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New Issues and Tools for Future Military Analysis: A Workshop Summary

Richard J. Hillestad, Reiner Huber,
Milton G. Weiner (eds.)

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New Issues and Tools for Future Military Analysis: A Workshop Summary

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Prepared for the
Defense Advanced Research Projects Agency
United States Air Force
United States Army

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PREFACE

The workshop on "Future Military Analysis: New Issues, New Tools" evolved from considerations extending from the late 1980s, when arms control and potential force reductions in Europe were being analyzed. Those analyses implied that with force reductions would come the need for very different force compositions and deployments, new force-employment concepts (strategies and tactics), and new tools to evaluate them. As the face of Europe changed fundamentally with the end of the Cold War and the unification of Germany, dramatic military changes became a certainty and then an emerging reality that would take some years to fully play out. Finally, the war with Iraq in 1990-1991 underscored the necessity of changed concepts, dramatizing for the entire world how much technology has changed the nature of warfare and illustrating the differences between a hypothetical war over Europe's Central Region and wars elsewhere.

At RAND, there was considerable interest in pursuing the new conceptual and analytic challenges. As part of doing so, Natalie Crawford, Director of the Theater Force Employment Program of Project AIR FORCE, proposed a series of visits by RAND staff to a number of U.S. and European analytic organizations. These visits (by Weiner and Hillestad) revealed a widespread interest in an international workshop to discuss new issues and tools for military analysis.

A project to prepare for and conduct such a workshop was approved by Dr. Paul Davis, Corporate Research Manager for RAND's Defense Planning and Analysis Department. The effort was made possible by the general sponsorship of RAND's three federally funded research and development centers: Project AIR FORCE (Air Force), the Arroyo Center (Army), and the National Defense Research Institute (NDRI) (Office of the Secretary of Defense and the Joint Staff). Preparation of this Note on the workshop was accomplished as part of a project on military science in the Applied Science and Technology Program of NDRI under sponsorship of the Defense Advanced Research Projects Agency (DARPA). In the interest of distributing this workshop summary as soon as possible, the Note does not attempt to "correct" or "improve upon" the comments and reasoning of the workshop members. The purpose of this summary is to report the workshop proceedings and the conclusions reached.

SUMMARY

Events in Central/Eastern Europe in the fall of 1989 and subsequent developments there as well as in Southwest Asia have dramatically undermined the basic assumptions underlying Western military planning and raised entirely new issues and questions from those of the past 40 years. These developments confront military analysis with not only new and different issues of a significantly wider scope in many cases, but also a new style of analysis capable of addressing the high degree of variability and uncertainty inherent in the new security environment. At the same time, advances in computer technology and the development of new software and analysis tools may help to somewhat mitigate the problems the analysis community is faced with. However, opinions differ regarding the magnitude of the challenge and approaches to meet it. To discuss and debate these issues a workshop, *Future Military Analysis: New Issues, New Tools*, was held on 8-10 May 1991 at RAND in Santa Monica.

Workshop participants included a broad cross section of military and civilian analysts from approximately 25 defense analysis institutions in the United States and Western Europe. The format of the workshop included a keynote address about the changing situation, an introductory general session, a series of briefings about U.S. and British analysis in direct support of Operations Desert Shield/Storm, three concurrent panel sessions, and a general wrap-up session. The panels focused on the following problem areas:

Panel 1: Issues and contexts for future military analysis
Panel 2: Representing military activities in modeling and analysis
Panel 3: Tools and techniques for future military analysis

ISSUES AND CONTEXTS

Panel 1 identified the major changes affecting future analysis as a result of the reduction of the Soviet and Warsaw Pact threat, the need to restructure NATO, the possibility of increased instability in the Third World as well as Eastern Europe, and declining Western defense budgets. The major implications for defense analysis included the increased complexity of problems, the shorter time constraints for analyzing problems, and the large uncertainties in dealing with scenario,

capabilities, and operational objectives. The panel concluded that a Quick Reaction Analysis (QRA) concept must be developed to perform viable analysis within the likely time constraints. This concept must include fast running, easy to use and understand models that give good first approximations to solutions. QRA will also require highly experienced analysts with a good understanding of the problems and implications of the underlying issues. QRA must include considerable sensitivity testing to acknowledge the large uncertainties. Finally, QRA must be supported by relevant knowledge bases, which in turn require long-range programs of systematic research and training/mentoring of junior analysts. Panel 1 also concluded that the increased uncertainty of scenario and capability should be accommodated by results presented over the regions of uncertainty and that windows of risk be used rather than point estimates. Thus, to cope with the challenges of the future, panel 1 suggested that both a new analysis culture as well as an extension of the toolbox are needed.

REPRESENTING MILITARY ACTIVITIES

Panel 2 focused more narrowly on the implications of the events in Europe and Southwest Asia for modeling military operations. To this end, the panel first compiled a list of key phenomena that should be represented and then made recommendations for improved modeling and analysis. Categorization of the list and identification of the analysis community's current capability to include list elements in analysis led to a number of conclusions. It was observed that considerably more attention should be given to representing the qualitative factors of leadership, training, morale, cohesiveness, and the like in analysis and models to the extent possible, because such factors can dominate military outcomes. Furthermore, more attention should be given to integrated military systems as opposed to weapons systems. The implication is that military analysis will become increasingly complex because of the need to consider the integrating elements of command and control, synergies between weapons systems, and so forth. Furthermore, the uncertainties will increase because quantitative values for many of the qualitative factors are either unknown or unknowable. The panel members concluded that because uncertainties will increasingly dominate analysis, they should not be "hidden" from the decisionmakers by providing point estimates. In fact, the direct confrontation of uncertainty should frequently lead to solutions of a different character. If the lethality of air defenses is unknowable, for example, then an operational strategy of probing may be important. If logistics demands in wartime are highly uncertain,

then it may be important to institute wartime logistics-management and support structures that can adapt to the uncertainty rather than attempt to predict it better. Finally, panel 2 concluded that it was very important to develop a long-term program of basic research in which there are incentives for publications, peer review, and open conferences to foster improved quality and higher standards within the military analysis community.

