INSTITUTE FOR DEFENSE ANALYSES

A Half Century of Progress in Training, Modeling, Simulation, and Analysis

Frederick E. Hartman

December 2021

Approved for public release;
distribution is unlimited.

IDA Document NS D-22769

Log: H 21-000290

INSTITUTE FOR DEFENSE ANALYSES
730 East Glebe Road
Alexandria, Virginia 22305

About This Publication

This work was conducted by the IDA Systems and Analyses Center under contract HQ0034-19-D-0001, Project AI-2-3077, "Modeling and Simulation Strategic Planning and Outreach (MSSPO)," for the Office of the Under Secretary of Defense for Research and Engineering, Director, Modeling and Simulation Enterprise. The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

For More Information

Frederick E. Hartman, Project Leader
fhartman@ida.org, 703-578-2776

Leonard J. Buckley, Director, Science and Technology Division
lbuckley@ida.org, 703-578-2800

Copyright Notice

INSTITUTE FOR DEFENSE ANALYSES

IDA Document NS D-22769

A Half Century of Progress in Training, Modeling, Simulation, and Analysis

Frederick E. Hartman

A Half Century of Progress in Training, Modeling, Simulation, and Analysis

Frederick E. Hartman
Institute for Defense Analyses
Pebble Beach, CA
fhartman@ida.org
hartmanfe@aol.com

ABSTRACT

Modeling and simulation (M&S) and related analyses will continue to have a pervasive influence in the Department of Defense (DoD) for the foreseeable future. M&S provides a tool that will continue to facilitate future operations and training missions in the DoD. The long history of progress in M&S software development suggests a positive future for the M&S workforce as well as corporate opportunities. The use of M&S as a tool for multiple Defense applications has radically improved in the last 50 years, but persistent issues have plagued users for decades. Today many of these issues have been resolved and are within our grasp of providing real-time environments across the Department both efficiently and effectively. In the past, these M&S environments were created at great expense in terms of time and money. The use of existing and emerging technologies will serve to lower both technical risk and costs of future M&S systems and applications. The contents of this paper reflect the author's perceptions in witnessing firsthand a slice of M&S history that spans numerous innovations in hardware and software to enable progressively better M&S applications.

Although this paper focuses primarily on the author's experience in training and analysis M&S, it is relevant to the multiple M&S domains across the spectrum of applications. The paper provides a number of personal examples taken from a professional lifetime that has chronicled the progress of, and shaped the perspectives of, how multiple technological improvements, management, analysis, and innovation have resulted in the robust set of models, simulations, and simulators that are available today and provide insights into future opportunities. The final section investigates the current and emerging technologies for future progress and provides a summary of my personal observations recorded along the way.

ABOUT THE AUTHOR

Frederick E. (Fred) Hartman (LTC USA, Retired), joined the Institute for Defense Analyses research staff in 1996 after building an extensive background in models, simulations, and training applications in Defense-related analysis and management positions. Fred graduated from the U. S. Military Academy with a BS in engineering and a commission as a Field Artillery (FA) Officer. After an initial tour in Korea in 1968 as an FA Battery Commander, CPT Hartman was selected for flight training and qualified as an Army aviator in both fixed- and rotary-wing aircraft, with an FAA commercial pilot's license, before flying radio research missions in Viet Nam in 1970–71. After receiving an MS in operations research from the Naval Postgraduate School in 1974, Fred completed several Army analytic assignments before leaving active duty in 1981 for an industry career.

Fred joined CACI, Inc. as an analyst and over the next 10 years progressively grew from department manager to executive vice president by building a software development and analysis business group consisting of professionals in operations research, software engineering, software development, logistics engineering, and financial analysis. In 1991, after a brief stint as the Chief Operating Officer of Cyber Communications Technologies (CCT), Fred was founding partner of Applied Solutions International, Inc, a technology applications and analysis company.

Fred became an IDA adjunct in 1996 to support training and readiness, and in 2000 he was appointed as an IPA with OSD as a technical advisor to the Army PEO STRI for the Joint Simulation System (JSIMS) program. He had concurrent duties in OSD as the DMSO Enterprise Division Manager. In 2003 Fred returned to OSD in the Office of the USD (Personnel and Readiness) to serve as co-lead of the Training Capabilities Analysis of Alternatives, and Director, Training Transformation Joint Assessment and Enabling Capability. He also served as Deputy Director, Readiness and Training (Policy and Programs), returning to IDA in 2007. Fred has served as a member of the Army Science Board, led a study panel for the National Academy of Sciences, Board on Army Science & Technology; was an Executive Committee Member of the Simulation Interoperability Standards Organization (SISO); and is a past President and Fellow of the Military Operations Research Society (MORS).

A Half Century of Progress in Training Modeling, Simulation and Analysis

Frederick E. Hartman
Institute for Defense Analyses
Pebble Beach, CA
fhartman@ida.org
hartmanfe@aol.com

"History is the version of an event that people have decided to agree upon."
—Napoleon Bonaparte

HISTORY AND BACKGROUND

Perspectives are formed by events and experiences as we journey through life. Each of us sees the world in the context of our particular background. The previous I/ITSEC Fellows have provided a rich accounting of their professional lives in modeling and simulation (M&S) and recorded their contributions to the M&S profession over many years as they lived it. Several Fellows provided their experiences and predictions of the future based on first-hand experiences of the SIMNET program and other seminal M&S projects. This paper, which is broad in nature, is based on the author's experiences as a military analyst, trainer, modeler, and technical project manager. These perspectives are based on the many professional activities formed by the author's career in designing, producing, managing, and using M&S software and applications.

The author's work in military operational analysis while on active duty in the Army is coupled with progressive industry and government technical and management assignments to provide a broad involvement across M&S development and training applications. The use of operations-research techniques has provided a scientific framework to problem-solving for models, simulation, and training for the future. This retrospective starts with a brief reference to Army theater-level combat simulations as they existed on early mainframe computers with card readers and dumb terminals in the mid-1970s. The critical issues to overcome at that time were primarily driven by limitations on computing power and data storage—even for the relatively small combat models then available. The journey progresses to the present where we see many of the same issues and gaps with interoperability and reuse are still critical and provide challenges for the future. Previous I/ITSEC Fellows have provided us with their experiences with multiple examples and lessons learned over the years.

What was once a convenient tool has become an imperative in each of the Defense operational areas. In the past, many of the shortcomings in hardware and software technologies forced model designers and builders to be creative and sometimes accept "workarounds" as model representations and data to overcome the algorithmic and logical model shortfalls and data gaps. To some degree this is still a challenge, but the software and tools today are much more robust. The need for analysis in M&S remains critical to ensure certifiable outcomes. The ideas of model designers and users are frequently hampered by the state of the art in hardware, software, and data availability and resolution. In the early days of what are now considered as primitive computers, the users and analysts employed what I refer to as "proximate analysis" solutions, which settle for approximations of some data inputs. This was frequently a matter of employing one's own judgment as well as the knowledgeable perspectives of users, software designers and engineers, and knowledge experts.

In the 1970s critical issues to overcome for M&S development were primarily driven by limitations on lack of data, computing power, and data storage—even for the relatively small combat models available.[1]

While studying at the undergraduate level (USMA 1967), my first experience with computers was the venerable IBM 360 in 1965.[2] The interface/input was laborious, requiring batch processing using punch cards, and the outputs were

---

1 My personal observations are provided in italics and captured again at the end of the paper.

2 IBM 360 (S/360) is a family of mainframe computers announced in 1964 and delivered by IBM between 1965 and 1978. https://www.ibm.com/ibm/history/exhibits/mainframe/mainframe_PR360.html.

frequently hard to interpret. Some seven years later, while studying at the Naval Postgraduate School (NPS), I again used an IBM 360, but a later, more powerful version. NPS students still used punch cards in the 1972–74 time frame for batch input. After I graduated from NPS with a master's degree in operations research, an Army technical utilization tour followed at the Concepts Analysis Agency (CAA)[3] in Bethesda, MD, where the dominant model set was used primarily for force structure and logistics support areas.

Army Analysis: M&S in the 1970s

After studying Lanchester equations[4] at NPS, my assignment at CAA was with the combat model user's team for the Concepts Evaluation Model (CEM.)[5] The CEM was a theater-level combat simulation that played force-on-force combat with submodules for various combat and logistics functions. The CEM was employed as the primary analysis support tool for several major Army force-structure studies, cost and operational effectiveness analyses, and wargames. The CAA mainframe in 1974 was a Univac 1108[6] with user interfaces via dumb terminals. The terminals proved to be a significant improvement and time saver after the punch-card experiences in school. However, the interface from the terminals was still in batch-mode processing. Executing a CEM scenario to simulate 180 days of combat would almost totally saturate the mainframe capacity for up to 12 hours. The CEM runs were therefore usually made overnight to allow other users to run their work during the day. Late-night trips to the office were sometimes necessary to fix data bugs, insert checkpoints, and restart the model so the study members could see a fresh run the next morning. As the model manager for CEM, I learned a great deal about the logical "break points" for unit personnel and casualty levels based on force-on-force exchange ratios. This required familiarity with the internal algorithms and data necessary for a given scenario. There were also many errors that would pop up as the model logic evolved over the years to meet various study scenarios. One such discovery, which sticks in my mind all these years later, was the ability to change the forward edge of the battle area (FEBA) movement in a given 12-hour slice of combat. The distance of FEBA movement was one of the primary outputs for a given force-structure scenario. As the battle progressed within CEM in 12-hour increments, a knowledgeable analyst could determine the distance for a FEBA movement outcome with a single data input changing the rate of movement during the 12-hour increments. This experience later helped me understand the skepticism that analysts meet when briefing their results. This was especially true when presenting what might be a radical or counterintuitive study result. I quickly learned that when individuals disagreed with your findings and recommendations, their challenges to the study effort followed a predictable pattern. First a challenge for the choice of models, then the relevance of the scenario(s) and use of supporting data, next how the model was employed (e.g., how many runs were made for sensitivity), then finally the quality of the data and data sources.

Another interesting example from the mid-1970s was an analysis that required an early computer graphical networking application. The Management of Change (MOC) study (Distasio, Bonnett, & Hartman, 1977) was performed by CAA for the Army ODCSOPS.[7] The MOC study team was charged to analyze Army management systems for applying authorization changes and to prescribe measures to facilitate changes from HQDA, major commands, and subordinate commands. The research centered on the impact of controls and schedules on the incorporation of changes and updates to both the personnel and equipment levels in the unit authorizations documents for accountability and readiness considerations. The study was to determine the frequency, magnitude, and types of changes documented in The Army Authorization Documents System (TAADS) and to develop procedures that would reduce the number of changes and time required for units in the field to respond. The study presented a classic operations research problem for controlling

---

3 CAA, renamed in 1988 as the Center for Army Analysis, was created in 1973 to function as the central force analysis activity for the Department of the Army. Its leadership and was initially under the jurisdiction of the Assistant Chief of Staff of the Army.

4 Lanchester's equations are named for the Englishman, F.W. Lanchester, who formulated and presented them in 1914 in a series of articles contributed to the British journal, *Engineering*, which then were printed in toto in 1916.

5 Concepts Evaluation Model (CEM) was a fully automated, deterministic combat simulation that could simulate months of theater land and air combat in a few hours at all levels from Division to Theater.

6 UNIVAC 1108 was the second member of Sperry Rand's UNIVAC 1100 series introduced in 1964. See http://www.computinghistory.org.uk/det/15633/Univac-1108-System-Description/.

