Army Science Board
Fiscal Year 2020 Study

Army Modeling and Simulation (M&S)

Final Report
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ASB members and consultants are eminent authorities in the disciplines of science, technology, engineering, math, social science, business, and governance. The Board also draws upon the expertise of senior retired military officers from all branches of service. All are dedicated experts who volunteer their time to provide independent assessments to Army civilian and military leadership.

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EXECUTIVE SUMMARY

This report summarizes the results of the Army Science Board (ASB) study on "Army Modeling and Simulation (M&S)" sponsored by the Secretary of the Army (SECARMY). Consistent with the Terms of Reference (TOR), the objective of the study was to "assess the Army's M&S capabilities in support of strategic decision making, acquisition, training, and test and evaluation (T&E)." Specifically, the study team was tasked with determining Army M&S capability needs, gaps in current Army M&S capabilities to meet these needs, state-of-the-art capabilities external to the Army that can be leveraged to close the gaps, and how the Army is organized and manages talent to meet its M&S needs.

Study Background and Motivation

The SECARMY commissioned this study because the future operational environment (OE) and the Army's operational concept for competing and winning in that environment, Multi Domain Operations (MDO), are substantially different than those defining the conflicts of the past 20 years. In previous conflicts, Joint Forces have had the benefit of superiority in all domains (land, air, maritime, space, and cyber/electronic warfare (EW)) against non-peer adversaries. In future conflicts with peer competitors, Joint Forces will contest in all domains in a more complex and lethal OE across all phases of conflict.

The Army will confront more lethal kinetic systems and a variety of increasingly effective non-kinetic capabilities, including space, cyber, EW, autonomy, AI, and information warfare. Many of these non-kinetic means are already employed with great effectiveness by adversaries in the compete phase of conflict. Additionally, the global trend toward urbanization makes it increasingly likely that the Army will engage in the complex terrain of dense urban areas, bringing with it the requirement to influence the collective behavior of non-combatants.

These increasing complexities necessitate robust M&S capabilities. Army senior leaders have relied on experience and intuition to make important strategic and operational decisions for the past two decades, but the efficacy of innate human factors will diminish when the paradigm upon which they are based changes drastically. To paraphrase one systems analyst, "complex systems defy intuitive solutions."

In response to this future, complex OE, the Army has promulgated MDO as its operational concept, requiring an unprecedented level of System-of-Systems (SoS) interdependencies among heterogeneous, Joint systems. Non-intuitive, innovative concepts of operations (CONOPS) and tactics, techniques, and procedures (TTPs) will be required to fully exploit the potential value of the MDO concept. As a complement to hypothesis-based experimentation, M&S will be critical to define the SoS architecture for MDO and to develop innovative CONOPS and TTPs. Without simulation-based analysis and experimentation, the SoS architecture for MDO will evolve in a piecemeal fashion and will not enable the full capabilities of the operational concept.

The Army has ambitious modernization plans that entail the near simultaneous development of 31 systems. Even in the best of fiscal environments, the resources for such an ambitious plan would be difficult to sustain. Moreover, the defense budget for the foreseeable future will be under pressure, exacerbating the fight over competing demands within DoD's Future Years Defense Program (FYDP). The Army will need to make a solid case for its modernization programs, including an effective advocacy campaign that presents credible combat effectiveness analysis utilizing a full spectrum of M&S tools.

The Army developed its current M&S evaluation tools 20-30 years ago and they reflect the Cold War perspective. If the Army does not revitalize its M&S capability to model future warfare realities, consequences will include: (1) being unprepared, unable to adequately define MDO, and relegated to an Ill-defined role in Joint All Domain Operations (JADO); (2) having modernization systems potentially fail due to inadequate development with proper M&S; and (3) losing DoD and Congressional leaders' confidence in Army assessments and capabilities because of a lack of credible, analytical justification for modernization funding requests.

The potential for realizing these consequences motivated the study and necessitate action to revitalize Army M&S capabilities.

Army M&S Organization, Leadership, and Governance

Six communities in the Army use M&S and their applications vary as follows:

- Analysis – support a variety of strategic and pre-acquisition decisions, including analysis of alternatives (AOA), capability-based assessments (CBA), modernization program prioritization, force design, concept development and CONOPS/TTP evaluation

- Acquisition – supports requirements definition, systems engineering and integration, design development, and verification and validation (V&V) for programs of record

- Experimentation and Test & Evaluation (T&E) – use M&S for experimental/test design, predictions of expected results, V&V of results, and extrapolation of the limited set of test conditions to a broader spectrum of conditions

- Training – uses live-virtual-constructive (LVC) simulations to train forces in the use of systems and to develop proficiency in mission command

- Intelligence – provides Red force assessments for M&S.

The Army Modeling and Simulation Office (AMSO) and a General Officer Steering Committee (GOSC), both operating under the Army Deputy Chief of Staff, G-8, coordinate integration across these communities. These are strictly coordinating bodies. They have no authority for directing horizontal integration of data and/or models across the communities, or for defining and resourcing a coherent, top-down vision and product improvement plan for meeting Army

M&S capability needs. Any integration across the communities is achieved through a coalition of the willing within each community, which is strictly relationship based and therefore, ephemeral. Subsequently, the communities operate essentially as organizational silos with little incentive or forcing function to work together and share data or tools.

Moreover, since the dissolution of the Office of the Deputy Under Secretary of the Army (Operations Research) office over two decades ago, the Army has lacked a single, dedicated senior (SES- or GO-level) leadership position with the responsibility, authority, and accountability for ensuring Army M&S needs are met and for verifying the quality of M&S products or analytical results. Alternately, both the U.S. Air Force and Navy have recently established SES-level leadership positions.

The Army has a cadre of skilled and dedicated M&S practitioners, including Operations Research/Systems Analysis (ORSA) Analysts (FA49), Simulation Operations Officers (SOO) (FA57), and civilian counterparts (1515, etc.). However, over the past several years, the number of these practitioners has gradually declined, with FA49 analysts experiencing a decrease of 55%. Only 250 FA57 personnel are assigned out of a total authorization of 315 personnel. Likewise, despite 229 vacancies, there has been no increase in the number of authorized civilian (1515) analysts. Part of the problem is the competition for resources with industry and other users and the lack of a career path for military personnel to incentivize them to take a FA49/57 position after company command. Consequently, senior leaders have little exposure to M&S and lack an appreciation for the value of M&S and analysis in making informed decisions.

To effectively compete with the private sector and other government agencies for people with M&S expertise, the Army must proactively recruit talent like, for example, the U.S. Air Force, which actively recruits undergraduates in M&S related fields. Once talent is acquired, the Army must establish a robust training and development program to enhance skills. For example, FA57 requires only an 8-week simulation operations course. There are no requirements for advance degrees in M&S related fields for FA57 officers.

Army M&S Technical Capability Needs

The Army must be able to credibly model the combat effectiveness of its forces in the MDO OE. Doing so will require the following M&S capabilities which are not well represented in current Army or Joint models and simulations:

- SoS Interactions – The implementation of MDO will require an unprecedented level of interfaces, interactions, and interdependencies among Army systems and heterogeneous Joint systems. Modeling these interactions will be vital in evaluating Army CE in future MDO scenarios. Army M&S must also account for the impact on measures of effectiveness (MOEs) during degraded connectivity between systems due to adversary actions and counteractions. The definition of the SoS architecture will specify the information exchange requirements among Joint entities on the battlefield to achieve MOEs and mission objectives. Army/Joint M&S must be capable of evaluating

alternative SoS architectures to select a baseline architecture that offers the best level of effectiveness across multiple scenarios and capabilities (current and future, friendly and adversary). The baseline SoS architecture will be necessary to develop interface specifications and information exchange requirements for Army modernization programs. Joint systems will need to be modeled at appropriate levels of fidelity and security classification to conduct these evaluations, driving the need for a distributed simulation framework/environment that facilitates a composable federation of U.S. Army, Air Force, Navy, and Marine models at useable security levels.

- Non-Kinetic Effects – Non-kinetic phenomena and systems have become increasingly important in conflict, including space, communications, Mission Command, cyber, EW, autonomy/AI, human-machine interactions, and Information Operations (IO). While high fidelity models of many of these non-kinetic systems and phenomena exist at the engineering level, embedding them directly into constructive CE models proves technically challenging. For example, space, cyber, and EW M&S and analyses are classified and embedding them into higher level CE models would require that the entire simulation be run at the highest classification level. Alternately, the models need to be run independently to develop algorithms or parametric relationships at lower security levels that represent their effects and that can be input into Force-on-force (FoF) CE models. Parametric modeling of non-kinetic phenomena as functions of multiple, independent variables presents an arduous and time-consuming process that will need to be aided by embedded AI within the engineering models.

- Human Cognition and Behavior – Convergence, a key tenet of MDO, involves the rapid and continuous integration of capabilities in all domains, the EM spectrum, and the information environment. The aim is to optimize effects through cross-domain synergy and multiple forms of attack. Future MDO convergence will require exquisitely synchronized C2 at all echelons, across domains and Services. The Army and DoD need improved modeling of Joint All-Domain Command and Control (JADC2), including the impact of human cognition and behavior on the speed and quality of command decisions. To develop heuristic models of the human dimension with and without AI decision aids, the Army will need LVC simulation capabilities operating in virtual human-in-the-loop and AI software-in-the-loop modes.

- Simulation Enabled Experimentation – The Army must run experiments on its systems within a Joint construct to (a) advance MDO from concept to doctrine, and (b) develop the MDO SoS architecture. It will use M&S to complement and augment live experiments to alleviate the high cost of live exercises and mitigate the limited capability of field experiments that operate across the full spectrum of scenarios, conditions, and Red/Blue system capabilities. A distributed, LVC simulation environment will provide the experimental results used to refine and validate M&S tools. For Joint force evaluations, the LVC environment should have the capability to easily compose an experiment with “plug and play” models of any Joint system at various levels of fidelity and classification.

- Data Management – The availability and consistency of certified data in every domain for kinetic and non-kinetic, Blue/Red systems will drive the need for common data standards, more rigorous non-kinetic effects databases, and certified current and future threat data. Joint data standards are important for sharing common data and composable models across the Services. The Army and other Services should develop rigorously certified databases like the Joint Munitions Effectiveness Manuals (JMEM) for non-kinetic effects. Current threat and counter threat data for M&S uses are limited by security classification. Joint M&S of the future battlefield will need certified threat data at usable classification from DIA; a means for developing authoritative, certified, coherent threat data for future systems; and MDO scenarios with valid threat data.

External Technical Capabilities to Help Satisfy Army Needs

The Army M&S community is working diligently to meet some of these capability needs. However, it has limited capacity to make timely progress within its resource constraints. Fortunately, outside of the Army, noteworthy progress has been made in many critical need areas that the Army should be able to leverage to supplement its efforts:

- Multi-domain federated M&S frameworks – Industry, DARPA, and the other military services are all engaged in developing and/or using federated, multi-domain, multi-security constructive or LVC simulations for multiple applications. These include concept development, CONOPS/TTPs evaluation, simulation enabled experimentation, and training. Defense industry prime contractors have been using LVC SoS integration laboratories (e.g., “virtual warfare centers”) for the past 20 years to support military contract customer needs or internally to understand future customer needs. The U.S. Air Force and U.S. Navy have also been developing federated M&S tools, such as the Advanced Framework for Simulation, Integration, and Modeling (AFSIM), which is purported to have a distributed framework that enables plug & play federated modules. In addition, DARPA’s Assault Breaker II program is developing an advanced M&S environment to support the analysis of cross-domain, cross-Service warfighting constructs.

- High-fidelity engineering M&S tools for non-kinetic phenomena – Many specialized companies have developed high-fidelity, engineering-level M&S tools for use in modeling and evaluating non-kinetic phenomena, including communications networks, cyber and EW. These tend to be stand-alone tools used for constructive simulation and/or hardware/software in the loop emulation, or for product T&E or V&V. The Army has several of these tools in respective Combat Capabilities Development Command (CCDC) labs and in the Data Analysis Center (DAC), but could do better at vertical integration with higher-level combat effectiveness models.

- Human cognitive and behavior M&S and research/analysis – Within academia, FFRDCs and industry, the R&D on modeling human cognition and behavior occurs regularly.

Several of these projects could provide a sound basis for developing a virtual simulation capability for evaluating the human dimension on the speed and quality of command decisions within the JADC2 construct. Additionally, there is a tremendous amount of work on AI/ML algorithms which could be used for applications such as autonomous target recognition and decision aiding. The virtual simulation capability should allow for insertion of AI/ML decision aiding software in the loop combined with operator in the loop to determine effectiveness of AI aided human decision performance.

- Digital Engineering (DE)/Model-Based Systems Engineering (MBSE) – The value of DE/MBSE has been proven on several programs of record and it is used routinely by defense prime contractors and top tier subcontractors on large, complex programs. Its value lies primarily in providing a single, authoritative database for horizontal integration of multiple analytic, design, development, production, and sustainment applications across the acquisition lifecycle.

- Groundbreaking infrastructure capabilities – Several game-changing technologies have emerged over the past decade that enable significant enhancement to M&S capabilities. Among these are cloud-based environments, exponential GPU performance growth, massively parallel computing, and quantum computers.

Army M&S Organizational and Talent Management Capability Needs

The Army must recruit, employ, develop, and retain adequate talent adept in M&S to have the expertise needed to model the complexities of MDO and JADC2. If the Army were to initiate a program to build the talent pool tomorrow, it would not have enough STEM experts to meet its M&S needs. To begin correcting the situation, the Army could unilaterally adopt the following:

- Require more United States Military Academy (USMA) and Reserve Officers Training Corp (ROTC) cadet STEM majors. The USMA does not have a STEM major quota for cadets, and despite the legally mandated Bachelor of Science degree conferred, the most prevalent USMA major is history. The Navy, highly dependent on STEM in its officer corps, mandates a 65% quota for STEM majored midshipmen at the Naval Academy.

- Partner with college and university STEM departments known for producing highly competent graduates in targeted disciplines. Previously, the Army would select junior officers (mostly captains/majors) to attend graduate school for one to three years and post them after graduation at USMA, the Pentagon, or to other major acquisition projects.

- Augment the career path for military personnel to obtain a graduate degree in STEM. The Army can reinfuse STEM into the Service culture by providing opportunities for junior commissioned officers to obtain a graduate education (at MS and PhD levels) in key Centers of Excellence sponsored by the Army. Increasing the number of

professionals with higher academic backgrounds will also help to make the Army a "smart buyer" of new and advanced technology and a better strategic partner in decisions on modernization activities.

- Ensure individuals have (or are eligible for) the appropriate security clearances.

- Expand recruitment efforts to account for the nation's changing demographics. Initiatives exist to broaden the participation of women and minorities in STEM, several of which are supported by the National Science Foundation (NSF), and these funded programs graduate highly skilled individuals. For example, the Directorate for Computer and Information Science and Engineering (CISE) funds colleges and universities to train students in STEM.

Recommendations

The study team's findings and recommendations are presented by topic in the body of the report. In summary, the study team recommend the Army take the following actions:

<u>M&S Development</u>

- AFC – Establish and resource a cross-cutting M&S CFT to develop requirements to enable a suite of federated M&S tools to model and evaluate combat effectiveness of Army systems for the future Joint MDO battlefield

- G8, AFC, ASA(ALT):

  – Partner with DARPA to exploit new advances in Joint MDO Simulation

  – Establish and resource a well-funded agile acquisition program to deliver modern analytical M&S capabilities and a SoSIL to model the Joint MDO operational environment

<u>Talent Management</u>

- G1:

  – Civilians: Increase the opportunity for civilians to obtain graduate degrees in M&S related fields, to include computer programing and systems engineering

  – Officers:

    - Increase the rate of graduate education for FA57 officers

    - Facilitate FA49/FA57 officers to be Operating Force relevant

Resources

- SECARMY
  - Develop a capability to model MDO operations within a distributed Joint LVC simulation framework with appropriate Army models that fix non-kinetic deficiencies starting with the network convergence and resources equivalent to those provided by the Air Force
  - Create and manage a centralized Army Model Improvement Plan (AMIP) to enable S&T advancements for MDO across Army M&S applications and communities

Governance & Organization

- SECARMY
  - Appoint a dedicated, Senior Official on the Secretariat
    - Who is an expert in the M&S field
    - Whose sole responsibilities are leading Army M&S and be the senior advisor to the CSA and SECARMY for M&S
    - Positioned above the heads of the current stovepipes
    - With authority and resources to guide and enforce priorities for advancing Army's capabilities
    - Provides quality control for major Army analyses
    - Who is the focal point for enterprise-wide M&S decision making

1. INTRODUCTION

1.1 STUDY OBJECTIVES, TEAM, SOURCES OF INFORMATION, AND DEFINITIONS

The Secretary of the Army (SECARMY) requested the Army Science Board (ASB) conduct a study entitled, "Army Modeling and Simulation (M&S)." As stated in the Terms of Reference (TOR) for the study (Appendix A), the objective was to "assess the Army's M&S capabilities in support of strategic decision making, acquisition, training, and test and evaluation (T&E)." The TOR also specified the following tasks:

- Identify the range of applications for Army M&S.
- Determine the M&S capabilities needed to deliver this range of applications, including data, algorithms, models, simulations, hardware, and talent.
- Determine the state of current Army M&S capabilities that support the needs identified above. Examine overarching challenges and assess how the Army is organized and trained to deliver M&S capabilities.
- Compare current Army capabilities to those employed by the commercial sector, DOE Labs, and other services and government agencies.
- Examine new techniques being used in the commercial sector that are relevant to supporting strategic decision making, training, and T&E. Consider the uniqueness of Army needs when compared to needs and techniques of other organizations.
- Develop a plan for the Army to modernize M&S.

To meet SECARMY's request, the ASB built a study team (Appendix B) of members and consultants with a broad spectrum of experience and expertise in modeling, simulation, analysis, operations research, digital science, and Army operations. The team received assistance from senior leaders of the Army M&S community, including the Army Futures Command (AFC) G3/5/7, the Army Modeling and Simulation Office (AMSO), the Center for Army Analysis (CAA), and the Army Engineer Research and Development Center (ERDC).

Data gathering on state of the art (SoTA) M&S practices, tools, activities, plans, and talent was conducted by means of extensive visits and video conferences with numerous Army and other military Services and organizations, government laboratories, and private sector companies (Appendix C). The study team also conducted a review of the literature, including previous studies on M&S. Based on its review of the DoD M&S Glossary,[1] the study team adopted the following working definitions:

[1] DOD 5000.59-M DoD Modeling and Simulation (M&S) Glossary. Available at: https://www.msco.mil/MSReferences/Glossary/MSGlossary.aspx.

- **Model** – a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

- **Simulation** – a method for implementing a model over time.

- **Live Simulation** – a simulation involving real people operating real systems.

- **Virtual Simulation** – a simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills, decision skills or communication skills

- **Constructive Models or Simulations** – involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations but are not involved in determining the outcomes.

- **Distributed Simulation** – a disparate set of models and/or simulations operating in a common synthetic environment over a network with two or more nodes. The terms Distributed and Federated are used interchangeably in this report.

1.2 STUDY METHODOLOGY AND STRUCTURE

In the Army, M&S is used for multiple applications (Fig. 1).

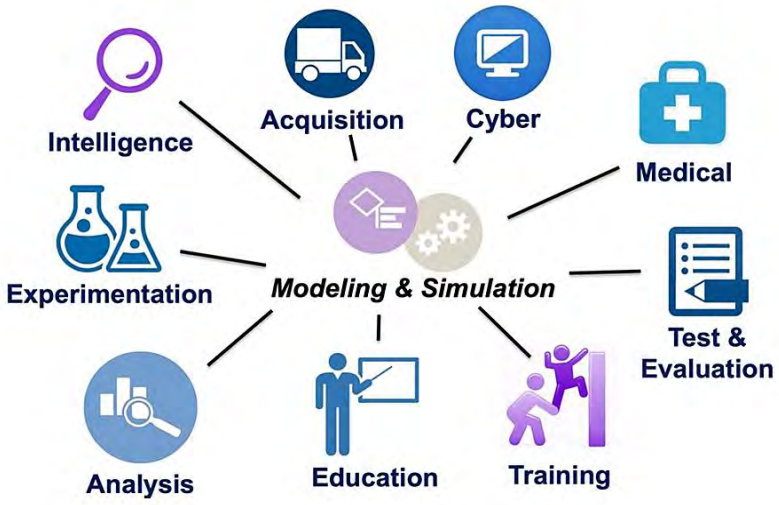

Figure 1. Army Applications for M&S

The Army's M&S organization consists of communities that focus on separate applications, generally operating independently, with no single, senior, dedicated official to enforce integration across applications or to establish an integrated vision and plan.[2]

The study team examined the current organization and status of Army M&S and identified needs and gaps in four areas: (1) governance and organization, (2) M&S technical capabilities, (3) talent management, and (4) resource allocation. Each is addressed in subsequent sections of the report. The study team's findings and recommendations are incorporated into each section.