TOOLS AND TECHNIQUES

Panel 3 considered the tools and techniques of analysis and how changes in the analysis requirements combined with new capabilities would affect future military analysis. It also addressed how management and cultural "tools" could improve future analysis. Independent of the first two panels, this panel also concluded that the issues to be faced were more complex, that there was far greater uncertainty in many dimensions, and that the resources available for analysis were decreasing. At the same time, military analysis and models are being used by an ever broadening set of decisionmakers. The panel noted that evolving trends include more reliance on gaming and quick reaction analysis of the type suggested in panel 1 and the growing need for databases of results for such analysis. With respect to tools, computer graphics was recognized as an important means of reducing apparent complexity, communications technology could increase cooperative analysis and gaming across the analysis community, new software languages could promote reusable software and self documentation, and database technologies should be used to improve the quality and speed of analysis. Management tools that should be exploited include accreditation of analysis and algorithms (as opposed to accreditation of models). *Cultural tools* are important as well. Clearly, *education of analysts* has always been important, but the panel pointed out that the education should include not only the tools of analysis, but the process of synthesizing defense problems and skills in the presentation of concepts and results. *Education of decisionmakers* in the use of military analysis is more important than ever, because of the increased reliance defense establishments will need to make of analysis and simulations, as well as the increased uncertainty and complexity of problems analyzed. Finally, the panel concluded that *cooperation among analytic agencies* will take on increased importance, both because of the decreasing analytical base and the complexity of issues.

WRAP-UP AND INTEGRATION

Common themes that cut across the panel discussions were:

- *We appear to be at a turning point in military analysis and the problems, requirements, and tools for future military analysis are likely to be changing faster than during the past 40 years.*

- *Uncertainty of scenario and threat will be much larger than in the past because of the changes in the world political-military situation.*

- *The context for military analysis is likely to be significantly broadened by the need to take greater account of both political and policy considerations.*

- *The nature of military operations to be analyzed is likely to be dramatically different, not only because of changes in threat but also because of new technologies being exploited by the military—information systems, long-range precision-guided weapons, etc.*

- *A broader set of decisions and decisionmakers will require military analysis and the time available for analysis in support of decisions will shrink.*

- *The issues and resulting analyses will be more complex, at times requiring aggregation mechanisms to reduce complexity and in many cases teaching decisionmakers to deal with complexity.*

- *New software and hardware tools can be used to accommodate these new analysis requirements, but management and cultural "tools" should be exploited as well.*

Some specific recommendations to the military analysis community and its sponsors as the result of this workshop are:

1. *Continue to discuss issues of military analysis in open forums such as this. NATO and MORS meetings provide additional opportunities, but are not open to as broad an audience and are generally too large to have the type of focused discussions allowed by the workshop. Future workshops should have specific themes and limit attendance to continue this focus. Several organizations volunteered to sponsor the next workshop.*

2. *Develop a "quick reaction analysi (QRA) to military analysis and supporting tools to enable quick turnaround and high-level decision support. This approach requires the development and support of results databases generated through a program of forward-looking basic research.*

3. *Reinstitute basic principles of systems analysis, which may have atrophied because of the relatively stable planning scenario of the past decades. These principles include considerable attention to uncertainty, multiple scenario analysis, parametric analysis, comparative analysis, etc. Basic principles also require peer review of models and analysis fostered by incentives to publish and otherwise disseminate information.*

4. *Promote basic research founded in scientific principles on complex phenomena such as the qualitative factors affecting military performance (training, morale, leadership), behavior of complex military systems (C3I), and new types of conflict; encourage their inclusion into military analysis.*

5. *Promote multi-organization analysis of complex issues as well as supporting multiple analyses of the same issues. At the same time, encourage efficient use of analysis resources by cataloging and disseminating information on algorithms, approaches, databases, and "results bases."*

6. *Promote education of junior analysts in the synthesis and solution of defense problems. Promote the education of decisionmakers in the use and limitations of analysis.*[1] *Recognize that training and education are the key to quality in future military analysis.*

The authors and many of the workshop participants view the workshop as the first in a continuing series organized around issues raised in this meeting, to be held at several of the represented organizations.

[1]For example, the tendency to avoid redundancy and competing views should be avoided because of the large uncertainties involved in future military analysis. A decisionmaker who receives two competing views of a problem and who then makes the effort to understand the differences is likely to learn more about his problem and its sensitivities than the decisionmaker who accepts a single analysis or, even worse, receives only a point estimate of results.

ACKNOWLEDGMENTS

The editors are grateful for the detailed review of this material by Jack Craigie. We thank Paul Davis and Natalie Crawford for their support in initiating the workshop. Irene Gordon has our utmost gratitude for her patience and perseverance in putting together this Note as well as for her assistance in the administrative details of the workshop itself. We also thank Cathy Jensen for her assistance during the workshop.

