

Modeling & Simulation, Analysis, and Experimentation

Purpose. The purpose of this paper is to present a vision for the development, fielding, and employment of appropriate models and simulations, analysis systems, and experimentation techniques for the year 2020. Although this is an Army focused product, it also is relevant to Joint, Interagency, and Multinational (JIM) support.

Introduction: Modeling and simulation (M&S), analysis, and experimentation are vertical integration mechanisms that cross most functional areas and lines of operation, and have far reaching impacts across the entire Army, past, present and future. There is pervasive use of these mechanisms for spiral development and resource decisions, as well as for operational and institutional support.

The Joint, Interagency, Multinational role for these mechanisms is essential in the areas of training, test and evaluation, military operations, concepts and requirements, and in research, development and acquisition. The Department of Defense analytical framework is based on a top-down capabilities-based approach to requirements, the Joint Capabilities Integration and Development System (JCIDS). This top-down approach to force planning 15-20 years in the future utilizes concept development and experimentation to derive desired joint capability for acquisition. Army requirements in this functional area are therefore driven from, and focused on, a Joint or Office of Secretary of Defense (OSD) set of needs.

Many, although not all, the major challenges of synchronization, integration, and resource optimization have been overcome. However, the individuals who use these systems were raised in a culture that was computer savvy and are comfortable in simulation-based environment. The issues are not in teaching the value of using M&S, analysis, and experimentation tools and techniques, but in keeping up with the demand.

The 2020 Environment: In 2020 the Army exploits a collaborative, re-configurable, immersive simulation network for system-of-systems concept exploration and experimentation, development, testing, training, operations, support, and lessons learned in a Joint, Coalition environment. This robust, networked, live, virtual, and constructive environment is essential for innovation and rapid deployment of transformational capabilities. It is also essential for cost containment.

The experimentation environment and infrastructure is adaptable, scalable, and JIM. It enables quick, exponential builds of experiments which merge soldier-centric and equipment-centric experiments to depict, explore, measure, and analyze synergistic capabilities and effects in a fully JIM context. Analytical rigor for concept exploration and experimentation is a standard – not an exception.

The Army also works with a full-spectrum of adaptable, analytical tools, available from platform (both embedded and reach back) to institution and installation, supporting both parametric and non-parametric analysis. This enables rapid, decentralized analytics with quality assurance, supported by a collaborative environment of databases, communications, and intelligent aids.

The Army now uses modeling and simulation, analysis, and experimentation tools and techniques in decision support from “foxhole to factory” and from “mud to space”. It builds upon its baseline high fidelity M&S, analysis, and experimentation tools and techniques, developed or acquired in the science and technology (S&T) and research, development, and acquisition (RDA) sectors, to more fully support test and evaluation (T&E), costing, advanced concepts and requirements (ACR) exploration, and training, exercises, and military operations (TEMO). It possesses comparable capabilities for institutional support, whether it is personnel, policy, infrastructure, or funding. This permits the size of staffs to diminish, yet be more effective.

The result is quick and efficient innovation in a "safe" environment, the testing and analysis of cutting edge concepts with minimal risk to participants and equipment and minimal expenditure of resources. Although these tools and techniques are primarily used in decision support, risk mitigation, and resource (time, money, people, equipment) conservation roles, users adjust them for their particular need, just as they do their computers and personal digital assistants (PDAs). They are not dependent on technicians for "common changes". The following enables them:

- Leveraging a JFCOM managed Joint, Interagency, Multinational distributed collaborative environment, available Army-wide, that provides users access, linkage, and integrated use of a diverse set of JIM-sanctioned models, simulations, simulators, data bases, intelligent agents, and analytical tools available from DOD, other government agencies, industry, academia, and coalition partners on demand. With minimal integration timelines, there is no need for months of negotiations and preparations for a few days of collaborative experimentation. Short focused issues can be examined with minimal participants and then worked later in complex extensive experiments or exercises. The captured data allows for further "what if" drills.
- The technical base, tools and services to represent and visualize (in very high fidelity if required), exercise, test and evaluate, through distributed modeling and simulation, a wide range of concepts, technologies, military systems, mission equipment, and battle space capabilities. Within this environment it is also relatively transparent to the user whether any stimulus is from a simulator, a live force, or a constructive simulation.