7 Office of the Deputy Chief of Staff Operations for U.S. Army.

and sequencing data input and scheduling a large, multifaceted set of data with continuing updates to ensure currency of the authorization documents. In mid-1970s the choice of optimization models for use on the Univac 1100 was limited and required special software to accommodate the thousands of events and activities needed to find the critical path and optimize the process. Fortunately, Sperry-Univac was able to provide a recently acquired software package, Optima 1100 Project Management System, to support the PERT (Program Evaluation Review Technique) diagrams and the optimization of events and activities that could be adapted for the study and interface the output with the system's Calcomp plotter.[8] The large amount of data produced printouts that required two parallel runs (30-inch-wide drum printouts) to capture the depth of the simultaneous events and plots that extended up to 20 feet long. Fortunately, there were some interior hallways without doors that provided the opportunity to post the parallel plots for visual analysis. Also during this period, CEM was used at CAA to support several major COEAs for major new weapons systems, including the XM-1 Tank and the Hellfire Fire and Forget Missile.

During the 1970s there was widespread belief among the Army analysts that computer simulations were a useful tool for military analysis and training but frequently were too expensive and time consuming for quick-turn applications. Many study managers felt the model input and output requirements proved to be too laborious to adequately prepare and analyze. My actions to better prepare the military analysts were to prepare and present classes on CEM training for incoming analysts and new study teams and to provide examples of model runs for various types of scenarios. Which leads to another observation:

Project managers frequently felt models took too much time to see results, and they were more costly since they required a significant investment in terms of hardware, computer time, and personnel work hours for required data preparation.

My next assignment in the Army was as a student at the Armed Forces Staff College (now the Joint Forces Staff College) in Norfolk, VA, in 1977. This school helped me appreciate the cross-service, interagency, and international aspects of military operations, which were to be very useful in my later assignments. It also was a good training experience since I was responsible for conducting classes in my section for Army operations, computer processing, and M&S topics. The staff college experience was to come in handy during later years of work in simulations required for joint training of the operational forces. Next was an assignment at the Army HQ, Program Analysis and Evaluation (PA&E), as an operations research analyst and then a tour in the Office of the Deputy Under Secretary of the Army (Operations Research). These assignments provided a rich perspective into senior staff management and Headquarters DA positions that borrowed from my previous M&S analysis assignments and would prove to be useful in future work at the Office of the Secretary of Defense (OSD). Key issues at that time were analysis of chemical protective gear, including gloves, and an Army zero-based truck study that justified to Congress the release of over $2 billion for tactical and commercial vehicles; the money had been held up for three years waiting for the Army justification.

Industry M&S Software (1981–1995)

After leaving active duty in 1981, I joined CACI, Inc. and over the next 10 years progressively grew from program analyst to executive vice president by building a division group consisting of analysis, software design and engineering, logistics engineering, financial analysis, and modeling and simulation development and applications. CACI at that time was primarily known for its SIMSCRIPT (Markowitz, Hausner, & Karr, 1962) simulation language applications and Navy program support. My key projects included building and modifying inventory models to determine the fly-away kits and stockage levels for the new Navy Lamps Mark III program; designing and implementing an overarching framework and implementation plan for the Headquarters Army information support system; designing, developing, and implementing an econometric model for independent construction cost estimating for Air Force construction projects; and designing, developing, and supporting the Army Training Resource Model to predict operating and support costs for major hardware systems and battalion-level units. The Training Resource Model effort provided the analytic underpinning for the Army tank operating tempo number of 860 miles per year, adopted as the baseline goal for Army unit cost submissions for many years.

---

8 The early plotter, which could print on a 30-inch drum, was manufactured by Calcomp Technologies, originally known as California Computer Products, Inc., founded in 1959. http://www.fundinguniverse.com/company-histories/calcomp-inc-history/.

Again leveraging my Army experience, our CACI team conducted several independent Analysis of Alternatives (AoA) studies to support industry participation in advanced aviation and unmanned aerial vehicle programs. Several of my consultants collaborated to provide technical and operational expertise to support the AoA studies and developed an in-house PC-based combat simulation called Combined Arms Model (CARMO) to support the small studies. The model was composable for a full range of military combat functions, including relevant missile and look-down sensor systems. My division group separately provided analysis support and models for a number of classified government programs.

The decade of the 1980s witnessed a rapid increase in both hardware and software. The computing power and simulation software available to support developing and using models and simulations were growing exponentially. The use of micro-technologies with the IBM PCs and minicomputers such as the DEC VAX,[9] along with emerging spreadsheet programs, permitted easier input for data and allowed the construction of simple models built in a spreadsheet environment. My CACI software engineers learned to connect and "stack" worksheets in early spreadsheet software to produce models before Microsoft produced Excel.[10] Observation:

One of the lessons learned during the early 1980s was that applications software, such as early spreadsheet programs being developed for PCs, had been refined more for the large commercial market and was much more cumbersome to export or use on a minicomputer.

In 1991, after leaving CACI, I performed a brief stint as Chief Operating Officer of Cyber Communications Technologies, and in 1992 joined one of my Army Science Board colleagues, John Johnston, to start a new company, Applied Solutions Inc. (ASI). The startup company specialized in consulting services for the defense industry and international trade. One of the most interesting projects during this period was a special technical assignment in China sponsored by the United Nations Development Programme. I led a month-long multinational review of China's progress on an UN-funded program for developing and using transducer technologies (both capacitance and piezoelectric) for automated manufacturing and control device producers. Other projects included research on consolidation of the Army laboratories, support for the Army's Small Business Administration, and quality improvement reviews.

At the end of 1995 I left ASI and joined IDA to provide technical support and research for the first Deputy Under Secretary of Defense (Readiness) (DUSD (R)), Lou Finch. What originally had been discussed as a technical position to help scope out the automation and models necessary for the military readiness reporting system was quickly changed on my arrival to concentrate on the newly formed Training Council as part of the Executive Council for Modeling and Simulations (EXCIMS) led by Dr. Anita Jones. The timing of my arrival in ODUSD (R) coincided with the standup of the Joint Simulation System (JSIMS) program, the EXCIMS, and Training Council and Training Working Group. This assignment was to continue my earlier focus on modeling and simulation to support military readiness, joint training, and exercises and set the course of my professional concentration for the next 20-plus years.

M&S HISTORICAL PERSPECTIVES

One of the early events that had significant impact on the future of M&S was a Defense Science Board Study published in May 1988. The Task Force on Computer Applications to Training and Wargaming (Defense Science Board, 1988) had an illustrious group of senior academics, technicians, and military trainers.[11] The study, which was requested by the Chairman of the Joint Chiefs of Staff, was chaired by Dr Anita Jones, University of Virginia (Dr. Jones later served

[9] Digital Equipment Corporation introduced the VAX 11/780 in October 1977. History of the ISA: Digital Equipment Corporation - News (allaboutcircuits.com) https://www.allaboutcircuits.com/news/history-of-the-isa-digital-equipment-corporation/.

[10] VisiCalc was brought to the market in 1979 and thought to be the first powerful spreadsheet application. Microsoft Excel provided graphical interface and pull down menu capabilities when it was introduced in 1984-85 (Power, 2000).

[11] One of the key study team members was General Paul F. Gorman, 2011 I/ITSEC Fellow.

as OSD Director, Defense Research and Engineering 1993–97), and had a number of notable members.[12] The Task Force provided a series of recommendations that guided Defense progress and research in M&S for the next several decades. Although a 1988 publication, the Terms of Reference letter was dated September 10, 1985, and the meetings were conducted from October 1986 through July 1987.

The DSB Study Objective as stated in the Terms of Reference: "The objective of this study should be to develop a plan of how to integrate anticipated advances in computer technology with our computer simulation efforts, supporting training and wargaming for joint warfighting" (Defense Science Board, 1988, p. A-1).

The Task Force provided a number of recommendations that guided Defense research in M&S for the next decade.

For our purposes here, it is instructive to observe that reaching back to the mid-1980s, the study recommendations contained many of the same issues familiar to the training and M&S communities today, summarized here:

- Make joint simulations interoperable and distributed
  - Commanders and staffs can train from home duty station
  - Facilitate sharing of simulation data
  - Create shared data repositories and libraries (registries) for DoD-wide access
- Promote joint simulation use
  - Extend involvement of most senior joint commanders
- Establish long-term joint training requirements for future combat capabilities
- Establish a prototype program
- Undertake a major joint training initiative
  - Arrive at more effective simulation-based training with less developmental redundancy

The DSB findings and recommendations recognized at this early date that distributed and interoperable constructive M&S and simulators could provide joint training capabilities that would be both more effective and more efficient. The study also addressed the critical need for simulation data and for shared repositories and registries of validated data and descriptions. Observation:

The 1988 DSB report served to provide the logic, and justified the initial funding, for the formation of the Defense M&S Office (DMSO), JSIMS, and many simulation and simulator efforts.

The Defense study efforts during the 1980 – 1990 time frame have a common thread that has endured over the years. They recognized the importance of M&S for joint training and operations, making simulations interoperable and, to as large an extent as possible, reusable. They also recognized the importance of "certified" data that could feed the models and simulations.

These early studies, in concert with the excellent capture of M&S experiences during these formative years by previous I/ITSEC Fellows, provide insights into the work yet to be done in our M&S communities. Early areas of concentration included the need for interoperable and distributed interactive simulations, examples of two dominant M&S topics today. The seminal work in the 1980s was later operationalized and expanded by the Defense Modeling and Simulation Office (DMSO). In particular the 1995 DoD *M&S Master Plan* (*MSMP*)[13] has provided relevant content and guidance for modeling and simulation that are remarkably current in today's context, some 25 years after being published. The training community prepared a draft training annex to the MSMP in September 1996, capturing the specific training shortfalls in both service-specific and joint training.

It is useful as we go through the training M&S gaps analysis process to also look back to the MSMP and the Training Community Appendix to the MSMP that was prepared and delivered to DMSO in draft form in September 1996 as

---

[12] In addition to Dr. Jones and General Gorman, another key member was Fred Brooks of IBM OS/360 project management and known for authoring "The Mythical Man-Month" in 1975.

[13] "DoD 5000.59-P, Modeling and Simulation (M&S) Master Plan," September 1995.

"The Draft Training M&S Functional Plan."[14] A sticky note written by Sherrell Mock at that time, and attached to the document at the time recorded the disposition of that effort by DMSO:

> Because of the size of the Training M&S Functional Plan it was agreed between DMSO and the Functional Area Councils (Acquisition, Analysis & Training) that they would each produce a short executive summary as their functional area appendix for publication in an update to 1995 DoD MSMP & the full plans would be published separately.

The training M&S plan served to benchmark many of the early guidance documents that implemented the joint training categories (Figure 1) in that era and introduced the gaps found in each of the Services' training tools and models. You

JOINT EXERCISE AND TRAINING CATEGORIES

VI	Interagency/Intergovernmental Training
V	Joint/Multinational Training
IV	U.S./Multinational Interoperability Training
I I I	Joint Training
I I	Component Interoperability Training
I	Service Training

Figure 1. Joint Exercise Training Categories (Hartman et al., 1996, Table 1)

will note the tiers illustrated in the "joint exercise and training categories" extracted from that document were later captured by the three-star-level participants in the requirements game in the 2004 Training Capabilities Analysis of Alternatives (TC AoA) as guidance to the analysis team.

The vision in 1996 as the training M&S plan was produced was that the newly established JSIMS would provide a more capable tool to support future joint training. The next table (Figure 2) lists the M&S Technical Shortfalls (gaps as defined later in the TC AoA.) at that time. It is illustrative that more than 20 years later, many of the M&S technical shortfalls listed below are still critical areas for improvement today. In my later experience with the JSIMS program, the "Thrust 1, Near Term" represented many of the implementation problems for that program, and some led directly to the conditions that fatally impeded the program's very progress to delivery. Note that "Lack of Centralized Management" is present in each of the thrusts and was eventually the major impediment to JSIMS delivery.