1.3 THE GOOD NEWS

The study team identified several positive elements within the Army M&S organization:

- Infrastructure components that cover the force and can be linked
- Operations Research/Systems Analysis (ORSA) and M&S talent who understand the limitations of current simulations
- An M&S office and venues to help bring willing members of multiple communities together for discussion of Army M&S needs
- A wealth of kinetic data to support MS&A
- Experience with existing simulators for the current operational environment (OE)

These elements enable the successful employment of M&S capabilities across Army applications. For example:

- The Acquisition community is using M&S extensively to reduce costs and improve system performance.
- Project Convergence, run out of AFC, actively uses live experiments to gather data for Multi Domain Operations (MDO). The latest demonstration included a live-fire simulation with unmanned-to-unmanned teaming, and with drones and satellites relaying target coordinates to ground artillery.

1.4 BACKGROUND AND MOTIVATION FOR THE STUDY

Several previous studies of DoD and Army M&S have identified issues with leadership, governance, skills, technologies, and tools. For example, the Decker-Wagner Review highlighted the need for analytic tools:

[2] Medical and educational applications were not examined in this study.

> The G-8 needs to assess the capabilities, contribution to Army force effectiveness and costs of existing and proposed systems within portfolios, but it does not have an analytic tool to support this effort. The VCSA needs the same capability to support the conduct of CPRs. Even more critically, both the G-8 and the VCSA need analytic tools to aid in examining capabilities, contribution to force effectiveness and costs across capability portfolios. The Army does not have such tools and needs to and validate them to enable the conduct of credible CPRs and tradeoffs among portfolios to support POM [Program Objective Memorandum] and budget decisions, and to justify modernization investment strategies with OSD and the Congress.[3]

Most recommendations for resolving the issues have gone largely unheeded, indicating that the improvement of Army M&S capabilities has not been considered a sufficiently high priority relative to other critical manpower, readiness, and modernization needs. The situation is understandable given the Army's continuous engagement in conflicts over the past 20 years. Wars and other contingency operations have demanded resources that could otherwise have been applied to modernization and capability improvements.

What, then, is the value of conducting yet another study of Army M&S? Why should the ASB expect Army leadership to be any more receptive to M&S improvement recommendations than previously? In short, what is different today that motivates another look at Army M&S capabilities and gaps?

There are several factors:

1. Old Models: New Complex Operating Environment – The future OE and the Army's operational concept for competing and winning in that environment are substantially different than those from the conflicts of the past 20 years. Previously, Joint Forces have enjoyed superiority against non-peer adversaries in all domains (land, air, maritime, space and cyber/EW). In future conflicts with peer competitors, Joint Forces will be contested in all domains in a more complex and lethal OE across all phases of conflict. The technology advances that underscore this rapid evolution in peers' military capabilities are not reflected in Army simulations, which have also failed to take advantage of modern computer science and technology advancements, such as game processing units (GPU) and cloud environments.

Many of the Army's M&S tools in use today were developed around the year 2000 (Fig. 2). Some models, e.g., Joint Integrated Contingency Model (JICM), were developed in the 1990s. Since 2000, computer performance has risen at least 2-3 orders of magnitude. Also, the warfighting paradigm that serves as the basis of these models is largely an attrition-based, kinetic land battle, with kill/loss measures of effectiveness (MOEs). The new complexities and realities of the future battlefield are not well represented.

[3] Army Strong: Equipped, Trained and Ready, Final Report of the 2010 Army Acquisition Review

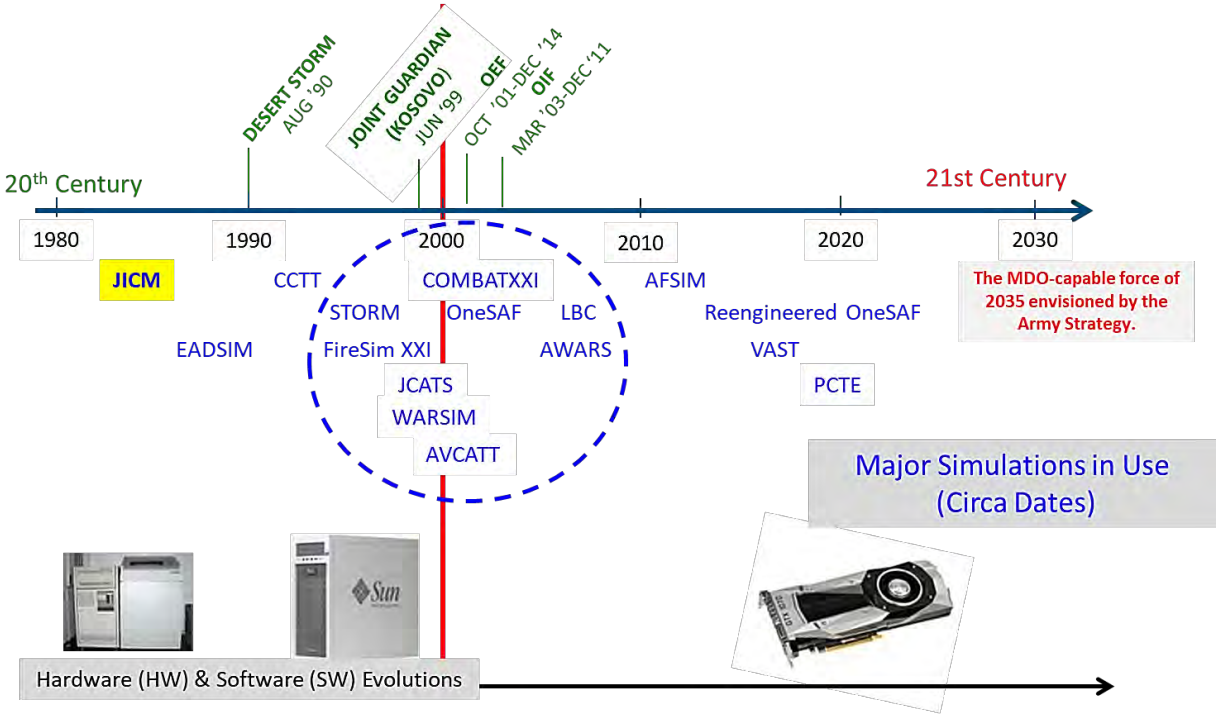

Figure 2. Army M&S Capabilities

Several Army M&S capabilities were developed when computers could provide a few megaflops, when 1 megabit was a high-speed network, and the requirements were to model a future Army of 2000. The oldest model, JICM, is still used today by CAA and Program Analysis & Evaluation (PA&E) for campaign planning. Originally, JICM ran on MicroVAX, and Leonid Brezhnev was the leader of the Soviet Union. Today, petaflop computing drives machine learning (ML) and artificial intelligence (AI), and JICM cannot adequately model MDO.

In a complex, future OE, the Army will face more lethal, kinetic systems as well as a variety of increasingly effective non-kinetic capabilities, such as cyber, electronic warfare (EW), autonomy, AI, and IO. Adversaries already employ several of these non-kinetic effects in the competition phase of conflict. For example, the global trend toward dense urbanization makes it increasingly likely that the Army will conduct operations in urban areas where adversaries have demonstrated influence over the collective behavior of non-combatants. Current Army combat effectiveness (CE) M&S fail to adequately capture the effects of non-kinetic phenomena or human cognition and behavior.

Complex, future Oes will make M&S a critical element of informed decision making. For the past two decades, Army senior leaders have relied upon experience and intuition to make important strategic and operational decisions. This approach will become obsolete, as Army leaders will have limited experience operating in increasingly contested domains. The future OE will defy intuitive solutions. As a result, resource allocation decisions on modernization and force structure/design will rely on M&S and experimentation to a much greater extent than in

previous eras. The Chief of Staff, Army has highlighted the growing importance of M&S in a complex, resource-constrained environment:

> I think modeling simulations is absolutely critical. And it really comes down to, I want to say, resources. We can save money, upfront, by modeling, simulating, whether it is designing prototypes and actually it is amazing what you can do, in a computer right now, before you actually build prototypes…. And the same thing with training, and even testing on our systems. We are experimenting and simulating with the type of units that we are going to develop for multi-domain operations. So, we know whether they will be successful in combat or not.[4]

2. New Operating Concept and Mission Command – In response to the new OE and contested operations in all domains, the Army have promulgated MDO as a new operational concept, with the corollary JADO. The central idea of MDO (and JADO):

> Army forces, as an element of the Joint Force, conduct Multi-Domain Operations to prevail in competition; when necessary, Army forces penetrate and dis-integrate enemy anti-access and area denial systems and exploit the resultant freedom of maneuver to achieve strategic objectives (win) and force a return to competition on favorable terms.[5]

The three tenets of the concepts are calibrated force posture, multi-domain formations and convergence. Convergence is defined as:

> [T]he rapid and continuous integration of capabilities in all domains, the EMS, and the information environment that optimizes effects to overmatch the enemy through cross-domain synergy and multiple forms of attack all enabled by mission command and disciplined initiative. The Joint Force currently converges capabilities through episodic synchronization of domain-federated solutions. Future operations against a near-peer threat, however, will require the Joint Force to conduct continuous and rapid integration of multi-domain capabilities to gain cross-domain overmatch at decisive spaces.[6]

MDO convergence will require an unprecedented level of interfaces, interactions, and interdependencies among heterogeneous Joint systems. Defining SoS architectures will be vitally important for MDO implementation. Also, non-intuitive concepts of operation (CONOPS) and tactics, techniques, and procedures (TTPs) will be required to fully exploit the full potential of convergence. M&S as a complement to hypothesis-based experimentation will be critical to defining the SoS architecture for MDO and to develop associated CONOPS/TTPs. Without simulation-based analysis and experimentation, the SoS architecture for MDO will evolve in a

[4] GEN James McConville, CSA, House Armed Services Committee Holds Hearing on the Fiscal 2021 Budget Request for the Army, Mar 3, 2020
[5] TRADOC Pamphlet 525-3-1, The U.S. Army in multi-Domain Operations 2028
[6] Ibid.

piecemeal fashion and will not enable the full capabilities that could accrue from the MDO operational concept.

MDO convergence will also require a new and more complex Joint All Domain Command and Control (JADC2) system to exquisitely synchronize C2 across all echelons of all services and all domains. The resulting complexity on Army Mission Command of JADC2 adds to and amplifies the complexities of the threat-driven OE.[7]

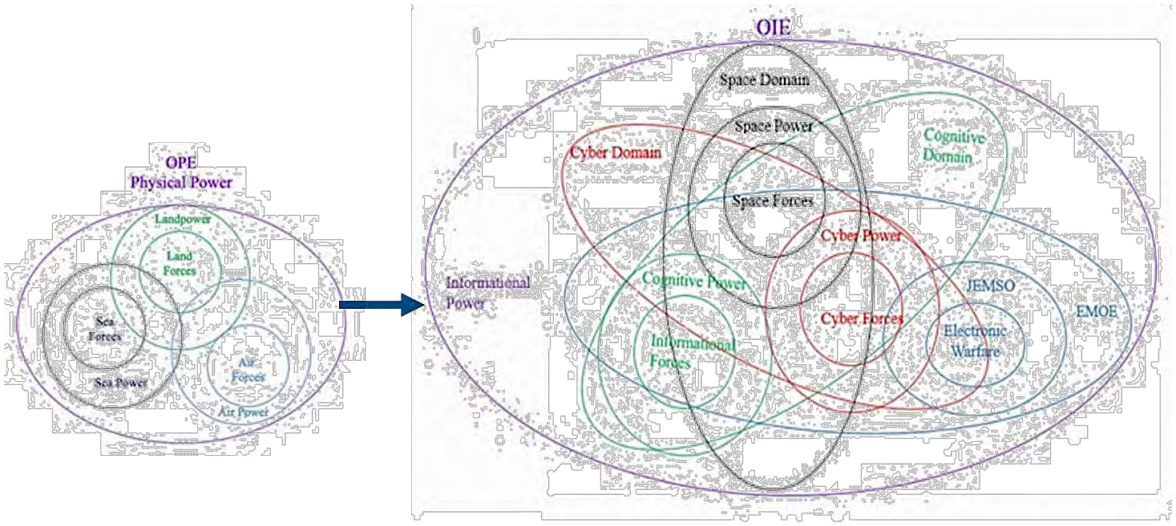

Figure 3. Increasing complexity of the MDO OE

3. Rapid Technology Advancement – Two trends are shaping the competition for technological superiority on the future battlefield: (1) the ubiquitous availability of commercially sourced technology, and (2) the rapid maturation rate of advanced technology. Together, the trends are driving the obsolescence of DoD technologies that depend on protracted product development lifecycles. In such an environment, it is crucial for operational and system requirements to be well-defined to facilitate technology insertion over the product life cycle and for the requirements definition process to be as rapid as possible. Ill-defined requirements lead to acquisition failures, which open a technological gap compared to adversaries who are more agile in product development.

M&S will play a key role in effective and efficient requirements definition. For complex systems like MDO in the future OE, systems analyses using a variety of M&S live-virtual-constructive (LVC) tools will be essential to understand the myriad tradeoffs between variables and to identify the most cost-effective balance of competing requirements. These tradeoffs become critical when material solutions are dependent on rapidly evolving technologies. The Army cannot afford the cost of failed acquisition programs or rapid technological obsolescence caused by ill-defined or non-optimal requirements. It must re-learn to appropriately analyze both the potential and risk associated with developing advanced technologies.

[7] Mission Command of Multi-Doman Operations, Strategic Studies Institute, Sep 2020; pp. 19-20.

4. Advocacy in Fiscally Constrained Environments – The Army's ambitious modernization plans entail the near simultaneous development of over 30 systems. Under the best fiscal conditions, the resources for such an ambitious plan would be difficult to sustain. Moreover, it seems clear that the defense budget for the foreseeable future will be under pressure, exacerbating the fight over competing demands. A solid case and effective advocacy campaign for Army modernizations programs will be essential, and these will rest on credible CE analyses utilizing a full spectrum of M&S tools.

The National Defense Strategy (NDS) Commission was initiated by Congress as part of the 2017 National Defense Authorization Act (NDAA) to provide an independent, nonpartisan review of the 2018 NDS and its shift from counterterrorism to peer- and near-peer competition. Among its findings, the Commission expressed its concern that:

> Making informed decisions about strategic, operational, and force development issues requires a foundation of state of the art analytical capabilities. In the course of our work, we found that DoD struggled to link objectives to operational concepts to capabilities to programs and resources. This deficit in analytical capability, expertise, and processes is intolerable in an organization responsible for such complex, expensive, and important tasks, and it must be remedied.[8]

To address the perceived lack of analytic rigor supporting strategic decisions, the Commission recommended, in part, that new operational concepts be rigorously validated through "experimentation, exercises, and training, and subjected to the systematic analysis necessary to generate the associated time-phased force deployment data (TPFDD)."[9]

Likewise, the GAO noted that:

> DOD often does not perform sufficient up-front requirements analysis via systems engineering on programs to determine whether the requirements are feasible and there is a sound business case to move forward. Programs are proposed with unachievable requirements and overly optimistic cost and schedule estimates and, usually, participants on both the requirements side and the acquisition side are loath to trade away performance.[10]

5. Army Reorganization – One measure contributing to the revitalization of Army M&S is the establishment of the Army Futures Command, which pulls together previously disparate organizations associated with modernization and technology development. Several organizations engaged in M&S, including the Army Training and Doctrine Command (TRADOC)

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[8] Providing for the Common Defense: The Assessment and Recommendations of the National Defense Strategy Commission.

[9] Ibid.

[10] GAO Report 15-469, DEFENSE ACQUISITION PROCESS, Military Service Chiefs' Concerns Reflect Need to Better Define Requirements before Programs Start

Analysis Center (TRAC), the DAC and the battle labs now reside under a single command, providing an opportunity for improved integration of M&S tools and skills.

In summary, the motivation for conducting another study on Army M&S is driven by the need for Army M&S tools to model the new, complex OE, the new operational concept, MDO, and the non-intuitive CONOPS/TTPs needed to implement MDO. Current Army M&S tools used to evaluate CE were developed 20-30 years ago and reflect obsolete concepts skewed to kinetically dominated CONOPS and MOEs. If it continues to use these M&S tools: (1) the Army will be unprepared for the new realities of warfare, unable to adequately define MDO, and relegated to subordinate roles in JADO; (2) modernization systems may fail or be cancelled because of misdirected or misaligned development; and (3) DoD and Congressional leaders' confidence in Army assessments and capabilities will degrade due to a lack of credible analytical justification for funding requests.

1.5 BOTTOM LINE UP-FRONT

Army M&S is a large, inefficient, mostly software-driven enterprise with over $2 billion in the POM. While supported by talented personnel, its capabilities and limitations are poorly understood by senior Army leaders. It is organized as a set of communities (analysis, acquisition, experimentation, training, T&E, and intelligence). The communities are managed as an assemblage of diverse, competing fiefdoms (for funds) under a General Officer Steering Committee (GOSC). They operate independently, with no dedicated senior leader to enforce horizontal integration or to establish M&S priorities consistent with an overarching vision.

Considerable disparity exists among the communities, creating a lack of cohesiveness and the fragmentation of advocacy, R&D, programs, and sustainment of M&S tools and capabilities. Training and acquisition activities tend to be more aligned while analysis lacks integration. The resulting structure creates redundant platforms; maintains old, incoherent software and disjointed data; and underfunds R&D needed to address persistent and well-known problems. Despite having the most people and talent among the military Services, Army M&S is viewed as inferior to the other Services and slow to response to senior leader needs.

Current Army M&S tools inadequately model MDO/JADO and emerging critical, non-kinetic phenomena and therefore cannot answer significant questions related to the future, complex, operational and information environment.

Despite the severity of these issues, they can be fixed with a plan for governance and organization, M&S development to meet capability needs, talent management, and resources.

2. SOTA EXTERNAL CAPABILITIES FOR M&S DEVELOPMENT

The use of computers by the Army for M&S dates to the development of ENIAC, used in the 1940s to understand atomic weapons effects. It was not until the 1980s that the Army innovated and used computer-based simulations more broadly. Then, digital computers became inexpensive enough to be used in Army training systems, tank simulators, and constructive simulations for wargaming. For example, battalion staff exercises used the Army Training Battle Simulation System (ARTBASS), which had then SoTA 3D graphics. Armor Soldiers trained endlessly on the Unit Conduct of Fire Trainer (UCOFT) with virtual sabot rounds, competing to win the Canadian Trophy for best NATO tank gunnery team. (Fig. 4).

Figure 4. Army Training Battle Simulation System with Perkins-Elmer 3210 (l,c) and Unit Conduct of Fire Trainer with MicroVAX II ®

The pace of disruption for M&S technology was demonstrated by U.S. the victory in Operation Desert Storm. It also challenged the companies providing the technology. Perkins Elmer could not compete and quickly sold its minicomputer business, while Digital Equipment Corporation, which made the MicroVAX, disappeared in mergers. The Army still uses a version of UCOFT today, now called the Advanced Gunnery Simulator.

Recent, explosive growth in processing power, microelectronics, computer vision, and transmission technologies has created phenomenal potential for refinements and expansion in M&S capabilities in industry, government labs, and academia. Laptops are approaching super-computing capability with modularity in parallel processing GPUs. Digital twins, AI, ML, and other SoTA techniques provide potential value to the military in terms of improving M&S and allowing for rapid adaptability. Modern, algorithmic enhanced capabilities may also impact the lifecycle cost of weapons in terms of downtime and maintenance expenditures.