CONTENTS

PREFACE iii

SUMMARY v

ACKNOWLEDGMENTS xi

FIGURES xv

Section

1. INTRODUCTION 1

2. THE CHANGING NATURE OF MILITARY ANALYSIS: FUTURE WARS AND THE EXPERIENCE OF OPERATION DESERT STORM 5
   - Chariots of Fires: Thoughts About the Nature of Future Wars and Their Implications for Analysis 5
   - Analytic Support for Desert Shield/Desert Storm 20

3. REPORT ON PANEL 1: ISSUES AND CONTEXT FOR FUTURE MILITARY ANALYSIS 30
   - Panel Objective 30
   - The Changing Global Environment 30
   - New Demands on Analysis 32
   - Issues 35
   - On the Critique of Military Modeling 37
   - Summary 39

4. REPORT ON PANEL 2: REPRESENTING MILITARY ACTIVITIES 40
   - Panel Objective 40
   - Key Phenomena 40
   - Implications for Military Analysis 42
   - An Approach for Improved Modeling and Analysis 46

5. REPORT ON PANEL 3: TOOLS AND TECHNIQUES FOR FUTURE MILITARY ANALYSIS 48
   - Panel Objective 48
   - Characteristics of Future Military Analysis 48
   - Evolving Trends in Analysis Methods 51
   - Technical Tools 52
   - Management Tools 53
   - Cultural Tools 54

6. WRAP-UP, CONCLUSIONS, AND RECOMMENDATIONS 56

Appendix

A. POINT PAPERS SUBMITTED TO THE WORKSHOP 61
B. CONFERENCE ATTENDEES LISTED BY PRIMARY PANEL ASSIGNMENT 63
C. WORKSHOP ON FUTURE MILITARY ANALYSIS: AGENDA 66
D. WORKSHOP PANEL TERMS OF REFERENCE 67

FIGURES

1. Locations of Possible Future Military Conflicts 7
2. Examples of Future Scenarios in Terms of Force Involvement and the Nuclear Shadow 8
3. Examples of Future Scenarios in Terms of Their Technological Levels 9
4. Campaign Phase Variations in Future Conflicts 10
5. Systems that Have Changed the Flow of Information on the Battlefield 12
6. Close Air Support Aircraft Delivery Capabilities (measured in pounds of munitions) 13
7. Deep Fire Smart Munition 14
8. The Littoral Nature of Future Theaters of Operations 17

1. INTRODUCTION

For more than forty years, the global political-military environment was dominated by the confrontational East-West relationship that emerged in the wake of World War II. The military focal point was the European Central Region along the Inner-German and German-Czechoslovakian borders that marked the demarcation line between the military forces of the Soviet-led Warsaw Pact (WP) and the U.S.-led NATO alliance. From the very beginning, the principal objective of Western military policy was essentially to maintain military forces sufficient for a credible deterrence of attacks by the WP's ready forces deployed in East Germany, Poland, and Czechoslovakia, followed by those of the second strategic echelon in the western part of the Soviet Union. Western Alliance military planning was focused on maintaining, in a cost-effective manner, a credible deterrence posture in response to the perceived evolution of the WP threat. Thus, by and large, it implied only incremental changes of weapon systems, command and control, and force structures within a set of generally accepted "certain" conditions regarding strategy (Flexible Response), defense concept (Forward Defense), and design scenario (massive Warsaw Pact attack).

The unexpected turn of events in Central/Eastern Europe in the fall of 1989 and the subsequent developments there as well as in Southwest Asia have pulled the rug from under the basic assumptions underlying Western military planning, raising entirely new issues and questions. Many of the problems of the past appear in comparison to have been rather static and well defined. Indeed, there is a widespread feeling that we may have arrived at a point of discontinuity in international security affairs requiring nothing less than the formulation of a new grand strategy for the United States and the Atlantic Alliance and the redefinition of the role of military power.

These developments confront military analysis with an unprecedented challenge that seems to imply not only new and different issues of a significantly wider scope in many cases, but also a new style of analysis capable of addressing the high degree of variability and uncertainty inherent in the new security environment. At the same time, advances in computer technology and the development of new software and analysis tools may help to somewhat mitigate the problems the analysis community is faced with. However, opinions differ regarding both the magnitude of

the challenge and the approaches to meet it. There are many open questions that require debate within the analysis community. Answers to them should be greatly facilitated through appropriate cooperation of the analysis community. RAND researchers visited a number of European and U.S. defense analysis agencies in early 1991 and found surprising consistency in discussions regarding:

- The need to address dramatically new scenarios.
- Demand for analysis from a much broader set of decisionmakers and at higher levels.
- Approaches to new analysis issues involving games and simple models to accommodate the increased uncertainties and short times in support of the decision process.
- The use or planned use of new software and hardware tools to support analysis.

For these reasons, the RAND researchers suggested organizing an international workshop for the discussion of how future military analysis would be influenced by the revolutionary changes in the international security environment as well as by the new hardware and software technologies. This idea found enthusiastic support by the military analysis institutions in the United States and Western Europe and the workshop was organized as a three-day meeting on 8-10 May 1991 at RAND in Santa Monica, California.

The workshop had three objectives:

1. to provide a forum for the exchange of information on the current military analysis interests and activities of the participants
2. to identify some of the issues, future contexts, methods, and tools appropriate to future military analysis
3. to explore the utility of additional cooperative activities and meetings of the participants on topics developed during the workshop.

The workshop was organized in three parts corresponding to the three days of the meeting.

The first day was devoted to an introductory address—a broad, speculative presentation on some of the potential areas of future conflict, some of the improved military capabilities that may develop, and some of the possible consequences for military analysis and modeling. This was followed by brief presentations in which the organizations attending the workshop briefly described their interests and identified points that they regarded as relevant to future military analyses. The final presentations of the day covered the use of military analysis in the Desert Shield/Desert Storm operations as illustrating the current use of analysis and modeling for an actual conflict.

On the second day the workshop was organized around three parallel panels to avoid the pitfalls often associated with the discussion of complex subjects by a large group of people. The three panels focused on different, but related, subjects.

Panel 1:	Issues and context for future military analysis
Panel 2:	Representing military activities in modeling and analysis
Panel 3:	Tools and techniques for future military analysis

To facilitate the debate, the organizers had provided the panels with terms of reference describing the important issues to be discussed and possible panel outputs. The terms of references are given in Appendix D.

Two additional guidelines were agreed upon–that discussions not focus on specific models of the various institutions and that the panels attempt to discuss solutions rather than just debating the changes and problems.