---

[14] F. E. Hartman, et. al., "Training M&S Functional Plan," was drafted by the Training Working Group with information provided by each of the Services and presented to DMSO in September, 1996.

Time Frame	Technical Shortfall
Thrust 1 Near Term	Integrated Database Preparation Multiple Scales of Resolution and Fidelity Representation of Intelligence Functions C4I Integration Graphical User Interface Interaction of Forces After Action Review Lack of Centralized Management
Thrust 2 Mid Term	Inadequate Representation of Air and Space Unbalanced Representation of Ground Limited Representation of Naval Combat and Amphibious Operations C4I Linkage with Real-World Systems Limited Impact of Logistics on Combat Representation of Joint Operations Mission Rehearsal Lack of Centralized Management
Thrust 3 Long Term	Imperfect Relationship of Models in ALSP High Exercise Overhead Functional Limitations of Existing Service Models Lack of Centralized Management

Figure 2. Time-Phased Technical M&S Shortfalls (Hartman et al., 1996, Table 3)

I have been fortunate to have had a relatively constant involvement in M&S for training, beginning in 1995 when I joined the IDA Simulation Center and began strategic research and operational support to the Under Secretary of Defense, Personnel and Readiness (USD (P&R)) in the areas of readiness and training.

JOINT TRAINING

Although the Goldwater-Nichols Defense Reorganization Act[15] was signed in 1986, the DoD establishment was slow to fully implement the requirements for joint training. The impact of the joint changes operationally was successfully tested in 1989 when my old boss in Army PA&E, General Max Thurman, who commanded the invasion of Panama (Operation Just Cause; see Schaller, 2008), put it to practice in Panama. Each of the Service elements functioned under General Thurman as planned in the reorganization act in a successful operation. The careful planning and intensive training in advance directly contributed to the successful execution of the operation. Despite its complexity, the plan represented a clear understanding of immediate military and political goals of rapidly destroying the enemy's ability to fight, without needlessly endangering Panamanian lives or property.[16]

A historic anecdote comes to mind regarding the event. When Manuel Noriega was "holed up" in the Papal Nuncio's Residence in Panama City, his capture was temporarily stalemated when he refused to leave sanctuary. The Army used psychological operations in the form of loud music outside the building to encourage Noriega to surrender himself to U.S. forces. Predictably, there was a formal protest from the Papal Nuncio, and during the evening news coverage I vividly remember seeing General Thurman, in his inimitable fashion, respond to a media question regarding the music: "You can tell the Papal Nuncio that I am the commander in chief of music and it will continue for this operation." The music remained loud and contributed to the desired operational objectives for Noriega's capture.

[15] Public Law 99-433-OCT. 1, 1986.
[16] Ibid.

It is useful to provide some background on joint training based on my years of involvement with training M&S at the OSD level. That experience served to provide context for the specific programs and activities that followed during my time at IDA. The existing practice through the mid-1990s, as I was reentering the training field, was for the Services to independently train their warfighters, even for joint combat operations, and provide some reference to the training for jointness. Although by this time each Service had developed distributed simulations for battlefield conditions during functional training, the combat training models were unable to interoperate with other Services simulations. Joint training is usually conducted by bringing one or more of the Services together under a Joint Task Force or combatant command headquarters for exercises. In the absence of joint training simulations, the technique was to provide “role players” for other Service functions in a cursory manner—or not at all. Each Service typically would employ its independently developed training tools and simulate the play of other combat functions. There were many heroic attempts to merge or interoperate with (link together) other independently developed training systems. Because these systems were not designed to be interoperable and work together seamlessly, players used various means to resolve the resulting issues. Typically, one Service’s functions were simulated for its contributions to the particular training scenario and then manually provided as input into the joint training simulation. This was labor intensive and required a large number of “pucksters”[17] behind the curtain to both provide data input to the simulation and to translate the desired role-playing data for the large white cells. In summary, many of the critical joint tasks were trained inadequately or not at all. To enhance joint training at all levels and to conduct the combatant commanders’ required training for a number of joint initiatives, several were started as separate programs. It became the practice moving into the new millennium to regularly identify “gaps” in training with the community at the after-action reviews and develop training alternatives to work around or repair gaps in the emerging systems.

Those familiar with Service training will recall that there are a number of ways to define and break out the appropriate levels and types of functional training, depending on the audience and desired outcomes, in the form of tactics, techniques, and procedures. The push for jointness in operations made it mandatory to train as we operate—at a joint level. One artifact from that period was the Joint Training System (JTS), which included four phases (Figure 3):

- Requirements Phase—Translate strategy to mission and task.
- Plans Phase—Develop a joint training plan and training events schedule.
- Execution Phase—Conduct and evaluate training events.
- Assessment Phase—Aggregate training evaluations to determine the command’s overall mission capabilities.

[17] The term “puckster” is widely used for those players with computers who make the “moves” for opposition forces. The positions are frequently populated by retired military officers or other subject-matter experts.

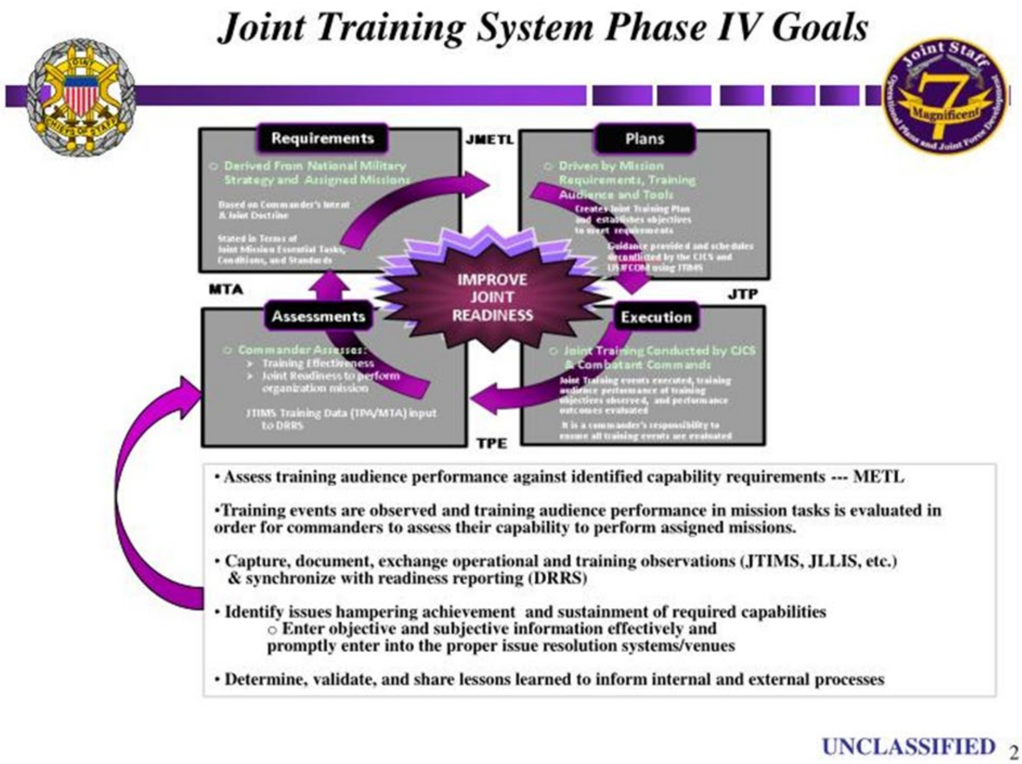

Figure 3. Joint Training System Phase IV Goals. Source: Presentation by Joint Staff J7, Worldwide Joint Training Conference, March 2009.

The JTS was not automated, but used a simple quadrant (see Figure 3) to illustrate the joint training process. The JTS is rooted in joint training policy, and DoD components employed it to assess training programs based on the mission-essential tasks. Note that in the fourth phase, the analysis part of JTS is assessment. This area included analysis to determine and incorporate the lessons learned as well as the operational and training observations.
Another characteristic was to support "jointness" in a new context at much smaller unit levels than the previously envisioned large Joint Task Force. Smaller joint operations were being planned at that time and became much more widely used with operations in Afghanistan following the 9/11 attack. Therefore, to "train as we fight" became instead to "train as we operate," and it was necessary to reengineer the scope of joint training and exercises and events to meet the current training needs. Due to the difficulty in interoperability of the functionality of Services' models for joint training, there was a valid requirement for a new joint program. The Joint Simulation System (JSIMS) appeared to be the answer.

Joint Simulation System

By the 1990s simulations were developed and defined as live, virtual, and constructive.[18] The JSIMS was planned to produce a constructive simulation system for training that would enable the interoperability required for integration of simultaneous play of live and virtual training audiences with simulated assets of the Services, Intelligence Community, and U.S. allies on a single simulated battle space. The JSIMS development was intended to satisfy both joint and Service training requirements in a single, reusable, composable, extensible simulation federation. One of JSIMS program's primary contributions was to be able to support the large joint training exercises conducted by what would become the U.S. Joint Forces Command's Joint Warfighting Center. The JSIMS program began in 1994 with an agreement among Services, the Joint Staff, and supporting DoD agencies to supply the necessary resources and to

[18] Live, virtual, and constructive simulation definitions are found in "The DOD 5000.59-P, "Modeling and Simulation Master Plan," Washington, DC: OUSD(Acquisition and Technology), September, 1995.

form an alliance for JSIMS development. At inception the JSIMS was to replace the legacy simulations in the Joint Training Confederation (JTC) with updated technology and broader functional capabilities. In addition to the increased effectiveness of the training, the strongest arguments (and justification) for the significant development costs were in the efficiencies gained through reuse of many common software components and interoperability of battle-space environments. These features were intended not only to facilitate jointness but also reduce the required workforce in the support team for large joint training exercises. These features would therefore find JSIMS both more effective as a joint training tool and more efficient to operate. In addition, the new system was intended to interface with real-world C4I systems and provide a real-time training environment transparent to the users. The JSIMS program received the required approval in the Operational Requirements Document (ORD) published in January 1996. The user community was represented by a Joint Training Requirements Control Board, chaired by the Joint Forces Command Joint Warfighting Center.

The JSIMS overarching architecture was designed to provide a core with common simulation services, utilities, and mission space objects. The developers chose to use object-oriented programming to build the system. However, as in earlier structured systems design approaches, detailed data flow diagrams were not captured and kept up to date as the JSIMS program grew. A common simulation engine was envisioned for system software to provide the opportunity to compose a given scenario with the functional modules as needed to provide play by each of the joint training audiences as appropriate. As envisioned, this would provide JSIMS with the capability to run on commercially available, open-architecture computer hardware and networks. In early 2000 the program concentrated on an effort to change the JSIMS architecture from that of a single integrated software system to a system of federated components based on the OSD-mandated rules and specifications of the High Level Architecture (HLA) approach. In operation, the JSIMS exercises were to integrate the various operational functions models through the approved HLA. This change required each of the Services' functional federates to be HLA compatible. The Army's module was known as the Warfighter's Simulation 2000 (WARSIM 2000). The Air Force's module was the National Air-Space Module (NASM). The Navy's module is called the Maritime Simulation Model (MARSIM).

As the program progressed, the number of Services or agencies directly involved in the proposed development grew to nine with the addition of the intelligence agencies (Intel), which had created (or updated) simulation programs during that time. The replacement of the stovepiped, legacy simulations that were in use by the Services and Intel proved to be a collaboration challenge as well as a technical challenge. As history had indicated, it again proved difficult to achieve the envisioned unified, interoperable system of composable modules with seamless data transfers between modules. Also, a JSIMS management challenge arose as the program was faced early on with funding issues that were exacerbated by the lack of centralized management of the cross-domain funding. Observation:

The lack of centralized funding was likely the fundamental issue that led to many later technical issues and therefore resulted in ultimate breaches in cost schedule and performance.