2.1 FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDC) & NATIONAL LABS

The national laboratories have been involved with the M&S of combat operations for almost a half century. Because of a strong scientific legacy, it was natural for the laboratories to analyze and study conventional military forces by mathematical-statistical methods. The way modelers at these institutions approached the M&S for combat operations reflected many of the lessons learned over decades of modeling nuclear weapons. Specifically, modelers leveraged years of using Monte Carlo calculations to develop a stochastic approach to modeling combat.

Experience had shown that these kinds of calculations usually reflected the most accurate way to model phenomena.

This approach led to modeling detailed aspects of conventional war, rather than aggregate modeling of large units, and it required tracking individual events down to extremely high detail (e.g., Soldier or combat vehicle level), then integrating the data into cohesive models of combat and maneuver by larger units, like companies, battalions, brigades, or even divisions. The greater dependence on large scale computing required by this kind of approach to modeling was made possible because the modelers had access to extremely fast computers with large memory space that had been developed while modeling nuclear weapons.

In the 1970s, the Lawrence Livermore National Laboratory developed a combat simulation model known as Janus that included an analysis of the effects of tactical nuclear weapons on the battlefield. This was truly a stochastic model in which individual Soldiers and combat vehicles were tracked during combat. The DoD Test and Evaluation Office determined casualties and CE based on calculations using experimental data.

The RAND Corporation made a comprehensive effort in 1975 with a landmark publication, J. A. Stockfisch' report entitled "Models, Data, and War: A Critique of the Study of Conventional Forces." He laid out some of the basic principles needed for the M&S of combat forces to produce reliable, useful results for the Services. Ironically, Stockfisch identified one of the major problems with the M&S endeavor at the time lay with the leadership of the Services, who did not appear to be well versed in using operational and systems analyses to make decisions.

2.2 HIGH-FIDELITY ENGINEERING M&S TOOLS FOR NON-KINETIC PHENOMENA

Many specialized companies have developed high-fidelity, engineering level M&S tools for use in modeling and evaluating non-kinetic phenomena, including communications networks, cyber and EW. These tend to be stand-alone tools for constructive simulation and/or hardware/ software in the loop emulation for performance evaluation, or for product T&E or V&V. The Army has several of these tools in respective CCDC labs and in DAC. Better vertical integration of these engineering tools with higher-level CE models would be more advantageous–either via directly embedding them into the CE models or using them to develop parametric relationships for insertion into the higher-level models.

2.3 HUMAN COGNITIVE AND BEHAVIOR M&S AND RESEARCH/ANALYSIS

The R&D in understanding and modeling human cognition and behavior is widespread within academia, FFRDCs and industry. Several of these projects could provide a sound basis for developing a virtual simulation capability for evaluating the human dimension on the speed and quality of command decisions on CE within the JADC2 construct. A tremendous amount of work on AI/ML algorithms also needs to be accomplished for applications such as autonomous target recognition and decision aiding. The virtual simulation capability should allow for insertion of

AI/ML decision aiding software in the loop in conjunction with operator in the loop to determine effectiveness of AI aided human decision performance.

2.4 GROUNDBREAKING INFRASTRUCTURE CAPABILITIES

Several game-changing technologies have emerged over the past decade that enable significant enhancement to M&S capabilities. Among these are cloud-based environments, exponential GPU performance growth, and massive parallel computing.

Army M&S suffers from a lack of investment in several key technologies, such as non-virtual simulations. Virtual simulation involves real people interacting with a virtual system, the primary focus of the Synthetic Training Environment (STE) Cross Functional Team (CFT). Constructive simulations are programs where almost all the interactions apart from human decision making occur inside the computing environment. In the Army, constructive simulations are primarily used for training echelons at battalion and above (e.g., Warsim) and in campaign models (e.g., JICM) used to understand Army level impacts of MDO.

The Army does not plan to develop a new constructive simulation until the 2030s, long after it plans to develop its modernization priorities (Fig. 5).

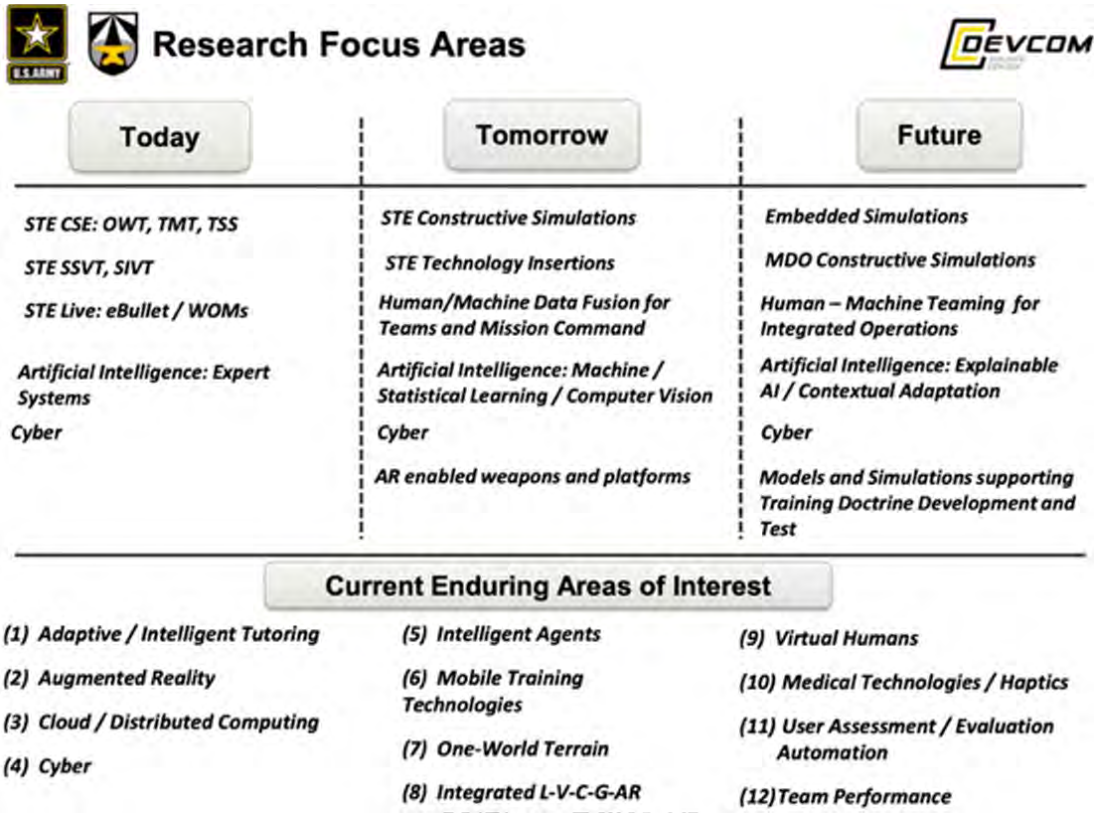

Figure 5. Research Focus Areas

The Defense Advanced Research Projects Agency (DARPA) has several programs under development that support Army M&S improvements:

- **Assault Breaker** – addresses challenges posed by near peer competitors that pace requirements for the Army's MDO capabilities. The program will tie advanced M&S into an interactive experiment environment to support the exploration of complex, interdependent warfighting approaches that capture the future of warfighting. Two major objectives:
  - First objective–architect warfighting operational constructs based on new and emerging technologies and capabilities.
  - Second objective–develop an advanced M&S environment to support analysis of true cross-domain (seafloor to space), cross-Service, warfighting constructs.

- **Safe Sim** – an all-domain, Multi-Level Security (MLS) enabled M&S environment addressing the Army's need to perform mission-level M&S. Senior-level military decision makers, technology developers, and acquisition professionals will use it to develop CONOPs, force structure composition, resource allocation, and targeted technology insertion. Its primary sponsors are the Air Force and the Navy, but the director of CAA is in discussion with DARPA regarding Army participation.

- **LogX** – Aims to build a capability to work alongside existing logistics information systems to exploit the recent migration of logistics information into digital formats and the cloud. The goal is to develop and demonstrate software for real-time logistics and supply chain system situational awareness (diagnosis), future state prediction (prognosis), and assessment of resilience at unprecedented scale and speed. It is primarily sponsored by The Defense Logistics Agency (DLA) and U.S. Transportation Command (TRANSCOM) but The Combined Arms Support Command and Sustainment Center of Excellence (CASCOM) could potentially benefit given the Army's new tasking to model contested Joint logistics in the Pacific.[11]

2.5 DIGITAL ENGINEERING (DE)/ MODEL-BASED SYSTEMS ENGINEERING (MBSE)

Defense prime contractors and top tier subcontractors routinely use DE and MBSE on large, complex programs. The value of DE/MBSE has been proven over the entire acquisition life cycle on several programs of record. Its value lies primarily in providing a single, authoritative database for horizontal integration of multiple analysis, design, development, production, and sustainment applications across the acquisition lifecycle. A digital model or digital twin provides an important advantage with the ability to prototype a system before committing to fabrication and production.

[11] Hearing before the House Armed Services Committee, Subcommittee on Intelligence and Emerging Threats and Capabilities (March 28, 2019).

Computer Aided Design (CAD) M& tools provide an exact definition of a system in 3D solids and in a single authoritative database. Once modeled, the digital twin can be used for multiple systems engineering, DE, production engineering, and maintenance engineering. For example, the digital twin for an Army system such as Future Vertical Lift (FVL) would provide the exact data on the planform shape, leading edges, propulsion inlet and nozzle, rotor system, windows, doors, seals, sensors, and protuberances as input to the Radar Cross Section (RCS) and infrared signature analysis tools. The exact definition of all structural components would serve as input into high fidelity structural analyses. But digital twins are not limited to physical systems. They can also be used for communications networks or other electromagnetic systems to prototype the systems and perform design/performance tradeoffs.

The DoD has a joint program to develop an integrated suite of modern computational engineering tools within an architecture that aligns both acquisition and operational business processes. The suite includes models, simulations and related capabilities, and trade space assessment and visualization tools. The Army is implementing a lifecycle approach for the extensive and complex product data required in the engineering design, acquisition, and sustainment of military systems that is being adopted by the Army CCDCs (Fig. 6).

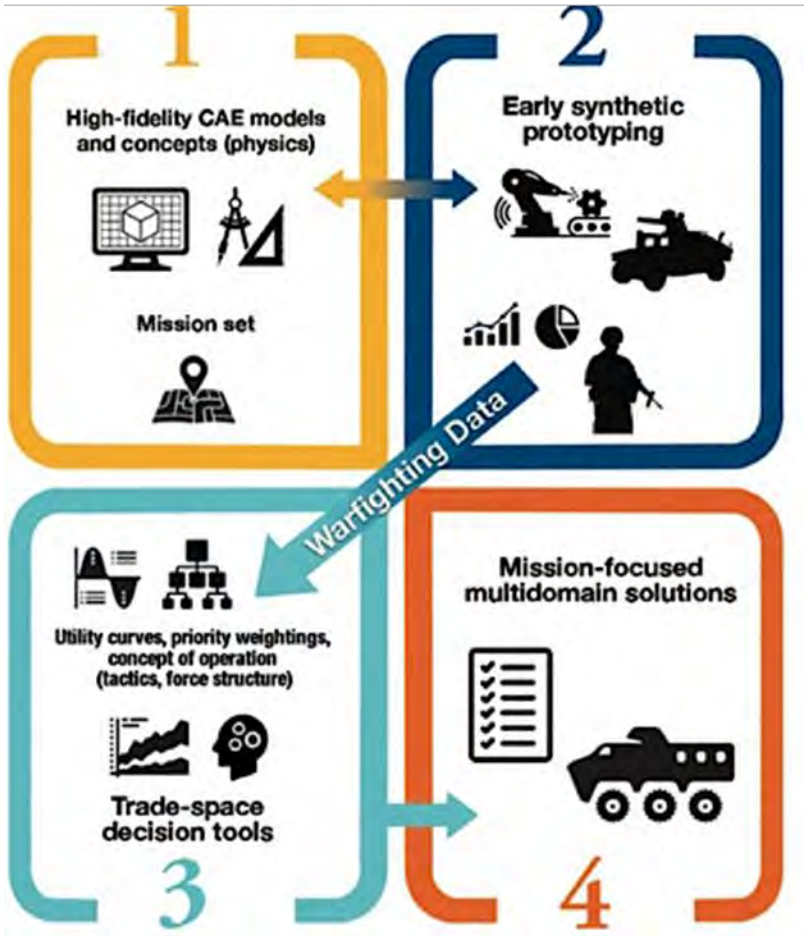

Figure 6. DE for M&S

However, several missing links or gaps exist in commercial DE:

- Little to no integration with combat models such as OneSAF for understanding system effectiveness with respect to TTPs.
- Lack of weapons system data shared with training system developers.
- Limited, non-real-time feedback mechanisms from testing and logistics operations to adapt the models.
- No global management of the processes involved.

Digital twin technology shows potential for Army applications but much of the data produced for DE is often proprietary (not owned by the Army) though there are several examples with the CCDC Ground Combat Vehicle robotics program.

Companies such as Northrop Grumman are using MBSE and software development (Dev) and IT operations (Ops) (DevOps) to rapidly evolve their systems. To replicate commercial DevOps and assure Army M&S has rapid, continuous adaptability and improvement, the Army will need common M&S platforms, data, and algorithms across the enterprise.

The Air Force developed Simulator Common Architecture Requirements and Standards (SCARS) to transform the simulation enterprise, partnering with L3 Harris on $900M IDIQ. They are also a participant in the DARPA Sim Safe program. For its part, the Army could use operational concepts from Project Convergence that co-evolve with technology and support rapid incorporation of user feedback.

3. M&S DEVELOPMENT

3.1 M&S CAPABILITY NEEDS

Will the Army have the means to credibly model the CE of its forces in MDO and Joint operations? Modeling MDO will require capabilities which are not well represented in current Army or Joint M&S, including an unprecedented level of interfaces, interactions, and interdependencies among Army and heterogeneous Joint systems. Modeling these interactions–and the impact on MOEs during degraded connectivity due to adversary actions–will be critical to evaluate MDO scenarios. The Army will need to define the SoS architecture which will specify the information exchange requirements among Joint entities on the battlefield. Army and Joint M&S must evaluate alternative SoS architectures to select a baseline that offers the best level of effectiveness across multiple scenarios. The baseline SoS architecture will also help develop interface specifications and information exchange requirements for Army modernization programs. Joint systems will need to be modeled at appropriate levels of fidelity and security classification to conduct these evaluations, which drives the need for a distributed simulation framework that facilitates composable federation of each Service's models at useful security levels in a common environment. The framework, a SoS Integration Laboratory (SoSIL), will enable the exploration of acquisition concepts before contracting for design and the development of requirements for future combat systems. Integrated with live exercises, such as Project Convergence, the SoSIL would serve as an ideal means for designing exercises, predicting the results, and providing feedback from the exercises to refine and validate the M&S tools.

It is likely that MDO will require innovative CONOPS/TTPs to be effective. Currently, the Army evaluates CE with constructive FoF models (campaign, theatre, mission, or engagement) which do not lend themselves well to evaluating alternative CONOPS/TTPs. Typically, CONOPS and TTPs are defined through table-top exercises and captured as a set of conditional rules that are input into the constructive model. Once developed and inserted, the rules cannot be readily changed, making parametric assessment of alternative CONOPS/TTPs difficult and time consuming. It is not unusual for development of a new scenario and associated CONOPS/TTPs to take 6 months, a lag that precludes providing answers to any senior leadership questions in a timely manner. A better tool to evaluate alternative CONOPS/TTPs would involve a distributed simulation framework operating primarily in a constructive mode but with a virtual component to allow real-time operator-in-the-loop interactions to adjust he CONOPS/TTPs.

3.1.1 MODELING NON-KINETIC EFFECTS ON CE

Non kinetic phenomena and systems have become increasingly important in warfare, including space, communications, Mission Command, cyber, EW, autonomy/AI, human-machine interactions, and IO. While high fidelity models of many of these non-kinetic systems and phenomena exist at the engineering level, embedding them directly into constructive CE models is challenging for technical and security reasons. For example, space, cyber, and EW

M&S and analyses are highly classified, so embedding them into higher level CE models would require that the entire simulation be run at the highest classification level.

Alternatively, the engineering level models can be run independently at appropriate classification to develop algorithms or parametric relationships at lower security levels that represent their effects. These can then be input into FoF CE models. Because of the large number of independent variables, parametric modeling of non-kinetic phenomena as functions of the variables is an arduous and time-consuming process. AI algorithms within the engineering models may prove to be valuable as a means for developing the relationships.

3.1.2 MODELING OF HUMAN COGNITION AND BEHAVIOR

In MDO, convergence is the rapid and continuous integration of capabilities in all domains, the Electromagnetic spectrum (EMS), and the information environment. Convergence requires exquisite synchronization among C2 at all echelons across all domains and services. Improved C2 modeling is needed of Joint C2 systems (i.e., JADC2) and of the impact of human cognition and behavior on the speed and quality of command decisions. A LVC simulation capability operating in virtual human-in-the-loop and AI software-in-the- loop modes will be important for developing heuristic models of the human dimension with and without AI decision aids.

The continuous growth of urban centers throughout the world also places a premium on the need for understanding and modeling the human dimension. The role of non-combatants is an important factor influencing Blue Force CONOPS and TTPs in urban scenarios. Non-combatant behavior in either aiding or thwarting Red and Blue Forces will be a critically determining factor in urban warfare and must be modeled to evaluate CE and CONOPS/TTPs.

3.1.3 SIMULATION ENABLED EXPERIMENTATION

Experimentation of Army systems with Joint systems will be a critical component of a campaign plan to advance MDO from a concept to doctrine and to develop the MDO SoS architecture. M&S complements and augments live experiments because of the high cost of live exercises and the limited capability of field experiments to operate across the full spectrum of scenarios, conditions, contingencies, and Red/Blue system capabilities. A SoSIL distributed LVC simulation environment will provide M&S/Experimentation synergy with the experimental results used to refine and validate M&S tools. For Joint force evaluations, the LVC environment should have the capability to easily compose an experiment with “plug and play” models of any Joint system at various levels of fidelity and classification.

3.1.4 DATA MANAGEMENT

The availability and consistency of certified data is critical in every domain, for kinetic and non-kinetic systems, both Blue and Red. The Army needs common data standards, more rigorous non-kinetic effects databases, and certified current and future threat data. Common Joint data standards are important for sharing of data and composable models across the Services.

Rigorous, certified databases (like the Joint Munitions Effectiveness Manuals (JMEM) for kinetic effects) are needed for non-kinetic effects,

The Army also needs coherent threat data for both current and future threats that can be used across all its models. Threat and counter threat data for M&S purposes are limited due to classification. Joint M&S of the future battlefield will need certified threat data at usable classification from DIA; a means for developing authoritative, certified, coherent threat data for future systems; and MDO scenarios with certified threat data. A senior intelligence official from TRADOC G2 provided the study team with the following comments on threat modeling issues that need to be resolved:

- Our need to model RED systems and processes to a very detailed level even for training MDO is going to be an expensive proposition and likely the long pole in the tent.

- Everyone needs to use M&S tools to solve the same problem. There must be an oversight process that ensures consistency in threat data used and the simulation algorithms that describe how the data will interact. Home grown threat simply confuses comparison of outcomes across M&S tools.

- Army M&S is driven by Killer-Victim Scorecards. Other factors that affect the outcomes of battle are modeled poorly if at all. Modeling the OE is an afterthought.

- The holistic battlefield system from threat observables (the signatures produced by threat activities or platforms in the context of time) to sensors of all types that can "see" the threat observable, PED, to the command-and-control system that moves the "observations," and finally the command processes that produce a decision that changes the battlefield dynamic is simply not modeled very well. We overcome some of this by man-in-the-loop wargames.

- BLUE systems and process flows are modeled exquisitely; RED is whatever we can throw together that kind of sort of looks right. Surrogation is a huge issue.