- Multi-use tools and services to address and analyze issues from both an individual platform and a system-of-systems perspective for the optimal development, test, acquisition, integration, and evolution of information, communication, mission equipment, weapon systems, training, and platform technologies. These tools are not only modular, but also scalable and link M&S with different levels of resolution. For example, initially a specific task may be trained, then a complex series of tasks trained, and finally a set of collective tasks on a new system analyzed to determine their contribution to combat. All are tightly connected and interoperable. These tools are also used to address a variety of institutional as well as operational support issues, such as logistics, personnel, or infrastructure. For urban operations, cities will be modeled as a system of systems, to include a transportation system, a communications system, etc., within larger country systems, and even larger regional systems. For the personnel community, the total Army community will be modeled as a system of systems, representing each component system, the DA civilian system, the contractor system, and the family member system. The full continuum of service will be represented for exploration of policy impacts, economic factor impacts, etc. Results are consistent across the multiple levels of resolution and from component level to large system-of-systems level.
- Embedded simulations, manuals, intelligent agents, 3-D visualization assets, analysis tools, and decision aids in support of training, personnel, medical support, maintenance, anticipatory logistics, mission planning and rehearsal, course of action analysis, decision support, and battle management.

The 2020 culture is fully supportive of transformation. The “collaborative environment” is now a robust, dynamic group of subject matter experts supported by interoperable tools and data bases, authoritative information resources, and product/process models that are focused on a common domain or set of problems.” The Army is using collaborative environment concepts under an advanced Simulation and Modeling for Acquisition, Requirements and Training (SMART) Concept. SMART enables the Army to capitalize on M&S tools and technologies and information management technologies to address system development, operational readiness, and life-cycle cost through the collaborative efforts of the requirements, training and operations, and acquisition communities.

The gaps have closed between these communities as they now universally draw upon the same set of M&S tools, services, components, and networks despite their differing reasons for using the tools. The communities have become truly interdependent. One result is a shift in policy and organization to more effectively address Army-centric capabilities in a JIM environment and to ensure compliance with JIM standards. Another result is the merging of the modeling and analysis personnel into multi-functional experts. They provide the “higher

order analysis” to augment the high quality “lower order analysis” performed in the field, allowing greater agility under time constraints. They also provide focus for future efforts. This “bench” of multi-functional experts is built using experiential assignments, some JIM, and advanced civil schooling in operations research, modeling and simulation, systems analysis, and experimental design. It includes military, civilian, and contractor personnel. Cooperative arrangements and partnerships with industry and academia are an essential element in the development of this “bench” as well as its tools and techniques.

Furthermore, collaboration is a standard form of teamwork, with live activities and modeling and simulation capabilities that are complementary, interdependent, and integrated-not competing. This collaboration routinely encompasses Joint, Interagency, and Coalition partners and capabilities and is interoperable, and in many cases, interdependent. The conduct of Joint research, development, acquisition, test, and analysis as well as Joint training, concept exploration/experimentation, and military operations, is a way of life, each enabled or enhanced through modeling and simulation. These communities, which are widely dispersed, both geographically and organizationally, share information (studies, scenarios, data, M&S, intelligent agents, and visualization and analysis tools) using a common framework to access resources instead of maintaining separate, duplicative capabilities.

