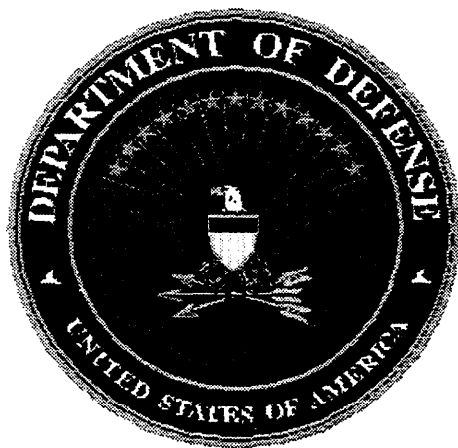


**REPORT OF THE
DEFENSE SCIENCE BOARD
TASK FORCE
ON
ADVANCED MODELING AND SIMULATION FOR
ANALYZING COMBAT CONCEPTS IN THE
21ST CENTURY**

May 1999



**OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR ACQUISITION & TECHNOLOGY
WASHINGTON, D.C. 20301-3140**

This report is a product of the Defense Science Board (DSB). The DSB is a Federal Advisory Committee established to provide independent advice to the Secretary of Defense. Statements, opinions, conclusions, and recommendations in this report do not necessarily represent the official position of the Department of Defense.

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BOARD

MAY 28 1999

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION &
TECHNOLOGY)

SUBJECT: Final Report of the Defense Science Board Task Force on
Advanced Modeling and Simulation for Analyzing Combat Concepts in
the 21st Century


I am forwarding the final report of the Defense Science
Board Task Force on Advanced Modeling and Simulation for
Analyzing Combat Concepts in the 21st Century.

The Terms of Reference directed that the Task Force address
the needs for modeling and simulation (M&S) in the DOD with
special emphasis on the role of M&S to support the development
and analyses of advanced warfighting concepts.

Of concern are the rudimentary applications of M&S toward
exploring new warfighting and operational concepts particularly
with respect to new joint concepts in support of Joint Vision
2010. The Task Force found extensive and successful use of M&S
for training and weapons system design trade-offs and capability
evaluation, however, there was little flow of tools and methods
between M&S using communities. M&S was found to quantify and
support the known and expected, but not adequately adapted or
employed as a way to develop new insight. Furthermore, key Joint
Vision 2010 elements do not appear to be addressed by either the
M&S or analytic community and there is ambiguity in planning for
the evolution of next-generation models and systems of models to
address these needs.

The report offers several recommendations to redress these
problems and deficiencies with the major thrust being a more
informed and proactive community for M&S support of innovative
concepts

I endorse all of the Task Force's recommendations and
propose you review the Task Force Chairman's letter and report.


Craig Fields
Chairman



DEFENSE SCIENCE
BOARD

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301-3140

MAY 24 1999

MEMORANDUM FOR CHAIRMAN DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board Task Force on Advanced Modeling and Simulation for Analyzing Combat Concepts in the 21st Century

Attached is the report of the Defense Science Board Task Force on Advanced Modeling and Simulation for Analyzing Combat Concepts in the 21st Century.

The Terms of Reference directed that the Task Force address the needs for Modeling and simulation (M&S) in the DoD with special emphasis on the role of M&S to support the development and analyses of advanced warfighting concepts.

The Task Force found extensive and successful use of M&S for training and weapons system design trade-offs and capability evaluation. The training community in particular provides a demanding involved customer base and could if so motivated, expand the use of its environments and tools to serve other purposes. The Task Force did not find much flow of tools, methods and development activities among the several using communities: training, acquisition, concepts,

Of greater concern was that the Task Force found only rudimentary applications of M&S toward exploring new warfighting and operational concepts. This lack is particularly acute with respect to new joint concepts as embodied in Joint Vision 2010 (JV-2010). Furthermore, we found much of the M&S culture not well attuned to the challenges of exploration of new concepts, doctrines and new systems. Instead we perceive that the characteristics and attitudes essential to analysis for innovation are not particularly welcome in much of the analysis and simulation community. We further found a strong market for quantifying and supporting the known and expected, and exploring only to the edges of the known and understood. We did not find a similar market for new insights and surprise. Too often M&S and analyses are tools for advocacy, much less often for discovery. These conditions and attitudes (and the concomitant lack of analytic foundation and appropriate M&S tools) will seriously hamper the experimentation and pursuit of the objectives and capabilities of Joint Vision 2010.

Key elements of Joint Vision 2010 are not well addressed in M&S or by the analytic community. These elements include notions of information (and knowledge and decision) superiority, the value of situational awareness, many aspects of maneuver warfare, dismounted combatants, urban operations, and adaptive command and control which could exploit both decentralization (robustness and flexibility) and centralization (more efficient use of scarce resources.) Further, we did not find clear plans for the evolution of next-generation models and systems of models to address these needs.

The Task Force believes that a challenging demand for models and simulations (and federations of models and simulations) is the need to far more readily accept new concepts and doctrines. M&S tools to support the development of innovative concepts and doctrine will have different characteristics than those used for other purposes. For example, flexibility (to rapidly vary environments, situations, adversary responses, etc.) will likely be more valued than fidelity. Capturing the human elements is essential; thus human-in-the-loop models must play a vital role

While there are serious shortfalls in the M&S tools we believe much of the problem with the application and misapplication of M&S lies with the demand side. To orient the models and simulations to support innovative joint concepts, the customer community needs to take a far more active role in defining simulation needs and setting priorities. The focus seems to have been most often placed on the supply side – developing "better" general-purpose models.

The report offers several recommendations to redress these problems and deficiencies. The major thrust of our recommendations is to foster a much more informed and proactive customer community for M&S support of innovative concepts. They should be empowered to define M&S needs and set priorities. The customers we have in mind are those responsible for implementing JV-2010: developing concepts, experimenting, allocating resources. These include the JROC, elements of the Joint Staff and OSD, and USACOM in an increasingly important role as joint experimenter. The M&S tools should be designed to explore and analyze the new concepts and must begin to do a better job of accounting for the human dimensions of conflict including the notions of knowledge superiority, adaptive command and control and other critical enablers of JV-2010.

The Task Force would like to express its appreciation for the cooperation, advice and help provided by the government advisors, support staff, and the many presenters.



Theodore S. Gold
Co-Chairman



Larrv Welch, General, USAF (R)
Co-Chairman

Defense Science Board Task Force
on
Advanced Modeling and
Simulation for Analyzing Combat
Concepts in the 21st Century

Dr. Theodore Gold & Gen. Larry D. Welch, USAF (Ret)
Co-Chairs

May 1999

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Terms of Reference

- . **Focus on the advanced M&S tools is motivated by:**
 - The need for a concept prototyping capability for the CINCs and Services
 - A wider range of global political-military scenarios
 - Revolutionary warfighting concepts challenging current analysis capabilities
 - Emerging technologies, including commercially driven information technologies with short cycle times

The 1996 DSB Summer Study on 21st century operational innovations once again highlighted the need for simulation environments and tools to help explore innovative operational concepts and capabilities.

The concern for better environments and tools to explore a wider range of operational concepts and capabilities has been further heightened by the recognition that US military forces are operating in an ever wider range of operational scenarios. Further, it is increasingly clear – and explicitly stated as an outcome of the Quadrennial Defense Review – that these scenarios call for war-fighting (or peacekeeping) concepts that are more revolutionary than simply as subsets of large contingency concepts and capabilities.

There is a wide and growing range of technologies available globally that further accelerate the demand for innovative new concepts and capabilities -- none more important and none more universally available than information technologies.

Terms of Reference (2)

- **Address the following questions:**
 - How to conduct analysis in the future?
 - What is the right relationship among constructive, live, and virtual simulations?
 - How to provide concept prototyping capability?
 - What tools are needed?
 - What tools are available?
 - What technologies are required?
 - What DOD organizational and policy changes are needed?

Accordingly, the task force was asked to address the specific questions listed here, starting with the broader subject of how to conduct meaningful analyses, to include the full range of simulation capabilities.

The end goal is to provide analysis environments where operators and decision makers can be immersed in new situations and can experiment with prototype concepts and capabilities.

At the outset, there was an implicit assumption that, among the plethora of analysis and simulation capabilities in government, industry, and academia, there must be tools available that can be identified, organized, and exploited for this purpose.

At the same time, there was an assumption that there could be significant gains from further exploitation of emerging technologies.

Finally, the task force was asked to search out promising existing organizations and capabilities within DOD and to recommend changes to enhance the utility of environments and tools to explore innovative concepts and capabilities.

Modeling and Simulation

Four Perspectives

- **Concept Development**
 - JV2010
- **Applications of Modeling and Simulation**
 - **Training**
 - Acquisition of systems
 - Concept development
 - Mission planning and real-time decision support
- **Characteristics of the models and simulations**
 - Model content and underlying theory
 - Computer simulation software and hardware compatibility
- **Processes and organizations**
 - How M&S are developed, modified, maintained
 - How M&S are used to support analysis

The task force focused on the use of models and simulations for concept development, with particular emphasis on the concepts embodied in Joint Vision 2010. We also looked at the use of M&S for training and other applications to identify the relevance of these activities to concept development.

In this same context, we examined the characteristics of models and simulations to better understand the underlying basis and purposes of the range of M&S efforts and their relationship to the intended applications.

We considered approaches to M&S development and the relationship of the process for development and maintenance to the purposes and the kinds of analysis they are intended to support.