The JSIMS Program Manager was funded for the core and common software only; the Services retained their own program structures for management and funding approvals, including their respective PMs, acquisition oversight, and funding channels. To make the problem even harder for JSIMS developers, there was continuing "requirements creep"—emerging requirements above and beyond the original (1996) ORD. These updates, which were added by users, resulted in increased complexity of the proposed software modules—all of which later resulted in cost and schedule breaches early in the program because they affected integration with the core. In many instances, external system interfaces were still needed as the functional software modules were introduced to the core and other functional systems.

The following is a critical events timeline as presented by the JSIMS Program Manager at a DMSO Industry Days briefing in May 2000 (Knight, 2000):

- June 1994 program initiated
  - Core underfunded, Intel community functionality not included
- December 1996 revised MOA approved
- October 1999 OSD technical review concluded
  - Serious technical risks, management problems, and funding problems were found
- November 1999 the DUSD(S&T) chaired a Senior Review Board
- December 1999 Acquisition Decision Memo and guidance
  - Designated JSIMS as ACAT 1D

  - Changed PEO from Air Force to Army
  - Transition program to HLA Architecture
  - Re-baseline program to accommodate additional guidance
  - Development agents report to new PEO
- January–March 2000 program re-baselined with new architecture
- IOC dates moved
  - December 1999 established by June 1994 MOA, moved to April 2001 delayed due to re-baselining and inadequate funding
  - November 2002 delayed due to core infrastructure issues and inadequate funding

By May 2000 the program had just completed a re-baseline of the architecture in an intense effort, beginning in January 2000, to include the software changes needed to transition to the HLA architecture. A thorny issue on software assurance and security had been put to bed by this time by the decisions made in 1998 to build parallel enclaves in the architecture to allow security levels or enclaves at different levels of classification for system security assurance. Although this solution achieved multiple levels of security, it significantly increased the workload by all developers to populate the parallel enclaves.

One of early issues facing the interoperability of JSIMS across the Service functional domains was the way in which each conducted their training. To reach the large training audiences in the Army, the various types of data were typically provided at the unclassified level to the greatest extent possible. This was not the case with the Air Force and to some degree with the Navy. The Air Force opinion at that time was that the unclassified systems data did not provide the proper training environment for the warfighting audience and might introduce negative training when joined in multi-Service scenarios. It became clear that the JSIMS would need to employ a "multiple-levels of security" software solution since true multilevel security was still not available. The technology at the time simply did not support an approved multi-level security solution for software. A working group of experts in 1998 decided on what was then a relatively new device, Radiant Mercury, to provide a trusted guard from low to high. The technology has improved over the years, but this solution was sufficient to provide for the one-way transport of data from low- to high-side enclaves—in this case, the low side was unclassified to the system high side, which operated at the secret level. The security solution required the program to instantiate two functional enclaves for the Services and Intel functional models to reside in the two levels of security. The security solution was provided in a chart presented by Program Manager, Laura Knight at the 20 May briefing previously cited (Knight, 2000). Of course, the security solution necessitated additional software production work for the federate managers.

The JSIMS program provided a number of firsts in terms of training simulations and took a logical next step forward toward interoperability of functional simulations to meet the standing joint training and exercises for the combatant commands. Some combat functions and Intel modules from JSIMS were to continue on in development by the Services and respective agencies. As part of the final termination guidance by OSD (PA&E), an AoA was directed to be conducted in one year.

Training Capabilities Analysis of Alternatives

As directed by the Program Decision Memorandum (PDM) terminating the JSIMS program (OSD, 2002), the training community conducted a detailed cost and operational effectiveness AoA commencing in October 2003 (FY 04), The required analysis was later to be named the Training Capabilities Analysis of Alternatives. Figure 4 summarizes the PA&E guidance as briefed to the first Senior Steering Group (SSG) meeting on November 3, 2003.

The OSD Program Decision Memorandum 1, "Joint Simulation System (JSIMS)," December 12, 2002, directed that an AoA be conducted for joint and Service training. In a memorandum of July 17, 2003, the Under Secretary of Defense, Acquisition, Technology and Logistics (USD (AT&L)) specified that oversight for the TC AoA be provided by a SSG co-chaired by the organizations of the Under Secretary of Defense, Personnel and Readiness (USD (P&R)), Dr. David Chu, and the Commander, United States Joint Forces Command (JFCOM), ADM Edmund Giambastiani. Figure 5 provides a list of SSG membership for historical purposes.

The memorandum further specified that the AoA be completed by August 1, 2004. The SSG Membership was represented by the most senior training stakeholders for both joint and Service training and the intelligence agencies. Mr. Steve Moore of JFCOM and I were assigned as co-chairs of the TC AoA.

The study was conducted in five steps: (1) identifying gaps in current and programmed capability, (2) developing alternatives, (3) assessing effectiveness, (4) estimating costs, and (5) determining cost-effectiveness. These analysis steps were supplemented by three business games conducted during the course of the effort, including industry and senior military training stakeholder participation and feedback at critical intervals. Figure 6 provides a schematic diagram of the methodology for determining the training requirements and alternatives employed by the AoA team.

One alternative, Alternative 4, drew heavily on the insight of industry representatives to assess potential efficiencies and effectiveness of corporate-level DoD strategies and acquisition processes for purchasing future training and training support.

Figure 4. Training Capabilities Analysis of Alternatives Kickoff Chart (Hartman, 2003)

Senior Steering Group (SSG)

Training Capabilities AoA

Senior Steering Group (SSG) Membership

Organization	Member	Alternates	POC
Co-Chairs			
USD P&R	Dr. David Chu	Dr. Paul Mayberry Mr. Tom Hall	Fred Hartman CAPT Newton
US JFCOM	ADM Giambastiani	LTG Wagner	Steve Moore
USD AT&L	Mike Wynne	Mr. Bob Nemetz	Dr. Buhrkuhl Ms Mona Lush
DDR&E	Dr. Ron Sega	Dr. Robert Foster	CDR Steele
USD Intel	Dr. S Cambone	LTG Boykin	Sean Nolan
	DIA	Dr. Tom Richardson	Mr. Rich Lilly
	NRO	BG Halter	Lt Col Johnson
	NSA	MG Quirk	Mr. Cristopher Wojtal
	NGA	Mr. Irv Buck	Dave Cook
USD Policy	Mr. Ryan Henry	Mr. Rich Davison	COL Kelly
Dir, PA&E	Ken Krieg	VADM Szemborski	Tom Simoes
ASD NII	Mr. John Stenbit	Dr. Ronald Jost	CDR Griffiths
Joint Staff	VADM Keating	LtGen Cartwright	CDR Seliga COL Gilliam
Army	GEN Casey	LTG Cody	Mr. James Gunlicks
Navy	ADM Mullen	VADM Konetzni	CAPT Shegrud
Air Force	Gen Moseley	Lt Gen Hobbins	Jeff Bradshaw
USMC	Gen Nyland	LtGen Hanlon	Dr. Mike Bailey
SOCOM	VADM Olson	BrigGen Hejlik	Col Howard

22

Figure 5. TC AoA Senior Steering Group Membership

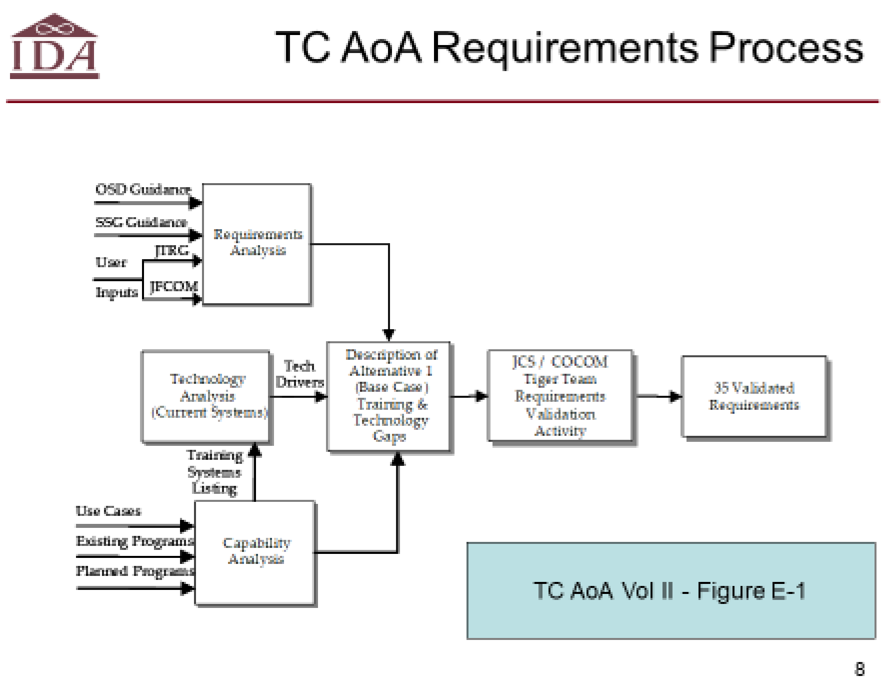

Figure 6. Training Capabilities Requirements Process. Source: Training Capabilities AoA (TC AoA), Vol II, Figure E-1, July 2004

The TC AoA listed training gaps (training needs) and an M&S capabilities baseline of then-current capabilities to fill those gaps and provided a series of alternatives to meet the validated joint training requirements. The stated purpose of the TC AoA was (1) to compare current training capabilities with training requirements to identify gaps in our current joint training capability, (2) to identify alternatives for removing those gaps, and (3) to assess the cost and effectiveness of these alternatives. The report described and expanded on the five alternatives that were originally directed in AoA guidance and tracked how these alternatives were further defined for the detailed analysis of cost and effectiveness. The study initially defined 13 areas of deficiency, or "gaps," by comparing current capabilities for joint training with joint training requirements. These gaps were expanded to a list of 35 more narrowly defined and prioritized gaps through the deliberations of a Tiger Team composed of representatives of the Joint Staff (J7), the combatant commands, and the Services. The resultant coordinated list of training requirements could be met by a variety of training methods and tools as discussed in detail in the report. Five directed alternatives were specified:[19]

- Alt 1. The Base Case.
- Alt 2. A single centralized federation consisting of tightly coupled simulations.
- Alt 3. A loosely coupled federation of Base Case systems and additional enhancements to these federates that are designed to eliminate the training gaps identified by the requirements analysis.
- Alt 4. Innovative acquisition approach for training. Including buying training from industry vendors who provided environment and tools to include models. (See Figure 10.)
- Alt 5. Reengineering joint training. Alternative 5 focused on innovative training methods and technologies other than the use of large-scale constructive simulation exercises for joint training.

The final study briefing to the SSG was presented on June 3, 2004. Given the level of the decision-makers on the list of SSG members, this proved to be an important meeting that set the ground rules for allocating joint training investments over the coming years of the Future Year Defense Program (FYDP). Since none of the five directed alternatives provided a complete solution to the DoD vision of joint training, the study team recommended a blended solution with aspects of three alternatives. The SSG voted to approve a blended course of action incorporating constructive simulations, alternative training methodologies, and clear management and oversight that would better meet DoD's joint training requirements and desired training capabilities. The SSG approved a recommended course of action that included a blending of Alternatives 3, 4, and 5 and also addressed the joint management responsibilities for Training Transformation (T2).

The TC AoA findings and observations, which were summarized on a single chart (Figure 7) for the final SSG briefing, addressed the issues in a more generic joint training thrust—entertaining live, virtual, and constructive solutions.