To summarize: as M&S technology continues to advance at a rapid pace, it will enable the development of M&S tools that can fill the Army's capability needs, including DE, MBSE, cloud computing environments, and high-speed computing enabled by GPUs. The Army, other Services, DARPA, and industry are all working to exploit these advances to greatly improve M&S capabilities. The Army M&S community has limited capacity to make timely progress. Fortunately, noteworthy progress is being made by industry in many critical need areas that the Army should be able to leverage to supplement its own internal efforts.

3.2 DISTRIBUTED M&S FRAMEWORKS AND CLOUD COMPUTING ENVIRONMENTS

Industry, DARPA, and the other military Services are all engaged in developing and/or using federated, multi-domain, multi-security constructive or LVC simulations for multiple

applications. Defense system prime contractors have been using LVC SoSILs for the past 20 years for internal purposes (e.g., understanding future customer needs for Independent Research and Development (IRAD) prioritization) or under contract with the Services to support customer specific needs. The Air Force and Navy have also been developing federated M&S tools, such as the Advanced Framework for Simulation, Integration and Modeling (AFSIM), which is purported to have a distributed framework that enables "plug & play" federated modules. The DARPA Assault Breaker II program is developing an advanced M&S environment to support analysis of cross-domain cross-Service warfighting constructs.

Advances in cloud computing (Fig. 7) provide the means for hosting the run time infrastructure as well as the federated models that can be accessed at distributed sites. For Example, The Army OneSAF BiFrost environment is a Cloud-enabled/Service-Oriented Architecture (SOA) permitting simulations to share using modern commercial approaches and technology.

Figure 7. Cloud Architecture

The DoD cloud strategy recognizes the Services suffer from multiple, disjointed, and stovepiped information systems distributed across modern and legacy infrastructure around the globe. The problems raised by this impact the ability to make timely, data-driven decisions. According to the strategy, only cloud computing, rather than traditional data centers, will "enable the department to harness the full power of its data and information systems."[12] This raises the question of whether Project Convergence could model MDO as a digital twin in the cloud. Digital twins integrate IoT, AI, and ML to create living digital simulation models that update and change as their physical counterparts change, which may fit MDO.

3.3 THREAT REPRESENTATION

The Army needs to do a better job modeling adversary systems with consistency in threat data, particularly in federations composed of multiple simulations. Currently, there is no Army

[12] Shopp, Brandon. "DOD Cloud Strategy Aids Information Dominance." Signal; 3 Feb 2020.

oversight or enforcement of baseline threat data in homegrown models, and consistency is essential to experimentation in MDO. Going forward, the Army needs to do more that attrition modeling with killer victim score cards to understand the future OE. White carding that has no basis in reality will no longer be useful. In addition, the Army will have to develop an understanding of adversaries' decision processes. This problem will grow exponentially with advancing AI/ML, as demonstrated with counter- Integrated Air Defense System programs.

3.4 SOSIL

Currently, the Army has no LVC SoSIL or digital twin to conduct simulation-based experimentation of alternative MDO SoS architectures, and therefore, no associated method to exploit the data from Project Convergence. Moreover, the Army lacks an LVC simulation framework to develop requirements for future combat simulations and analytic tools.

Ideally, a SoSIL would:

- Include models the Information Operational Environment (IOE)
- Have trained analysts and developers
- Provide “Operator-in/on-the-loop” to generate data on cognitive effects
- Be in a government-owned cloud-based architecture

3.5 M&S DEVELOPMENT FINDINGS AND RECOMMENDATIONS

The study team made the following findings:

- Most critically needed M&S capability: credibly model Army combat effectiveness in Joint MDO operational environment
- Need a distributed Joint LVC simulation framework (i.e., SoSIL) to facilitate federation of Army system models with accredited USAF and USN system models in a common synthetic environment to:
  - Evaluate Joint SoS architectures for effectively implementing MDO and establish interoperability requirements
  - Define interface & information exchange specs for Army Big 6+2 systems with Joint systems
  - Integrate M&S with Project Convergence experiments to support experiment design and provide experimental data feedback loop for VV&A MDO M&S

  - Provide virtual human-in-the-loop and AI software-in-the- loop modes for developing heuristic models of the human dimension with and without AI decision aids

  - Provide a digital twin of Army communications networks to conduct simulation-based prototyping of network improvements required for MDO

- New/improved models needed to:

  - Better integrate non-kinetic effects into force-on-force (FoF) models, e.g., space, cyber, EW, autonomy/AI, IO

  - Capture future weapons effects, e.g., hypersonic missiles, long-range cannons & high-speed rotorcraft

  - Incorporate improved C2 modeling of the C2 synchronization that MDO convergence demands at all echelons across all domains and services

  - Assess the impact of human cognition & behavior on the speed and quality of command decisions

- Need more M&S "life blood" experimental data for VV&A that:

  - Are collected and stored using common data standards, and readily accessible

  - Drawn from accredited databases of future MDO scenarios, future threats, and Joint systems/effects

Based upon these findings, the study team made the following recommendations:

- AFC – Establish and resource a cross-cutting M&S CFT to develop requirements to enable a suite of federated M&S tools to model and evaluate combat effectiveness of Army systems for the future Joint MDO battlefield

- G8, AFC, ASA(ALT):

  - Partner with DARPA to exploit new advances in Joint MDO Simulation

  - Establish and resource a well-funded agile acquisition program to deliver modern analytical M&S capabilities and a SoSIL to model the Joint MDO operational environment

4. TALENT MANAGEMENT

For over a decade, military officials have cited the need to recruit and develop more STEM professionals to meet the challenges of a dynamic national security environment. Before the gaps can be closed, Army culture must evolve to appreciate the "Soldier-scholar equally esteemed as the muddy boots Soldier."[13] Until then, the Army will face challenges trying to entice and encourage its personnel to pursue career paths they have been conditioned to perceive as potentially limiting for promotion. In stark contrast, the industry and commercial sectors not only recognize the significant economic value provided by advanced technical expertise, they also actively recruit STEM professionals and incentivize the assignments with higher salaries and more flexibility than the military offers. The competition continues to limit the talent pool from which the Army might draw and/or retain potential M&S professionals.

Currently the Army (1) does not designate ORSA FA49s or SOO FA57s until after company command; and (2) does not provide a clear career path or opportunities for the FA49s or FA57s to rise to the flag officer level, thereby ensuring a process that unfairly rates them with Operating Force equivalency for General Officer promotions opportunities. Furthermore, the Army's minimal investment and lack of commitment to advancing the active Army and civilian M&S expertise with graduate degree work is alarming. Approximately 12% of FA57s have M&S related master's and PhD degrees, and only 1.5% are sent to graduate programs each year.

The Army personnel system, "requires officers to successfully navigate a series of wickets to remain competitive for advancement. The result is to reward tactical expertise while capping the careers of the best strategic minds."[14] The Army's cultural biases and promotion practices that discriminate against the intellect have been readily apparent for some time, as noted by retired personnel and defense policy experts. For example:

> Spending time earning a civilian graduate degree, teaching at West Point, or serving in a broadening assignment away from troops was quietly denigrated as 'taking a knee' and often harmed the career prospects of those who had done so.[15]

Current Army practices reflect and embody 20th century environments, falling short of 21st century expectations and demands. Consequently, the Army remains ill-prepared to adequately model the game-changing technologies anticipated in the future character of warfare, and its leaders risk making ill-informed decisions.[16]

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[13] War on the Rocks "Soldier-Scholar: Anti-Intellectualism in The American Military," James Joyner, Aug. 25, 2020, Available online: https://warontherocks.com/2020/08/soldier-scholar-pick-one-anti-intellectualism-in-the-american-military/

[14] Ibid.

[15] War on the Rocks "Six Ways to Fix the Army's Culture," David Barno and Nora Bensahel, Sep. 6, 2016, available online at https://warontherocks.com/2016/09/six-ways-to-fix-the-armys-culture/

[16] The Operational Environment and the Changing Character Of Warfare, TRADOC Pamphlet 525-92; available online at https://adminpubs.tradoc.army.mil/pamphlets/TP525-92.pdf

Given the rapidly evolving complexity of threats posed by peer adversaries, the Army cannot afford to lag in military M&S capabilities. The Army must aggressively ramp up its efforts to recruit, employ, develop, and retain adequate M&S talent to meet the complexities of MDO and JADC2. In the interim, M&S shortfalls will continue to exist, so to address the escalating need, the study team recommends the Army G1 unilaterally adopt the following:

Recruit

- Expand and modify recruitment efforts to account for changing demographics. Initiatives exist to broaden the participation of women and minorities in STEM, several of which are supported by the National Science Foundation (NSF), which graduate highly skilled individuals. For example, the Directorate for Computer and Information Science and Engineering (CISE) funds colleges and universities to train students in STEM, and the Army could easily recruit individuals from this program and others like it.

- Establish a percentage quota (≥ 25%) for USMA and ROTC cadet STEM majors. Despite the legally mandated BS degree, the most prevalent USMA major is history, i.e., cadets receive a BS in History. Comparatively, the Navy, highly dependent on STEM in its officer corps, mandates a 65% quota for STEM majored midshipmen at the Naval Academy.

Retain and Develop

- The Army can reinfuse STEM into its culture by providing opportunities for junior commissioned officers to obtain graduate education (at master's and doctorate levels) in key Centers of Excellence. As a model, the STEM program could use the Goodpaster Scholars program, which sends a small cohort of officers to top civilian Ph.D. programs and the elite School for Advanced Military Studies.

- Partner with more college and university STEM departments known for producing highly competent graduates in targeted disciplines. The Army has a policy to select junior officers (captains/majors) to attend graduate school with a follow-on assignment to USMA, the Pentagon, or other major acquisition projects.

- Increase funding for active military and civilian personnel to obtain graduate degrees in STEM and relevant adjunct fields, such as computer programing and systems engineering. Growing the number of professionals with advanced STEM expertise will help to make the Army a smart buyer of new and advanced technology and a better strategic partner in decisions on modernization activities.

- Ensure individuals have or are eligible for appropriate security clearances earlier in the career development process to ensure the requirements are met.

- Establish a process for FA49/FA57 officers to have OF equivalency for promotion opportunities.

From its data gathering, the study team made the following findings:

- Challenging recruitment and retention of qualified officers:
  - ORSA Analysts (FA49s) and Simulation Operations Officers (FA57s) are designated after company command
  - Industry and Government are stiff competition for M&S expertise with clearances
  - No GO positions have been designated for either FA49 or FA57 officers
- Falling short on education:
  - FA57 officers and civilians increasingly require technical expertise and education
  - Only 12% (37 MS and 3 PhD) FA57s have M&S-related graduate degrees
  - Only 1.5% (4 MS and 1 PhD) FA57s officers are sent each year
  - No central funding for civilian ORSA and M&S advanced degrees

Based upon these findings, the study team made the following recommendation:

- G1:
  - Civilians: Increase the opportunity for civilians to obtain graduate degrees in M&S related fields, to include computer programing and systems engineering
  - Officers:
    - Increase the rate of graduate education for FA57 officers
    - Facilitate FA49/FA57 officers to be Operating Force relevant

5. RESOURCES

The Army M&S Enterprise consists of six broad components including acquisition (requirements definition, systems engineering & integration, design/development, V&V), analysis, experimentation, intelligence (threat and OE), T&E (experimental design and evaluation, V&V), and training (LVC), with some cross-cutting M&S tools, data, and services. In the distribution of funding for M&S applications, training dominates the POM, historically receiving the most significant portion of the M&S enterprise budget, most recently greater than 70% (Fig. 8).

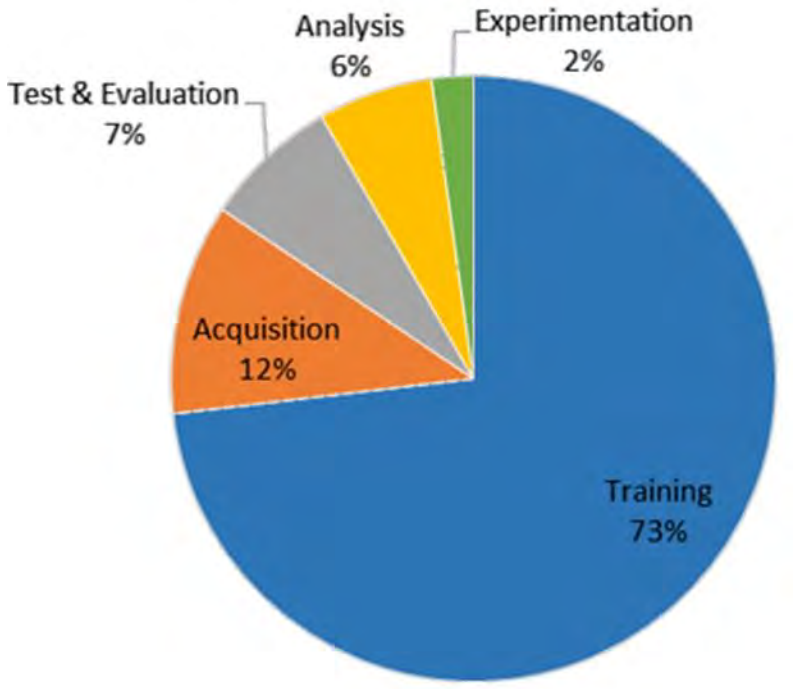

Figure 8. Army M&S Investment Silos

Training plays a significant role in assessing operational capacity and effectiveness under different practice scenarios by employing LVC techniques. The Army must upgrade the other M&S categories as well to ensure that its M&S capabilities will be prepared to address the complexity and demands of modeling the CE in MDO and JADC2. For example, OneSAF, though developed for the training community, is the only major Army entity level simulation that is used by multiple communities. OneSAF eliminates the need for multiple simulation tools across the M&S enterprise and uses current mission command systems.

From its data gathering, the study team made the following findings:

- M&S training community is relatively well funded and well organized, with single dedicated organizations for advocacy, resource sponsorship, R&D, acquisition, and sustainment

- Analysis community is the most fragmented and underfunded relative to the capability improvement needs to modernize combat M&S of the future battlefield

- Analytical M&S un-funded requirements are for incremental improvements

- Funding MDO requirements would be substantial; Air Force program Simulator Common Architecture Requirements and Standards (SCARS) is $900 million in POM

- Major constructive simulations investments are not slated to occur until next decade; far too late given computing and military technology rapid advances.

Based upon these findings, the study team made the following recommendations:

- SECARMY

  – Develop a capability to model MDO operations within a distributed Joint LVC simulation framework with appropriate Army models that fix non-kinetic deficiencies starting with the network convergence and resources equivalent to those provided by the Air Force

  – Create and manage a centralized Army Model Improvement Plan (AMIP) to enable S&T advancements for MDO across Army M&S applications and communities

6. GOVERNANCE AND ORGANIZATION

Throughout the Army, M&S often provides the best or only way to address issues in planning, acquisition, analysis, and training. As DE emerges as the fundamental means of expressing products from design through maintenance, new standards and common asset libraries will become the primary means of communicating requirements from procurer to designer and developer. The reliance on simulation, commonly accessible digital libraries, and the ability to share design information across multiple users and communities all point to the need for greater coordination and integration across the users and proponents of M&S.

As the Army's industry partners have moved forward in the use of DE and incorporating AI into their products – products that Army will procure, employ, and maintain – they have recognized that their ability to function in an increasingly digital environment depends upon:[17]

- Strong leadership at the top willing and able to set a vision, provide clear policy guidance, and the means to ensure compliance

- The ability to work across the various organizational divisions, creating coordinated approaches to development and the use of M&S across the company

- Consistent, stable resourcing to encourage and enable cross-organizational coordination

The continued development of M&S, from infrastructure and algorithms to collection and certification of data at every level of aggregation, depends upon an unprecedented degree of coordination. The following issues in M&S development are critical to the Army's ability to train, analyze, plan, and rehearse in the battlespace of the future:

- The Army's most critical M&S capability gap lies in its inability to credibly model the CE of Army forces in the future, Joint/MDO OE. The CE model is the aggregate of representations of capabilities (both U.S. and adversary) ranging from systems, platforms, and Soldiers. Data acquisition for the representations must be consistent from system development to operations, across all applications in planning, training, and analysis. This implies an enterprise vision and management at an executive level with the ability to establish coordination across all development activities.

- The Army is being thrust into DE by the DoD's "Digital Engineering Strategy"[18] and its industrial partners who are rapidly converting their systems to fully digital representations, from design to fielding. The promise of DE will not be realized fully

[17] Research into this area was accomplished by the Defense Science Board through site visits with Army CCDC GVSC, Ford Motor Company and General Motors, Detroit Michigan, May 2019.
[18] Office of the Deputy Assistant Secretary of Defense for systems Engineering, "Digital Engineering Strategy," June 2018, https://ac.cto.mil/wp-content/uploads/2019/06/2018-Digital-Engineering-Strategy_Approved_PrintVersion.pdf.

without a common understanding of what the process entails; the standards that will make if functional across all systems and digital representations; and common approaches to procurement using digital models as part of proposals. This cannot be accomplished at the level of program management but must be coordinated at a higher, managerial level.

- The constituent domains in MDO involve physical, environmental, and information effects not currently represented in Army models. Individual communities are developing their own, independent approaches for these representations with no consistency across programs, projects, and/or responsible offices.

- The degree of synchronization in C2 across all echelons cannot be achieves with each program or application area developing separate representation, particularly at the level of the human decision making with AI augmentation.

- The ability to create and operate a distributed/federated LVC framework for training and system evaluation both within Army and in the Joint arena depends on architectures with standard interfaces, information exchange specifications, and model design at appropriate levels of aggregation with the same valid behavior whether used in training, system assessment, or operational planning.

- Representing systems employed by Soldiers depends upon certified data available in accredited databases for systems at all levels of aggregation. This type of data collection spans all levels of representation and must be consistent across all application areas. Modeling the behavior of future threat systems for which little or no certified data will be available through the usual sources will require an authority above the program level to enforce consistency and avoid individual programs filling the data vacuum by creating their own unique behaviors.

Army Regulation 5-11, Management of Army Modeling and Simulation, states:

> The framework supports management activities such as centralized information dissemination, integration of modeling and simulation needs and requirements, and coordination while recognizing and facilitating the decentralized execution of modeling and simulation activities throughout the Army.

As a result, the Army's M&S enterprise is organizationally stove-piped and aligned along types of application areas and users of the technology (Fig. 9). The current Army communities and community lead organizations, each of which generates its own requirements and resources its own programs, include:

- Acquisition - Office of the ASA (ALT)

- Analysis - Office of the DCS, G–8
- Experimentation - TRADOC
- Intelligence - Office of the DCS, G–2
- T&E – ATEC
- Training - Office of the DCS, G–3/5/7

The complexity of the Army M&S enterprise extends beyond these large, definable communities and includes other applications, some outside of the Army, making integration across all these communities a daunting task that is currently attempted largely through a coalition of the willing (Fig. 9). While this approach provides some coordination, there remain numerous communities unwilling or unable to share their data, representations, or technology.