While a discussion of all these relationships is outside the purpose and scope of this report, it was clear to the task force, that for concept development applications, there needs to be a greater effort to match M&S characteristics – and the processes and organizations for their development and sustainment – to the intended applications (exploring innovative concepts).

The Search for Capabilities and Insights

- **Military department organizations**
- **Joint organizations**
- **Defense Department laboratories**
- **Joint Program Offices**
- **Defense industry**
- **Academia**
- **Entertainment industry**
- **Information industry**

The task force cast a wide net in examining existing organizations and capabilities that are specifically oriented or that could be oriented to the special purpose of exploring innovative concepts and capabilities.

Approach

- ➔ . **Bottom Lines**
- . **The Customers and Needs**
- . **Meeting the Needs**
- . **Recommendations**

To report the results of this effort, we will first look at the “bottom lines” derived from our work; then move to material in support of those bottom lines, including the customers and their needs; then potential suppliers and products; and finally, our recommendations.

Current and Needed Focus

- **There is extensive and successful use of models and simulations for training, weapons systems design trade-offs and evaluation, and engineering simulations**
- **We need greatly expanded application of M&S to explore and exploit new concepts needed to support implementation of Joint Vision 2010**
- **Much of the M&S culture is not attuned to the demands of exploration and evaluation of new doctrine, CONOPS, or new systems concepts**
- **Need informed, involved customers to focus M&S&A (Analysis) -- particularly in the joint community**
 - **Need to focus on support of open-minded analysis of the new and innovative -- seek insight, not advocacy**

We found that the training community has a demanding, involved customer base, that it dominates the simulation business, and that it could, if so motivated, expand the use of its environments and tools to serve other purposes.

We also found heavy and successful reliance on modeling and simulation to include human-in-the-loop, weapons system design trade-offs, and capability evaluation. This experience also has high relevance to simulation for innovation.

However, we found only rudimentary applications of M&S toward exploring new warfighting and operational concepts.

We also found that the characteristics and attitudes essential to analysis for innovation are not particularly welcome in much of the analysis and simulation community.

The task force started with an assumption that defense operators and decision makers were hungry for better ways to understand and evaluate innovative concepts, and we did find some of that interest. Still, it proved difficult to find demanding customers.

We further found a strong market for quantifying and supporting the known, and exploring only to the edges of the known and understood. We did not find a similar market for surprising new insights.

Some Potential in Organizations

- Changes in organizations and responsibilities are needed to make better use of mature M&S for training, for application to acquisition, for doctrine development, etc.
- Encouraging examples of the attitude and orientation applied to the exploration of new concepts are resident at the Army's TRADOC and the Marine Corps' Combat Development Command.
- Potential for joint focus and leadership (for M&S support to explore new concepts) can found in newly created and expanding centers
- **Hampton Roads, Orlando, Kirtland, Industry**

but...

Just at the leading edge of progress on the problem

- Need critical mass and assigned responsibilities
- Need involved, demanding customers for simulations that explore rather than advocate or verify

We also found there is a need for a freer flow of tools, methods, and development activities among the using communities. Hence, there is a need for changes to organizations and processes to better use the potential of existing simulation capabilities. AF/XOM is an example of an activity established to effect a more unified approach.

We visited organizations that reflect the attitude and orientation needed, including TRADOC and the Marine Corps' Combat Development Center. However, they were focused on Service capabilities and operating environments, not on joint operations; and, even for that purpose, they need better tools to examine new concepts and equipment.

There also are organizations and centers that have the potential for becoming needed joint centers of excellence for such capabilities, although none is currently focused on these needs. Importantly, we found some significant understanding of what is needed.

And yet, there needs to be specific and well-supported charters and expectations for any of these organizations to realize its potential to become a center of excellence for exploring innovative concepts and capabilities.

Some Basic Shortfalls

- **Capturing command and control and situation awareness**
- **Considering the overriding impact of the human dimension**
- **Addressing other key elements of Joint Vision 2010 (e.g., dominant maneuver)**
- **Need simulations (and federations of simulations) that allow concepts and doctrines to be freely introduced and altered**

As to the available tools, there are long recognized critical deficiencies, but the owners of these models need additional motivation to add the significant complexity (and producers of real world variability) of joint C3 and other innovations whose potential impacts are not well understood. Further, it is unlikely that the architectures of these models would provide a cost-effective approach to adequately address the needed functionality.

Consequently, key elements of Joint Vision 2010 are not addressed. For example, ongoing efforts do not include adequate research on ways to capture in models and simulations critical features and characteristics of JV2010 and the emerging security environment. These features include information warfare, the value of situational awareness, much greater dispersion of forces, maneuver over strategic distances, dismounted combatants with unprecedented potential, urban operations, and command and control arrangements which can provide the benefits of both decentralization (robustness and flexibility) and centralization (more efficient use of scarce resources.)

Further, there are no clear plans for the evolution of next-generation models and systems of models to address these needs.

A challenging demand for models and simulations (and federations of models and simulations) is the need to far more readily accept new concepts and doctrines. For the exploration of future concepts, flexibility (to vary environments as well as concepts) becomes a higher valued M&S feature than fidelity.

Empowering the Customer as the Driving Force

- **The current approach: give resources to M&S developers to build "better" tools to support a variety of customers. This is producing some important benefits, but...**
- **In spite of a theoretical promise of validation, there needs to be greater visibility into process, and greater transportability; general purpose models rarely can bear the weight of important decisions, or how to deal with new "stuff" (situations, environments, concepts)**
- **Still need to give control of significant resources to M&S customers who need the insights, with support from the M&S experts**
- **Need a balance between tailored simulations for every customer and the hope for near universal applications**
- **The challenge is to choose the right approach for the intended use of the simulation**


The current approach to serving innovative experimenters and decision makers has been to ask M&S developers to build better tools. And there has been a great deal of emphasis on general-purpose models and tools.

This approach was intended to promote reuse and to reduce duplication. In practice, however, such tools are not sufficiently trusted to have much influence on the tough decisions or to deal with the unfamiliar.

Depending on the purpose of the simulation, there continues to be a need for customers to exercise more direct responsibility for the details of defining and overseeing the product they need. JWARS is an example of one that blends both the current approach and the need for high confidence to support hard decisions.

Furthermore, when looking at innovation, where there are no reliable benchmarks, the best basis for validation may just be what makes sense.

The Approach

- . **Bottom Lines**
-  . **The Customers and Needs**
- . **Meeting the Needs**
- . **Recommendations**

Some Varieties of Customer Needs

- **Training: Primary application focus of DOD simulations**
 - **Individual --**
 - > Widely used, large customer base
 - > Need far more attention to the combatant afoot
 - **Unit – Developed, understood, varied types, customer base**
 - **Task Force – Developing, understood, supported, need jointness, growing customer base**
 - **A major current shortfall is the cost of running exercises**
 - > Size of support staff often exceeds number of training participants
 - > Problem well recognized by users
- **Engineering development, mission assessment, systems trade-offs: Primary industry focus for in-house use of simulations**
 - **Sub-systems -- widely used, high fidelity**
 - **Weapons system – Some successful uses**
 - **Computer interfaces adapted from commercial practice, rarely tailored for DOD use**

The training community heads the list of active and influential customers for simulation environments.

Even so, this community faces significant shortfalls in providing satisfactory field exercise experiences to train joint forces. The user community recognizes the need for a richer synthetic contribution to the training environment and a substantial reduction in the manpower currently required to support the simulations.

The degree of acceptance and the range of use in the training community and in the engineering community suggests, properly, that this is a promising starting point to define approaches to the ranges in the employment of simulation.

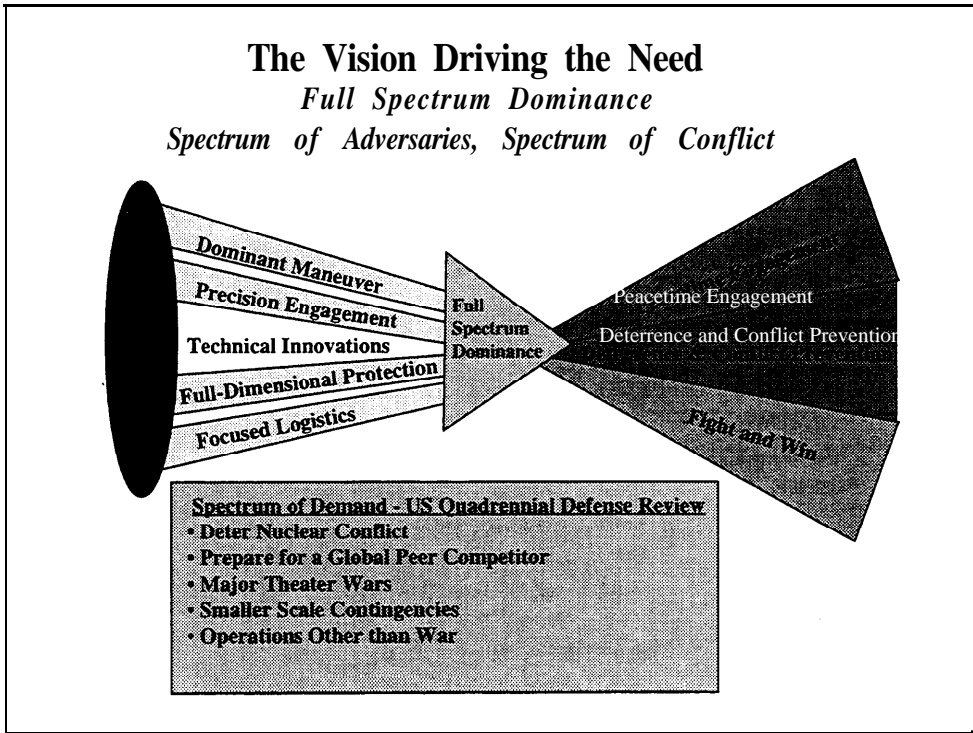
Some Varieties of Customer Needs (2)