---

19 TC AoA, Vol 1, July 2004.

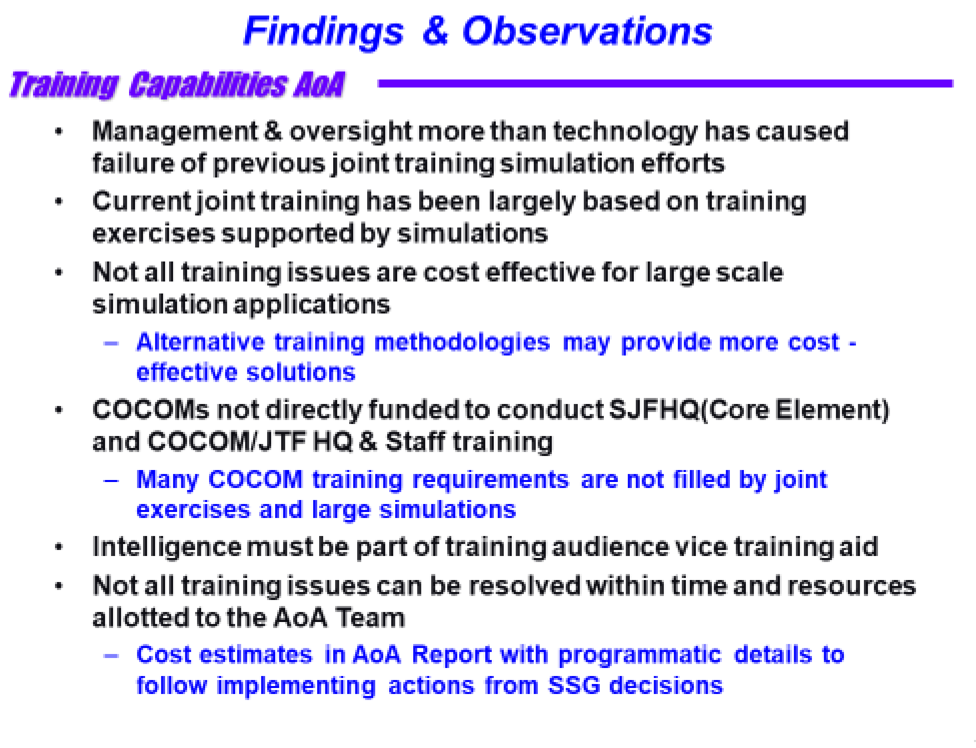

Figure 7. TC AoA Findings and Observations (Hartman, 2004)

In the initial step of the requirements analysis, the Training Panel had identified 13 broad areas in which current and programmed training capabilities (the Base Case) failed to meet the requirements of training transformation. Identifying these gaps drew on the following inputs:

- Joint Mission Essential Tasks identified by the combatant commands and Services.
- Higher level guidance and directives (e.g., Quadrennial Defense Review).
- Training requirements and capabilities identified at the Joint Training Review Group.
- The Requirements/Alternatives Business Game and the Senior Steering Group, meeting in January 2004.
- Data gathered by JFCOM and the Services.

The Joint Staff J7 led a Tiger Team to conduct a review of the initial 13 gaps. Over the course of the AoA the Tiger Team met with the combatant commands and Services to validate and prioritize the gaps, which led to an expansion to a more detailed list of 35 gaps. The 35 prioritized gaps form the basis for the effectiveness analysis in the AoA. The top-10 ranked requirements to fill training gaps are displayed here:

1. Train Combined Joint Task Forces (CJTF) (includes need for Individual Joint Training)
2. Train Standing Joint Force Headquarters (SJFHQ) (includes need for Individual Joint Training)
3. Train on Crisis Action planning and deployments
4. Provide faster/higher fidelity Mission Rehearsal
5. Train forces on Joint Urban Operations
6. Train forces on Information Operations (IO) (including Info Warfare, Computer Network Exploitation (CNE), Command and Decision (CND) and Computer Network Attack (CNA))
7. Train forces in a Joint Interagency Intergovernmental, Multinational (JIIM) environment (including Intel)
8. Provide Homeland Defense Training
9. Provide multi-command missile defense training
10. Train forces in enemy Chemical, Biological, Radiological, Nuclear, and High Yield Explosive (CBRNE) exploitation and destruction

These top training gaps formed the basis for further analysis after refinement by a crosscutting tiger team of combatant commands and Services.

Insights in filling the needs of the top training gaps from an M&S perspective were provided by the Training M&S Business Plan (Fletcher et al., 2007) and summarized in the condensed table of training priorities (Figure 8).

The AoA conducted three "business games." The first of these, Game 1, in January 2004, was dedicated to joint training requirements. The requirements game was led by the Deputy JFCOM Commander with two-star-level representatives for the Services. The Services and Intelligence Community provided recommendations to enhance joint training requirements from their functional perspectives. Figure 9 illustrates the joint training requirements as briefed by the Deputy JFCOM Commander at conclusion of the first business game.

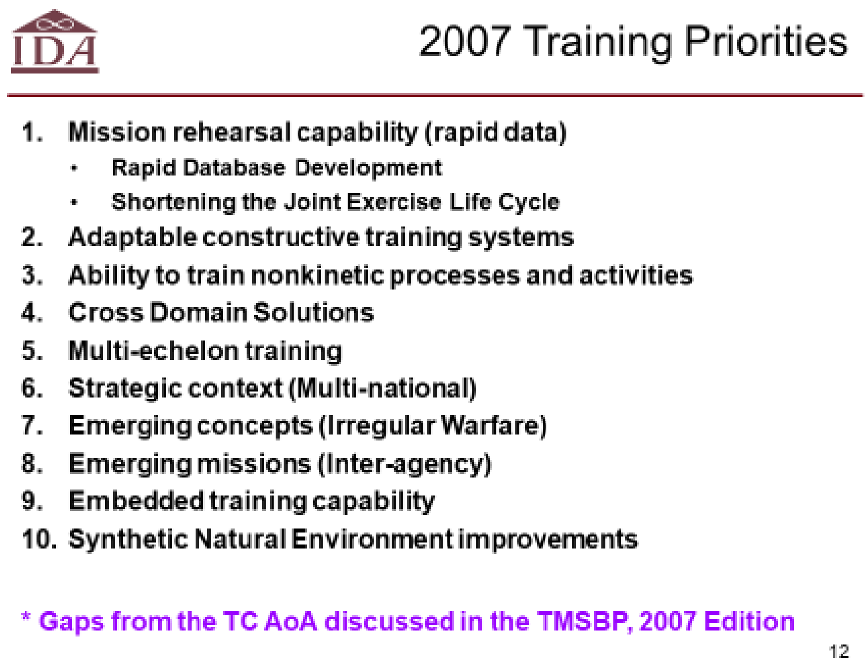

Figure 8. Training Priorities from Fletcher et al., 2007 (Hartman, 2004)

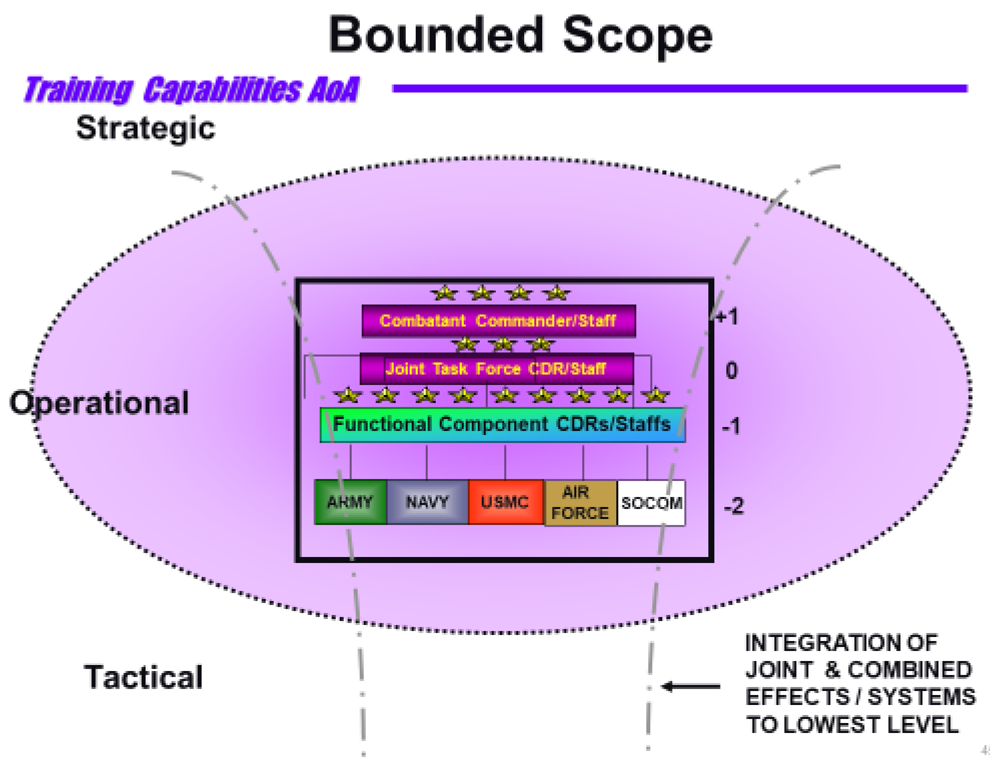

Figure 9. Bounded Scope. Prepared from LTG Wagner, Deputy JFCOM Commander, remarks following at conclusion of the first business game. Presented to TC AoA SSG, February, 2004

The AoA Game 2 conducted in February 2004 focused on the issues surrounding the acquisition of training M&S. In addition to the military stakeholders in the requirements game, this game included a number of business leaders from the simulation and gaming communities and Wall Street. The outcome of Game 2 was an innovative (at the time) approach of military users purchasing training as a service from commercial training providers. The government maintained control of requirements for the data, exercise details, and simulations in a "tool kit" selected from industry by the training-support provider. Figure 10 provides a detailed depiction of the fourth alternative proposed business process.

The AoA Game 3 conducted in April 2004 was presented to the SSG Deputies to determine the priority for presenting study recommendations for the Final Briefing to the SSG in June, 2004.

In the final TC AoA briefing, the SSG approved future management and technical actions, including an evolutionary path for future enhancements to constructive simulations and expanding alternative training capabilities to include individual training to support Joint Task Force and Standing Joint Task Force training. The continuing oversight of the SSG decisions was delegated to the Executive Steering Group (ESG) that had been set up for the T2 Program and was also jointly chaired by Dr. Chu and ADM Giambastiani. The T2 ESG provided oversight and management input and worked with a T2 Functional Capabilities Board and with a Joint Requirements Office (JRO) for the three joint training T2 programs. Oversight of post-AoA actions was officially transitioned to the T2 ESG on August 1, 2004. Additional recommendations included designating JFCOM to stand up a Joint Requirements Office for post-AoA implementation. During the conduct of the AoA there was overwhelming concern among some AoA principals that joint training systems were not being sufficiently addressed in the joint requirements process. In July 2004, a Joint Training Functional Capabilities Board (JTFCB) was formed to focus on analyzing capabilities of existing and future programs, projects, and initiatives; the live-virtual-constructive environment; and non-material approaches to training.

The SSG approved the blended-simulation course of action described above as a "constrained enhancement" to the base case and approved funding through the FY06–11 FYDP. The JFCOM, in its role as the JRO for joint training, was designated to oversee the SSG joint simulation development, including:

- Spiral developments to address training gaps.
- Improving and developing simulations for joint federations to support joint training exercises.
- Developing tools to enhance joint training federations (common data, terrain, AAR, runtime infrastructure, and C4I interfaces).
- Joint collaboration with the Services and Intel on federations.
- Minimizing the number of joint training federations to two initially, with a goal of one.
- Maintaining the JTC until FY07.