On the third day, summaries of the panel reports were presented by the chairmen to the plenum for further discussion. The full-length panel reports are contained in the three sections following the keynote paper. The final section summarizes the findings and proposes a series of steps that the analysis community might take in following up the findings and recommendations of this workshop.

The organization of this workshop report follows the structure of the workshop itself. Section 2 summarizes the keynote talk by Sam Gardiner that speculates about important issues in the changing nature of warfare and new analysis requirements. Section 2 then briefly summarizes a series of discussions about operations analysis during Operation Desert Storm. Sections 3 through 5 present the panel summaries. Section 6 summarizes conclusions reached in the workshops. The appendices list the

workshop attendees, point papers discussed during the panel sessions, terms of reference for the panels, and the workshop agenda.

This Note attempts to report on an informal set of proceedings. Although we have organized and summarized the material, we have not changed the conclusions reached in the sessions or resolved inconsistencies.

2. THE CHANGING NATURE OF MILITARY ANALYSIS: FUTURE WARS AND THE EXPERIENCE OF OPERATION DESERT STORM

This section is divided into two parts. The first is based on the keynote speech by Sam Gardiner and describes his thoughts on how the nature of warfare may change as a result of global change and modern technology. The talk was meant to stimulate discussion and was not intended to represent completed research. The second part of this section summarizes the briefings about the experiences of a group of operations analysts directly supporting Operation Desert Storm.

CHARIOTS OF FIRES: THOUGHTS ABOUT THE NATURE OF FUTURE WARS AND THEIR IMPLICATIONS FOR ANALYSIS[1]

Sam Gardiner[2]

"To prepare for war demands, then, exercise of the imagination. We shall glance at the wars of the past long enough to retrace their essential features; we shall ask of the present what it is preparing for the future; and, finally we shall try to decide what modification will be made in the character of war by the causes at work today." (Douhet)

Background

Much has been said and written about the implications of the changes in Central/Eastern Europe and of the war with Iraq for military strategy, operational concepts and tactics in general, and of the Western Alliance in particular. Despite their very different conclusions in several respects, most authors agree that the end of the Cold War does not mean that the risk of war is diminishing. On the contrary,

[1]"Chariots of Fires" is meant to convey a notion of one of the characteristics I see in future war—maneuver by fires. I picked up the title from Richard Simpkin, the author of a book on future warfare, *Race to the Swift: Thoughts on Twenty-First Century Warfare* (New York: Brassey's Defence Publishers, 1985). Simpkin was going to use the title for his next book. Much of my own thinking about maneuver by fires comes from extended conversations I had with him at his home in Scotland a few weeks before his death from cancer.

[2]The work this presentation summarizes is an effort of Bruce Bennett, Dan Fox and me. It was originally done for the Office of the Secretary of Defense (Net Assessment) and in support of the concepts we are developing for the future RAND Strategy Assessment System. The particular twists put on the presentation for the "Military Analysis for the Future" workshop are mine. Subsequent RAND publications will explain the work in more detail.

the absence of constraints imposed by the hegemonial powers in the bipolar East-West confrontation of the past forty years might well exacerbate many of the latent conflicts on the globe. Thus, the United States and its allies could become involved in a series of rather diverse post-cold war military conflicts of which the war with Iraq might be regarded as the first one.[3]

The preliminary assessments of the Iraq war suggest that the nature of future wars might be very different from what we have seen and thought about in the past. In fact, this author is convinced that we are at a point of discontinuity. We can no longer project the past to understand the future. The world of war and warfare is different enough that its analysis must be approached in new ways.

In the following, an attempt is made to present the underlying arguments in a structured manner by first looking at possible future wars and their characteristics, and then by analyzing the key factors affecting the nature of modern warfare. The conclusion will address the consequences for analysis and modeling.

Possible Wars and Their Characteristics

To come to some conclusion about the kinds of war that might take place, we began by reviewing the various theories on why nations go to war that have been put forward based on historical observations. We distinguished the following principal causes:

- Uncontrolled Accident (Barbara Tuchman)
- Arms Sales (weapons cause wars, Arms of Krupp)
- Ideology (communism vs. capitalism)
- Revenge (Israeli security policy)
- Aggressive World (foundation of containment)
- Uncontrollable Domestic Pressures (Argentina and the Malvinas)
- Economic Gain (colonies, mercantile theory, oil)
- Control of Vital Areas (Mackinder)
- Balance of Power (Bismark's Wars, Persian Gulf)
- Ambitious Dictator (Hitler)

[3]Over the past 3500 years of recorded history the world has been without war only 10 percent of the time [Will and Ariel Durant, *The Lessons of History* (New York: Simon and Schuster, 1968), p. 81]

- Discounted Future (Persian Gulf War)

With these in mind, we hypothesized a series of possible conflicts around the year 2015,[4] the locations of which are indicated in Fig. 1. The conflicts span the range from theater wars with regular (conventional) forces and traditional military objectives, such as defeat of the opponent, to insurgencies with highly political objectives.[5]