- **Acquisition and test support**
 - Wide use in separate areas - e.g., COEA's, hardware-in-loop testing, augmentation of operational tests
 - Growing attention to simulation-based acquisition - the integration of simulation tools across acquisition functions, phases, and programs
 - Innovative concepts, and tactics and doctrine
 - Growing customer base -- Army approach an example of a mature and institutionalized process
 - Joint Vision 2010 a premier need, but joint community has least mature process
 - Some essential pieces in-hand or in development:
 - > Environments (terrain, weather, etc)
 - > Object-oriented systems' descriptions and performance
 - > Rule-based automated opposition forces
 - Major pieces still missing, e.g., depicting effect of information dominance to include broader capabilities in automated opposition forces
 - Human-in-the-Loop needed (to capture behavior of red as well as blue)

In fact, many of the essential pieces needed to provide useful analytic environments for acquisition and test support and for innovation are in hand or in progress. Some are listed here.

But there also are major pieces still missing; for example, exploring and depicting the impact of information dominance on concepts, doctrines, and outcomes.

Understanding the human dimension is a key aspect of understanding and evaluating innovative concepts and capabilities. Hence, simulation environments useful for exploring the utility of innovative operational concepts and capabilities have the need for human-in-the-loop interface with training environments.



The demands inherent in Joint Vision 2010 make implementers of the vision the demanding, involved customer for the analytical environments sought by the task force. The primacy of information superiority, the importance of dominant maneuver throughout the battlespace, the expansion of focus from large-scale contingencies with characteristic force-on-force focus to regimes far less amenable to existing analytical tools -- all demand analytical environments far more complex and adaptable than the cold war "tool set."

Supporting Joint Vision 2010

- **New capabilities are needed to meet the challenges wrought by new missions, tough environments, resourceful adversaries employing asymmetrical strategies**
- **Application of new technologies will be necessary, but not sufficient**
- **New technologies must be coupled with new operational concepts, doctrine, tactics, techniques, and procedures**
- **Timely and affordable experimentation and implementation of these new concepts and capabilities will be heavily reliant on modeling and simulation**
- **Need a concept prototyping capability to immerse warfighters and providers to “try before buy” (or sell)**
 - **Keep it simple - fidelity only as needed to create the environment**
 - **Simulation Based Acquisition (SBA) initiative to outline approaches to this objective**
 - **Significant development activity under way**

In searching for the demanding, involved customer base that could be the driving force needed to create the necessary environments and tools, we should look no further than those who must implement Joint Vision 2010.

To more fully realize the innovative potential of that vision, operators and force planners will need simulated environments to immerse themselves in unfamiliar future environments, using new capabilities and old capabilities in new ways.

Still, the need for insights into these complex situations does not necessarily equate to a need for greater numbers of entities in simulations, or more faithful representation of the entities (not withstanding some of the current model building goals). The Simulations Based Acquisition (SBA) initiative is charged with outlining how this might be achieved and there are several developmental efforts under way. These will need the focused attention of a demanding, involved customer.

To meet this need, the analytic environment must provide the necessary level of decision maker with virtual experiences, bringing together relevant concepts, capabilities, etc.

Some Opening Issues

- **DOD needs a better focus on using current capabilities to understand new systems, challenges, or concepts of operations**
- **DOD needs both the structure and the policies to take better advantage of current M&S capabilities**
 - **Not enough technology push or user pull exerted on simulations for combatant afoot**
 - **Need focus on neglected drivers -- situational awareness, information dominance, more capable combatants afoot**
- **Joint Vision 2010 should become, a prime driver for simulations in support of innovative concepts, doctrine, acquisition**
- **A significant cultural change is required to foster the same type of involved, demanding customers for simulations that examine innovative operational concepts and systems as exist for training and traditional engineering simulations**

Unfortunately, the task force found progress toward simulation support for this vision to be uneven, at best. We searched, with disappointing results, for focus on using current capabilities for insights into new concepts and capabilities.

Instead, we found that that part of the DOD community responsible for providing system capabilities to underwrite new concepts tightly focused on meeting specifications and performance, with insufficient focus on exploring the broader implications of concepts and capabilities. This tendency is particularly manifest in the area where major systems are not major players – the increasingly important combatant afoot.

Some Emerging Customers

Army Force XXI and Army After Next

- **Army is committed to “digitization,” and matching gains in force effectiveness with reformed structure**
- **“Spiral development” is under way for Force XXI**
 - **Early recourse to virtual simulation, and to extensive interaction with behavioral scientists**
 - **Emphasis shifted to live simulation (e.g., Advanced Warfighting Experiment)**
- **Progress evident for mounted combatants, much less so for those on foot**
 - **Future M&S plans emphasize mounted combat**
 - **Coherent remedial action needed for fighters afoot**
- **The Army After Next will require an infusion of advanced information systems into combat support, combat service support, and training**

We did find important sub-sets of customer bases that are demanding new kinds of analytical capability and tools. Army Force XXI and the Army After Next are important examples, as is the Marine Corps’ Operational Maneuver from the Sea concepts. There also are concepts for meeting the challenge of exploiting new enabling technologies for combat air operations of all kinds. In each of these cases, the information dimension – with yet-to-be fully understood demands and leverage for forces from the squad afoot to the large armored force – is particularly demanding of the analytic environment.

Further, distributed force concepts and increased empowerment at lower echelons, needed to leverage new capabilities, places new demands on combat leaders and individual combatants.

The same is true of the increasingly important urban operating environment characteristic of many smaller scale contingencies and operations other than War.

These three factors alone – the primacy of information, increased empowerment at lower echelons, and the urban environment – are adequate justification for a radically altered analytic environment.

Some Challenges in Simulating Conflict *Scenarios and Outcomes*

- . **Everything is simulation except actual combat**
- . **Even actual combat is a poor source of validation for modeling the next combat**
- . **Future outcomes may be strongly driven by factors not previously understood or even evident**
- . **Analyses of systems with high human interaction seldom produce highly discriminate answers**
- . **Needed are solutions that are robust and adaptable across a range of uncertainties; exquisite point solutions will likely be fragile**
- . **Verification and validation concepts and standards appropriate to support examining new concepts are different than for environments designed to quantify and/or compare the known and understood**

There are a number of mind sets that need to be changed to create the kind of environment needed to explore innovative concepts and to understand and evaluate potential new and revolutionary capabilities.

One such mindset is the notion that “live” experience is automatically more real or more valid than is virtual or constructive experience. In fact, it is *all* simulation. Often, the “live” environment suffers from more artificiality and limitation than does the “artificial” environment of virtual and constructive simulation.

Further, when dealing with potential future capabilities, even actual combat may be a poor source of validation. While experience is immensely valuable, it is most valuable when tempered with the realization that the next experience is likely to be very different.

Unlike sensitivity analyses intended to provide some quantification useful for choosing evolutionary changes in capability, what is important to the future may not be addressed by showing incremental changes in performance from incremental changes in system or force characteristics (traditional sensitivity). This is particularly true where the human dimension plays a powerful role.

The objective is not point solution. It is, instead, to discover those concepts and capabilities that are robust across a range of uncertainties.

Some of the traditional verification and validation practices can be obstacles to concept exploration. The different purpose calls for more adaptability in V&V approaches as described in DOD VV&A instructions.

Some Basic Obstacles to Serving Customers' Needs to Change Attitudes and Expectations

A paradigm shift in demand and expectation

- **A far richer set of validated objects (attributes of systems, responses of systems to standard external influences, etc.) to be used in simulations**
- **The ability to incorporate new concepts and doctrines as objects or in federations of simulations**
- **Credible interactions and outcomes, validated by operational judgments about outcomes and reasons for outcomes**
 - Verification and validation to serve the objective of credibility
 - Focus on simulations as a source of new insights rather than as validations of things thought to be already known and understood
 - Understanding that digital representations of objects, environments, and actions can be more “valid” (i.e., useful) than physical representations or exercises, given the constraints on such live representations -- ranges, safety, hardware, etc.
 - The objective is insights into likely robustness, applicability, effectiveness, etc., of new operational concepts and postulated systems.

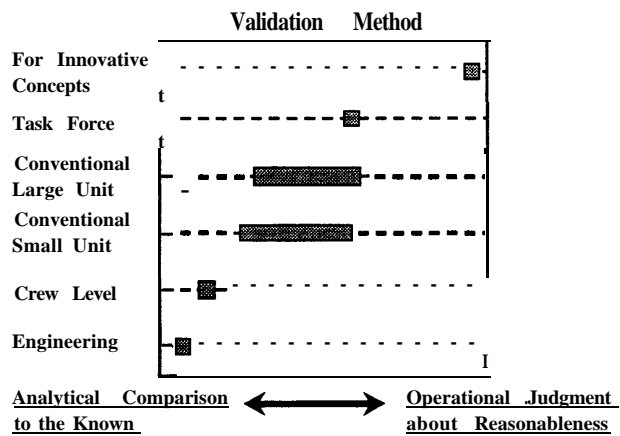
This chart further highlights necessary changes in attitudes and expectations to create the kinds of analytical environments needed. We did not underestimate the challenge: Producing the demanding, involved customers that will drive the development of the needed environments will require a paradigm shift in both customer demand and expectation. The operational and force planning community charged with implementing JV2010 must demand and expect to be able to test possible solutions in an analytic environment that gives confidence in understanding before moving to concepts, systems, and forces that add up to fielded capability.

