in Twentynine Palms; all companies staged and ready to LD." *The Six* nodded and confidently gave him the thumbs up.

As the NDS moves into great power competition, the services must adapt training efforts to contend with adversary capabilities in an ever-evolving dynamic environment. The Marine Corps must adapt its training "in a manner consistent with the threat and anticipated operational challenges," as the CMC states, and focus on succeeding "in the most challenging conditions and operating environments – from the thin air and high altitudes of the mountains, to the sweltering heat of triple canopy jungles, and including the sprawling self-organized chaos of dense urban terrain."[57] Current limitations to training, including availability of suitable areas and facilities, and budget and materiel constraints make it difficult to produce training scenarios that fit the CMC's description. M&S offers a cost-efficient and flexible solution; however, the capability would yield the most effective results if efforts were unified across services and functional areas, and broadly extended into live training. Current M&S programs do not demonstrate adequate interoperability with each other and DoD C2 systems, limiting the potential for combined arms training at every echelon.

In order to effectively use M&S to support training efforts, the live training environment must be fully integrated with the synthetic environment. Improving technology and current programs at each of the service levels have demonstrated that it is possible to create an ILSTE, however, in order to achieve it, the functional elements must be organized into a comprehensive line of effort. LVC simulations, proprietary DoD programs and systems, communication networks, and coordinators are the components of the ILSTE, which can be organized into functional layers that perpetually interact and mutually support one another. This proposal would need to address the physical requirements necessary to construct the infrastructure (i.e., instrumentized personnel and systems, dedicated communications networks), software requirements (i.e., simulation interoperability programs, security protocol), and identify an

authoritative support organization capable of coordinating and directing efforts under a unified command. The result would be a permanent and reliable training instrument available at every echelon, from the individual through large-scale, joint task-forces. A fully integrated live-synthetic training environment would change the paradigm on how the military approaches training.

Appendix A: Thunder Lab After Action Report

Summary:

Subj: AFTER ACTION REPORT FOR 3D BATTALION, 11TH MARINES TACTICAL DECISION MAKING LABORATORY (THUNDER LAB) CONFERENCE, 16 – 17 OCTOBER, 2018

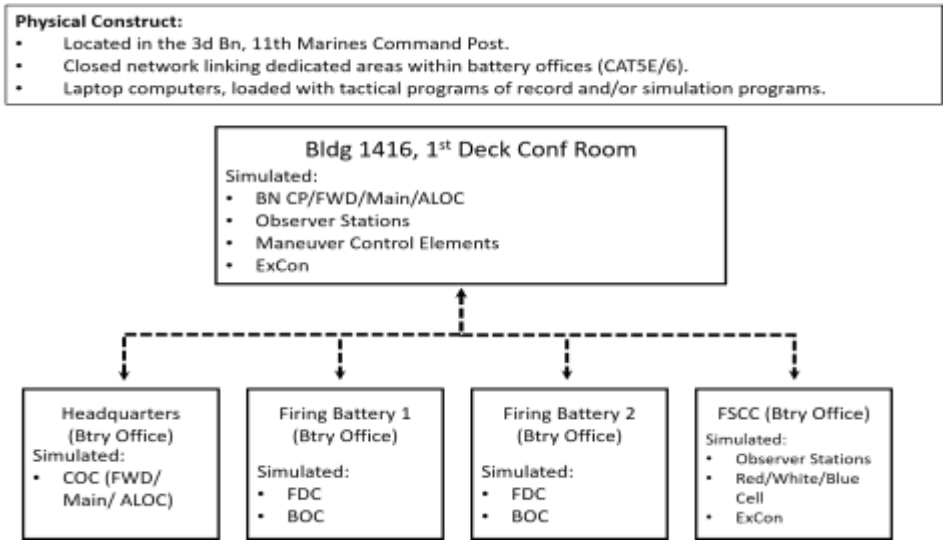
On 16 and 17 October, 2018, 3d Battalion, 11th Marines (3/11) conducted a conference at their command post building at Marine Corps Air Ground Combat Center (MCAGCC), in Twenty-Nine Palms, CA, to discuss the overall concept, construct and potential us of a tactical decision-making laboratory, utilizing simulation. It was an open forum discussion covering modeling and simulations, its application within the Fires community and how 3/11 is using it to supplement training. The conference included a facilities tour, simulation demonstration, and interactive discussion about the limitations, shortfalls and issues with the concept, and potential future requirements and opportunities. Attending the conference were: Mr. F. Rott, Portfolio Manager for MAGTF Training Simulations at Training Education Capabilities Division (TECD) of Training and Education Command (TECOM); Mr. J. Hamby, Lead Engineer for Program Management Training Systems (PM TRASYS) DVTE/CACCTUS; Mr. M. Denney, Operations Officer for the Training Support Center (TSC) at MCAGCC; Major J. Attig, Modeling and Simulation Officer at the MCAGCC Battle Simulation Center (BSC). The conference was hosted by the primary lab developers, Captain S. Burkhart, and Captain A. Bock.