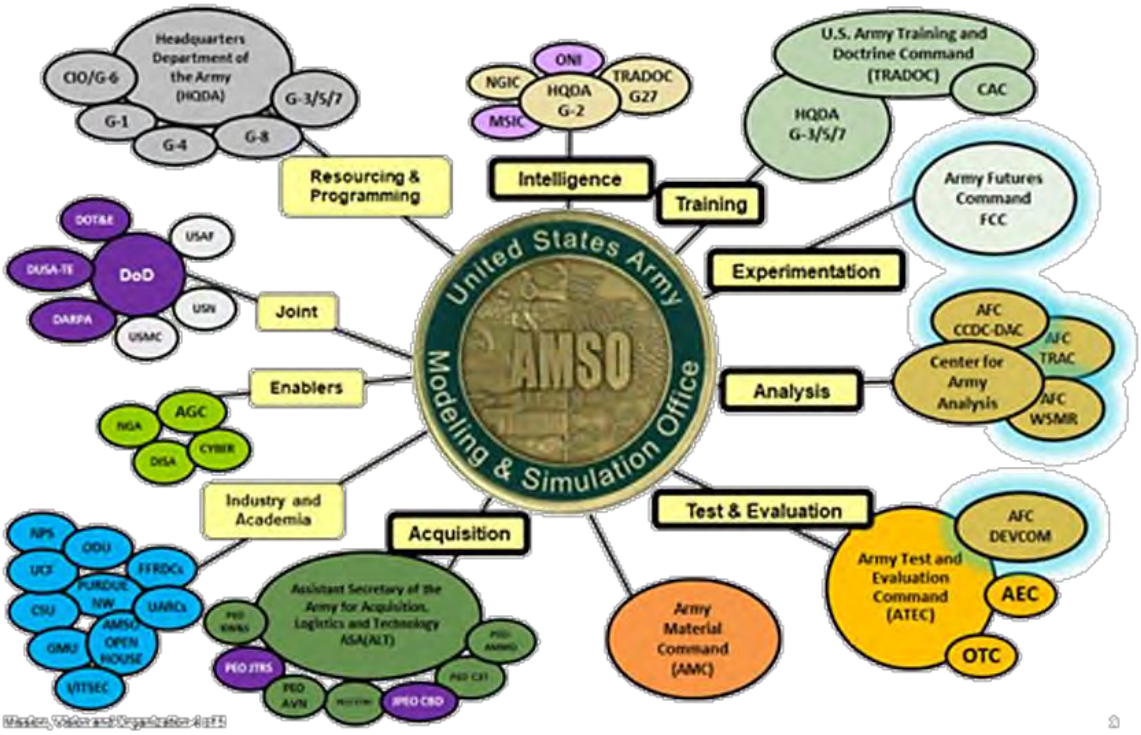

Figure 9. Army M&S Enterprise

The Army lacks an enterprise vision for sharing and managing M&S data, people, algorithms or models. There is no senior leader whose acknowledged job is to fulfill the CSA's strategy to use M&S to modernize the Army in all aspects. In that vacuum, there is little incentive and no forcing mechanism for sharing data, software, or models. Without a central strategy or integrator for the enterprise, M&S capabilities have become skewed, moving in different directions under diverse priorities, often established by a customer's discretionary funds. For

example, integration after-the-fact has created the perennial problem of sharing terrain files across different simulation, even those functioning in the same organizational silo.[19] Continued integration issues and lack of shared data and models will make it difficult to support efforts like Project Convergence and to play a role in Joint programs.

The Army organization and governance for M&S management consists of the DCS G-8 and deputy, and the AMSO, responsible for daily Army M&S operations (Fig. 10). The AMSO, an O-6 level command, has a modest budget for fostering coordination among Army M&S communities and augmenting some of the more promising M&S programs. Since AMSO is led by a Colonel, there is no senior leader with day-to-day responsibility for the Army's M&S enterprise. Army M&S is managed by a GOSC composed of leaders from all the major M&S communities that meets quarterly and is chaired by the Deputy Assistant Chief of Staff, G8.

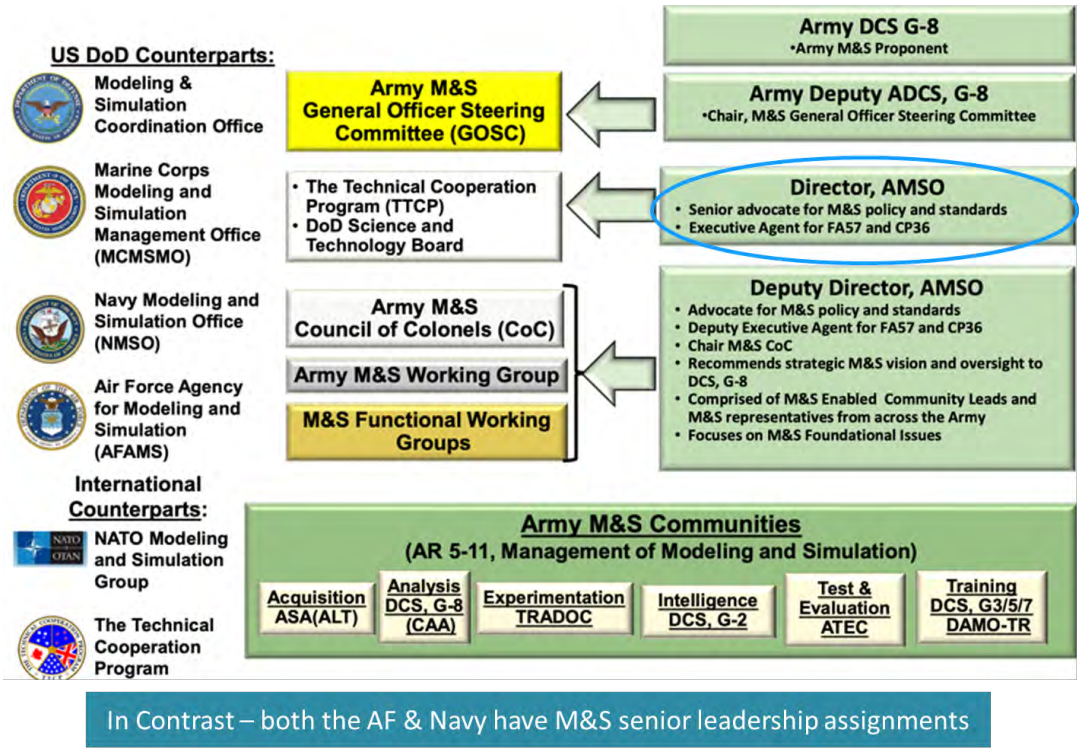

Figure 10. Army M&S Governance

The DoD organizations that serve as the counterparts to AMSO are also action officer level groups that lack the authority over prioritizing requirements and/or resourcing M&S in their respective Services. However, recognizing the growing demands for M&S, both the Air Force and Navy have reworked their M&S enterprise organizations to provide senior leaders with day-to-day responsibility for, and authority over, the development and use of M&S. For the Air Force, the office head is a member of the Senior Executive Service and the head of the technology office is a GS-15 (Fig. 11). Placing civilians in charge of the office provides for a

[19] K. E. Shaefer, et al., "US Army Robotic Wingman Simulation: June 2018 Integration Workshop," US Army Research Laboratory, AR-TR-8572, Nov 2018, https://apps.dtic.mil/dtic/tr/fulltext/u2/1064385.pdf

degree of continuity lost with active-duty military assignment turnover. The remaining positions are staffed by military officers, yielding a structure that provides the essential senior leadership for establishing standardization and a forcing mechanism for model improvement.

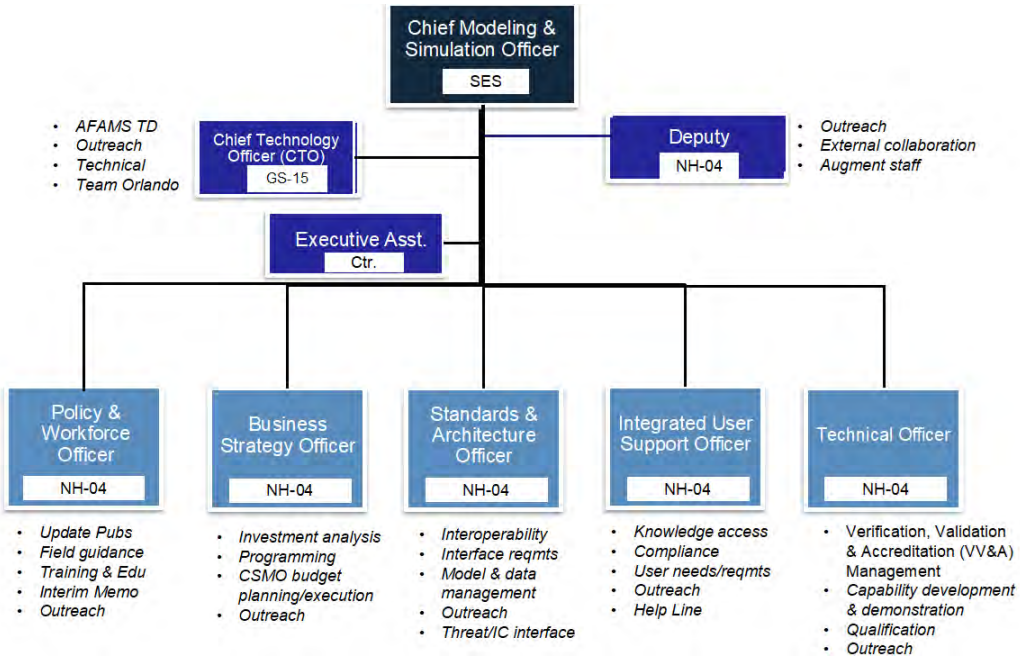

Figure 11. CMSO Structure

The Navy has likewise placed its M&S office under a senior executive service position situated in the office of the Assistant Secretary of the Navy for Research, Development, and Acquisition. The position reports directly to the Deputy Secretary of the Navy and has a growing budget used to influence coordination and collaboration among proponents for development of M&S capabilities. The office's primary goals include establishing and use of common standards.

The fractured nature of the Army's M&S management has led to gaps in some areas where there is no clear organization responsible for part of the development lifecycle. Of all the M&S silos in the Army, the analytic community has the greatest need to address the issues of CE in present and future OEs, but the separate analytic communities, working their own science and technology (S&T) and development, have gaps within and across their M&S lifecycles. Though the CSA declared experimentation critical to the Army, the activity does not have its own acquisition programs or sustainment funding. It is accomplished in an ad hoc manner by individual programs and available forces. The intelligence community has larger, external organizations developing much of the technical products it needs, but the ability to consistently include human decision making in models is a scientifically challenging and persistent gap (Fig. 12).

Community	Requirements	S&T / R&D	Acquisition (Procurement)	Usage	Sustainment
Training	**TRADOC**	**STTC PEO STRI**	**PEO STRI**	**TRADOC / Operational Force**	**PEO STRI**
Test & Evaluation	**ATEC**	**STTC PEO STRI**	**PEO STRI**	ATEC	ATEC
Acquisition	CCDD/Customer	CCDC STTC	CCDC	CCDC	CCDC / Customer
Analysis	TRAC CAA CCDC-DAC	TRAC, CAA CCDC-DAC STTC	TRAC CAA CCDC-DAC	TRAC CAA CCDC-DAC	TRAC CAA CCDC-DAC
		Internal Business Processes			
Experimentation	TRADOC / CCDC0- DAC	STTC	GAP	TRAC CCDC-DAC	GAP
Intelligence	AFC CDIDs	GAP	GAP	Army G2 INSCOM TRADOC G2	GAP

Figure 12. Gaps for Army M&S Stakeholders

Many of the communities developing M&S capabilities do so with discretionary funding from customers outside their organizational structures requesting specific analytic products. External funds drive M&S development in many directions and essentially establish goals and objectives by default. The impact can be most significant in domains that are difficult to model but essential for MDO applications, such as electromagnet effects, communications, cyber, and the effects of introducing AI across the battlespace. The issue needs focused attention, a clear goal, and consistent resources from a robust S&T organization. The training community has the most recognizable and consistent lifecycle path, but their S&T will not focus on the needs for MDO until sometime in the future. Likewise, acquisition is well defined, including an S&T pipeline, but fragmented along program lines.

With the pressing need to address the future battlespace and to have the capability to determine the right mix of existing and future platforms and weapons, the analysis community's reliance on internal business processes for funding activities such as R&D and sustainment will leave Army lagging rather than leading into the future.

Other communities do not have such rigor or processes. They also rely on internal business processes for funding activities such as sustainment and R&D.

To realize the potential of M&S, the Army's enterprise organization must take responsibility for providing the vision, leadership, and persistent resourcing to enable the changes needed across the disparate M&S communities. Coordination on standards within the Army and with the Joint community is vital to interoperability and inter-functionality. Without standards, there can be no fully accessible libraries of data, performance specification, scenarios, algorithms and/or models. All these are necessary for the Army to exploit the benefits of cloud computing. The

leap-ahead capability desired by Army leadership cannot be built on a fractured governance structure.

Where senior leadership has directed development and execution of M&S with the resources to support critical functions, the Army has reaped its benefits. Currently, the training and T&E communities enjoy the benefits of such leadership. To similarly shore up the Army M&S organization across the enterprise, the study team made the following findings:

- Army has no single dedicated authority to provide an enterprise vision and leadership for M&S needed to credibly prepare the Army and Joint forces for MDO
- Army's current organizational silo structure results in:
  - Integration accomplished only by means of a "coalition of the willing" via periodic forums and GOSC meetings
  - Little incentive and no forcing mechanism for sharing of data or models
  - M&S development gaps
  - Uncoordinated and redundant M&S development
  - Congress is not satisfied with Army ability to justify recommendations
- The DUSA (T&E) has proven the merit and value of leadership over a critical Army enterprise function
- Closing the gaps in M&S capability in the Army requires sustained commitment from a given senior official, and expert in M&S, whose sole responsibility is enterprise-level M&S.

Based upon these findings, the study team made the following recommendations:

- SECARMY
  - Appoint a dedicated, Senior Official on the Secretariat
    - Who is an expert in the M&S field
    - Whose sole responsibilities are leading Army M&S and be the senior advisor to the CSA and SECARMY for M&S
    - Positioned above the heads of the current stovepipes

- With authority and resources to guide and enforce priorities for advancing Army's capabilities

- Provides quality control for major Army analyses

- Who is the focal point for enterprise-wide M&S decision making

The study team strongly recommends the Secretary of the Army appoint a senior official on the Secretariat whose sole responsibility is the governance of Army M&S. The position on the Secretariat is necessary to preside over the existing M&S communities and activities. The position must also have authority and resources to set a vision, promulgate that vision across the Army (by policy if necessary), and to both guide and enforce priorities for advancing Army's M&S capabilities. This official would also need to be of sufficient rank to be able to negotiate with senior leaders in the other Services and to warrant the attention of organizations such as DARPA and industry leaders.

7. SUMMARY: PLAN FOR ARMY M&S MODERNIZATION

The study team recommends the Army senior leadership consider, at a minimum, the five following high-level elements for an Army M&S modernization plan:

1. SECARMY appoint a senior independent official on the Secretariat to manage, resource, and guide Army enterprise M&S in support of evaluating MDO CE.

2. The Army must develop a capability to model MDO operations within a distributed, Joint, LVC simulation framework and appropriate Army models that fix non-kinetic deficiencies, starting with the network convergence and resources equivalent to those provided by the Air Force. The study team estimates a cost of $900 million or more will be required to establish a SoSIL that can model the Joint MDO operational environment (JAD2C), synchronize M&S efforts with AFC's ongoing Project Convergence, and continue to develop more of the vital M&S experimental data essential for V&V and analyses. These experimental data must be collected and stored using common data standards, readily accessible, and be drawn from accredited databases of future MDO scenarios, threats, and Joint systems/effects.

3. The Army must improve M&S development to support agile and timely decision making; represent Joint asset performance/vulnerability; represent AI in systems (e.g. autonomous C2, aided or ATR); model contested logistics; and represent cyber network connectivity.

4. Army leadership should continue to proactively partner with DARPA M&S programs to accelerate MDO and leverage innovation.

5. The Army should focus on improving civilian M&S capabilities and talent management with oversight by a senior M&S official.

APPPENDICES

APPENDIX A: TERMS OF REFERENCE

SECRETARY OF THE ARMY
WASHINGTON

06 JAN 2020

MEMORANDUM FOR

Deputy Under Secretary of the Army, 110 Army Pentagon, Room 3E650, Washington, DC 20310-0110
Chairman, Army Science Board, 2530 Crystal Drive, Room 7098, Arlington, Virginia 22202

SUBJECT: Terms of Reference (TOR) for Army Science Board Study "Army Modeling and Simulation (M&S)"

1. I request the Army Science Board (ASB) conduct a study entitled, "Army Modeling and Simulation (M&S)." The purpose of the study is to assess the Army's M&S capabilities in support of strategic decision making, acquisition, training, and test and evaluation (T&E). Specifically, the study should determine Army M&S needs, where the Army's M&S capabilities are state-of-the-art (SOTA) and where they are not, then develop recommendations to close any shortfalls.

2. As part of the National Defense Authorization Act of 2017, Congress established the National Defense Strategy Commission to provide an independent, nonpartisan review of the 2018 NDS and its shift from counterterrorism to peer and near-peer conflict. Among its findings, the Commission expressed its concern that:

> (T)he NDS too often rests on questionable assumptions and weak analysis, and it leaves unanswered critical questions regarding *how* the United States will meet the challenges of a more dangerous world.

To address what it perceived as a lack of analytic rigor supporting strategic decisions and directions, the Commission recommended, in part, that:

> Any new operational concepts must be rigorously validated through experimentation, exercises, and training, and subjected to the systematic analysis necessary to generate the associated time-phased force deployment data (TPFDD).

3. The Army faces unique challenges with strategic decision-making. One such challenge is validating operational concepts involving emerging technology. For example, the Army's ability to investigate the interaction between warheads and armor is excellent, but its ability to analyze software and information systems critical to the conduct of Multi Domain Operations (MDO) is limited. Given the need for M&S development to address future peer threat capabilities, the ASB study team should identify the computational tools necessary to meeting the needs of MDO.

4. Similarly, recent advances in computational power and virtual reality technologies portend wholesale changes in the Army's ability to provide realistic training at home station, with the potential for significant enhancements in training efficiency and force readiness. T&E activities, too, may benefit immensely from advancements in these and other relevant technologies.

5. The ASB study team should assess the level of investments in people and M&S technology. To be relevant, the Army must be able to model Joint operations with multi-service contributions; operations in dense urban areas while interacting with non-combatants; and the employment of electronic warfare, swarming drones, robotics, and massive inter-netted Joint systems operating across multiple domains, including cyber and space. The commercial sector and the Department of Energy (DOE) National Laboratories may provide bases for comparison, as they have pioneered new approaches employing advanced computational techniques such as massively parallel computation.

6. To assist the Army with the transition to new M&S capabilities, the ASB study team's tasks shall include, but not be limited to, the following:

a. Identify the range of applications for Army M&S. At a high level, these include, but aren't not limited to: basic and applied research; concept definition and assessment; requirements development; system/system of systems development and effectiveness; T&E; simulated training; war plans; mission planning/COAs; financial analysis; and data development/reduction associated with experimentation.

b. Determine the M&S capabilities needed to deliver this range of applications, including data, algorithms, models, simulations, hardware, and talent. Assess commonalities, differences, and the potential for integration and interoperability across these applications. Examine emerging challenges, given near-term and anticipated future operating environments.

c. Determine the state of current Army M&S capabilities that support the needs identified above. Examine overarching challenges and assess how the Army is organized and trained to deliver M&S capabilities.

d. Compare current Army capabilities to those employed by the commercial sector, DOE Labs, and other services and government agencies.

e. Examine new techniques being used in the commercial sector that are relevant to supporting strategic decision making, training, and T&E. Consider the uniqueness of Army needs compared to the needs and techniques of other organizations.

f. Develop a plan for the Army to modernize its M&S capabilities that includes:

SUBJECT: Terms of Reference (TOR) for Army Science Board Study "Army Modeling and Simulation (M&S)"

(1) Estimated resources and time to implement.
(2) A first-order cost estimate.

(3) The talent required to implement the plan and populate the agencies responsible for analysis.

(4) Determination of who should execute.

7. The Secretary of the Army is the sponsor of this study. ASA(ALT), CG AFC, CG TRADOC, and CG ATEC will assist the study team in accessing information pertinent to conduct their study, to include classified information.

8. A briefing with findings and recommendations will be provided by 30 September 2020 to the Secretary of the Army and the Chief of Staff of the Army. The study will operate in accordance with the Federal Advisory Committee Act and DoD Directive 5105.4, DoD Federal Advisory Committee Management Program. It is not anticipated that this study will need to go into any particular matters regarding the meaning of United States Code, nor will it cause any member of the study team to be placed in the position of acting as a procurement official that may constitute a conflict of interest.

Ryan D. McCarthy

CF:
Chief of Staff, Army
Under Secretary of the Army
Vice Chief of Staff, Army
Assistant Secretary of the Army (Acquisition, Logistics, and Technology)
Chief Information Officer/G-6
Deputy Chief of Staff, G-2
Deputy Chief of Staff, G-3/5/7
Deputy Chief of Staff, G-4
Deputy Chief of Staff, G-8
Commander
U.S. Army Futures Command
U.S. Army Forces Command
U.S. Army Materiel Command
U.S. Army Training and Doctrine Command
U.S. Army Test and Evaluation Command

3

APPENDIX B: STUDY TEAM MEMBERS

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Teresa Smith

Mark Swiatek
Tech Writer/Editor

APPENDIX C: DATA GATHERING

As part of its data gathering process, the study team visited and/or received briefings from the following individuals and organizations.