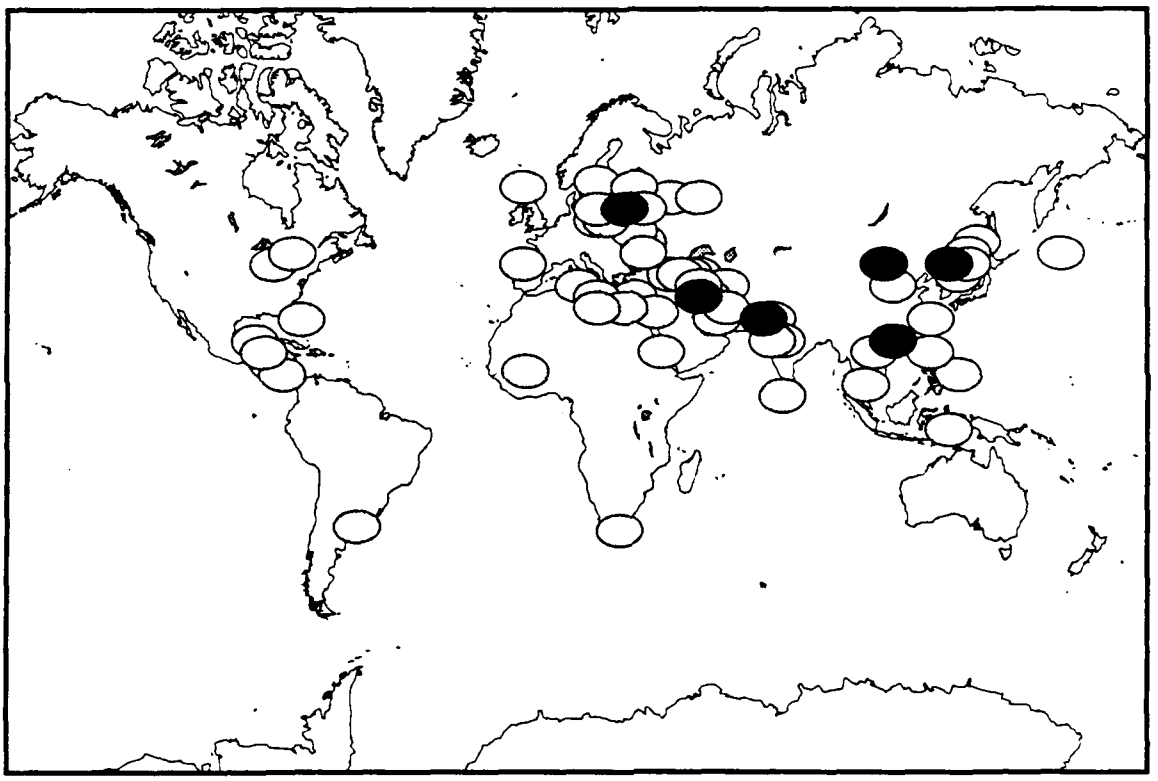

Fig. 1—Locations of Possible Future Military Conflicts

[4]The year 2015 was selected because the weapons fielded then, must be in basic research today (6.1 R&D funding in the DoD budget). The Army has run a series of seminar war games over the past two years that have had a focus on 2015. This author's thinking has been enriched by having had an opportunity to participate in those games.

[5]This assumes continuity in the relationship of war and the nation state. Martin van Creveld has argued to the contrary. He has set down the proposition that the Clausewitzian Trinitarian ideal—the people, the government, and the military—may not apply in the future. He argues that a separation of these three will change the entire framework of war. See Martin van Creveld, *The Transformation of War* (New York: The Free Press, 1991).

These possible conflicts represent a spectrum of situations where ground, naval, and air forces might be employed. In addition, there are varying degrees of presence of the nuclear shadow, although in the period addressed it is more widespread than would be found in an analysis of current conflict areas. Figure 2 illustrates five major conflicts out of the more than fifty conflicts considered possible.

Some samples	Ground	Air	Naval	Nuclear Shadow
"NATO"–USSR	Major	Major	Moderate	Major
India–Pakistan	Major	Minor	Minor	Moderate
China–Taiwan	Moderate	Moderate	Major	Moderate
North–South Korea	Major	Minor-Major	Minor	Moderate
Arab–Israel	Major	Minor-Major	Minor	Moderate
China–India	Moderate	Moderate	Major	Moderate

Fig. 2—Examples of Future Scenarios in Terms of Force Involvement and the Nuclear Shadow

In addition to differences in the degree of involvement of ground, naval, and air forces and presence of the nuclear shadow, a significant diversity must be expected with regard to the technology of the combatants, when compared to each other and when viewed on a broader scale.[6] This is illustrated by Fig. 3.

[6]In the early stages of the analysis, the dimension of weapon systems cost was considered. Because of the high cost of technology, the world of 2015 will probably see even more of a range than we see today. The obvious difficulty for a country like the United States is designing weapons that can deal with a high technology threat as well as a very low technology threat.