In an effort to continue to improve tactical fire support proficiency, 3/11 has identified a significant shortfall in training for staffs and commanders. On average, the battalion conducts two to three training exercises annually where staff collectively employ and tactically and technically direct warfighting assets. With a high frequency of key leader turnover, coupled with an inconsistent overlap of officer and enlisted counterpart transition, 3/11 has noticed that, despite having a written standard operating procedure (SOP), sustaining aggregate staff proficiency has become problematic. Staffs are not able to maintain consistent skill operating as a battalion. This is likely due to a lack of consistent and frequent quality battalion-level training exercises. While supporting service-level training as a battalion, like Integrated Training Exercises (ITX), does give commanders and staffs an opportunity build proficiency, it comes at a cost. The physical toll on

weapons and equipment is not sustainable if the battalion must maintain the ability to consistently support tenant or transient unit training at the company or battery level. Therefore, 3/11 has been developing options to create more opportunities to train as a battalion, without amplifying the physical cost and diminishing maintenance readiness.

Simulation offers a unique, low cost, time saving opportunity to augment training. Current simulation technology is able to create synthetic environments to a high degree of fidelity. Users are able to create scalable scenarios, with multiple, detailed entities on computer programs such as Virtual Battlespace 3 (VBS3), and link them to other USMC programs of record like Advanced Field Artillery Tactical Data System (AFATDS). Leveraging this technology, 3/11 has developed a laboratory concept that will provide fire supporters a semi-permanent opportunity to exercise command and control (C2), technical and tactical fire direction, observed fires, and enhance decision-making skill. The 'Thunder Lab' concept aims to network multiple tactical programs of record with several simulation programs, physically array support equipment in dedicated office spaces, with a primary focus on training commanders and staffs. The potential uses for the lab include using the simulated environment to model and test operations and conduct various training including: rehearsal of concept (ROC), combined arms rehearsal (CAR), command post exercise (CPX), tactical decision game (TDG), convoy training, observed fires, and battle drills.

Lab Construct.



8. Conclusion.

The Thunder Lab does not seek to replace live training, but rather supplement that option by adding another; one that reduces physical maintenance cost, saves time, and provides a quality solution that is standards-based and repeatable. This concept offers an option that is scalable along the training continuum, from the individual to the staff level. Its target audience is commanders and staffs, and its focus is on exercising and improving decision making and aggregate execution. The lab is not reinventing technology, or requesting a new program be developed, but rather combining existing tactical programs with simulations to create a realistic, flexible and sustainable training environment. 3/11 intends on applying this concept in the near future, exercising staffs in the lab on a scenario they will execute live in the following weeks. If the concept proves viable, commanders, staffs and Marines and Sailors across the battalion will demonstrate a higher degree of proficiency.