One requirement to provide the adaptability needed will be to expand the use of doctrines, concepts, and behavior “objects.”

The earlier point about the need for change in some validation practices and expected products of analysis is repeated here for emphasis. This is not intended to undermine the demand for quantified results for many legitimate purposes. It is instead to underline a difference in approach when the purpose is to develop, understand, and evaluate new, largely unquantifiable concepts and capabilities with more dimensions (to include the human dimension) than is possible with even greatly improved quantitative analysis.

One hurdle that needs to be overcome is too much faith in “live” trials using “real” objects. One of the lessons of modern aircraft and ship design and development is that digital representation in computerized tools can be more “realistic” than 3D physical mock-ups in their contribution to producing the desired final product. This is also true in force exercises, due to the great simplification required for affordable, achievable, and safe “live” trials. Hence, live trials need to be carefully constructed to examine those aspects that can be realistically accommodated.

Need for the Full Range of Validation Approaches



This chart further illustrates the differences in the appropriateness of verification and validation approaches, depending on the purpose of the simulation and analysis. DoD's instructions on VV&A embrace the full range; current practices lean heavily to the left side of this chart.

Some Basic Obstacles to Serving Customers' Needs for a Cultural Change (2)

- . Need high skepticism about modeling for system advocacy. Define what is definable -- discover the value and how to enhance the value**
- . Provide simulation environments that can immerse decision makers in virtual situations to provide insights and experiences with proposed (or imagined) systems and concepts**

Moving to additional obstacles, much of the analytical culture and some of the models have been so deeply involved in advocacy for systems, forces, and concepts that there is a high (and appropriate) skepticism about their ability to objectively examine concepts that may not validate some cherished concepts and systems.

Moving the objective to learning the unknown rather than verifying what is thought to be known can be a wrenching cultural change.

A Summary of Some Needed Attitude Changes

From . . .

- . Protected Outcomes
 - bureaucratic review
- . Model Orientation
 - mechanical
 - limited to validated data
 - stable, traceable algorithms
- . Suppress Uncertainty
- . Cold War Orientation
 - few accepted scenarios
 - force-on-force analysis, generally symmetrical forces
- . Limited Trade-offs
 - force structure, military worth of equipment

To . . .

- . Open Outcomes
 - subject to expert review
- . Subject Matter Orientation
 - transparent processes
 - include possibilities in data
 - allow for the non-linear
- . Illuminate Uncertainty
- . Oriented to Broader Needs
 - full range of scenarios
 - asymmetrical forces, concepts
- . Full Range of Trade-offs
 - forces, equipment, doctrines & concepts, training, C2, environments, etc.

This chart summarizes some needed change in attitudes and expectations. It is an adaptation from an annex to the 1996 summer study report. A sub-title for the “from” column could well be “current force structure and budget analysis,” while the “to” column could be sub-titled “future concepts and force capabilities.”

The two contrasting lists illustrate what is perhaps the most important distinction between most current analyses in support of force development activities and that needed to underwrite Joint Vision 2010. That difference is moving from a stakeholders aversion to unwelcome outcomes to a genuine seeking of new insights by those with no stake in the outcome beyond the new insights themselves.

Some Specific Model Content Needs

- **Accounting for the effects of information, C2, human decision making, aggressiveness, etc., across operational concepts embodied in JV2010**
- **Representing and evaluating concepts for distributed forces in expanded battlespace**
- **Analyzing complex adaptive systems**
- **Better accounting for the spectrum of maneuver - strategic to small unit**
- **Ability to quickly search large spaces of tactics, concepts, behavior to evolve promising sets of tactics and concepts for further experiments**
- **Transparency of reasons for outcomes**


It is useful to summarize some specific demands of the expanded analytic environment. Perhaps the most obvious (but so far illusive) need is accounting for key human-dimension-driven phenomena. Among these is simulating and accounting for the effects of communicating the commanders' intent and the control feedback that tells commanders the force's progress in carrying out that intent. Included is the need to account for such qualities as aggressiveness, ingenuity, experience, etc. (or the lack thereof). There are models of behavior available to examine such effects but are so far not seriously considered for incorporation into larger analytical models.

Moving from traditional organizations designed for force-on-force, largely symmetrical engagements to distributed forces and asymmetrical approaches is clearly part of many future scenarios.

The need to understand non-linear effects will demand the capability to simulate complex, adaptive behavior rather than the rigid rule-based algorithms that characterize current analytical approaches. There is work ongoing in academia and elsewhere that can bear fruit.

One approach to introducing complexity more appropriate to the range of impacts of human behaviors is to use massively parallel computing power to quickly examine large numbers of possible behaviors, with scoring approaches that identify sets of capabilities most robust across the widest range of possible behaviors. The added complexity of these analytic environments will affect the approach to validation, with a heavier reliance on expert visibility into both the outcomes and the reasons for the outcomes.

The Approach

- . **Bottom Lines**
- . **The Customers and Needs**
-  . **Meeting the Needs**
- . **Recommendations**

DOD'S M&S Vision
Executive Council on Modeling and Simulation
March 1992

- **Defense modeling and simulation will provide readily available and operationally valid environments for use by DOD components**
 - To train jointly, develop doctrine and tactics, formulate operational plans, and assess warfighting situations
 - To support technology assessment, system upgrade, prototype and full scale development, and force structuring
- **Common use of these environments will promote a closer interaction among the operations and acquisition communities in carrying out their respective responsibilities.**

The Executive Council on Modeling and Simulation is providing a reasonable and useful vision of the role of M&S in the Defense Department. The vision articulated by the Council calls for operationally valid environments that cover the full spectrum -joint training, operational concepts, technology assessment, prototyping, force structure work, etc.

This vision, which includes common use of the environments for multiple purposes, is supportive of providing analytical and simulation environments suited to developing, understanding, and evaluating innovative concepts and capabilities.

Key Technical Challenges

- **Simulations must be capable of representing postulated future warfare situations - e.g., combinations of asymmetric force engagements, scenarios with large uncertainties**
- **Existing constructive simulations and semi-automated forces are missing important features (C2, human performance, etc.) -- demanding requirement for new features to be developed as part of JSIMS and JWARS**
- **Use of simulators and live elements depends on ingenuity of exercise designers**
- **Need simulations or federations of simulations with flexible/modular structures that will allow modifications in objects or modules to accommodate a variety of new system and process concepts**
- **Simulations must be accessible to a wide variety of decision makers for “test drives”**

This and the next chart suggest some key technical challenges. The need for flexibility – to rapidly represent alternative environments, adversaries, materiel, organizations, doctrine – presents a formidable, but resolvable, challenge for M&S developers. On the other hand, demands for “fidelity” will be relaxed (at least compared to test and evaluation, training, and acquisition applications).

A characteristic of models and simulations that may become increasingly important as they are used to explore potential breakthrough concepts and capabilities goes beyond transparency. Providing results from the M&S tools to decision makers may be insufficient. Decision makers will likely want to try the M&S tools themselves, to immerse themselves, to “test drive.” Thus, if M&S tools are to be agents of change, they must be more accessible to a wider variety of users and they must accommodate a higher throughput of users.

Key Technical Challenges (2)

- **Have to conceptualize before simulating -- demanding too much flexibility may make simulation too ill-defined to build -- not unique to concept exploration**
 - JWARS must analyze systems and scenarios not yet conceived
 - JSIMS must eventually be flexible enough to train for established doctrine and concepts *and* for new concepts as they are adopted
- **Simulations must evolve along with concepts**
 - **Should not be considered a ‘finished, validated’ tool**
 - **Continuous need to be modified/adapted**
 - > A significant configuration control challenge -to evolve rapidly but under control
 - **Implies a much closer relationship between user and developer**

An appetite for greater flexibility should stop short of quests for model universality. A simulation that explores a reasonable set of conditions is far more useful than any quest for universal applicability.

In any case, simulations intended to explore innovative concepts must constantly evolve to meet new needs.

Some Simulation Components

- Current training and test facilities provide the environment for live elements of simulation
 - As a matter of policy, consider allocating a small fraction of time at these facilities to concept exploration
- STOW: DARPA technology program providing synthetic battlespace with human-in-the-loop interface
- JSIMS, JWARS: Major simulation developments, but utility to concept exploration not yet clear
 - Validation concept needs to be tailored for exploration - may demand more flexibility in configuration control of some versions of models
 - Highly modular architecture for models allowing insertion of new systems and operational processes is planned, but realization is not yet evident
 - JWARS might allow only limited human-in-the-loop during execution
- Increasingly, future investment decisions will involve trade-offs in desired capabilities - a significant challenge for evolving JSIMS and JWARS design to illuminate choices

There are important components of the needed environment available or in development, including a reasonably rich set of training and test facilities and simulations.