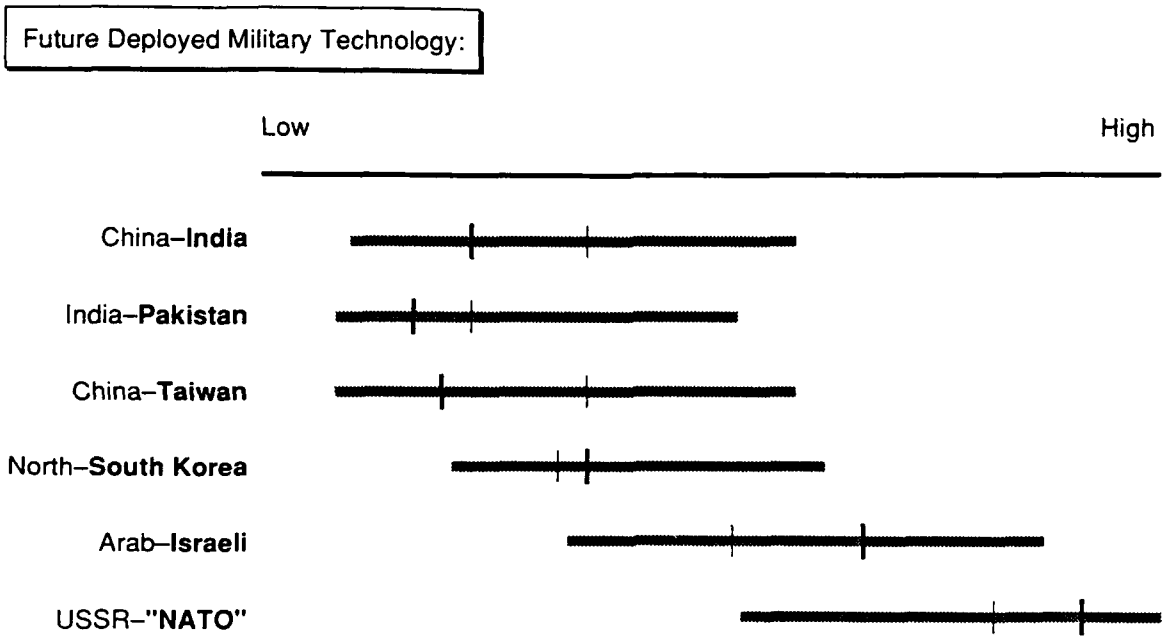

Fig. 3—Examples of Future Scenarios in Terms of Their Technological Levels

Terrain is another characteristic that sets the possible conflicts apart. There is a broad spectrum distinguished in many cases by what the Soviets would call special terrain conditions—mountains, jungle, desert, and urban areas.[7]

In addition to the forces involved, their technological level, and the terrain prevalent in the theater, there is another significant level—the way in which the campaigns might unfold. The historical (for the United States anyway) idea of a campaign with deployment, defense, and counterattack in sequence could be found in only a few of the hypothetical year 2015 wars.[8] Figure 4 shows three examples.

[7]Based on conditions in Europe, the Soviets have decided that urbanization is one of the major characteristics of modern combat. See David M. Glantz, *Soviet Military Operational Art: In Pursuit of Deep Battle* (Portland, OR: Frank Cass, 1991) p. 251.

[8]One of the products of the Persian Gulf War has been a broader acceptance of the idea of a military *campaign*. When massive retaliation and flexible response dominated our thinking about war strategy, a conventional military campaign was considered mostly a prelude to nuclear response. For awhile, the Joint Chiefs of Staff (JCS) dictionary even dropped the term "campaign plan."

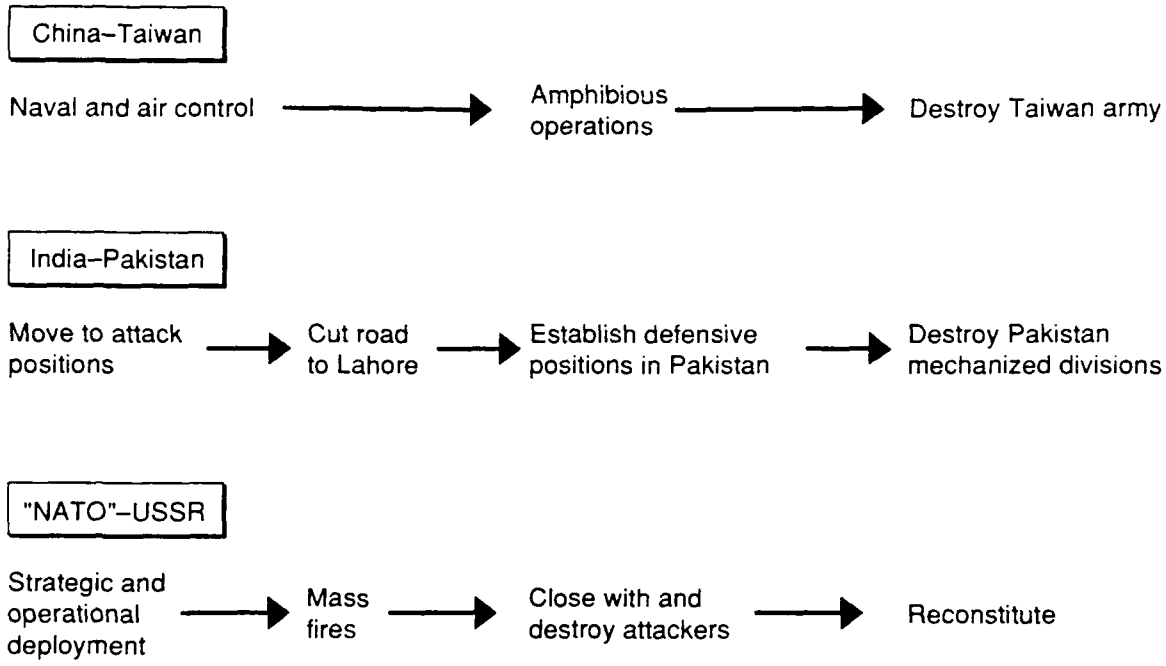

Fig. 4—Campaign Phase Variations in Future Conflicts

In summary, we found that the warfare variants could be described by seven principal variables:

- Policy objectives of the participants
- U.S. objectives and alternatives
- Doctrine of the participating military forces
- Equipment
- Terrain
- Logistics
- Command and control.

Nature of Modern Warfare

To appreciate the kinds of analyses that need to be done in the future, it must be understood that the analyst is confronted not only with a new diversity of scenarios, but also with changes in the nature of warfare brought about by technology.

The four most important changes that seem to stand out refer to

- The way in which information flows in C3I systems
- The dramatically increased lethality of weapons
- The concommitant reduction of force density on the battlefield
- The range of modern weapons.

When the Germans attacked the Allies in 1940, there was an interesting disparity in information about the condition of the French Army. In Berlin, intelligence showed the French still to be strong. But the German commanders leading the attack had a different, more accurate view of the war.

Whether it was in 1940 or even during the U.S. Civil War when commanders operated under a tactical axiom to "move to the sounds of the guns," the historic flow of battlefield information was from the bottom to the top once the fighting started. Lower echelons needed to keep higher echelons informed.

As a consequence of modern technology, the direction of the flow of information seems to be changing. More and more systems are being designed to collect information and provide it to the tactical commanders. Even information on targets is coming from higher echelons. The extreme case is the target information and enemy status provided by satellite during the Gulf War. The trend is there in current systems, and it can be seen in future systems. It can be seen in Army, Air Force, and Navy systems (see Fig. 5). The possible effects of this and implications for analysis are described later.