Appendix B: Acronyms

ACE	Air Combat Element
AI	Artificial Intelligence
AFAMS	Air Force Agency for Modeling and Simulation
AR	Augmented Reality
C2	Command-and-Control
CD&I	Combat Development and Integration
CE	Command Element
CERTEX	Certification Exercise
CFT	Combat Fitness Test
CMC	Commandant of the Marine Corps
COC	Combat Operations Center
CP	Command Post
DASN(RDT&E)	Deputy Assistant Secretary of the Navy Research, Development, Test and Evaluation
DL	Distance Learning
DoD	Department of Defense
DSP	Defense Standardization Program
EWTGPAC	Expeditionary Warfare Training Group - Pacific
F3	Form-Fit-Function
GCE	Ground Combat Element
ILSTE	Integrated Live-Synthetic Training Environment
ISMT	Indoor Simulated Marksmanship Trainer
ITESS	Instrumented Tactical Engagement Simulation System
LCE	Logistical Combat Element
LD	Line of Departure
LVC	Live, Virtual, and Constructive
LVC-IA	Live, Virtual, Constructive – Integrating Architecture
LVC-TE	Live, Virtual, Constructive Training Environment
M&S	Modeling and Simulation
MAGTF	Marine Air Ground Task Force
MET	Mission Essential Task
MILES	Multiple Integrated Laser Engagement System
MOS	Military Occupational Specialty
MOVES	Modeling Virtual Environments and Simulation

NATO	North Atlantic Treaty Organization
NCO	Non-Commissioned Officer
NDS	National Defense Strategy
NMSO	Navy Modeling and Simulation Office
NPC	Non-Player Character
OA	Operational Area
OpsO	Operations Officer
PEO STRI	Program Executive Officer Simulation, Training and Instrumentation
PFT	Physical Fitness Test
PM ITE	Project Manager Integrated Training Environment
PME	Professional Military Education
PTP	Pre-Deployment Training Program
SEPME	Senior Enlisted Professional Military Education
SESAMS	Special Effects Small Arms Marking System
SOP	Standard Operating Procedure
STE	Synthetic Training Environment
TADSS	Training Aids, Devices, Simulators, and Simulations
T&R	Training and Readiness
TECOM	Training and Education Command
TEEP	Training, Exercise, and Employment Plan
T/O	Task-Organization
TSPG	Training Systems Product Group
TTP	Tactics, Techniques, and Procedures
UAS	Unmanned Aerial System
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
VR	Virtual reality

GLOSSARY OF TERMS

Augmented Reality: Defense Modeling and Simulation Coordination Office

A type of virtual reality in which synthetic stimuli are registered with and superimposed on real world objects; often used to make information otherwise imperceptible to human senses perceptible.

Constructive Model or Simulation: DOD Dir 5000.59-M, January 1998.

Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes.

Entity: DOD Dir 5000.59-M, January 1998.

A distinguishable person, place, unit, thing, event, or concept about which information is kept. (Military Handbook for Joint Data Base Elements for M&S.

Live Simulation: DOD Dir 5000.59-M, January 1998.

A simulation involving real people operating real systems.

Model: DOD Dir 5000.59-M, January 1998.

A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

Modeling and Simulation: DOD Dir 5000.59-M, January 1998.

The use of models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably.

Synthetic Environment: DOD Dir 5000.59-M, January 1998.

Inter-netted simulations that represent activities at a high level of realism from simulations of theaters of war to factories and manufacturing processes. These environments may be created within a single computer or a vast distributed network connected by local and wide area networks and augmented by super-realistic special effects and accurate behavioral models. They allow visualization of and immersion into the environment being simulated.

Simulation: DOD Dir 5000.59-M, January 1998.

A method for implementing a model over time.

Virtual reality: Defense Modeling and Simulation Coordination Office

An environment represented by models and simulations. This environment is interactive, allowing the participant to look and navigate about the environment, enhancing the immersion effect. Also known as virtual environment and virtual world.

Virtual Simulation: DOD Dir 5000.59-M, January 1998.

A simulation involving real people operating simulated systems. Virtual simulations inject human in-the-loop in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a C4I team).

Annotated Bibliography

Primary Sources

Commandant of the Marine Corps. *Annual Training and Education Requirements.* MCBul 1500 W/Admin Change, February 23, 2019.

This source identifies individual and unit training and education requirements that all Marines are directed to adhere to, every year.

Commandant of the Marine Corps. *Advance to Contact.* FRAGO 01/2016, January 19, 2016.

This source offers support to the impetus to develop M&S as a capability, as directed by the 37th CMC.

Commandant of the Marine Corps. *Commandant's Planning Guidance,* 2015.