DoD and Government Organizations:

- Army Futures Command (AFC)
- CCDC Data Analysis Center (DAC)
- TRAC
- FCC
- Army G8
- AMSO
- CAA
- Army G2
- ASA(ALT)
- Army Operational Test Command
- PEO STRI
- STE CFT
- Simulation Training Technology Center
- Air Combat Command (ACC) ACC A2/A29
- JADC2 AF/A2
- Air Force Academy of Military Science (AFAMS)
- NAWCTSD
- NAVAIR
- OSD/Joint: DARPA

Commercial Industry:

- Northrop Grumman
- Nvidia
- Bill Kewley, former Chair of USMA Systems Engineering Dept
- 4Cast, Malem Team (Israeli Company)
- CACI, LGS Labs-Cyberspace Solutions
- Cole Engineering Services (CESI)
- SWRI (Southwest Research Institute) Electronic Warfare T&E and V&V
- -CLEETS and SPARTA
- IDI, Innovative Decisions
- Metron Scientific Solutions, ORCA Ops Research and Cyber Analysis
- Scalable Network Tech (Network Digital Twin for DoD)
- Siege Technologies- Cyber Qualification Framework (CQF) for M&S
- Universal Studios Theme Park

FFRDCs, Academia, and Non-Federal Organizations:

- DOE/NNSA: LANL and LLNL
- GTRI
- Military Operations Research Society x2
- National Training Industry Association and IITSEC
- Rand
- University of Central Florida

APPENDIX D: ARMY M&S COMMUNITIES AND APPLICATIONS

The Army leverages M&S for S&T, training, and operations. Within the Army S&T enterprise, four distinct groups (Fig. D.1) each use M&S to various degrees in support of their mission.

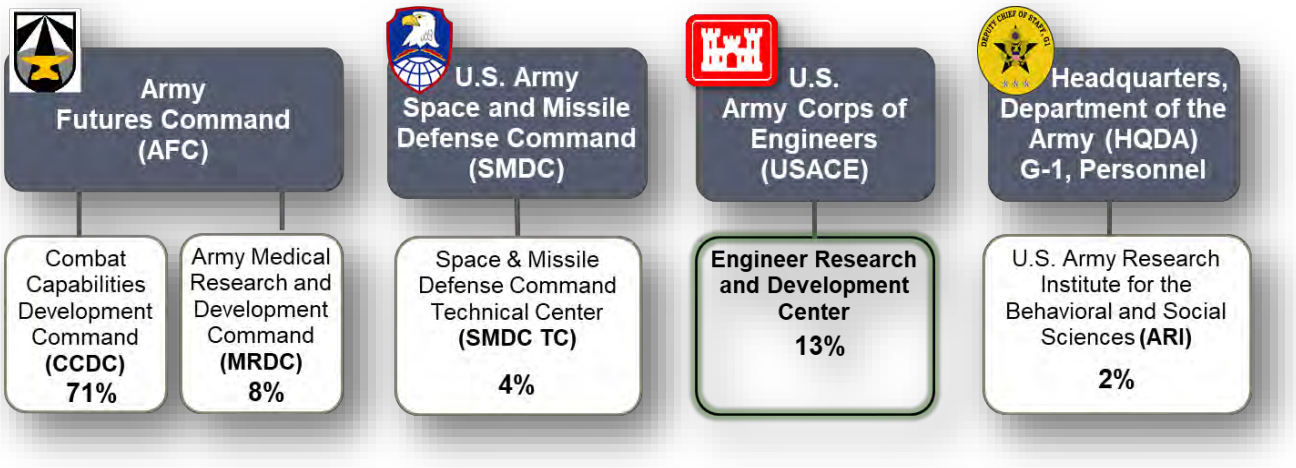


Figure D.1 Army S%T Enterprise

Each of these groups uses M&S to perform R&D, analysis, experimentation, acquisition, T&E, training, and intelligence. They work together and in collaboration with other government organizations, academia, and industry to ensure the Army can operate with other Services to execute Joint/MDO.

D.1 R&D

Army R&D organizations create, integrate, and deliver technology-enabled solutions. They include organizations such as:

- U.S. Army Engineer Research and Development Center (ERDC)
- Combat Capabilities Development Command (CCDC)
  - U.S. Army CCDC C5ISR Center
  - U.S. Army CCDC Army Research Laboratory (CCDC ARL)
  - U.S. Army CCDC Chemical Biological Center (CCDC CBC)
  - U.S. Army CCDC Soldier Center (CCDC SC)
  - U.S. Army CCDC Ground Vehicle System Center (CCDC GVSC)
  - U.S. Army CCDC Aviation & Missile Center (CCDC AvMC)
  - U.S. Army CCDC Armaments Center (CCDC AC)
  - U.S. Army CCDC C5ISR Center (CCDC C5ISRC)
- Army Medical Research and Materiel Command (MRMC)

ERDC is an integral component of the Office of the Assistant Secretary of Defense for Research and Engineering and helps solve challenging problems in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, Department of Defense, and civilian agencies.

ERDC's Military Engineering research area provides innovative technologies and capabilities to the warfighter to enable force protection and maneuver. The business area serves as the leader in developing novel, lightweight, rapidly constructed protection systems that can be expediently deployed in remote locations. From the research and development of these innovative protection systems, survivability decision aids have been developed to allow for rapid assessment of current protection postures and to provide enhanced designs to increase defense against attacks.

ERDC's Geospatial Research and Engineering research area provides the data, analytic tools, information, and decision framework capabilities to ensure superior situational awareness of the battlespace environment for the warfighter. It also develops terrain sets in support of several DoD models and simulations as location and spatial relationships, as well as geographical data and information are the central elements of success in the battlespace environment.

ERDC develops, manages, and runs several higher fidelity physics-based models in simulations in support of basic research and acquisition. It also develops surrogate models designed for use in operational simulations such as OneSAF and COMBATXXI. Many of the models run on the DoD's high-performance commuting assets managed by ERDC's Information Technology Laboratory (ITL). ITL also manages the classified and unclassified Defense Research and Engineering Network (SDREN and DREN) which provides robust, high-capacity, low-latency connectivity between DoD user sites. The DREN supports the DoD scientific research and development as well as test and evaluation missions.

M&S Tools used or underdevelopment by ERDC include but are not limited to:

- Army Geospatial Enterprise (AGE) Node
- Computational Research and Engineering Acquisition Tools and Environments (CREATE)
  - DaVinci
  - Kestrel
  - Helios
  - Rapid Ship Design Environment (RSDE)
  - Navy Enhanced Sierra Mechanics (NESM)
  - Capstone (Meshing and Geometry)
  - SENTRi
- Mobility Analysis Tool (MAT)
- Geo-Environmental Tactical Sensor Simulation (GEOTACS)
- Big Open-Source Social Science (BOSSS)
- Virtual Testbed for Installation Mission Effectiveness (VTIME)

- Surface-water Modeling System (SMS)
- Environmental Awareness for Sensor and Emitter Employment (EASEE)
- Standard for Ground Vehicle Mobility (STNDMob)
- Ground Contact Element
- Geospatial Capabilities for Security, Humanitarian Assistance, Partner Engagement (GeoSHAPE)
- Situational Awareness Geospatially Enabled (SAGE)
- Planning Logistics Analysis Network System (PLANS)
- Forward Operating Base (FOB) Unmanned Aerial Systems (UAS) Detection and Defense Planning
- Understanding the Environment as a Threat
- Streamflow Prediction Tool (SPT)
- Geospatial Weather Affected Terrain Condition and Hazards
- Land Information System

D.2 ANALYSIS

The Army conducts analyses as part of leaders' decision-making processes to:

- Organize, man, train, equip, sustain, station, and resource the Army
- Inform policy decisions and conduct strategic, operational, and tactical operations

The principal organizations that conduct analysis for Army include:

Center for Army Analysis (CAA) conducts analyses across the spectrum of conflict in a Joint, Interagency, Intergovernmental, and Multinational (JIIM) context to inform critical senior level decisions for current and future national security issues. CAA's activities include:

- Campaign Analysis: Analysis and modeling of Combatant Commanders' Operations Plans (OPLANs) and out-year strategic scenario assessments, including risk analysis of force structure and readiness on operational success in the theater conflicts. CAA's analyses of out-year scenarios have significant influence and impact on the shaping of the future forces not only within the Army, but also across DoD. Their efforts assist and inform Combatant Commanders in updating and maintaining plans to reflect the ever-changing environment in which they must be prepared to fight and win.

- Organizational & Force Structure Analyses/Total Army Analyses: Force structure analyses examine how the Army provides trained and ready forces to meet current, emergent, and contingency demands through requirements and capacity analyses. It also provides analysis of force mix, readiness, force generation, and force flow in support of Army, Joint, and Coalition contingency planning efforts and budgetary decisions of land component forces across Combatant Commands. The analyses broadly support the development of strategy, plans, and policy within Headquarters Department of the Army (HQDA), as well as DoD.

- Operational & Institutional Capability Analyses: Analytical efforts to ensure decision makers leverage the capacity and capabilities of the total force. These analyses inform senior leaders on how to optimize and align operational and generating forces in support of strategic priorities, policies, and commitments. CAA's analyses enable decisions that ensure the total force is manned, trained, organized, sustained, equipped, and employed to support Combatant Commander's requirements. CAA analyses support development of force packages tailored to achieve anticipated objectives and outcomes, and ensure the Institutional Army is more effective and efficient in areas as diverse as acquisition processes, force design, and stationing decisions.

- Wargaming: Strategic and operational level wargaming and campaign analysis of Combatant Command Operation Plans (OPLANs) and out-year strategic scenarios to provide insights and analysis of warfighting strengths, deficiencies, and risks to both mission and force. These efforts support AoA courses of action, innovative warfighting concepts, and employment of current, emerging, and future technologies.

- Analysis and Workforce Development: CAA is the Executive Agent and the proponent for military Functional Area (FA) 57–Simulation Operations Officers, and the civilian Career Program 36–Analysis, Modeling and Simulation workforce. AMSO provides for the management, selection, training (to include management and operations of the Army M&S School) and assignment of FA 57 officers across the Army

- Data Science: A multi-disciplinary field that uses scientific methods, processes, and algorithms to extract knowledge and insights from large volumes of structured and unstructured data. Combining skills from computer science with techniques from mathematics and statistics, CAA is partnering with domain experts to automate workflows, develop efficiencies, and enhance analysis.

M&S Tools used by CAA:

- Joint Integrated Contingency Model (JICM)
- Advanced Framework for Simulation, Integration, and Modeling (AFSIM)
- Combat Sample Generator (COSAGE)
- Extended Air Defense Simulation (EADSIM)
- Force Requirements Generator (FORGE)
- Modeling Army Rotation at Home or Not (MARATHON)

The Research and Analysis Center (TRAC) conducts research on potential military operations worldwide to inform decisions about the most challenging issues facing the Army and DoD. TRAC relies upon the intellectual capital of a highly skilled workforce of military and civilian personnel to execute its mission. It also conducts operations research on a wide range of military topics, some contemporary, but most often set 5 to 15 years in the future. For example, it addresses questions such as, how should Army units be organized? What new systems should be procured? How should Soldiers and commanders be trained? What are the

costs and benefits of competing options? What are the potential risks and rewards of a planned military course of action? TRAC directly supports the mission of TRADOC to develop future concepts and requirements while also serving the decision needs of many military clients.

M&S Tools used by TRAC include:

- COMBATXXI
- One Semi Automated Forces (OneSAF)
- Advanced Warfighting Simulation (AWARS)
- Versatile Assessment Simulation Tool (VAST)

CCDC Data and Analysis Center (CCDC/DAC) delivers objective analysis, experimentation, and data across the entire life cycle to ensure readiness today and a more lethal future force tomorrow.

As part of AFC, the center provides the analytical underpinnings to inform modernization decisions, while its lifecycle perspective enables it to also focus on near term readiness and operational tools for the warfighter. The center provides agile, timely, and integrated analytical products for item/system level performance and effectiveness, vulnerability/lethality, and human systems integration, enabling AFC to conduct streamlined decision processes that are underpinned by sound, evidence-based analysis.

The CCDC/DAC brought together three separate organizations: the U.S. Army Materiel Systems Analysis Activity, the Survivability/Lethality Analysis Directorate, and the Army Research Laboratory's Human Systems Integration Division. Aligned as one organization, DAC serves as the Army's authoritative source of integrated analytical solutions for the Soldier and Future Force Modernization Enterprise.

M&S Tools used by CCDC/DAC include but are not limited to:

- One Semi Automated Forces (OneSAF)
- Infantry Warrior Simulation (IWARS)
- GWARS
- Fuel Cell Power Module (FCPM)
- FOCUS
- LAM
- MUVES
- Advanced Joint Effectiveness Model (AJEM)
- Smart Weapon End-to-End Performance Model (SWEEPM)
- ORCA
- Situational Awareness Geospatially Enabled (SAGE)
- AMSAA Probability of Hit and Kill Simulation (APHAKS)

D.3 EXPERIMENTATION

For the purposes of this study, experimentation is defined as: a military activity conducted to discover, test, demonstrate, or explore future military concepts, organizations, and equipment and the interplay among them, using a combination of actual, simulated, and surrogate forces and equipment.

Army experimentation is managed by the Futures and Concepts Command (FCC), which assesses the threat and future OE, develops future concepts, requirements, and an integrated modernization pathway to increase lethality and over-match. FCC conducts mission command of Army experimentation activities supporting a campaign of learning. Modern data management solutions enable AFC to address the complex learning demands of MDO and project future data requirements to enable machine learning.

AFC activities include at least one CFT, its Capability Development Integration Directorate (CDID), and the associated Battle Lab for each Center of Excellence (CoE) working together to develop operational experiments and prototypes to test. These in turn validate DOTMLPF integrated combined arms capabilities that complement other JIIM capabilities.

Tools used for experimentation include but are not limited to:

- One Semi Automated Forces (OneSAF)
- Fires Simulation XXI (FireSIM XXI)
- Future Force Experimentation Air Defense Simulation (FFEADS)
- Extended Air Defense Simulation (EADSIM)
- Avenger Tabletop Trainer (AT3)
- Reconfigurable Tabletop Trainer (RT3)

D.4 ACQUISITION

The CFTs in AFC work to rapidly understand and realize technology prototypes, beginning with requirements, S&T, test, etc. prior to entering the acquisition process. AFC then partners with the ASA(ALT), who, as the Army Acquisition Executive (AAE), has milestone decision authority (MDA) at multiple points in a materiel development decision (MDD). Typically, the Army prototypes on its own. It currently initiates acquisition at Milestone B to have the AAE, with concurrence of the CSA, decide on production as a program of record (POR) at Milestone C. Prototypes are used to address the factors needed to pass the Milestone decisions A, B, and C, which require milestone decision authority (MDA) in an acquisition process. This consolidation of expertise reduces the risks in a MDD for the Army to admit a prototype into a POR.

M&S Tools used for acquisition include but are not limited to:

- Simulation Toolkit for Rigorous Interceptor Design and Evaluation (STRIDE)
- Armament Virtual Collaborative Environment (AVCE)
- Early Synthetic Prototyping (ESP)

D.5 TEST AND EVALUATION

U.S. Army Test and Evaluation Command (ATEC), a DRU, is responsible for developmental testing, independent operational testing, independent evaluations, assessments, and experiments of Army equipment.

With access to over 3.06 million acres between Fort Bliss and White Sands Missile Range, ATEC has access to enough area to test every non-nuclear weapon system in the Army's inventory. Joint Modernization Command at Fort Bliss runs live, developmental experiments to test and assess MDO concepts or capabilities that support the Army's six modernization priorities. These are then analyzed by The Research and Analysis Center (TRAC) or the DAC. CCDC consists of the several Army research laboratory locations (ARLs), as well as research, development and engineering centers (RDECs).

M&S Tools used for T&E include but are not limited to:

- OneSAF
- Advanced Range Tracking and Imaging System (ARTIS)
- Autonomous Systems Test Capability (ASTC)
- Accelerated Vehicle Durability Testing (AVDT)
- Directed Energy Test (DET)
- Electromagnetic Environmental Effects (E3) instrumentation
- Electronic Warfare Test (EDT)
- Fast Burst Reactor Upgrade (FBRU)
- Integrated Live-Virtual-Constructive Test Environment (ILTE)
- Mobile High Energy Laser Measurement (MHELM)
- Nuclear Effects Test Capability Modernization (NETCM)
- Robotics/Unmanned Autonomous Systems (R/UAS)
- System of Systems Cooperative Engagement Test Infrastructure (SCETI)
- Test Network Modernization (TNM)
- Telemetry System Modernization (TSM)
- Warrior Injury Assessment Manikin (WIAMAN)

D.6 TRAINING

Field Manual 7-0 provides training and leader development methods that serve as the basis for developing competent and confident Soldiers and units. Training provides the means to achieve tactical and technical competence for specific tasks, conditions, and standards. Leader Development consists of deliberate, continuous, sequential, and progressive process, based on values, to develop Soldiers and civilians into competent and confident leaders capable of decisive action. M&S supports both methods.

The Combined Arms Center-Training CAC-T) drives change in how the Army trains and prepares to prevail against a peer enemy in large scale combat operations, identifies and validates training gaps and requirements, manages training support for the Army, delivers leader training, and serves as the training management proponent to enable realistic, operationally relevant training for the Army's total force. CAC-T supports the Army by:

- Developing and sustaining the Integrated Training Environment and evolving towards a Synthetic Training Environment.
- Managing the Combat Training Center Program. Identifying requirements for and managing more than 900,000 Army training aids, devices, simulators and simulations.
- Managing Integrated Training Area Management, Sustainable Range and Standards in Training Commission programs.
- Managing the Army Training Support System Enterprise.
- Managing requirements for Army distributed learning and mobile applications.
- Training leaders and providing commanders the opportunity to train on Mission Command through the Mission Command Training Program.
- Managing the Army Training Network, Army Training Management System, Digital Training Management System and Combined Arms Training Strategies to provide units and leaders with training resources.
- Standardizing Mission Essential Task Lists to help brigade units and higher conduct realistic training.
- Integrating the Army's Science and Technology efforts for Training and Education.
- Integrating training and education in the Agile Process and the Joint Capabilities Integration and Development System.
- Providing Army and Joint air-ground operations education, training, and command and control systems integration.
- Writing FM 7-0, ADP 7-0 and ADRP 7-0, the Army's key documents for unit training.
- Enhancing learning in the Centers of Excellence by providing classrooms with wireless capabilities.
- Providing an enterprise Army Training Information System that optimizes leaders' and civilians' ability to plan, prepare, execute, and assess training, education, and leader development.
- Leading the Evolution of Training forum with designated Centers of Excellence to expand transparency, collaborate on and synchronize development of the Army's future training capabilities.