The Synthetic Theater of War program is designed to combine constructive, virtual, and live simulation. It provides a more realistic training environment that also can be adapted to wider purposes. STOW is currently at USACOM as an Advanced Concept Technology Demonstration.

JSIMS and JWARS include concepts that promise a greater capability to adapt to a wider set of needs than earlier large-scale models.

However, we believe that important drivers of future conceptual and materiel options will not be adequately served by the initial versions of JWARS and JSIMS. Executable plans are needed to address this need more fully in evolutionary versions.

Some Current Simulation Capabilities for Concept Exploration

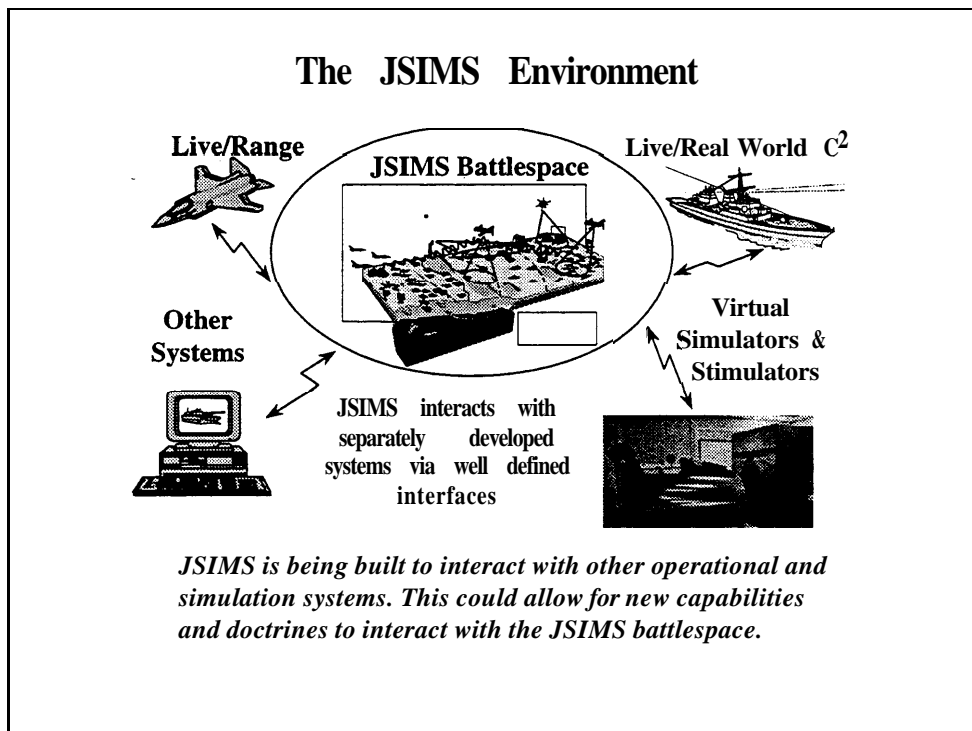
- **The ability to “wire up” environments suitable for concept exploration has been demonstrated**
 - E.g., USMC’s Hunter Warrior, Joint Staff’s All Service Combat Identification Center, Boeing’s ITDL
 - But setup can be laborious
- **Facilities exist to accommodate live simulation elements**
 - Although further instrumentation may be required
- **Virtual simulations have demonstrated capabilities, but a full set of capabilities does not now exist**
 - No full suite of simulators or environmental representations
 - Nothing yet to accommodate combatant afoot
- **Constructive simulations currently have limited utility**
 - Little human in the loop or flexibility in systems & tactics
 - Limited visibility to understand nature of outcomes
 - Semi-automated forces need flexibility for exploring tactics and possible additional functionality

There are also important examples of progress in environments that can have application.

Both DOD and industry have demonstrated the capability to provide concept exploration environments, but they lack the necessary flexibility and adaptability.

There has been significant investment in facilities; again, this can be a basis for further progress.

Virtual simulations, essential to human-in-the-loop simulations of things that do not yet exist, are progressing rapidly. These are essential to address the inherent limitations of purely constructive models and simulations.



Looking more specifically at ongoing work to meet new challenges, JSIMS has been in joint development for some time. There currently exists a challenge for expanding JSIMS and JWARS to be more useful tools for exploring innovative concepts and capabilities.

The current focus of JSIMS is on training, since that is the primary capability to be provided at IOC in 2001. However, in the longer term JSIMS could have utility in providing an environment for concept exploration. JSIMS itself will provide battlespace entities with a moderate degree of resolution (e.g., aircraft, battalion), interacting in a simulated physical environment. Furthermore, JSIMS is being developed to allow coupling with real-world command and control systems, instrumented live platforms, and virtual simulators. Thus, JSIMS can be used as a stand-alone simulation for exploring new warfighting concepts, but it also can be used as a “driver” for C2 systems and real/virtual platforms.

JSIMS Challenges

- **Achieving large-scale system integration across multiple developers**
- **Developing and facilitating access to the set of mission-space objects necessary to represent the range of combat scenarios**
- **Maintaining the necessary flexibility and modularity in simulation structure to accommodate future evolution**
- **Developing and transitioning all necessary technical capabilities - e.g., C4I interface, security, and behavioral and environmental representation**

Both JSIMS and JWARS are ambitious undertakings. To achieve JSIMS goals and in particular to support concept exploration, several challenges must be met.

JSIMS is providing capabilities to all four Services and the Joint community; the Services and the Joint Program Office are building the components of JSIMS. Thus, JSIMS is faced with a difficult system integration problem, which has contributed significantly to the recent 24-month slip in IOC. Further, the management structure does not provide one common authority over all the developers.

To achieve the necessary integration, the concerned parties, under the leadership of the JPO, will have to agree on a necessary set of standards (e.g., for interfaces, resolution) while not being so restrictive as to stifle necessary innovation.

Ultimately, a rich set of mission-space objects will be necessary in JSIMS to represent a wide range of scenarios. These mission-space objects will represent not only physical behavior but also more abstract entities, such as command and control processes. Increased flexibility and modularity are necessary in the mission-space objects to allow the freedom to postulate and test new concepts and doctrine.

In addition, there are a range of other specific technical capabilities that are necessary for JSIMS, e.g., interfacing with C4I systems. Establishing those interfaces is complicated by the fact that control of those systems lies outside the immediate JSIMS community.

Still Missing?

. . . The demanding, involved customer for simulation environments that can immerse force and systems' decision makers, operational commanders, doctrine developers, etc., in a variety of new environments while experimenting with a variety of new concepts and systems.

To summarize to this point, the task force did not find the hoped-for demanding, involved customers for simulation environments that can provide immersion with new concepts and capabilities.

Absent such a set of customers, it is not surprising that the focus on satisfying the need has been inadequate.

However, we did find organizations who *want* to move in that direction, environments that *can* move in that direction, and significant pieces of the capability needed to do so.

The Approach

- **Bottom Lines**
- **The Customers and Needs**
- **Meeting the Needs**
- ➔ • **Recommendations**

Recommendations
Fix the Process
Some Tasks for JCS/JROC

- CJCS identify a few critical enablers/operational concepts of JV2010 for simulation focus
- JROC issue a requirement for joint simulation environments specifically focused on examining innovative concepts and systems
- JROC drive significant M&S resources to this need - guide tailoring M&S tools to these challenges
- JCS be a lead, demanding, involved customer for products
 - J8 and the JWCA process should be the specific focal points for direction and the prime customers for the output
 - They should work very closely with USACOM as it assumes its new responsibilities for joint warfighting experimentation
- CJCS task the Joint and Service PME schools to develop course on how to be effective customers for M&S services

JV2010 is a logical and desirable driver of the demand for simulation support to examine innovative concepts enabled by emerging technologies with the promise of transforming the effectiveness of forces.

While the Services are also important customers for joint simulation tools and products, the JCS/JROC will need to exercise far more direct influence on priorities and direction with very clear and specific demands for analytical support aided by the right kind of simulation.

We believe much of the problem with the application and misapplication of M&S lies with the demand side. Corrective actions have focused on the supply side - better models. Courses for military and senior civilians on how to become an effective customer of M&S services could well have a more profound and immediate impact.

Recommendations

Fix the Process

JCS, USD(A&T) Joint Focus

- Choose and affirm centers of excellence for support for joint innovative concepts and systems, and commit resources and time to their success
- Separate from but reaching out to and leveraging Service centers and industry centers
 - USACOM's new responsibilities as executor of joint experimentation can be a major step
- Place premium on experimentation and discovery
 - Premium on learning what works before a large investment to make informed choices
 - Unpredicted outcomes welcome and valued
 - Demand transparency in the reasons for outcomes used by experts as the principal means of earning credibility
- Set up a small group of "conceptualizers" to make use of existing M&S tool sets (e.g., the training-related tools at "Team Orlando") to explore facets of JV2010

To focus on analytical and simulation support for joint innovative concepts and systems, the JROC needs to provide consistent support for centers of excellence dedicated to this purpose.

While such centers need to be connected to Service and industry centers, their function would be to serve the joint community. Ideally, such centers would be part of, or at least directly connected to, a CINC with responsibilities for the joint world similar to the responsibilities the Army's TRADOC has within the Army.

There should be heavy emphasis on identifying and sorting out technological enablers for promising joint concepts and experimentation to discover what works and what doesn't before heavily investing.

A small group, specifically charged to think out-of-the-box, is needed to explore key facets of support for implementing JV2010.