This source offers support to the impetus to develop M&S as a capability, as directed by the 36th CMC.

Commandant of the Marine Corps. *Commandant's Planning Guidance,* 2018.

This source offers support to the impetus to develop M&S as a capability, as directed by the 38th CMC.

Commandant of the Marine Corps. *Infantry Training and Readiness Manual,* NAVMC 3500.44C, November 04, 2016.

This source offers a general look at the Marine Corps' training standards and policies with descriptive measures of performance. Each occupational field has an associated manual.

Commandant of the Marine Corps. *Marine Corps Force Generation Process.* MCO 3502.6A, June 7, 2013.

This source is an authoritative order that identifies priorities for individual unit and service-level training. It offers a general approach to how units should conduct progressive training.

Commandant of the Marine Corps. *Marine Corps Modeling and Simulation (M&S) Management.* MCO 5200.28A, July 15, 2014.

This source is the senior authoritative directive governing Marine Corps M&S efforts.

Commandant of the Marine Corps. *Marine Corps Readiness Reporting.* MCO 3000.13A, July 18, 2017.

This source identifies the responsibility and frequency for Marine Corps units to report combat readiness of personnel, weapons and equipment.

Commandant of the Marine Corps. *Marine Expeditionary Unit (MEU) Pre-Deployment Training Program (PTP).* 3502.3C, September 13, 2019.

This source details the training requirements for units preparing for deployment. It reinforces the discussion about compounding training requirements for Marine units.

Commandant of the Marine Corps. *Professional Military Education (PME).* MCO 1553.4B, January 25, 2008.

This source details the education requirements for individual Marines as they progress through their careers. It reinforces the discussion about compounding training requirements for Marine units.

Commandant of the Marine Corps. *Systems Approach to Training User's Guide.* NAVMC 1553.1. Washington, DC: Headquarters US Marine Corps, October 27, 2010.

This is the senior authoritative doctrine establishing methods for Navy and Marine units to conduct training programs.

Commanding General, Marine Air Ground Task Force Training Command. *Marine Air Ground Task Force Training Command Integrated Training Exercise Order.* CCO 3500.14A, April 09, 2015.

This source serves as an example of specific and unique training requirements of a service-level, large scale exercise. It reinforces the discussion that training evolutions with vast scope and scale can have a significant physical toll.

Commanding General, Marine Corps Combat Development Command, Deputy Commandant for Combat Development and Integration. *Marine Corps Synthetic Training Enterprise Campaign Plan Draft, version 4.2.* Washington, DC: Headquarters US Marine Corps, May 2019.

This draft plan offers insight into the Marine Corps' plan for integrating the STE, and offers a potential opportunity to expand that environment into live training.

Headquarters US Army. *U.S. Army Training and Doctrine Command (TRADOC) Models and Simulations (M&S) and Data Management.* TRADOC Reg 5-11, November 16, 1998.

This source is the senior authoritative directive governing US Army's M&S efforts.

Headquarters US Marine Corps. *Unit Training Management Guide.* MCTP8-10A. Washington, DC: Headquarters US Marine Corps, May 2, 2016.

This is the authoritative doctrine establishing methods for Marine units to conduct training programs.

Headquarters US Marine Corps. *U.S. Marine Corps Concepts & Programs 2018.* Washington, DC: Headquarters US Marine Corps, 2018.

This source offers insight into current Marine Corps programs or developing programs. It highlights the use of M&S capability in individual and unit training, and the development of the integrated STE concept.

Headquarters US Marine Corps. *Range Safety.* MCO3570.1C. Washington, DC: Headquarters US Marine Corps, February 29, 2012.

This authoritative source identifies the regulations for conducting training at military ranges, including restrictive protocol. It highlights the concept of physically prohibitive elements of training.

Secretary of the Air Force. *Modeling and Simulation.* AFPD 16-10, January 23, 2015.

This source is the senior authoritative directive governing US Air Force M&S efforts.

Secretary of the Navy. *Department of the Navy Modeling and Simulation Management.* SECNAVINST 5200.38A, February 28, 2002.

This source is the senior authoritative directive governing US Navy's M&S efforts.