Martin van Creveld has argued that technologies developed for society in general and not specifically for the military have had some of the most significant effects on the battlefield.[9] Railroads allowed strategic maneuver, the internal combustion engine and the radio allowed tactical maneuver. Following this argument, it would seem that the future could be characterized as being oriented on information. In the *New York Times* list of ten critical technologies for the early part of the 21st Century, half are directly related to information:

[9]Martin van Creveld, *Technology and War: From 2000 BC to the Present* (London: Collier Macmillan Publishers, 1989).

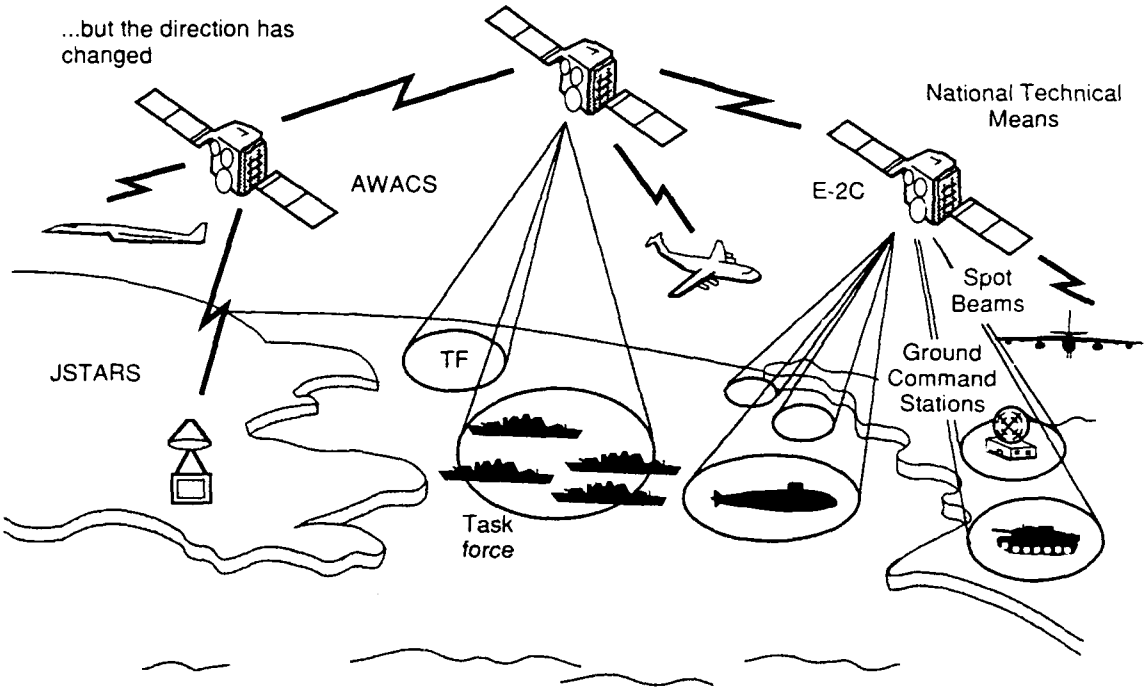

Fig. 5—Systems that Have Changed the Flow of Information on the Battlefield

- Fiber optics
- Massive computer parallel processing
- Digital imaging
- Silicon circuits
- Software writing.

The other half comprises:

- New materials (ceramics)
- Micro motors
- Solar energy
- Genetic redesign
- Super conductors.

The same trend can be found in the critical technologies identified by the Services as they look at the 21st Century. Information systems stand out in the U.S. Army's list of emerging technologies. Information systems were found to be important in the "Navy 21" study. It is easy to argue, then, that understanding the flow of battlefield information will be a primary part of understanding the future battlefield.

The second change in warfare is lethality. By any measure, battlefields have become more lethal. More ordnance can be delivered more accurately than in the past. Figure 6 illustrates the tremendous increases in delivery capabilities of aircraft since World War II. Some of this advantage has been negated by fielding fewer of these later generation aircraft, however.

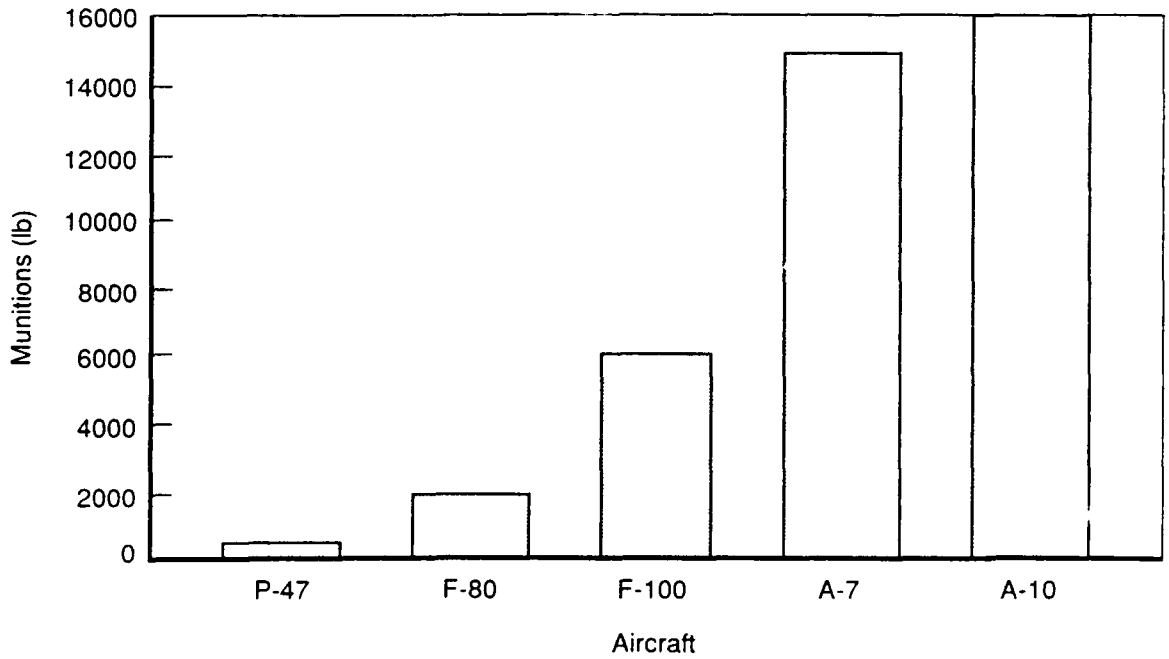

Fig. 6—Close Air Support Aircraft Delivery Capabilities (measured in pounds of munitions)