M&S Tools used for Training include but are not limited to:

- Joint Land Component Constructive Training Capability (JLCCTC)
- Live, Virtual, Constructive Integrating Architecture (LVC-IA)
- One Semi-Automated Forces (OneSAF)
- Aviation Combined Arms Tactical Trainer (AVCATT)
- Close Combat Tactical Trainer (CCTT)
- Reconfigurable Virtual Collective Trainer (RVCT)
- Persistent Cyber Training Environment (PCTE)

- Synthetic Environment Core (SE Core)
- Training Simulation management Tool (TSMT)
- Abrams Engine Diagnostic and Troubleshooting Trainer (ED/TT) Maintenance Training System (MTS)
- Basic Electronics Maintenance Trainer (BEMT-II)
- Common Driver Trainer (CDT) Virtual Product Line (VPL)
- Construction Equipment Virtual Trainer (CEVT)
- Counter-Rocket
- Artillery
- Mortar (C-RAM)
- Land-based Phalanx Weapon System (LPWS)
- Operator/Maintainer Trainer II (OMT)
- Family of Maintenance Trainer (FMT)
- Games for Training (GFT)
- Gunnery Training Systems (GTS)
- Howitzer Crew Trainer (HCT)
- High Mobility Artillery Rocket System/Multiple Launch Rocket System (HIMARS/MLRS) Operator/Maintainer Trainer (OMT)
- Maritime Integrated Training Systems (MITS)
- Soldier/Squad Virtual Trainer (S/SVT)
- Squad Advanced Marksmanship Training (SAM-T)
- Stinger Improved Moving Target Simulator (IMTS)
- Stryker Maintenance Trainer System (MTS)
- Virtual Clearance Training Suites (VCTS)
- Wideband Training and Certification System (WTCS)
- National Cyber Range Complex (NCRC)
- Intelligence Electronic Warfare Tactical Proficiency Trainer (IEWTPT)
- SOF Avn
- SOF Ground
- SOF JTAC
- Under development include but are not limited to:
- Synthetic Training Environment (STE)
- One World Terrain (OWT)
- Integrated Visual Augmentation System (IVAS)
- Squad Immersive Virtual Trainer (SiVT)
- Map Based Planning

D.7 INTELLIGENCE

The National Ground Intelligence Center (NGIC) provides foundational, all-source and geospatial intelligence on foreign ground force capabilities, related military technologies, and GEOINT targeting support to ensure that U.S. Army, DoD, Joint and National-level decision makers maintain decision advantage and prevent strategic surprise.

NGIC's general military intelligence mission focuses on foreign ground forces from the operational through small-unit level, maintaining detailed knowledge of current, foreign ground force capabilities as well as a focus of five, 10, and 20 years in the future. It includes irregular and conventional warfare analyses examining foreign ground forces from a perspective that includes battlefield operating systems, doctrine, TTP, training, maintenance, logistics, and order of battle.

NGIC also has highly skilled specialists including physicists, chemists, computer scientists, mathematicians, and engineers in diverse fields from aeronautics to robotics, along with modelers, simulation experts, and other technical specialists who evaluate the capabilities and performance data on virtually every weapons and future weapons concepts system used by a foreign ground force.

M&S Tools used for Intel but are not limited to:

- Integrated Threat Analysis and Simulation Environment (ITASE)
- Next Generation Threat Simulation (NGTS)

APPENDIX E: SOTA CAPABILITIES FOR ARMY M&S

As part of its data gathering activity, the ASB posted a public request for information to collect insights from industry on capabilities that could support the Army's M&S enterprise. The following companies replied and their presentations to the study team are summarized:

Southwest Research Institute (SwRI) has an electronic warfare T&E and V&V capability to evaluate how RF systems will perform in complex spectral environments. The capability can be configured to emulate complex threat and electronic countermeasure (ECM) signals in a typical operational environment. This type of test data can be used to develop realistic sensor models for simulations. The Army Research Laboratory is using the capability to evaluate new radar designs.

Innovative Decision Inc. uses commercial tools such as ExtendSim with in-house developed tools to rapidly design transportation and decision support simulations using small to large data sets. One of their key capabilities that should be investigated further is the use of AI within their simulations. With this capability, the system can be designed to make complex, multi-attribute decisions during the simulation which adds some level of realism to the results.

4CAST develops customized M&S platforms that facilitate and support decision making processes. Their Synthetic Areas Generator (SAG) is a constructive, multi-theater joint force simulation engine. It is designed to integrate all domains to replicate an MDO environment. Several domain modules are still in development, but the simulation engine and the system architecture are operational. The benefits of simplicity and speed should make the system a candidate for further evaluation to support a component of the Army's M&S needs.

SIEGE Technologies has developed the Cyber Quantification Framework (CQF) for automatically assessing cyber-attacks and defenses. The concept is in a V&V process with Cyberspace Operations Lethality and Effectiveness (COLE) organization. The system represents a mature cyber planning and testing capability which is continuing into advanced development and should have the capability to address current Army M&S needs.

CACI-LGS Labs has at three innovative products/solutions in use today with follow-on developments or extensions coming. They are Network Reconnaissance, Live RAN, and Device Farm. These products support their key capability of high-fidelity M&S for communication networks. There is a focus on global commercial networks which can provide in-depth understanding of network functionalities and topologies that could be of interest. Stealthy probes can provide fingerprints and identify vulnerabilities. Their test ranges are used to evaluate actual hardware and software capabilities which can be used as data sources.

METRON Scientific Solutions has developed a high-fidelity cyber assessment tool, Cyber Assassin. This tool explicitly models both Offensive and Defensive Cyber Operations. It models hardware/ software configurations, network topologies, and performs cyber and system level analyses. The product is an integrated suite of model based SoS engineering tools that can

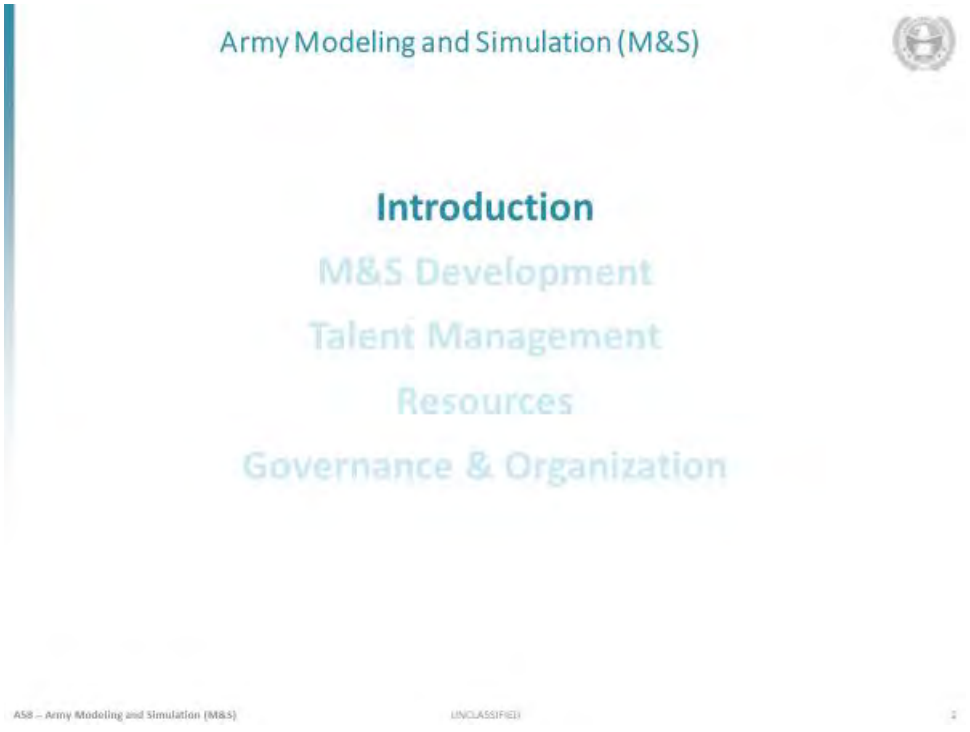
provide insights into the effects that cyber threats have at the mission level. The suite of tools has been used by the Army for several planning exercises and should be considered for the future MDO M&S needs.

Cole Engineering Services has been supporting the Army and other services for over 40 years. Their Live, Virtual, Constructive Integrating Architecture (LVC-IA) has operated with the Army's Synthetic Training Environment and the Army Mission Command Systems (MCS) for training. Enhancements to LVC-IA are under development for integrating into legacy training systems. Cole also supports the Army with Bifrost to connect simulation content and platforms with a high level of detail for collaborative simulations and exercises. This capability can be used to support MDO M&S and is ready now. The company has also developed the Parametric Data Service which is a web-service to model data and data relationships for use in independent simulations. This capability is used in the DARPA PROTEUS program in support of Mosaic Warfare constructs.

Scalable Network Technologies core areas are high fidelity, real time Network Simulation & Emulation and Cyber Behavior Models to simulate cyber-attacks, defense, and vulnerabilities. They provide these capabilities to defense, industry, and government markets. The key discriminators are (1) accurate real-time network emulation, (2) the ability to leverage parallel model execution for scalability, and (3) comprehensive communication and cyber models. The company also delivers LVC Network Digital Twins. These have representations of the operating environments, actual data/comm links, system in the loop interfaces, and human interactions. Their Joint Network Emulator (JNE) and EXata Information Warfare Visualizer emulate realistic battlefield operations. The JNE, at TRL 8, is being used by multiple Army programs. Both SOTA technologies are capable of supporting MDO M&S and are presently being utilized at several Army facilities.

APPENDIX F. ASB Approved Briefing with Findings and Recommendations

The following briefing was presented to ASB members in plenary session on 22 Oct 2020. The study team's findings and recommendations were adopted by the ASB membership.



M&S in 1980's

Army Training Battle Simulation System with Perkins-Elmer 3210

There Once Was a Simulation Revolution in the Army ....

Unit Conduct of Fire Trainer with MicroVAX II

BLUF

Army M&S is:

- A large, **ubiquitous** and inefficient activity
- Mostly a software-driven enterprise ($2.24B/year; 73% focused on Training systems)

Managed as stovepipes under a General Officer Steering Committee (GOSC) **without an enterprise-wide focus**

Results in:

- Redundant, non-interoperable combat simulation platforms
- Redundant data sourcing and costs
- Underfunded, piecemeal R&D to address persistent and well-know problems
- Army viewed as behind other Services
- Slow in response to meet senior leader needs
- Not ready for MDO

These issues can be resolved with a plan for:

- M&S Development
- Talent Management
- Resources
- Governance and Organization

So What?

If the Army Continues to Fight (and Model) the **Last War:**

- **Complex systems will defy experiential solutions**
- **We will fail to capture and integrate the new lessons we are learning through experimentation in Project Convergence**
- We may be unprepared for the new realities of warfare
  - Undefined MDO
  - Ill-informed investments
  - Negative training/planning
- We will continue to experience systems failure e.g. Crusader
- We will lose DoD and **Congressional** leaders' confidence in its assessments

Study Team Members

Study Team
- Dr. Michael Macedonia (Study Chair)
- Dr. Gisele Bennett (Co-Chair)
- Mike Heinz (Co-Chair)
- Mike Molino (Co-Chair)
- Heather Gerard (Study Manager)
- Prof. Inderjit Chopra
- Dr. Robert Douglas
- William Guyton
- Dr. Peter Hancock
- Dr. Jill Harp
- Dr. Deanne J. Idar
- Dr. Mohammad Jamshidi
- MG (R) Dr. Lester Martinez-Lopez
- Dr. Maria Mouratidis
- Dr. S. K. Numrich
- Thomas Ramos
- Dr. Susan Smyth

- Government
  - COL Scott Gillman, AMSO
  - Dr. Simon Goerger, ERDC
  - Dr. Charles Sanders, AMSO
  - Dr. Steven Stoddard, SES, CAA
  - Kirby Thomas, AFC
- Red Team
  - Dr. Leonard Braverman
  - Dr. Jeff Isaacson
  - GEN (Ret) David Maddox
  - Teresa Smith

Data Gathering: Visits and Briefings

- DoD / Government Organizations
  - Army Futures Command (AFC)
    - CCDC Data Analysis Center (DAC)
    - TRAC
    - FCC
  - Army G8
    - AMSO
    - CAA
  - Army G2
  - ASA(ALT)
  - Army Operational Test Command
  - PEO STRI
  - STE CFT
  - Simulation Training Technology Center
  - Air Combat Command (ACC) ACC A2/A29
  - JADC2 AF/A2
  - Air Force Academy of Military Science (AFAMS)
  - NAWCTSD
  - NAVAIR
  - OSD/Joint: DARPA

- Industry:
  - Northrop Grumman
  - Nvidia
  - Bill Kewley, former Chair of USMA Systems Engineering Dept
  - 4Cast, Malem Team (Israeli Company)
  - CACI, LGS Labs-Cyberspace Solutions
  - Cole Engineering Services (CESI)
  - SWRI (Southwest Research Institute) Electronic Warfare T&E and V&V
  - -CLEETS and SPARTA
  - IDI, Innovative Decisions
  - Metron Scientific Solutions, ORCA Ops Research and Cyber Analysis
  - Scalable Network Tech (Network Digital Twin for DoD)
  - Siege Technologies- Cyber Qualification Framework (CQF) for M&
  - Universal Studios Theme Park
- FFRDCs/Academia/Non-Federal:
  - DOE/NNSA: LANL and LLNL
  - GTRI
  - Military Operations Research Society x2
  - National Training Industry Association and I/ITSEC
  - Rand
  - University of Central Florida

Terms of Reference (TOR)

Identify the **range of applications for Army M&S**

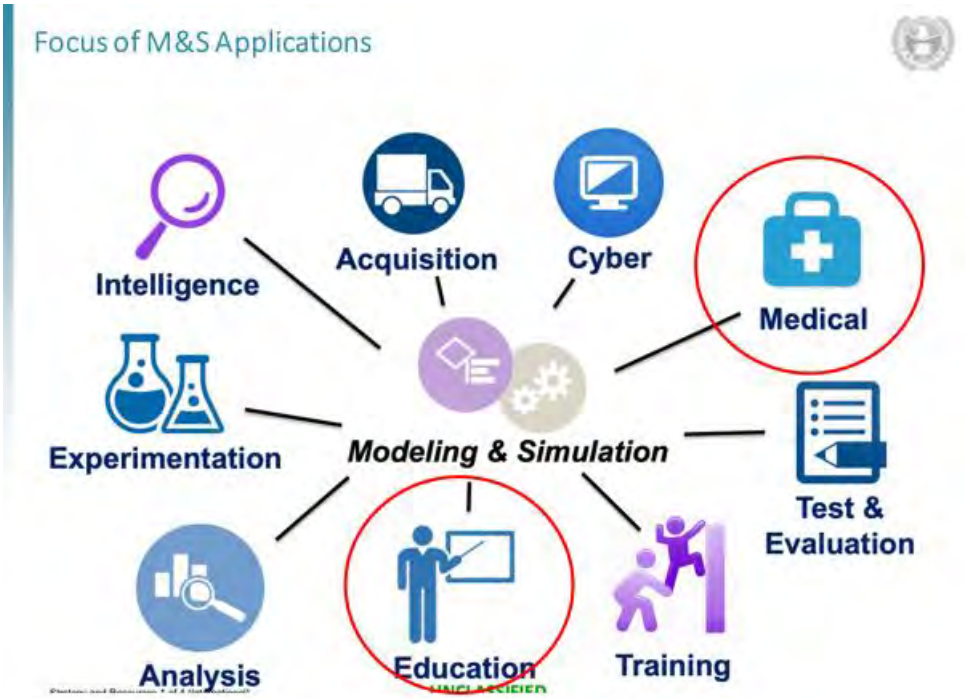
Determine the **M&S capabilities needed to deliver this range of applications,** including data, algorithms, models, simulations, hardware, and talent.

Determine the **state of current Army M&S capabilities** that support the needs identified above. Examine **overarching challenges** and assess how the Army is **organized and trained to deliver M&S capabilities.**

Compare current Army capabilities to those employed by the commercial sector, DOE Labs, and other services and government agencies.

Examine new techniques being used in the commercial sector that are relevant to supporting strategic decision making, training, and T&E. Consider the uniqueness of Army needs when compared to needs and techniques of other organizations.

Develop a plan for the Army to modernize M&S


Focus of M&S Applications
Intelligence
Acquisition
Cyber
Medical
Experimentation
Modeling & Simulation
Test & Evaluation
Analysis
Education
Training


Previous Studies
Modeling and Simulation
Linking Entertainment and Defense
Lessons from the Army's Future Combat Systems Program
1996 Summer Study
Army Simulation Implementation and Use
United States Army
Common Modeling and Simulation Environment (CMSE)
A NEW BATTLE COMMAND ARCHITECTURE FOR MULTI-DOMAIN OPERATIONS
Defense Modeling, Simulation, and Analysis
MODELING and SIMULATION
IN MANUFACTURING AND DEFENSE SYSTEMS ACQUISITION
A58 – Army Modeling and Simulation (M&S)
UNCLASSIFIED

The Good News

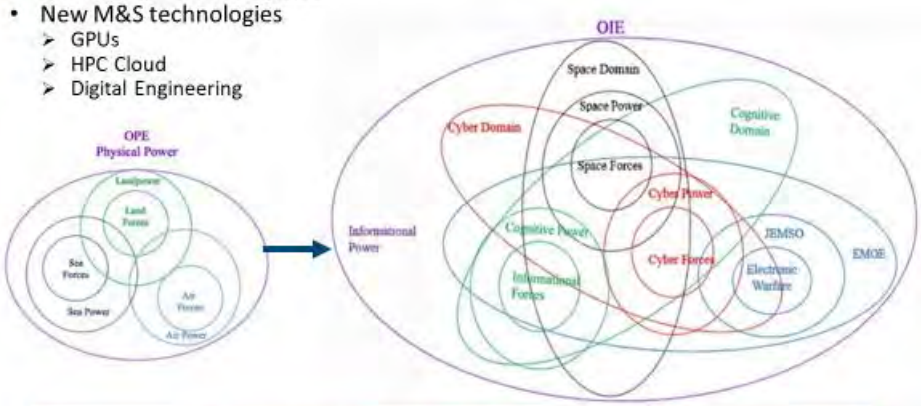
- The Army has:
  - infrastructure components that cover the force and can be linked
  - ORSA and M&S talent who understand the limitations of current simulations
  - an M&S office and venues to help bring willing members of multiple communities together for discussion of Army M&S needs
  - a wealth of kinetic data to support MS&A
  - is well-trained with existing simulators for the **current** operational environment
- The Acquisition community is using M&S extensively to reduce costs and improve system performance.

Project Convergence

- Army Futures Command is actively using **live experiments to get data for MDO**
- "The command recently conducted a live-fire simulation with unmanned-to-unmanned teaming, and with drones and satellites relaying target coordinates to ground artillery and other AI-enabled weapons systems."

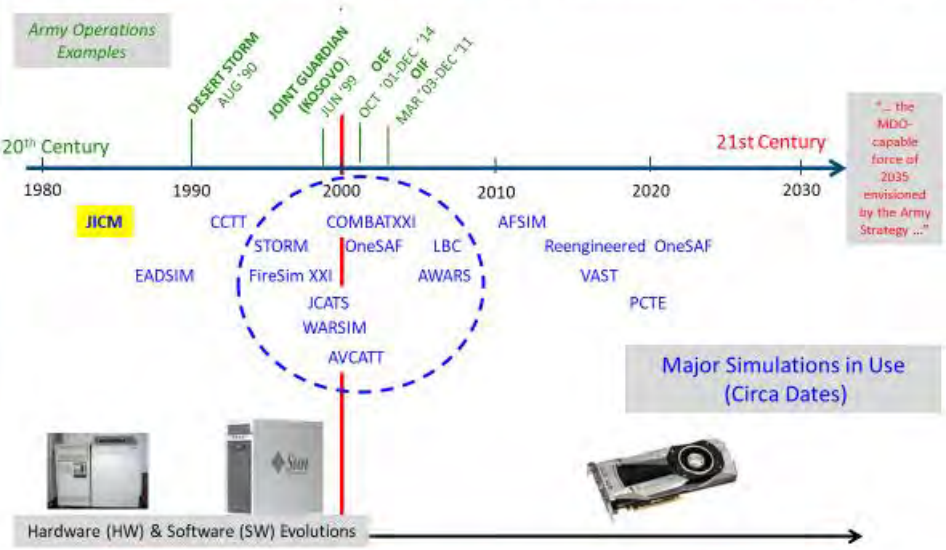
What's Different

- Peer adversaries' advancements
- Operational Information Environment (OIE)
  - MDO/JADO
  - Non-Intuitive CONOPS/TTPs with joint interdependencies
  - Battlefield Phenomenology
- AFC & Project Convergence
- New M&S technologies
  - GPUs
  - HPC Cloud
  - Digital Engineering



"Complex systems defy intuitive solutions"
Necessitates the utilization of *new* M&S for modernization, planning, and training.

M&S Capabilities Are Not Keeping Pace with Modern Technology



CSA's Strategic Perspective

"I think modeling simulations is absolutely critical.