Recommendations

Fix the Process

Organizing for Joint Operational Architectures

- JROC continue to support and leverage the JTAMDO “experiment” to add substance to the future joint voice
 - Don’t let it drift into a low-value “coordinating activity”
 - Connect Joint Operational Architecture agency to Joint Technical Architecture agency
- Apply the lessons learned to additional areas needing Joint Operational and Technical Architectures

The JCS and JROC should also push the frontiers in supporting other experimental approaches with better modeling and simulations.

The JTAMDO “experiment” has a good chance of demonstrating for the first time how to provide for a coherent, joint operational concept and joint architecture for a key joint function – in this case, theater air and missile defense. Still, the “experiment” will require continuing nurturing and attention to keep it from becoming just another joint coordinating activity. There also is a need for far better simulation support to try out joint concepts and doctrines.

Recommendations

Improve the Models

- **JCS and the Services task all efforts (at JWFC, others) examining new concepts to also identify supporting M&S priorities**
 - **Specific needs to address the concept, not just a long list of M&S requirements**
- **JCS and DDR&E increase the demand that simulations address the human element and the joint enablers that account for the most influential drivers of operational outcomes**
- **Must also be influential drivers of concepts and doctrines**
 - **Must have user-driven development**
- **JCS, DDR&E, and PA&E continue support for JSIMS and JWARS, but require specific future plans to more fully incorporate the JV2010 enablers, C4ISR, individual human potential, innovative concepts and systems, etc.**

To orient the models and simulations to support innovative joint concepts, the customer community needs to take a far more active role in defining simulation needs and setting priorities.

And greater attention needs be given what have been considered the imponderables that powerfully drive the outcome of battles – the human element and the joint connectors.

The DOD M&S Master Plan lists the human element as a major objective, and the Air Force Research Lab has a significant funded line to support this objective. However, this remains an important and difficult challenge and has yet to be demonstrated.

The task force spent some time examining JSIMS and JWARS and strongly supports continued development. JSIMS would enable more adaptive and efficient training and could also contribute to exploring new joint concepts. JWARS offers the promise of greater flexibility than previous large-scale models. However, its utility to concept exploration remains uncertain until it is demonstrated that it can adequately incorporate the emerging critical drivers of future joint warfare effectiveness. Not surprisingly, the early versions of these simulations will not adequately incorporate some important drivers of effectiveness. The JROC and OSD should insist on specific plans to incorporate these important features in future evolutionary versions.

Appendix A
Task Force Membership

Task Force Participants

Task Force Members

- . Dr. Ted Gold, Co-Chair
- . Gen Larry Welch, USAF (Ret)
Co-Chair
- . Dr. Joseph Braddock
- . Dr. David Chu
- . Gen Paul Gorman, USA (Ret)
- . ADM James Hogg, USN (Ret)
- . Mr. Don Latham
- . Delores Etter
- . Edward C. Brady
- . Dr. Richard Ivanetich

Government

- . Maj Skip Langbehn, USAF
- . Cmdr Dave Norris, USN
- . CAPT Jay Kistler, USN
- . Mr. Allen Murashigi, Air Force M&S
- . Mr. Vernon Bettencourt, Army M&S
- . Dr. Jackie Henningsen OSD PA&E
- . LtCol Illinger J-8
- . Mr. Vince Roske, J-8
- . Maj Matthew Lua, USMC
- . Col Crash Konwin, DMSO
- . COL Dave Hardin, USA
- . CAPT Hollenbach, DMSO
- . Mr. George Phillips, Navy M&S

Appendix B

***Organizations Visited & Consulted
The Search for Capabilities and Insights***

The Search for Capabilities and Insights

- 58th Special Operations Wing Training Support Squadron
- Airborne Laser Program Office
- Air Force Agency for Modeling and Simulation
- Air Force Air Combat Command
- Air Force Materiel Command
- Air Force Office of Aerospace Studies
- Air Force Operational Test and Evaluation Center (AFOTEC)
- Air Force Studies and Analyses Agency (AFSAA)
- Armstrong Laboratory
- Army Concepts Analysis Agency
- Army Research Institute
- Army Simulation, Training, and Instrumentation Command (STRICOM)
- Army Training and Doctrine Command

This and the following two slides list, alphabetically, some of the organizations that made presentations during various task force visits and meetings. Included are several locations where there are concentrations of analytic and simulation capabilities.

The Search for Capabilities and Insights (2)

- Boeing Corporation
- JAMIP Management Oversight Organization
- Joint C4I Battle Center (JBC)
- Joint Staff - J7,J8
- Joint Theater Air and Missile Defense Office (JTAMDO)
- Joint Theater Missile Defense Attack Operations project
- Joint Training, Analysis and Simulation Center (JTASC)
- Joint Warfighting Center (JWFC)
- JSIMS Program Office
- JWARS Office
- Lockheed Martin Advanced Development
- Lockheed Martin Information Systems Organization
- Los Alamos National Laboratory
- Marine Corps Combat Developments Command

As noted on this slide and the next, we included some analysis centers in the aerospace industry - defense and commercial.

The Search for Capabilities and Insights (3)

- **McDonnell Douglas Corporation**
- **MuSE Technologies Corp**
- **National Air and Space Model**
- **Naval Air Warfare Center Training and Support Division**
- **OSD/PA&E**
- **Paramount Studios**
- **Phillips Laboratory**
- **Real 3D Corporation**
- **Sandia National Laboratory**
- **Santa Fe Institute**
- **Theater Air Command and Control Simulation Facility (TACCSF)**
- **University of Central Florida Institute for Simulation & Training**
- **US Atlantic Command (USACOM)**
- **US Special Operations Command (USSOCOM)**
- **Visionarium, Silicon Graphics**

Appendix C

Some Existing Organizations for Analysis

This section quickly surveys some of the organizations for analysis that currently exist and some that hold promise for movement to the more complex, more adaptable environments needed.

The following is not intended to be comprehensive. It is intended to show that many of the pieces are well-understood and available, but are currently fragmented and need to be brought together. To bring these together in some cohesive fashion will collectively serve the larger joint need for simulation environments will underwrite the future concepts and capabilities development of the kind needed for JV2010

Army M&S Management Structure
Army Model and Simulation Office (AMSO)

- **-Training, exercise, and military operations -- system simulators, training simulations**
 - **Individual & collective training**
 - **Joint/combined exercises**
 - **Operational planning and mission rehearsal**
- **Advanced concepts and requirements generation -- simulators, constructive models**
 - **Force design and development**
 - **Operational requirements**
 - **Warfighting experiments**
- **RD&A -- system prototypes, engineering/physical models**
 - **Basic/applied research**
 - **Weapon system development**
 - **Materiel acquisition**
 - **Test and evaluation**

The Army has developed both the culture and several organizations that could be the basis for simulation environments for innovative concepts and capabilities.

This chart shows some of the range of the Army Model and Simulation Office's focus.

The subject titles match those of interest. What is needed are capabilities that match equally well.

Battle Lab
Reconfigurable Simulator Initiative (BLRSI)
Focus

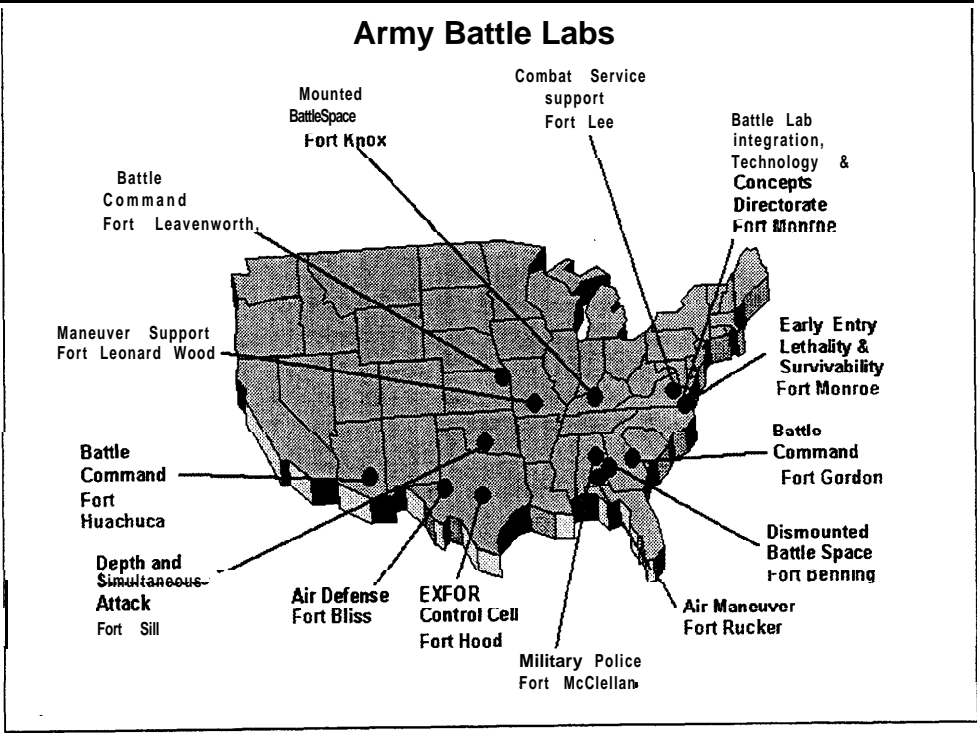
- **Missions:**
 - **Combat/force development**
 - **Virtual Prototyping**
 - **Cost and operational effectiveness analysis**
 - **Tactics, techniques, procedures**
 - **Training**
- **Seamless Linkage - live/virtual/constructive with C4I interface**
- **Semi-Automated Forces**
- **Distributed simulation**

A specific activity with some of the needed characteristics is the the Battle Lab's Reconfigurable Simulator Initiative. Again, it has the right missions and much of the right focus. However, it lacks the joint focus needed to underwrite JV2010.