US Department of Defense. *DoD Modeling and Simulation (M&S) Glossary.* Directive 5000.59-M, January 1998.

This source is the senior authoritative DoD publication defining M&S-related terms.

US Department of Defense. *DoD Modeling and Simulation (M&S) Management.* Directive 5000.59, October 15, 2018.

This source is the senior authoritative directive governing the DoD M&S efforts.

US Department of Defense. *DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A).* Instruction 5000.61, May 13, 2003.

This source identifies the methods for services to acquire M&S capabilities. It highlights the notion that each service is authorized to pursue its own interest, which can detract from interoperability.

US Department of Defense. *Modeling and Simulation (M&S) Master Plan.* Directive 5000.59P, October 1995.

This is the senior authoritative DoD doctrine which identifies the vision for M&S capabilities.

US Department of Defense. *Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)).* Directive 5134.01, April 01, 2008.

This source identifies the DoD decision-making authority for developing M&S capabilities.

The White House. *Summary of the 2018 National Defense Strategy of The United States of America.* Washington DC, 2018.

This source offers the impetus for the DoD to train to operate in a dynamic environment against a highly capable adversary. It supports the notion that identifying physical training venues to meet this directive can be challenging.

Secondary Sources

Cubic Global Defense. *Special Operations Forces – Weapons Engagement Simulation Systems.* San Diego, CA: Cubic Global Defense, 2016.

This source offers detailed information about the capabilities of an instrumentized weapon system, and how it can support simulated training.

Lord, William T. *Air Force Modeling and Simulation Vision for the 21st Century*. Washington, DC: Chief of Warfighting Integration and Chief Information Officer, July 06, 2010.

This source expounds on the Air Force vision for the use of M&S capabilities to support training.

McLaughlin, Steve, Mark Piling, Phillip Weber, Ba Nguyen. "Evolving NATO M&S Interoperability Standards." *Defense Standardization Program Journal* (January-April 2019).

This source touches on the DoD efforts to support standardization across M&S development efforts.

Moore, John S. *Navy Modeling & Simulation Overview for Modeling & Simulation Committee NDIA M&S System Engineering Division Brief*. Office of the Director, Navy Modeling and Simulation Office, April 19, 2016.

This source expounds on the Navy's vision for the use of M&S capabilities to support training.

US Department of Defense. *Department of Defense Modeling and Simulation Body of Knowledge (BOK).* June 2007.

This source provides a catalogue of information related to M&S capabilities. It offers standardized guidance for DoD developers.

Zhang, Lin, Xiao Song, and Yunjie Wu. T*heory, Methodology, Tools and Applications for Modeling and Simulation of Complex Systems.* Singapore: Springer Science + Business Media, 201.

This source offers insight into the challenges and viability of interoperability between simulation programs.