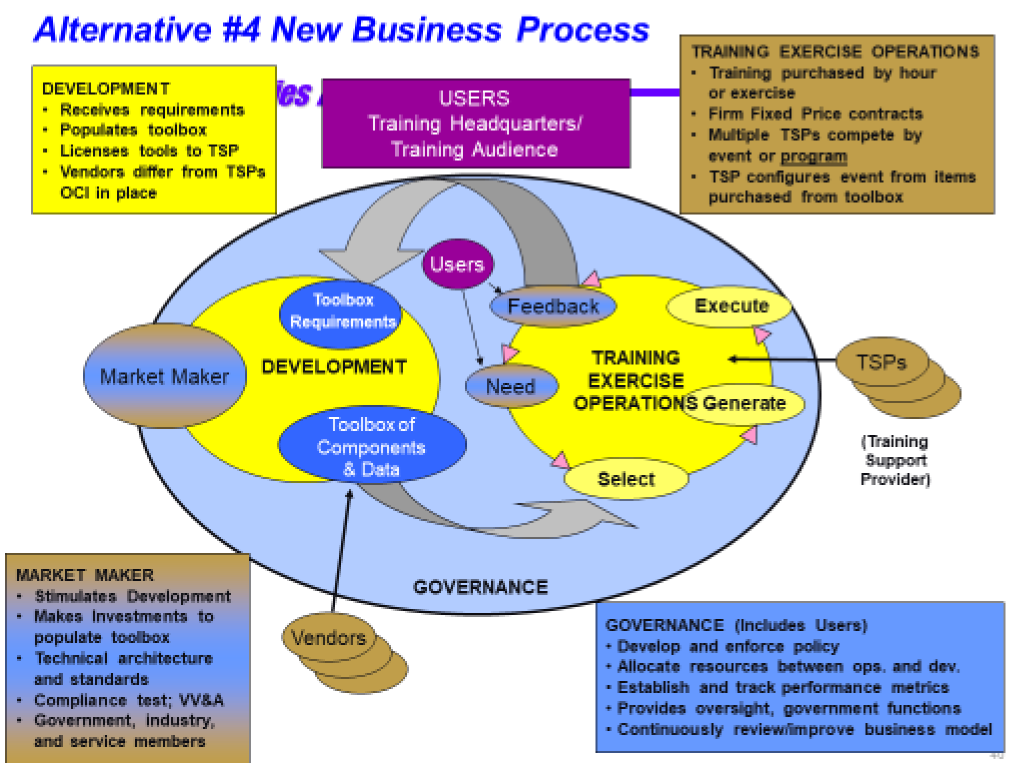

Figure 10. Alternative #4, New Business Process, prepared following the second business game, February 2004, presented to the TC AoA SSG, June 2004

The TC AoA also addressed the compelling need for realistic representations of intelligence in joint forces exercises and training. The AoA recommendations called for Intel to be integrated in joint training because it was then being incorporated into live operations at all levels of command. The concept of a Joint National Intelligence Training Federation had been proposed by the study and was considered by the SSG to be the desired path. The USD(I) was asked by the SSG to lead an effort to pull together the functional simulations across the Intel agencies. It was recommended that the JFCOM J7 Joint Requirements Office work with Intel to validate requirements and work with the Joint Warfighting Center to integrate software into the JTC. Unfortunately, this recommendation was not fully implemented due to insufficient funding.

As previously noted, the issue of multilevel security for training simulations had become an issue in the JSIMS program software development. Although the TC AoA recognized that the multiple levels of security would continue to be an issue for future joint training simulations, it was clear this issue was pervasive and beyond the scope of the TC AoA. Another such issue was the employment of what was known at the time as the Global Information Grid. The

AoA recommended the Global Information Grid (data and services) be fully integrated into future developments of training enterprise services. These capabilities are today largely being made available in the cloud.

The TC AoA final report made five far-reaching recommendations:

1. Improve management and oversight for training systems.
2. Establish, enhance, and evolve a joint M&S toolkit of existing constructive programs (Alternative 3).
3. Develop innovative acquisition approaches for joint training capabilities (Alternative 4).
4. Provide training methodologies as alternatives to large-scale constructive simulations and training exercises (Alternative 5).
5. Integrate the Intelligence Community into joint warfighting training.

Detailed implementation of the SSG guidance was to be accomplished under the T2 Executive Steering Group oversight. Although the Executive Steering Group was in place and continued to meet on a regular basis, the full list of recommendations was not fully funded by the sponsors in FY05, and it was not possible to secure the additional funding through the subsequent years' program-review process. The TC AoA provided an intense year of activity by all training partners from units and senior leadership levels and allowed a focus on training to provide a way forward for the Services and joint training community. The study remains as a valid reference document today. Volume I (Appendixes A–G) provides the complete requirements, gaps, and the simulation baseline in 2004 and other relevant issues for joint training execution. Volume II (Appendix H) contains a compendium of models with detailed descriptions and user self-assessments from the functional training communities. Although now out of date, the TC AoA baseline and models provide a window into the origins of many of the training tools in use today. The final briefing included a number of decisions and guidance for the meeting that would have an impact on the next several years of joint training. The TC AoA illuminated many of the issues in joint training M&S that lead us to this observation:

The current implementation of the concepts of M&S as a service and the use of cloud access to data, coupled with artificial intelligence (AI), are today providing significant opportunities to conduct training exercises and mission rehearsals in a much more agile manner. These capabilities will continue to improve in the foreseeable future.

Training Transformation (T2) Program

The FY04 Defense Planning Guidance (DPG) directed the USD (P&R) to develop a strategic plan and program to transform DoD training as a means to better enable joint force operations. The Training Transformation Program (T2) Program was formed in 2004 to comply with the DPG. All DoD forces were trained to provide the operational capabilities needed to meet dynamic challenges for the current and future national security needs. The T2 Program's primary missions were to (1) better enable integrated operations and (2) ensure the continuous capabilities-based transformation of the DoD. The T2 Program contained three components to provide support for all levels of training and to provide baseline assessments for reaching the T2 goals.

- The Joint National Training Capability focused on collective training. The primary tool was the Joint Training and Experimentation Network (JTEN), which provided permanently available connectivity between training locations. The JTEN provided a reduction in setup cost, offered more joint participation, and allowed for more participation from home station. It also provided the backbone to connect models, simulations and units for large joint training exercises. This component was led by JFCOM.
- The Joint Knowledge Development and Distribution Capability (JKDDC) focused on web-based individual training. This component was initially led by the Joint Staff J-7 and later moved to JFCOM.
  - The JKDDC early stages concentrated on development and distribution of joint training course content for the combatant commands that was relevant to the training audiences. It was designed to link with the Services' online training systems and eventually was hosted as the Joint Knowledge Online.
- The Joint Assessment and Enabling Capability (JAEC) focused on T2 program performance assessment and supporting training tools and processes. This effort was led by OUSD(Readiness).
  - This arm of T2 was formed to assess how well training was meeting current and future operational requirements and to determine the effectiveness of T2 on improving training. The JAEC analyses also recommended strategic and programmatic changes to improve the effectiveness of training.

The T2 Strategic Plan provided strategy and direction for joint training and a set of actions for planning and implementing T2 programs. To keep DoD leadership informed, the T2 Strategic Plan also directed a biennial assessment called the "Block Assessment." A common complaint over the years was that lessons learned were typically collected at the conclusion of each training event and recorded; however, in most cases, such lessons learned were "observed" and frequently no further action was taken. The end result was that many of same lessons were relearned at the next major exercise or training event. The intent of the JAEC was to institutionalize the fourth quadrant of the JTS, the Assessment Phase. That formalization of the process required common metrics and data collection to support those metrics.

The T2 Block Assessments were conducted by JAEC to provide feedback on:

- The effects of joint individual and collective training on the missions and objectives stated in the T2 Strategic Plan.
- The effectiveness of the T2 Program in enhancing training.
- The progress of the T2 Program in building capabilities, networks, systems, and other enablers to support T2.

In May 2004 I was appointed as the director for JAEC and began planning and assembling a team for the first Block Assessment report. The T2 Block Assessment Roadmap was created in 2005 in lieu of a full-blown assessment to provide and institutionalize the process and data-collection tools to ensure future Block Assessment outcomes would support T2 Strategic Plan directions. Guided by the 2005 Roadmap, the 2007 Block Assessment expanded on the Roadmap process by including the detailed data of specific training programs and events from the combatant commands and Services and collecting data representing a sample of designated joint training activities.

The 2007 Block Assessment demonstrated that DoD had improved the process for enabling joint operations through its accreditation of major joint training programs. The accredited programs deliver joint training to both the Joint Task Forces and Service Components. In addition, joint training met the operational needs of the combatant commanders, according to analysis of Joint Mission Essential Tasks trained in exercise data and comments made in structured audience interviews. For a more rigorous assessment, the joint training component of readiness should be more closely linked to the readiness reporting system through more frequent and comprehensive joint training assessments and through further progress in integrating automated systems for joint and service readiness reporting.

The T2 Strategic Plan described the scope and intent of training:

> The prevailing principle for the T2 program is that no one should experience a task in a real-world operation without having previously experienced that task in training or education. For this reason, individuals, units, and staffs must be trained to conduct integrated operations upon arrival, as well as during employment in the combatant command area of responsibility.[20]

The Block Assessment found that to a large degree, joint training was accomplished before unit deployments. Analysts were unable to determine, however, whether individuals reporting for joint assignment at combatant commands and individual augmentees[21] reporting for joint duty on joint staffs at joint force commands were fully prepared to operate in a joint environment or to what level individual training had been used.

The 2007 Block Assessment used four primary assessment methods:

- Quantitative assessments, which addressed aspects of joint training that can be described with numerical data.
- Qualitative assessments, which addressed high-priority issues not directly or fully addressed by the quantitative data-collection effort.
- T2 implementation outcomes, which measured whether JKDDC, Joint National Training Capability, and JAEC had met outcomes described in the T2 Implementation Plan.

---

[20] T2 Strategic Plan, May 8, 2006, p. 14.

[21] Individual augmentees in this case are military personnel to enhance the joint training (i.e., Reservists, Navy, Air Force, or Army, depending on the expertise needed for a specific scenario).

- Joint training community feedback, which sampled opinions of representatives from combatant commands and Services through structured interviews with senior leadership.

The 2007 Block Assessment found that DoD was meeting the first mission of the T2 Program, to enable better integrated operations. T2, through its accreditation of major joint training programs, provided the leverage for commanders and staffs to ensure joint training was meeting training needs. The assessment found that joint training was meeting the operational needs of the combatant commanders, reaching the full spectrum of the Total Force, and was being accomplished before unit deployments. Determining readiness improvements, however, proved more difficult. It was found that joint training and overall readiness needed to be linked more closely by designing more rigorous and comprehensive joint training assessments and through further progress in integrating results into the automated readiness reporting systems. At that time, the Defense Readiness Reporting System (DRRS) was being revised to include more automated data and feedback. The method for arriving at the assessment included the use of training attributes that were commonly in use by commanders to self-evaluate their training missions.

One of the primary challenges in assessing training was how to determine meaningful metrics and collect data on several reinforcing sources to provide credible results. Each Block Assessment became part of the T2 Program spiral-feedback mechanism to ensure lessons observed and relevant recommendations were provided to the responsible organizations in the T2 community. The T2 Program intended for the Block Assessment process to reach full operational capability in 2009.