And, it really comes down to, I want to say, ***resources.*** *We can save money, upfront, by modeling, simulating, whether it is designing prototypes and actually it is amazing what you can do, in a computer right now, before you actually build prototypes.*

...

And the same thing with training, and even testing on our systems. We are experimenting and simulating with the type of units that we are going to develop for multi-domain operations. ***So, we know whether they will be successful in combat or not."***

Photo: Paul Lara

GEN James McConville, CSA
House Armed Services Committee Holds Hearing on the Fiscal 2021 Budget Request for the Army
Mar 3 2020

Modernization Needs for Army M&S

- Agile M&S development for timely decision making
- Representing Joint asset performance / vulnerability
- Representing Artificial Intelligence in systems (e.g. autonomous command and control, aided or automated target recognition)
- Modeling Contested Logistics
- Representing cyber network connectivity, data transport, and battlefield effects
- Integration of various systems and dimensions of their operations and effects within the electromagnetic spectrum
- Representing time-dependent effects and interactions across domains (i.e., Cross-Domain synergy), rather than implicitly assuming independence of events
- Demonstrating impacts of human behavior and command and control elements (e.g. reaction to losing GPS, comms, known cyber attack, etc.)
- Representation of echelon-appropriate space-based assets
- Evaluating system effectiveness in the Compete phase

Gaps identified by DAC need to be addressed to meet Army modernization requirements

Army Modeling and Simulation (M&S)

Introduction

M&S Development

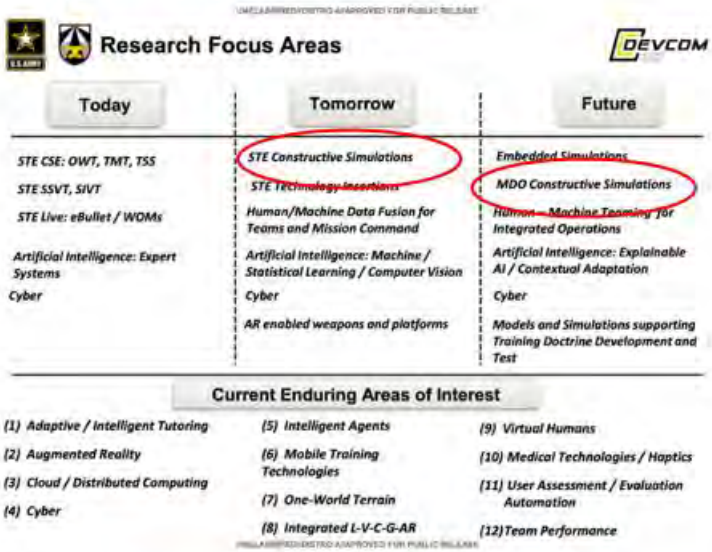
Talent Management

Resources

Governance & Organization

The Plan

M&S Development: Army S&T Focus Areas



Army S&T is a long way from tomorrow

M&S Development: DARPA

Assault Breaker addresses challenges posed by near peer competitors vital to the Army's MDO capabilities

- First objective–architect warfighting operational constructs based on new and emerging technologies and capabilities
- Second objective–develop an advanced M&S environment to support analysis of true cross-domain (seafloor to space), cross-Service, warfighting constructs
- Program ties advanced M&S into an interactive experiment environment to support exploration of complex and interdependent warfighting approaches that capture the future of warfighting

Safe Sim

DARPA is developing an all-domain, Multi-Level Security (MLS) enabled M&S environment that addresses the Army's need to perform mission-level M&S for senior-level military decision makers, technology developers, and acquisition professionals for use in concept of operations (CONOP) development, force structure composition, resource allocation, and targeted technology insertion.

LogX

- Aims to build a capability to work alongside existing logistics information systems to exploit the recent migration of logistics information into digital formats and the Cloud
- Goal is to develop and demonstrate software for real-time logistics and supply chain system situational awareness (diagnosis), future state prediction (prognosis), and assessment of resilience at unprecedented scale and speed

The Army should drive DARPA M&S activities

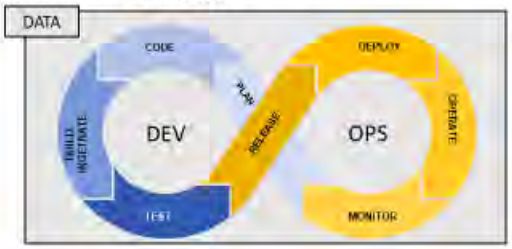
M&S Development: Exploiting Digital Engineering (DE) for M&S

- DE institutionalizes modern engineering processes and products and integrates them through the data they produce to create a Digital Thread
- Maintains traceability from system concepts through acquisition and fielding to divesting.
- Commercial world has embraced
- DE in the Army: a linear process
- CCDC Employs DE & Cloud for MUM-T; using iterative process
- Army is evolving separate, independent DE capabilities among new materiel acquisitions that must work together in the virtual environment and on the battlefield

M&S Development: Ideal– A Rapid Continuous Adaptation of M&S Software

Ideally, we exploit rapid and continuous adaptability and improvement with Model Based Engineering (MBSE)

- Use of common platforms/software/algorithms/data
- **Curation of data**, including truth labeling by humans and augmentation of real data with simulated that goes into our models
- Architecture and infrastructure that support data flows and high-performance computation
- **Operational concepts (i.e. from Project Convergence) that co-evolve with the simulations** and support rapid incorporation of user feedback and
- Focus on solving the highest value problems to bring best ROI
- **M&S-skilled human talent and MBSE**



M&S Dev-Ops Cycle

Air Force is exploring with SCARS and Kessel Run

M&S Development: Challenge of Common Threat Representation

- "Our need to model RED systems and processes to a very detailed level even for training MDO is going to be an expensive proposition and likely the long pole in the tent."
- "Everyone needs to use M&S tools to solve the same problem. There must be an oversight process that insures consistency in threat data used and the simulation algorithms that describe how the data will interact. Home grown threat simply confuses comparison of outcomes across M&S tools."
- "Army M&S is driven by Killer-Victim Scorecards. Other factors that affect the outcomes of battle are modeled poorly if at all. Modeling the OE is an afterthought."
- "The holistic battlefield system from threat observables (the signatures produced by threat activities or platforms in the context of time) to sensors of all types that can "see" the threat observable, PED, to the command and control system that moves the "observations", and finally the command processes that produce a decision that changes the battlefield dynamic is simply not modeled very well. We overcome some of this by man-in-the-loop wargames."
- "BLUE systems and process flows are modeled exquisitely, RED is whatever we can throw together that kind of sort of looks right. Surrogation is a huge issue."

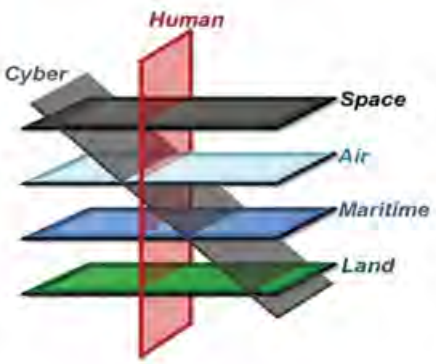
Senior Army Intelligence Official

M&S Development: Cloud

Need ability to collaborate between multiple geographically dispersed teams from different organizations and different applications

Cloud Architecture Has Potential to Break Down Technical and Administrative Stovepipes and Provide Common Data

M&S Development: Systems of Systems Integration Laboratory



- A Systems of Systems Integration Laboratory (SoSIL) could enable:
  - Exploration of acquisition concepts before contracting for design
  - Evaluation of current vs future forces which cannot be done today
  - Development of requirements for future combat simulations and analytic tools
- Currently there is no Army LVC Environment (SoSIL) to conduct simulation-based experimentation of alternative MDO SoS technical architectures and ***exploit Project Convergence lessons learned.***

M&S Development: Findings

- Most critically needed M&S capability: credibly **model Army combat effectiveness in Joint MDO operational environment**
- Need a distributed Joint LVC simulation framework (i.e., SoSIL) to facilitate federation of Army system models with accredited USAF and USN system models in a common synthetic environment to:
  - Evaluate Joint SoS architectures for effectively implementing MDO and establish interoperability requirements
  - Define interface & information exchange specs for Army Big 6+2 systems with Joint systems
  - Integrate M&S with Project Convergence experiments to support experiment design and provide experimental data feedback loop for VV&A MDO M&S
  - Provide virtual human-in-the-loop and AI software-in-the- loop modes for developing heuristic models of the human dimension with and without AI decision aids.
  - Provide a **digital twin** of Army communications networks to conduct simulation-based prototyping of network improvements required for MDO
- New/improved models needed to:
  - Better integrate non-kinetic effects into force-on-force (FoF) models, e.g., space, cyber, EW, autonomy/AI, IO
  - Capture future weapons effects, e.g., hypersonic missiles, long-range cannons & high-speed rotorcraft
  - Incorporate improved C2 modeling of the C2 synchronization that MDO convergence demands at all echelons across all domains and services
  - Assess the impact of human cognition & behavior on the speed and quality of command decisions
- Need more M&S "life blood" experimental data for VV&A that:
  - Are collected and stored using common data standards, and readily accessible
  - Drawn from accredited databases of future MDO scenarios, future threats, and Joint systems/effects

M&S Development: Recommendations

AFC

- Establish and resource a cross-cutting M&S CFT to develop requirements to enable a suite of federated M&S tools to model and evaluate combat effectiveness of Army systems for the future Joint MDO battlefield.

G8, AFC, ASA(ALT)

- Partner with DARPA to exploit new advances in Joint MDO Simulation
- Establish and resource a well-funded agile acquisition program to deliver modern analytical M&S capabilities and a SoSIL to model the Joint MDO operational environment.

Army Modeling and Simulation (M&S)

Talent Management: People and Skills Needs

Officer Functional Area 49 (FA49), Operations Research/Systems Analysis (ORSA)

- Problem solvers -- who produce analysis and decision support products/models to underpin critical decisions by leaders and managers at all levels of the DoD
- Officers recommend potential solutions for complex strategic, operational, tactical, and business issues.

Civilian Operations Research Series, GS-1515

- Professional positions that apply scientific principles and mathematical meth and analyze problems of complex systems and provide advice and insight about the probable effects of alternative courses of action.

Officer Functional Area 57 (FA57) Simulation Operations Officer

- **Officer with operational experience** who understands military operations and training
- Experts in M&S and Army Battle Command Systems
- Facilitate the training and operational environment for commanders to conduct first class mission planning and mission rehearsal exercises

Civilian Analysis, Modeling and Simulation Career Program (CP36)

- Civilians who support analysis, modeling and simulation which is pervasive throughout the Army
- Found in the Acquisition, Analysis, Operations, Testing, Training, Experimentation and Intelligence communities.

Talent Management: Findings

Challenging recruitment and retention of qualified officers:

- ORSA Analysts (FA49s) and Simulation Operations Officers (FA57s) **are designated after company command**
- Industry and Government are stiff competition for M&S expertise with clearances
- No GO positions have been designated for either FA49 or FA57 officers

Falling short on education:

- FA57 officers and civilians increasingly require technical expertise and education
- Only 12% (37 MS and 3 PhD) FA57s have M&S-related graduate degrees
- Only 1.5% (4 MS and 1 PhD) FA57s officers are sent each year
- **No central funding for civilian ORSA and M&S advanced degrees**

Talent Management: Recommendations

G1:

- **Civilians:** Increase the opportunity **for civilians to obtain graduate degrees** in M&S related fields, to include computer programing and systems engineering
- **Officers:**
  - Increase the rate of graduate education for FA57 officers
  - Facilitate FA49/FA57 officers to be Operating Force relevant

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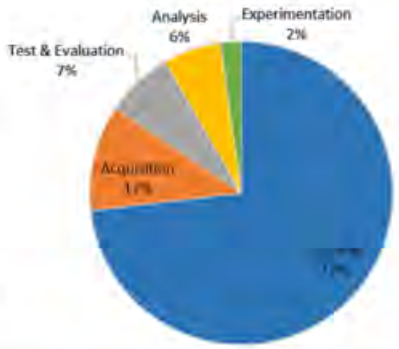
Resources: M&S Investments Compartmented in Six Siloes

- **Analysis**
- **Acquisition** – requirements definition, systems engineering & integration, design/development, verification and validation (V&V)
- **Experimentation** – Lowest funded component in RDTE M&S budget
- **Test & Evaluation (T&E)** – experimental design and evaluation, V&V
- **Training** – Live, Virtual, Constructive (LVC)
- **Intelligence** – Threat and OE



Opportunity exists for funding cross-community development of MDO simulation technology

Resources: Findings

- M&S **training community is relatively well funded** and well organized, with single dedicated organizations for advocacy, resource sponsorship, R&D, acquisition and sustainment.
- **Analysis community is the most fragmented** and underfunded relative to the capability improvement needs to modernize combat M&S of the future battlefield
- Analytical M&S un-funded requirements are **for incremental improvements**.
- Funding MDO requirements would be substantial; Air Force program Simulator Common Architecture Requirements and Standards (SCARS) is $900 million in POM
- Major constructive simulations investments are not slated to occur until next decade; far too late given computing and military technology rapid advances.

Resources: Recommendations

SECARMY

- **Develop a capability to model MDO operations** within a distributed Joint LVC simulation framework with appropriate Army models that fix non-kinetic deficiencies starting with the network convergence and resources equivalent to those provided by the Air Force.
- **Create and manage a centralized Army Model Improvement Plan** (AMIP) to enable S&T advancements for MDO across Army M&S applications and communities

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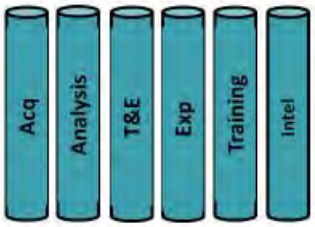
Governance & Organization: Army M&S Integration and Alignment



M&S conducted within organizational silos

Lacks common enterprise vision for sharing/managing M&S data, people, algorithms or models

Integration for cross-community cooperation is technically, organizationally, and fiscally challenging

Governance & Organization: Unclear C2 & Hierarchy

US DoD Counterparts:

- Modeling & Simulation Coordination Office
- Marine Corps Modeling and Simulation Management Office (MCMSMO)
- Navy Modeling and Simulation Office (NMSO)
- Air Force Agency for Modeling and Simulation (AFAMS)

International Counterparts:

- NATO Modeling and Simulation Group
- The Technical Cooperation Program

Army M&S General Officer Steering Committee (GOSC)

- The Technical Cooperation Program (TTCP)
- DoD Science and Technology Board

Army M&S Council of Colonels (CoC)

Army M&S Working Group

M&S Functional Working Groups

Army DCS G-8
- Army M&S Proponent

Army Deputy ADCS, G-8
- Chair, M&S General Officer Steering Committee

Director, AMSO
- Senior advocate for M&S policy and standards
- Executive Agent for FA57 and CP36

Deputy Director, AMSO
- Advocate for M&S policy and standards
- Deputy Executive Agent for FA57 and CP36
- Chair M&S CoC
- Recommends strategic M&S vision and oversight to DCS, G-8
- Comprised of M&S Enabled Community Leads and M&S representatives from across the Army
- Focuses on M&S Foundational Issues

Army M&S Communities
(AR 5-11, Management of Modeling and Simulation)

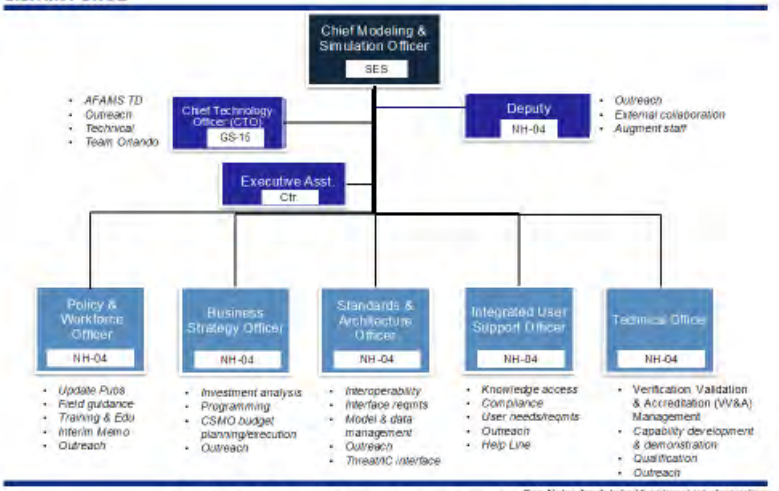
Acquisition ASA(ALT)	Analysis DCS, G-8 (CAA)	Experimentation TRADOC	Intelligence DCS, G-2	Test & Evaluation ATEC	Training DCS, G3/5/7 DAMO-TR

In Contrast – both the AF & Navy have M&S senior leadership assignments

Governance & Organization: Air Force

CMSO Org Structure

U.S. AIR FORCE



See Notes for detailed functional job descriptions

Integrity - Service - Excellence

State of Play: *Lifecycle Responsibilities for Army M&S Community, Both Formal & Informal (select examples)*

Community	Requirements	S&T / R&D	Acquisition (Procurement)	Usage	Sustainment
Training	**TRADOC**	**STTC PEO STRI**	**PEO STRI**	**TRADOC / Operational Force**	**PEO STRI**
Test & Evaluation	**ATEC**	**STTC PEO STRI**	**PEO STRI**	ATEC	ATEC
Acquisition	CCDD/Customer	CCDC STTC	CCDC	CCDC	CCDC / Customer
Analysis	TRAC CAA CCDC-DAC	TRAC CAA CCDC-DAC	TRAC CAA CCDC-DAC	TRAC CAA CCDC-DAC	TRAC CAA CCDC-DAC
Experimentation	TRADOC / CCDC- DAC	STTC	GAP	TRAC CCDC-DAC	GAP
Intelligence	AFC CDIDs	GAP	GAP	Army G2 INSCOM TRADOC G2	GAP

Complex Bureaucracy for M&S Stakeholders Leaves Gaps

Governance & Organization: Findings

- Army has no single dedicated authority to provide an **enterprise vision and leadership for M&S** needed to credibly prepare the Army and Joint forces for MDO
- Army's current organizational silo structure results in:
  - Integration accomplished only by means of a "coalition of the willing" via periodic forums and GOSC meetings;
  - Little incentive and no forcing mechanism for sharing of data or models
  - M&S development gaps
  - Uncoordinated and redundant M&S development
  - Congress is not satisfied with Army ability to justify recommendations
- The DUSA (T&E) has proven the merit and value of leadership over a critical **Army enterprise function**
- Closing the gaps in M&S capability in the Army requires sustained commitment from a given senior official, and expert in M&S, whose sole responsibility is enterprise-level M&S.

Governance & Organization: Recommendations

SECARMY

- Appoint a dedicated, Senior Official on the Secretariat
  - Who is an expert in the M&S field
  - Whose sole responsibilities are leading Army M&S and be the senior advisor to the CSA and SECARMY for M&S
  - Positioned above the heads of the current stovepipes
  - With authority and resources to guide and enforce priorities for advancing Army's capabilities
  - Provides quality control for major Army analyses
  - Who is the focal point for enterprise-wide M&S decision making

Summary of Recommendations

- Appoint a senior independent official on the Secretariat to manage, resource, and guide Army enterprise M&S in support of MDO
- Develop a capability to model MDO operations within a distributed Joint LVC simulation framework with appropriate Army models that fix non-kinetic deficiencies starting with the network convergence and resources equivalent to those provided by the Air Force ($900 million)
  - Use a SoSIL to model the Joint MDO operational environment
  - Synchronize with Project Convergence experimentation
  - Develop more M&S "life blood" experimental data for VV&A that:
    - Are collected and stored using common data standards, and readily accessible
    - Drawn from accredited databases of future MDO scenarios, future threats, and Joint systems/effects
- Prioritize improving Army M&S to support:
  - Agile M&S development for timely decision making
  - Representing Joint asset performance / vulnerability
  - Representing Artificial Intelligence in systems (e.g. autonomous command and control, aided or automated target recognition)
  - Modeling Contested Logistics
  - Representing cyber network connectivity
- Proactively partner with DARPA M&S programs to accelerate MDO and leverage innovation
- Focus on improving civilian M&S capabilities and talent management with oversight by a senior M&S official