Support of Joint Functional Concepts: In 2020 Army M&S, analysis, and experimentation are an integral part of the JIM environment that supports capabilities-based planning, mission-system analysis, and transformation. Joint guidance, prioritization and possible aggregation of the following Joint Functional Concepts ensures seamless development and validation through joint experimentation and other rigorous analysis, resulting in recommendations for DOTMLPF change to achieve future joint operational capabilities:

- **Battle space Awareness:** The COP for battle space awareness is spirally developed and transparently updated through extensive use of modeling and simulation, experimentation, and analysis. Training and human cognitive behavior insights pertaining to this area are enabled through M&S and include training for appropriate trust or skepticism of digital information and fall-back strategies for interruption of digital operations. Fusion is modeled from level 0 through level 4 and incorporates JIM approved algorithms and intelligent agents.
- **Command and Control:** Planning, preparing, and executing have their roots prior to deployment in Mission Planning and Rehearsal, and in deployment planning, all of which make extensive use of M&S and analysis, and some use of experimentation. Embedded COA analysis tools and training tools, as well as reach-back modeling and simulation capabilities enable the same capabilities during deployment, while dispersed globally, and in the theater of operations. Their adaptable,

reconfigurable aspects allow for much faster decision cycles. M&S and M&S- supported system upgrades are based on real-time feedback from deployed units and now include cultural decision-making and crowd behavior aspects. M&S enabled training for leaders ensures they are adaptable and have the communication and collaboration skills required for distributed operations and networks. In addition, gaming technologies are used to train leaders in the areas of risk assessment and risk taking, decisiveness, and tolerance/intolerance for ambiguity.

- **Force application:** Force application, is analyzed via the use of a variety of JIM M&S applications from the tactical to the strategic level. Some are COA analysis tools, some are training tools, others are used for war game support or concept development, and still others for driving force structure requirements. JIM experiments are also conducted in the course of concept development for this area. All are critical in producing the final effect. Low-level gaming technologies are now widely used for training in force application and have anticipatory and tailorable capabilities for individual, unit, higher-level and self-development training.
- **Protection:** As with force application, force protection is analyzed via the use of a variety of JIM M&S applications from the tactical to the strategic. Some are COA analysis tools, some are training tools, others are used for war game support or concept development, and still others for driving force structure requirements. All are critical in producing the final effect. JIM experiments are conducted in the course of concept development for this area and full collaboration with Homeland Security ensures that all efforts are leveraged, thus eliminating duplication of effort. M&S enabled analysis now includes sleep deprivation and stress reaction norms as well as crowd behavior and some elements of irrational behavior. All exercises are in an asymmetric environment.
- **Focused Logistics:** As with force application and force protection, logistics is analyzed via the use of a variety of embedded, reach-back, and institutional M&S applications that span the tactical to the strategic environments. Some are COA analysis tools, some are training tools, some are maintenance tools, others are used for war game support or concept development, and still others for driving force structure requirements. Experiments conducted in the course of concept development for this area are JIM by nature. All are critical in producing the final effect. Work done in the private sector is constantly reviewed as groundbreaking initiatives are developed.

Investment for Sustainment: The 2020 Army, in support of JIM analysis and experimentation efforts, maintains the focus of its investments for M&S on capabilities to represent current, projected, and proposed technology, equipment, concepts, and doctrine of friendly, neutral and threat elements.

These efforts support development and research programs that produce effective solutions to existing modeling shortfalls and voids. We have produced a new generation of M&S enabling the Army to address the Objective Force within the framework of Joint Vision 2020 issues and beyond. The M&S investments in the advanced SMART Initiative, the advanced concepts and requirements, life cycle cost models, and enhanced training simulations, have resulted in reduced risk and the identification, support, and transition to M&S leap-ahead technology and high payoff opportunities. The Army is realizing a return for its investments.

Army Science and Technology (S&T) investments in M&S to support the Transformation Operational Goals of Project and Sustain U.S. Forces, Warfighter Readiness, Survivability, and Sustainment have resulted in a transformation in the way the Army develops weapons systems, trains soldiers and units, develops leaders and performs combat mission rehearsals. Key technologies developed include: simulation software, decision aids, architectures for immersive environments, robotics, intelligent agents, gaming techniques, voice/speech recognition, and algorithms for virtual and constructive simulation environments.