During the data-collection phase of the 2007 Block Assessment, a large number of training events were represented. Figure 11 provides the numbers for training events and categories representing one key part of the analytic process.[22] It was also possible to compare costs of large exercises and other joint training events. For example, the JAEC team was able to access cost data indicating how the existence of a permanent training network in JTEN considerably reduced the time and costs of joint training and Service joint training participation. The numbers for home-station training increased significantly, which also drove down the transportation costs for the participating units. There was a follow-on effort with the JFCOM to participate in the new formation of the Joint Training Requirements Group and the Training Gaps Analysis Forum (TGAF) to work on closing the training gaps published in the TC AoA (Patenaude & Hartman, 2007). During my years as the JAEC director, I was joined by Ms. Annie Patenaude, who was an invaluable thought leader in our assessments and succeeded me as the director when I completed my IPA and returned to IDA in September 2007. Under Annie's leadership the JAEC team produced the 2009 Block Assessment.

[22] 2007 T2 Block Assessment, p. 6

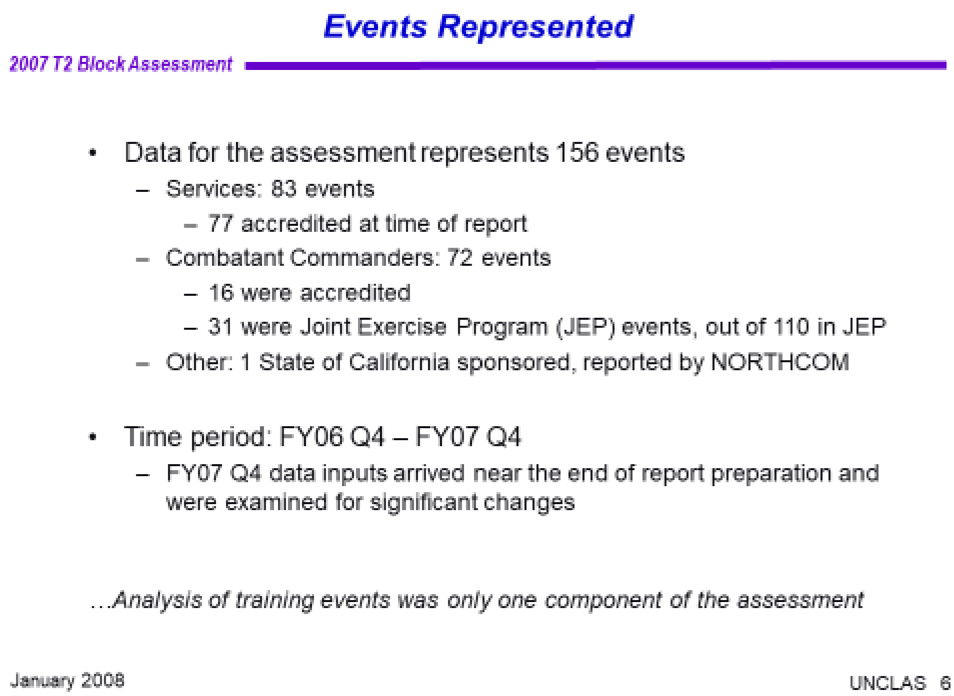

Figure 11. Scope of Events Represented in the 2007 T2 Block Assessment Indicating the Number of Accredited Training Events, January 2008

The efficiency of joint training continued to improve for both individual and collective training during the T2 Program. More collective training was taking place at home station, reducing costs and stresses on the force and equipment, largely caused by the relocation of units to participate in the live portions of the exercises. For individual training, improvements were largely due to the success of the Joint Knowledge Online, which provided the power of interactive, distributed networks reaching a larger audience for little additional cost. Each Block Assessment was an integral part of a T2 Program spiral-feedback mechanism to ensure lessons observed and relevant recommendations were being provided to the responsible organizations in the T2 community. The JAEC Block Assessment process reached full operations with the 2009 assessment.

M&S Gaps Analysis

In the years following the TC AoA, several initiatives continued forward and were partly funded to fill gaps identified in analyses. The gaps had been defined and expanded in the TC AoA to help the training community translate them into their particular training environment. With the input of the of the training community representatives the gaps were further expanded in the Training M&S Business Plan (TMSBP) and continued to be refined by the Training Gaps Analysis Forum (TGAF) led by the Joint Staff and JFCOM. The TGAF met with all the combatant command M&S representatives on a regular basis. Much of the following material is from a briefing presented in November 2008 to the Joint Training Requirements Group (JTRG).

Some 11 years after the 1996 Training Functional Plan we find several recurring themes, issues, or shortfalls (gaps) that were identified by the 2004 TC AoA and were validated again by the training community in the 2007 TMSBP three years later (Figure 7).

In most instances the 2004 TC AoA technical shortfalls are traceable to the persistent gaps of interoperability and reuse across the Service training domains.

The TMSBP provided an update of M&S training needs as they had been addressed in the TC AoA published in July 2004. The initial list of 35 training gaps was updated with the stakeholders by the TGAF in November 2008 in a continuing process through FY 09. The TMSBP progress was also briefed at the Worldwide Joint Training Scheduling Conferences in FY 09. Figure 12 is a summary chart presented at the FY 09 conference briefing.

Figure 12. Chart presented to the Training Gaps Analysis Forum (TGAF), November 2008 (Hartman, 2008).

At the TGAF, training stakeholders (the combatant commands, Services, and Defense agencies) provided a short list of top-three training M&S issues and voted to arrive at an overall list of top-five issues to influence near-term training R&D funding. (See Figure 13, for top-five issues in priority order.) The TGAF also voted to revise the priority order of the original 35 TC AoA training gaps and provided comments on a draft combined list of 10 training gaps, offering logical groupings for similar training needs. The training "problem areas" reflect the top TGAF issues and the updated priority order of the 35 training needs. The updated training needs list is linked to the original 35 TC AoA training gaps. This list of training needs forms a training-requirements baseline that is broader than the M&S capabilities tool set can handle, and specific training needs may be filled by other training tools or learning content. A corresponding baseline of training M&S capabilities had been updated from the material provided in the TC AoA final report, "Chapter V: Assessing Effectiveness." This updated baseline detailed those training models and federations identified by the training stakeholders as being relevant to training contained in the most commonly used M&S training federations.

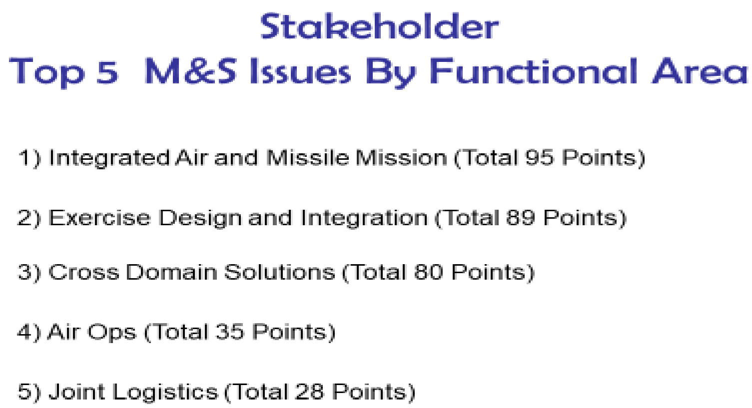

Figure 13. Top-Five Modeling and Simulation Issues (Davis, 2008)

An Update on M&S Gaps

The range of M&S issues has evolved gradually as both technology and Defense requirements have changed over the years; however, many of the gaps identified in the 1980s remain issues today. Figure 14, prepared in the 2007 time frame, lists the areas for improvement from that era, conveniently grouped into three categories. Note that data, infrastructure, and the ability to provide common, enterprise-level services were becoming even more important to the users. The data issues were specified and funded by the training M&S community to get at the ability to provide certified data and authoritative data sources for multiple applications and in a timely manner for initialization and conduct of simulations. Note the chart references the Global Information Grid (GIG). When first briefed of the GIG vision and concept in the late 1990s, we were optimistic that it would provide an environment that contained the data at multiple levels of granularity, access to services, and M&S environment models that could be adapted for reuse. Today, we have the cloud and the advantages for discovery and application of models with AI that may in the future be able to provide such data with the granularity needed for M&S operational and training needs.

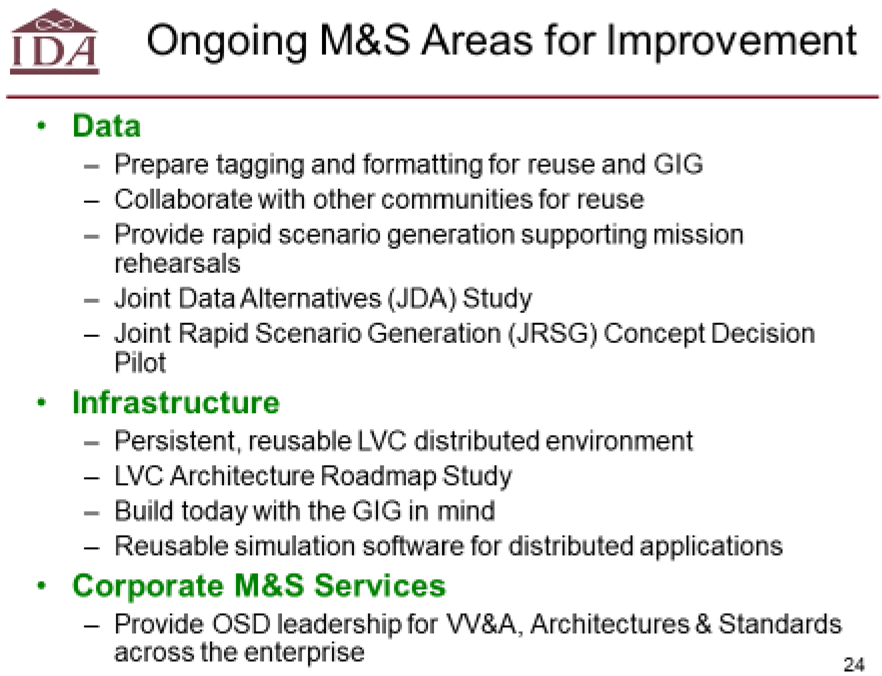

Figure 14. M&S Areas for Improvement (Hartman, 2007)

Fast forwarding to 2020, we find that in senior M&S meetings, current gaps were again brought forward to OSD by the M&S enterprise stakeholders as "pain points," or impediments to accomplishing desired missions and objectives. They reflect the fact that many of the decades-old issues listed above as areas of improvement or gaps are still major problems for the M&S community today (Miller, 2020):

The following list is derived from the M&S pain points identified for resolution.

- Interoperability: The interoperability issue still leads the list of concerns and includes the lack of standards, certified data, and multiple levels of security as primary impediments to seamless integration and reuse.
- Data: The spectrum of discovery, access, and the ability to share data remains a key area for improvement.
- Integrating Infrastructure: A common integrating infrastructure across DoD is needed to facilitate discovery, accessibility, and reuse of models and applications software.
- Standards: A need remains for M&S standards and V&V techniques to be updated to capture the potential of cloud computing, artificial intelligence, and autonomy.
- Virtual Reality: Virtual and augmented reality should be seamlessly combined in live training to provide better learning experiences.

RELATED M&S PROGRAMS

Although not discussed here, the SIMNET was an important early program for training that has been discussed by several I/ITSEC Fellows in previous years. Their papers provide unique perspectives and early examples from programs that forged the research underpinnings and future directions for distributed simulation and simulators. Moving forward in the 1990s and into the new millennium, the M&S community has provided additional M&S research and engineering funding, standards, and policies. Standards have been shepherded by SISO and DMSO (now the Modeling and Simulation Enterprise (MSE)) and have provided a DoD corporate-level role of M&S coordination, standards, and information for the community. The DMSO organization has sponsored development of more powerful technologies for the applications and use of simulation systems and data across the DoD. The continuing work enabled by these early research and development activities also serves to predict areas of concentration for the future. As I experienced the formative years in M&S development, I was optimistic that the advances in technology and data tools would fulfill the 1980's dreams for interoperability, reuse, and standardization. One such example of that early vision was shared by 2011 I/ITSEC Fellow, General Paul Gorman, and captured in the summary section of his Fellows paper: "it will be imperative to evolve provisions for training soldiers and units anywhere in the world, anytime. I foresee worldwide, wireless training support: 21st Century job-aids, FMs, TCs, and professional books" (Gorman 2011).