[1] Headquarters US Marine Corps, *Unit Training Management Guide*, MCTP8-10A (Washington, DC: Headquarters US Marine Corps, May 2, 2016), 1-1 – 1-4.
[2] Commandant of the Marine Corps, *Infantry Training and Readiness Manual*, NAVMC 3500.44C, November 04, 2016, 1-2.
[3] Commandant of the Marine Corps, *Annual Training and Education Requirements*, MCBul 1500 W/Admin Change, February 23, 2019.
[4] Commandant of the Marine Corps. *Marine Expeditionary Unit (MEU) Pre-Deployment Training Program (PTP).* 3502.3C, September 13, 2019.
[5] Commandant of the Marine Corps, *Professional Military Education (PME),* MCO 1553.4B, January 25, 2008.
[6] Headquarters US Marine Corps, *Unit Training Management Guide*, MCTP8-10A (Washington, DC: Headquarters US Marine Corps, May 2, 2016), 6-1 – 6-2.
[7] Ibid, 2-1.
[8] Headquarters US Marine Corps, *U.S. Marine Corps Concepts & Programs 2018* (Washington, DC: Headquarters US Marine Corps, 2018), 87 - 89.
[9] Ibid, 90 -94.
[10] Commandant of the Marine Corps, *Infantry Training and Readiness Manual*, NAVMC 3500.44C, November 04, 2016, 1-10 – 1-11.
[11] Headquarters US Marine Corps, *U.S. Marine Corps Concepts & Programs 2018* (Washington, DC: Headquarters US Marine Corps, 2018), 87 – 88, 95 - 102.
[12] Commanding General, Marine Corps Combat Development Command, Deputy Commandant for Combat Development and Integration, *Marine Corps Synthetic Training Enterprise Campaign Plan Draft, version 4.2* (Washington, DC: Headquarters US Marine Corps, May 2019), 2 – 3.
[13] Headquarters US Marine Corps, *U.S. Marine Corps Concepts & Programs 2018* (Washington, DC: Headquarters US Marine Corps, 2018), 98.
[14] The White House, *Summary of the 2018 National Defense Strategy of The United States of America* (Washington DC, 2018), 1.
[15] Commandant of the Marine Corps, *Commandant's Planning Guidance,* 2015, 11. Commandant of the Marine Corps, *Advance to Contact.* FRAGO 01/2016, January 19, 2016, 7 - 8.
[16] Commandant of the Marine Corps, *Commandant's Planning Guidance,* 2018, 17 – 18.
[17] Headquarters US Marine Corps, *Systems Approach to Training User's Guide,* NAVMC 1553.1 (Washington, DC: Headquarters US Marine Corps, October 27, 2010), 3-39, 4-13.
[18] Marines.mil, "Force-on-Force Training Systems," accessed February 3, 2020, https://www.candp.marines.mil/Programs/Focus-Area-2-Training-Simulation/Range-Training-Systems/Force-on-Force-Training-Systems/.
[19] Commandant of the Marine Corps, *Marine Corps Force Generation Process,* MCO 3502.6A, June 7, 2013, 11-12.
[20] Cubic Global Defense, *Special Operations Forces – Weapons Engagement Simulation Systems* (San Diego, CA: Cubic Global Defense, 2016).
[21] Commandant of the Marine Corps, *Marine Corps Readiness Reporting,* MCO 3000.13A, July 18, 2017.

[22] Commandant of the Marine Corps, *Marine Corps Force Generation Process,* MCO 3502.6A, June 7, 2013, 12 - 13.
[23] Commanding General, Marine Air Ground Task Force Training Command, *Marine Air Ground Task Force Training Command Integrated Training Exercise Order.* CCO 3500.14A, April 09, 2015, Enclosure (2).
[24] Range Facility Management Support System (RFMSS), "Scheduling," accessed February 3, 2020, https://home.army.mil/parks/index.php/about/Garrison/DPTMS/scheduling.
[25] Headquarters US Marine Corps. *Range Safety,* MCO3570.1C (Washington, DC: Headquarters US Marine Corps, February 29, 2012), 2, 4, 11-13.
[26] Marines.mil, "Indoor Simulated Marksmanship Trainer," accessed January 15, 2020, https://www.candp.marines.mil/Programs/Focus-Area-2-Training-Simulation/Individual-Training-Systems/Indoor-Simulated-Marksmanship-Trainer/.
[27] Bohemia Interactive, "VBS3 – Virtual Desktop Training & Simulation," accessed January 15, 2020, https://bisimulations.com/products/vbs3.
[28] US Department of Defense, *DoD Modeling and Simulation (M&S) Management,* Directive 5000.59, October 15, 2018, 2.
[29] US Department of Defense, *DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A),* Instruction 5000.61, May 13, 2003, 2.
[30] US Department of Defense, *Modeling and Simulation (M&S) Master Plan,* Directive 5000.59P, October 1995.
[31] US Department of Defense, *Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)),* Directive 5134.01, April 01, 2008, 5 – 6.
[32] Ibid, 5-6.
[33] US Department of Defense, *Modeling and Simulation (M&S) Master Plan,* Directive 5000.59P, October 1995, 2-1.
[34] US Department of Defense, *Modeling and Simulation (M&S) Master Plan,* Directive 5000.59P, October 1995, 4-1 – 4-29.
[35] US Department of Defense, *Modeling and Simulation (M&S) Master Plan,* Directive 5000.59P, October 1995, 2-1.
[36] Steve McLaughlin, et al, "Evolving NATO M&S Interoperability Standards." *Defense Standardization Program Journal* (January-April 2019).
[37] Defense Modeling and Simulation Coordination Office, accessed January 17, 2020, https://www.msco.mil.
[38] Air Force Agency for Modeling and Simulation (AFAMS), United States Air Force, accessed January 15, 2020. https://www.afams.af.mil/About-Us/Fact-Sheets/Display/Article/429786/afams/.
[39] Team Orlando Training Systems Product Group, "Strenthening the Warfighter through Simulation," accessed January 17, 2020, http://www.teamorlando.org/members-of-team-orlando-military-simulation/team-orlando-tspg/.
[40] William T Lord, *Air Force Modeling and Simulation Vision for the 21st Century* (Washington, DC: Chief of Warfighting Integration and Chief Information Officer, July 06, 2010).
[41] PEO STRI, "Systems," accessed January 15, 2020, https://www.peostri.army.mil/Systems/ByOrganization#PM%20ITE.