The synergies of these technologies have created environments for development of adaptive, high-performing leaders and soldiers, capable of improved battlefield performance, making informed decisions, and reducing time and cost. Massive parallel processing provides immersive first person play. Embedded training, in platforms and soldier ensembles, provides enroute and on-demand/on-site learning for a large percentage of Army mission essential tasks. Advanced leader training and development technologies provide virtual complex decision-making experiences enabling better and faster decisions in actual combat environments. Training costs are reduced significantly through virtual experiences -- focusing live training on essential tasks that require "hands-on" experience. New simulation tools and embedded training systems utilize databases that are compatible and integrated with JIM command and control systems.

M&S investments provide new ways to prepare soldiers and units for combat by providing simulations and training systems integrated directly into operational systems to support war-planning and course of action analysis, and to help prepare soldiers to fight in unfamiliar, fast-paced, dynamic environments. The integrated live and synthetic environment provides the foundation for an adaptable joint national training capability formed from existing military testing areas and training ranges capable of supporting advanced beyond-line-of-site weapons systems. Advanced simulation and augmented reality enables the development of future urban combat training centers for asymmetric warfare and unconventional operations.

JIM exercises and experimentation leverage the new M&S environment to test new concepts, doctrine, force structure, tactics, and operations. Simulation is

integral to Joint experimentation and is the primary means by which to capture the synergistic effects inherent in Joint Force and coalition operations. It is an iterative process with initial M&S outcomes providing focus for human-in-the-loop (HITL) trials in a live/virtual/constructive environment, a re-validation of models and scenarios in a constructive environment with excursions, followed by final HITL trials. Significant investments in M&S for logistics, intelligence, group and individual behavior, non-kinetic technology, OOTW, country infrastructure representation, NGO modeling, C4I, and information operations have provided a robust experimental capability. Experiment support requirements are also minimized due to the capability for rapid generation of runtime databases, a permanent network infrastructure, multi-level fidelity models that have a balanced Joint warfare representation as well as interagency, allied, and coalition aspects, flexible post processors that capture all desired outcomes, and a suite of standard AAR and analysis tools. As coalition operations and training are the rule versus the exception, multi-level security capability for databases, models, and output has become the standard.

Research, focused on modeling emerging critical mission areas, has also resulted in instantiating M&S usage in test and evaluation (T&E), thus reducing cost and time to field new systems. A similar cycle to that used for experimentation is used in testing. Initial M&S outcomes focus test trials, test outcomes validate models or provide model changes, excursions are run; and final tests are accomplished with a mixture of live, virtual and constructive elements. Increases in safety and security are an added benefit as well as a reduction in support requirements similar to that seen for experimentation.

The Army's use and management of M&S tools and techniques has resulted in the elimination of unnecessary duplication (fewer "specific use models"), maximum reuse within the JIM environment, interoperability with multi-level security solutions, sharing of information through collaborative environments, and availability of necessary data (i.e. geospatial, weather, etc.) and communications. The Army has realized its goals for investments in M&S and has reduced risk and identified, supported, and transitioned M&S to leap-ahead and high payoff opportunities. As a result, the M&S, analysis, and experimentation environment has become significantly more accessible, timely, relevant, effective, and cost efficient.

Conclusion: In 2020 the Nation has a capabilities-based Joint Force, one requiring a rigorous analysis of the capabilities needed to achieve defense policy goals. The Army's modeling, analysis, and experimentation efforts are developed for, driven by, and focused on, capabilities-based Joint Force requirements. To maintain its relevance and to ensure readiness, the Army has developed the Modeling and Simulation, Analysis, and Experimentation aspects described in this paper. Through these M&S, analysis, and experimentation capabilities it provides expedient insight into JIM concepts, requirements, design, and operations that would not be otherwise available.