**Army Test and Evaluation Command
Virtual Test and Training Range (VTTR) Focus**

- . Provide an interrelated set of synthetic environments to confirm a system's readiness and technical maturity
- . Live, virtual, human-in-the-loop, constructive
- . Support acquisition process
- . Potential customers
 - AAV - USMC
 - 21st Century Surface Combatant - Navy
 - Bradley Upgrade - Army
 - Low Cost Autonomous Attack Simulator - Air Force
 - Joint Advanced Strike Technology - Joint

Another specific example is the Army's Virtual Test and Training Range. Again, this presents many of the right characteristics and some of the tools and multi-Service customers.



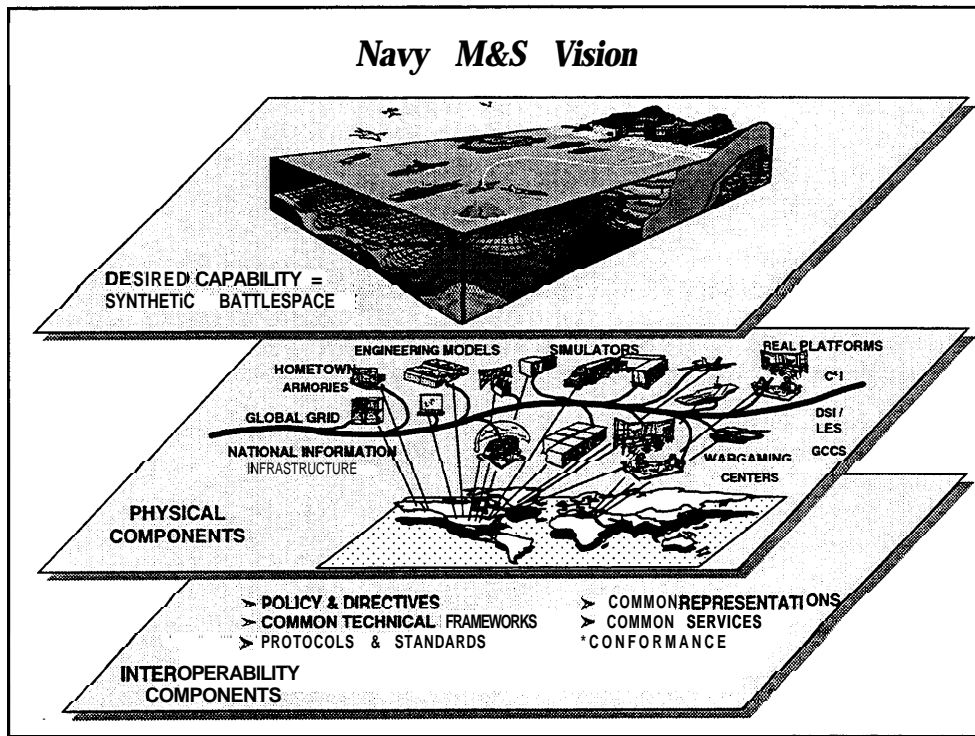
Navy M&S Vision

“In the 21st century, the United States Navy will use Modeling and Simulation to make better analytical decisions, improve warfighting skills, and develop superior systems to maintain the world’s most powerful maritime forces for the joint force commanders. Analysts will construct force structures; war-fighters will train and prepare for war; and system designers and engineers will develop new systems and platforms, all through the use of modeling and simulation in a synthetic battlespace credibly replicating the real world.”

--Navy Modeling and Simulation Master Plan (Feb 1997)

The Office of the Chief of Naval Operations has published an M&S Master Plan. It provides the Navy’s M&S vision, organization, strategy, and general guidance for the development and management oversight of the Navy’s M&S resources. It represents an overall plan for M&S across all seven Navy functional areas: Training, Training Systems and Education; Support to Operations; Acquisition, Research and Development, and Manufacturing; Assessment; Logistics; Doctrine; and Test and Evaluation.

The Navy M&S vision indicated here supports the DOD vision (noted earlier) and provides the basis for future decisions and direction of Navy M&S.



The synthetic battlespace noted in the Navy's M&S vision is that Service's implementation of DoD's plan to provide readily available, operationally valid environments for use by DOD components. It can be described as the collection of models and simulations and associated databases; the networks, including the supporting connectivity, interfaces, associated hardware, and underlying software and protocols; and the real-world operators, ranges, platforms, systems, and hardware. The three building blocks necessary for the evolutionary development of the synthetic battlespace are model standards, data standards, and communications.

The Navy envisions that this environment will enable analysts, warfighters, and system developers to work within a common battlespace from their workstations, simulators, aircraft, ships, and offices. The Navy expects initial operational capability of the synthetic battlespace to be in place around the turn of the century.

Navy M&S Goals

Training - support higher quality training at both force and unit levels through distributed simulation capability

Acquisition - reduce cost, cycle time, and risk of the acquisition process through Simulation-Based Acquisition

Assessment - provide a set of coherent analytical tools to support better decision making, both programmatic and operational

Synthetic Battlespace - provide the standards and infrastructure to create an integrated Navy M&S environment

The Navy M&S Master Plan focuses on the areas of training, acquisition, and assessment. As such, it does not explicitly refer to the use of simulation for the development of innovative concepts. However, such concept development may generally relate to all of these areas as part of acquisition and assessment, and as a user of training simulations.

Of the seven Navy functional areas, concept exploration most naturally fits in Doctrine. In fact, the doctrine objectives stated in the plan focus in two areas:

Simulation-based tools to support doctrinal and concept evaluation, development, assessment, and testing;

- A process to support development of authoritative representations of naval forces and capabilities in M&S.

The plan indicates that the training simulations will be the ones most used for doctrine and concept development, most notably, BFTT (Battle Force Tactical Training), JTCTS (Joint Tactical Combat Training System), and JSIMS.

The plan further notes that the battle lab concept demonstrated in efforts such as Kernel Blitz '95 will enable both doctrinal and conceptual experimentation. The more recent fleet battle experiments also provide such a vehicle.

Navy M&S End States

- . To exercise any size Navy battlegroup or expeditionary force as part of a combined or joint force from home ports or forward deployed through seamless integration of live, virtual, and constructive simulations
- . To conduct mission planning in a distributed environment
- . To conduct mission preview and rehearsal in port or at sea at all levels, from the individual ship to the baffle staff, within 24 hours of tasking
- . To validate Navy requirements, doctrine, logistics, and tactics using M&S as a primary tool
- . To improve the acquisition process by simulating and testing before we buy, build, or fight
- . To merge M&S and C4I systems
- . To support every major weapon system in the Navy with a simulator that can be networked into a common synthetic environment
- . To use M&S as a primary decision support tool

The Navy M&S Master Plan puts forward the end states as the basis for measuring progress toward achieving the M&S vision and estimating a return on investment. These are a broadly based set of measures, although as with the goals, the use of simulation for developing innovative concepts is not explicitly stated.

The Navy recently announced that a new Command – the Navy Warfare Development Command – will be created as part of the Naval War College. This Command will be responsible for doctrine development, fleet battle experiments, and concept development. As such, this Command should be a focal point for the application of simulation in the development of naval warfighting concepts. A challenge will be to see that these concepts relate adequately to joint concepts.

Marine Corps M&S Vision

- **To exercise any size MAGTF as part of a combined or joint force with seamless live, virtual, and constructive simulations**
- **To conduct mission planning in a distributed environment**
- **To conduct mission preview and rehearsal at all levels within 48 hours of tasking**
- **To validate requirements and doctrine using M&S as a primary tool**
- **To simulate before buy, build, or fight**
- **To seamlessly merge M&S and C3 system**
- **To support every major weapons system with a simulator that can be networked into a common distributed synthetic environment**
- **To use M&S as a primary decision support tool**

The Marine Corps also has a well-developed M&S vision that sets forth many of the goals and seeks many of the characteristics needed for a joint simulation environment to develop, understand, and evaluate concepts and capabilities.

One characteristic of the Marine Corps approach that seemed to the task force to be unusually strongly supported is the acceptability of failure, that is, the willingness to consider failure of a proposed concept or capability as a successful outcome of the simulation effort.