[42] PEO STRI, "Live, Virtual, Constructive – Integrating Architecture (LVC – IA)," accessed January 15, 2020, https://www.peostri.army.mil/live-virtual-constructive-integrating-architecture-lvc-ia-.
[43] PEO STRI, "Synthetic Environment Core (SE Core)," accessed January 15, 2020, https://www.peostri.army.mil/synthetic-environment-core-se-core-.
[44] Deputy Project Manager – Integrated Training Environment, "PM ITE," accessed January 17, 2020, https://www.peostri.army.mil/2016-12-01_iitsec_tsis_pm_ite.
[45] Marines.mil, "Navy Modeling & Simulation Office," accessed January 20, 2020, https://www.mccdc.marines.mil/Units/OAD/MCMSO/NMSO/.
[46] John S Moore, *Navy Modeling & Simulation Overview for Modeling & Simulation Committee NDIA M&S System Engineering Division Brief*, (Office of the Director, Navy Modeling and Simulation Office, April 19, 2016).
[47] Naval Postgraduate School, "MOVES Institute," accessed January 20, 2020, https://my.nps.edu/web/moves/home.
[48] Headquarters US Marine Corps, *U.S. Marine Corps Concepts & Programs 2018* (Washington, DC: Headquarters US Marine Corps, 2018), 87 – 105.
[49] Ibid, 98.
[50] Commanding General, Marine Corps Combat Development Command, Deputy Commandant for Combat Development and Integration, *Marine Corps Synthetic Training Enterprise Campaign Plan Draft, version 4.2* (Washington, DC: Headquarters US Marine Corps, May 2019).
[51] US Department of Defense, *DoD Modeling and Simulation (M&S) Management*, Directive 5000.59, October 15, 2018, 2, 4.
Secretary of the Air Force, *Modeling and Simulation*, AFPD 16-10, January 23, 2015, 2.
Headquarters US Army, *U.S. Army Training and Doctrine Command (TRADOC) Models and Simulations (M&S) and Data Management*, TRADOC Reg 5-11, November 16, 1998, 9.
Secretary of the Navy, *Department of the Navy Modeling and Simulation Management*, SECNAVINST 5200.38A, February 28, 2002, 3.
Commandant of the Marine Corps, *Marine Corps Modeling and Simulation (M&S) Management*, MCO 5200.28A, July 15, 2014, 1.
[52] US Department of Defense, *DoD Modeling and Simulation (M&S) Glossary*, Directive 5000.59-M, January 1998, 106.
[53] US Department of Defense, *Department of Defense Modeling and Simulation Body of Knowledge (BOK)*, June 2007, 3.
[54] US Department of Defense, *DoD Modeling and Simulation (M&S) Glossary*, Directive 5000.59-M, January 1998, 87, 91-92.
[55] Lin Zhang, Xiao Song, and Yunjie Wu, T*heory, Methodology, Tools and Applications for Modeling and Simulation of Complex* Systems (Singapore: Springer Science + Business Media, 2016), 651-662.
[56] Headquarters US Marine Corps, *U.S. Marine Corps Concepts & Programs 2018* (Washington, DC: Headquarters US Marine Corps, 2018), 104.
[57] Commandant of the Marine Corps, *Commandant's Planning Guidance,* 2018, 17.