One of my observations over the years has been that the acquisition community should include training M&S as integral parts of their programs from the earliest planning stages. In 2012 this was discussed in an I/ITSEC presentation with examples from five major defense programs. Each was unique, but all gave examples of how their final platforms could have been improved when introduced to the user with simple training applications. Observation (Hartman and Frumpkin):

Acquisition Program Managers frequently neglect to include training M&S tools and systems in early program planning and budgeting.

General Gorman mentioned seven training technologies for the 21st century. One of those that I consider still to be needed and much more likely to be feasible in the future is a combatant personal digital assistant (PDA). The DARPA project, "Personalized Assistant that Learns" (PAL),[23] was funded for five years beginning in 2003. This project provided many of the underpinning research and artificial intelligence concepts to make AI use a reality. One of the components of the research was referred to as CALO (Cognitive Assistant that Learns and Organizes).[24]

The funded PAL was conducted by a team of private and academic experts examining the basic AI underpinnings for improving the way computers learn and provide support for the human cognitive system. The team was led by SRI International, with a research team including Carnegie Mellon University, the University of Massachusetts, the University of Rochester, the Institute for Human and Machine Cognition (Florida), Oregon State University, the University of Southern California, and Stanford University. This research effort, which built the infrastructure for AI that enabled the incorporation of Siri in Apple devices in 2010,[25] potentially could be further developed by DoD to provide the underlying capabilities to enable a robust soldier PDA.

The PAL program was targeted to provide the technical infrastructure needed to develop a learning assistant tailored to an individual combatant's needs and preferred learning methods. The ultimate product would capture the advances in current and future AI capabilities and provide the capability to access, collect, organize, and store large amounts of data in the cloud. It will be adaptable to the next-generation cell phone capabilities and provide the user with a real-time, pervasive assistant. Such capabilities are more and more feasible as we move forward into the next decades. The requirements still exist for the development of a training continuum that leverages M&S, AI, and cloud computing that the Department can draw from over individual and collective professional experiences to influence solutions for future operational challenges (Hartman 2011).

More than a decade after PAL, we now find AI providing a pervasive capability to provide software that learns, as well as future opportunities for M&S technologies related to immersive environments, autonomy, robotics, and big data. Each of these areas (and in combination) has a potentially significant impact on how we train and operate in the future. The increased use of AI and data capabilities allow us to produce smarter vehicles and military platforms, as well as provide innovative technical solutions and products. Incorporating augmented realities, coupled with knowledge of cognitive behaviors and the ubiquitous nature of AI, can provide training effectiveness and efficiency and serve as an operational multiplier for our existing capabilities.

From an M&S perspective, AI and big data now have even more dramatic influence on future software developments. The use, and increased utility, of virtual and augmented realities is only one significant example of the power of AI coupled with big data. Other technologies are now promising a leap forward in our ability to deliver timely training

---

[23] Artificial Intelligence Center, "The PAL Framework," SRI International, Menlo Park, CA, https://pal.sri.com/.

[24] https://www.itpro.com/technology/34730/10-amazing-darpa-inventions.

[25] Ibid.

systems. For instance, the use of a system of low-Earth orbit (LEO) satellites[26] could provide the detailed data and communications needed for autonomous vehicle operations and also provide data to enhance DoD training systems and simulations with a real-time environment for simulations and augmented-reality systems. This would be a giant step forward to enable General Gorman's early vision to provide military training anytime and anywhere.

Augmented, virtual and mixed reality, in concert with AI, and the access to Big Data and cloud services are now providing a real accelerator toward the future in training. Users and training audiences can be immersed in their operational environment, which can be tailored for general or one-of-a kind situations on relatively short notice. What a great time to be in the training and M&S technology areas!

SUMMARY OF OBSERVATIONS

My background experiences, and thus my perceptions of M&S, has been dominated since 1995 by my involvement in training, modeling, simulation, and related analyses. Colleagues have frequently reminded me that my training focus might be misleading to those in other M&S communities. The use of models, simulations, and data is pervasive across multiple communities as evidenced by the growth of the first three functional areas—acquisition, analysis, and training—to a total of nine communities under the DMSCO. With the ubiquitous nature of models, simulation, and data, the following observations should be viewed in a wider M&S context beyond training.

In the 1970s critical issues to overcome for M&S development were primarily driven by limitations on lack of data, computing power, and data storage—even for the relatively small combat models available.

Project managers (in the early years) frequently felt models took too much time to see results, and they were more costly since they required a significant investment in terms of hardware, computer time, and personnel work hours for required data preparation.

One of the lessons learned during the 1980s was that applications software, such as early spreadsheet programs being developed for the PCs, had been refined more for the large commercial market and thus was much more cumbersome to export or use on a minicomputer.

The 1988 DSB report and a 1990 DSB policy study served to provide the logic, and justified the initial funding, for the formation of the Defense M&S Office (DMSO), JSIMS, and many later simulation and simulator efforts.

The lack of centralized funding in JSIMS was likely the fundamental issue that led to many later technical issues and therefore resulted in ultimate breaches in cost schedule and performance.

In most instances the 2004 TC AoA technical shortfalls are traceable to the early and persistent gaps of interoperability and reuse across the Service and joint training domains.

Acquisition program managers frequently neglect to include training M&S tools and systems in early program planning and budgeting, leading to poorly trained users at initial operating capability.

The use of augmented, virtual, and mixed realities is proving to be a valuable tool in creating robust training environments.

The current implementation of M&S as a service and the use of cloud access to models and data, coupled with artificial intelligence (AI), are providing significant opportunities to conduct training exercises and mission rehearsals in a much more agile manner. These capabilities will continue to improve in the foreseeable future.

The use of AI and cloud data capabilities provides an essential enabler for creating future M&S environments and systems.

---

[26] One such example is found in the DARPA Project Blackjack, launched in April, 2020 with Lockheed Martin. See https://defence.nridigital.com/global_defence_technology_yearbook_2020/blackjack-darpa-satellites.

ACKNOWLEDGMENTS

I'm deeply indebted to the previous I/ITSEC Fellows. Several Fellows participated in and provided many of the early breakthroughs in our M&S technology areas. Some also served as mentors and advisors to me at each stage of my professional career. A special thanks goes to my colleagues and managers at IDA, who have provided advice and counsel as well as technical support and insights into emerging technologies over the last 25 years. Most of all, recognition goes to my colleagues at the DMSO and follow-on organizations that have impacted my journey through M&S history.

REFERENCES

Davis, E. (2008). TGAF Executive Outbrief. USJFCOM Warfighting Center, Norfolk, VA.

Defense Science Board. (1988). Report of the Defense Science Board Task Force on Computer Applications to Training and Wargaming. AD-A199456. Washington, DC: OUSD (Acquisition).

Distasio, F., Bonnett, M., & Hartman, F. (1977). Management of change (MOC). CAA-SR-77-7. Bethesda, MD: Army Concepts Analysis Agency. Bethesda, MD.

Fletcher, J.D., Hartman, F.E., Halayko, R., Sargent, P.A., Citizen, J., Szych, W., Carr, F., Davis, J.J., Levine, D.B., Foster, S., & Horowitz, S.A. (2007). Training community modeling and simulation business plan, 2007 edition, Volume I: Review of training capabilities. IDA Document D-3562-VOL-1. Alexandria, VA: Institute for Defense Analyses.

Gorman, P.F. (2011). Learning to learn: Reminiscences and anticipation. I/ITSEC Paper IF1101. *Proceedings. Interservice / Industry Training, Simulation and Education Conference,* Orlando, FL.

Hartman, F. (2007). Ongoing M&S areas of improvement. Briefing to DMSCO, Alexandria, VA.

Hartman, F. (2008). Training, modeling, and simulation business plan.

Hartman, F. (2011). Research for future training M&S strategies. IDA Document D-4451. Alexandria, VA: Institute for Defense Analyses.

Hartman, F., & Frumpkin, L. (2012). Training systems acquisition for major defense programs. I/ITSEC Paper 12147, Alexandria, VA.

Hartman, F.E. (2003). Briefing to the TC AoA Senior Steering Committee.

Hartman, F.E. (2004). Final briefing to the TC AoA SSG.

Hartman, F.E., et al. (1996). The training M&S functional plan. Training Working Group document prepared as an annex to the DoD M&S Master Plan.

Knight, L. (2000). Joint Simulation System (JSIMS) program update. DoD, DMSO. https://apps.dtic.mil/sti/pdfs/ADA402117.pdf.

Markowitz, H.M., Hausner, B., & Karr, H.W. (1962). SIMSCRIPT: A simulation programming language. Rand Memorandum RM-3310-PR. Santa Monica, CA: The RAND Corporation.

Miller, B. (2020). DoD M&S CoP Working Group. Briefing to CoP WG Meeting, Modeling and Simulation Enterprise (MSE). Alexandria, VA.

OSD. (2002). Joint simulation system (JSIMS). OSD Program Decision Memorandum 1, December 12, 2002 (Washington, DC: The Pentagon).

Patenaude, A., & Hartman, F. (2007). Joint training assessment. I/ITSEC Paper 7188. Alexandria, VA.

Power, D.J. (2000). A brief history of spreadsheets. DSSResources.COM. http://dssresources.com/history/sshistory.html, version 3.6, 08/30/2004. Photo added September 24, 2002.

Schwaller, S. (2008). Operation Just Cause: The invasion of panama, December 1989. U.S. Army. https://www.army.mil/article/14302/operation_just_cause_the_invasion_of_panama_december_1989.

Washburn, A. (2000). Lanchester Systems. Faculty notes. Monterey, CA: Naval Postgraduate School.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED *(From–To)*
December 2021	FINAL	

4. TITLE AND SUBTITLE	
A Half Century of Progress in Training, Modeling, Simulation, and Analysis	5a. CONTRACT NUMBER HQ0034-19-D-0001
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	
Hartman, Frederick E.	5d. PROJECT NUMBER AI-2-3077
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Institute for Defense Analyses Systems and Analyses Center 730 East Glebe Road Alexandria, VA 22305	IDA Document NS D-22769
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
Director, Modeling and Simulation Enterprise OUSD(R&E) 4800 Mark Center Drive Alexandria, VA 22350	OUSD(R&E)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited (22 November 2021).

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Modeling and simulation (M&S) and related analyses will continue to have a pervasive influence in the Department of Defense (DoD) for the foreseeable future. M&S provides a tool that will continue to facilitate future operations and training missions in the DoD. The long history of progress in M&S software development suggests a positive future for the M&S workforce as well as corporate opportunities. The use of M&S as a tool for multiple Defense applications has radically improved in the last 50 years, but persistent issues have plagued users for decades. Today many of these issues have been resolved and are within our grasp of providing real-time environments across the Department both efficiently and effectively. In the past, these M&S environments were created at great expense in terms of time and money. The use of existing and emerging technologies will serve to lower both technical risk and costs of future M&S systems and applications. The contents of this paper reflect the author's perceptions in witnessing firsthand a slice of M&S history that spans numerous innovations in hardware and software to enable progressively better M&S applications.

15. SUBJECT TERMS

Modeling and Simulation (M&S); training

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Zimmerman, Philomena
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Uncl.	Uncl.	Uncl.	SAR	34	571-372-6787

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18