Air Force Agency for Modeling and Simulation Focus

- To develop a Joint Synthetic Battlespace supporting acquisition decisions and warfighting skills
- To coordinate support for AF/joint wargame training exercises
- To provide simulation program support
 - National Air and Space Warfare Model (NASM) - component of JSIMS
 - Joint Simulation System (JSIMS) - training
 - Joint Warfare Simulation (JWARS)
 - Joint Modeling and Simulation System (JMASS)

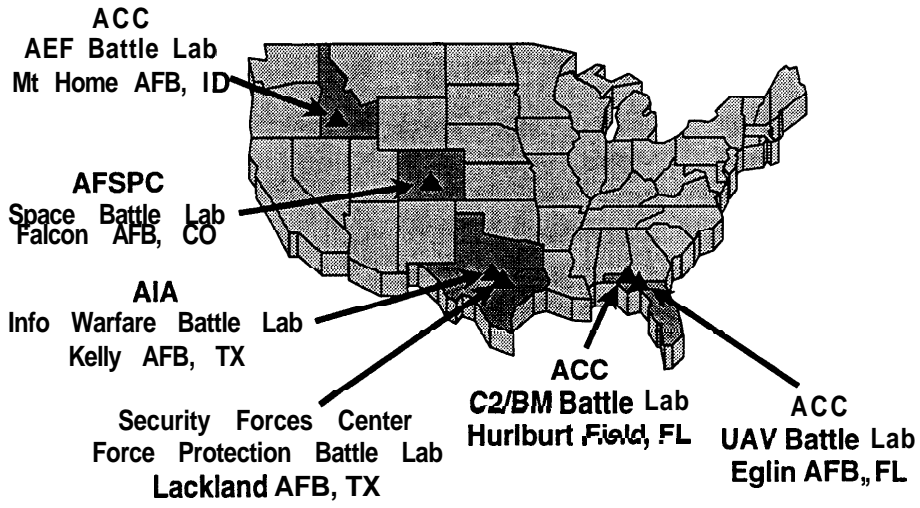
The Air Force effort seems to be more focused on bringing coherence to a variety of simulation efforts. The Air Force Agency itself is relatively new. The stated overall mission is certainly in consonance with the needed joint mission and joint simulation environment.

Air Force M&S Vision – Structure & Functions

- **Air Force Battle Labs (6)**
 - Link technology with operational concepts and doctrine
 - Output is revolutionary concepts and future requirements
- **Wargaming and Simulation Centers**
 - Train commanders and staffs in realistic operational training scenarios
 - Focus on winning the campaign today and in the near future with real-world equipment
- **Analysis Centers of Expertise**
 - Support to requirements, acquisition, T&E, and operations
 - Focus on support of the system life cycle

Listed here are some of the elements to underwrite the Air Force M&S vision. Again, the Air Force has recently redefined and reorganized simulation efforts to give them greater focus. The joint element in this focus is not yet apparent, though it could emerge quickly.

Air Force Battle Labs



Simulation Environments for Innovative Concepts

Some Organizations with Potential as Centers of Excellence

- **Hampton Roads, Virginia**
 - **USACOM**
 - **Joint Training, Analysis, and Simulation Center**
 - **Joint Warfighting Center**
 - **Training, doctrine, and analysis activities of all four Services**
- **Orlando, Florida simulation community**
- **Battle Labs:**
 - **Service battle labs tasked with developing advanced concepts - need joint analogue**
 - **Joint C4ISR Battle Center (JBC, Hampton Roads) provides an experimental environment**
 - **Federated Battle Lab concept is being developed to tie together Service C4ISR battle labs and JBC**

We did find a number of organizations and complexes that are clear candidates to form and nurture such centers.

The combination of joint activities and the concentration of key elements of each Service in the Hampton Roads area make it a likely candidate.

The concentration of Service, industry, and academic simulation and other analytic activities in the Orlando, Florida area also offer attractive benefits.

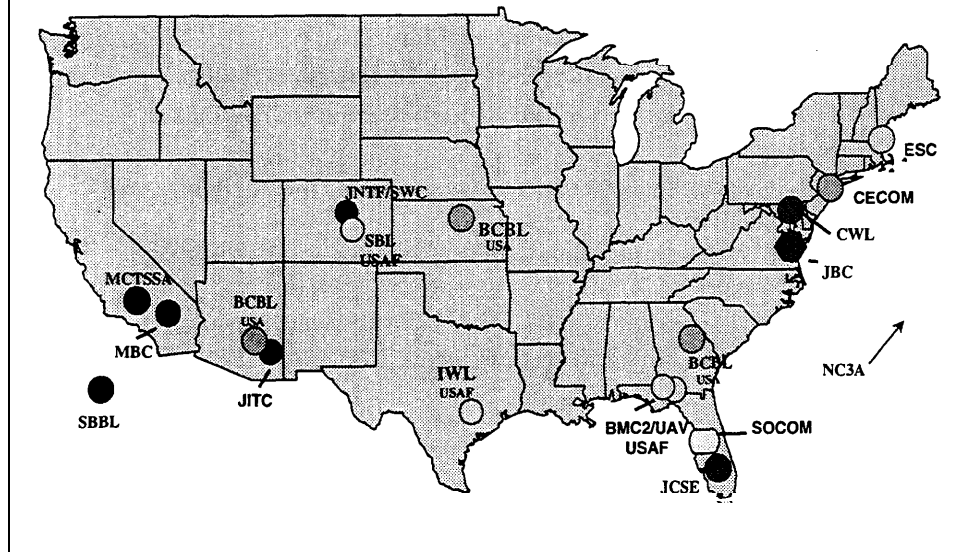
The Warrior Prep Center in Europe already serves a joint community with important training and analysis capabilities that could be expanded to examine innovative concepts and capabilities with a theater and related contingency focus.

Joint C4ISR Battle Center Mission

- **Provide the combatant commands, at the JTF level, with a joint assessment and experimental capability**
- **Be a forcing function for joint capability/interoperability**
- **Foster rapid insertion of C4ISR technology at the combatant command level**
- **Be a learning and experimentation center for the warfighter and the technologist**
 - **Supporting JV2010 and the CINCS' requirements for C4ISR capability**
- **Support integration of CINC-based C4ISR requirements and solutions into the formal requirements, PPBS, and JSPS processes**

The mission statement for the Joint C4ISR Battle Center (JBC) makes prominent mention of experimentation. Hence, the JBC could become a focal point for the use of simulation in developing joint warfighting concepts, particularly as they relate to the use of current and postulated C4ISR capabilities. The JBC has been operational for about a year now, and in that time has concerned itself mainly with efforts promoting interoperability among C4I component systems. Little if any use of simulation has been involved in carrying out such work. Thus, in the future it could be highly beneficial to place emphasis on the establishment of simulation capabilities at JBC, and their proactive use in support of warfighting concept development.

Federated Battle Lab Architecture (Key Connection Sites)



The Federated Battle Lab comprises the JBC plus the Service battle labs with C4I responsibilities. These facilities have agreed to cooperate with one-another to further mutual interests. Thus far, there have been efforts to establish a high-bandwidth communications connection among the sites and a limited set of FY98 activities has been defined, of the type described above for the JBC.

In the longer run, the Federated Battle Lab concept appears as a useful vehicle for pulling together Service capabilities in support of developing joint C4I war-fighting concepts. Recently, there has been general discussion among Service battle labs (not just the C4I ones) about collaboration aimed at joint experimentation.

Appendix D
Terms of Reference (memorandum)



THE UNDER SECRETARY OF DEFENSE
30 10 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-3010



ACQUISITION AND
TECHNOLOGY

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

JAN 27 1997

SUBJECT: Terms of Reference - Defense Science Board Task Force on Advanced Modeling and Simulation (M&S) for Analyzing Combat Concepts in the 21st Century

You are requested to form a Defense Science Board (DSB) Task Force to address modeling and simulation capabilities required for analyzing concepts for 21st century military combat operations. These capabilities should encompass the breadth of warfare from strategic to individuals fighting afoot for all phases of military operations (Air, Land, Sea, Information, Communications). The Task Force should focus on the requirement for advanced M&S tools motivated by:

- The need for a concept prototyping capability for CINCs and Services.
- A wider range of global political military scenarios than the cold-war environment.
- Revolutionary new warfighting concepts that challenge current analysis capabilities.
- Emerging technologies including commercially driven information technologies commercial development cycle times.
- An economic need for DOD to "try before it buys" new acquisition systems.

The Task Force should address the following questions:

1. How do we want to conduct analysis in the future and what should be the interrelationship between constructive, live, and virtual simulations? What methodological and procedural changes are required to improve DOD analysis?
2. How do we provide the warfighters and force providers with concept prototyping capability at various levels?
3. What tools are needed to perform these analysis? What tools are currently available?
4. What technologies are required to build needed tools?



5. What DOD organizational and policy changes are needed to research and effectively implement new analyses approaches?

In developing its findings and recommendations, the Task Force should:

- Examine tools and approaches for analysis in support of:
 - Concept exploration (including small unit operations, battle management (C3), information warfare, precision strike operations, logistics, and strategic deployment)
 - Functional topics which address the design of military capabilities (quantity and quality of systems, forces, and procedures)
 - DOD investment decisions
- Investigate current analysis capabilities and shortfalls and identify research opportunities.
- Investigate concepts for analysis such as "continuous war" in an integrated development environment, aimed at tradeoff analysis between different levels of detail (e.g. engineering, human, functions, and operations) and different phases of system development.
- Develop a road map to implement new DOD analysis capabilities to support research, development and application. Consider cost and affordability.

The study will be jointly sponsored by the Vice Chairman of the Joint Chiefs of Staff and the Director of Defense Research and Engineering. Dr. Ted Gold and General Larry Welch, USAF(Ret) will serve as the Co-Chairmen of the Task Force. Major Skip Langbehn, Air Force Directorate of Modeling, Simulation and Analysis will serve as the Executive Secretary. LTC T. Van Horn, USA, will serve as the DSB Secretariat Representative.

The Task Force will be operated in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DOD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Paul Kaminski

Paul G. Kaminski