The next generations of munitions are going to make the battlefield even more lethal and not in the form of just more tonnages. Target acquisition will be multispectrum, and multitarget capability will come from "smart" submunitions.[10] Lethality will increase through improved capabilities to find and hit targets. Figure 7 shows an example of the employment of a munition under development. Another aspect of smart munitions is the potential to reduce the logistics burden due to the need to field fewer systems.

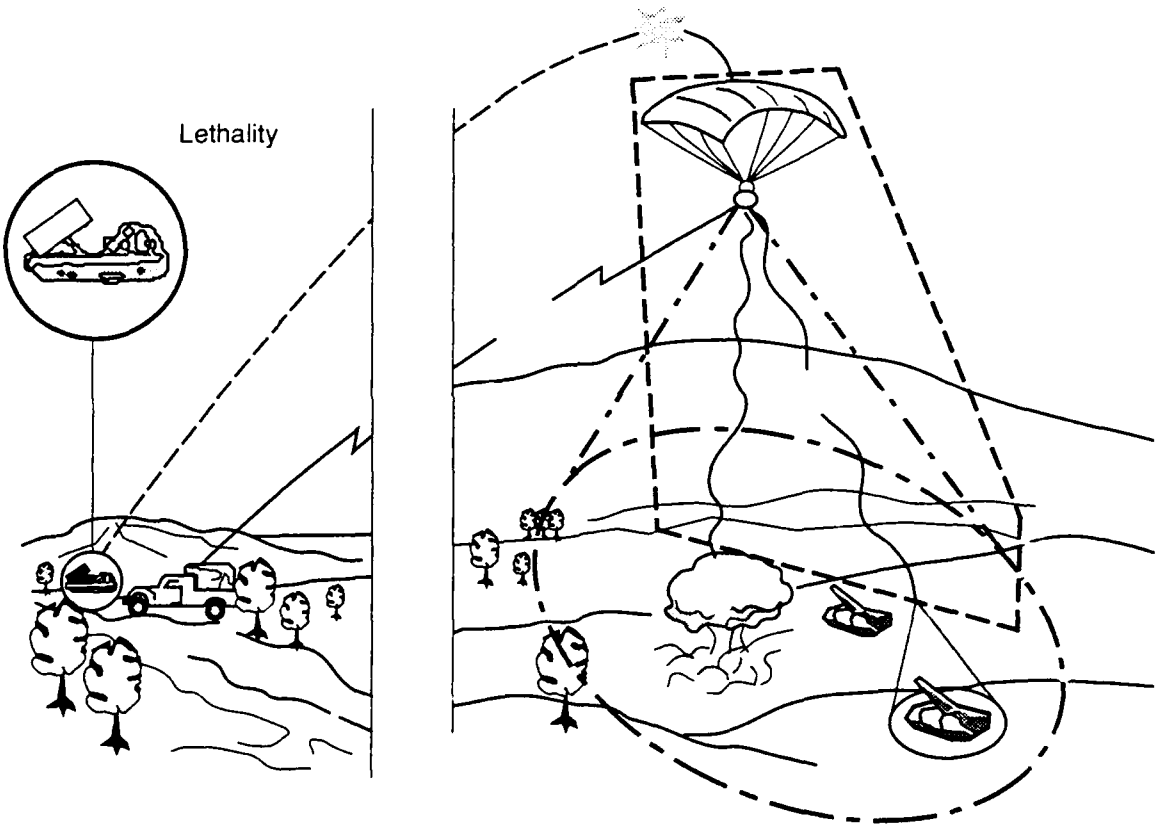

Fig. 7—Deep Fire Smart Munition

[10]The Soviets called cybernetics the "third revolution in military affairs" and some are arguing that smart conventional munitions represents the fourth. They may have gotten the two reversed. We have already seen the impact of smart munitions, but we have yet to see the real changes that will come from the effect of information on the battlefield.

During World War I, a division would occupy a front of approximately 10 kilometers; by 1986 in Europe, it had expanded to 30 kilometers. This indicates a third trend in warfare, reduced battlefield density.

Armies of the world have adjusted to lethality by reducing density. In fact, the reductions in casualties per day of combat over time suggest that density has been reduced faster than lethality has increased.[11]

One of the graphics the U.S. Navy often uses in explaining the Maritime Strategy shows a carrier battle group formation in relation to a map of the United States. The formation stretches from the East Coast almost to the Mississippi River.

Even though there might be a lower limit for the reduction of weapon density on the battlefield for operational reasons, human density on the battlefield may be reduced further by use of remotely controlled or robotic systems such as unmanned guns and intelligent minefields. In addition, the observable density may be reduced by employing various stealth techniques that reduce active and passive emission characteristics of objects as in advanced decoys and through multispectral camouflage and smoke.

The reduction of density has several operational consequences. The U.S. Army is arguing that the battlefield becomes nonlinear. The Soviets generally are thinking along the same lines and are calling it the fragmented battlefield. Moreover, the questions of how and what to attack will take on a different quality. The question is how to attack a distributed enemy. Rather than focusing on a single target, there may be a "group" of critical targets. For example, during the 1968 Tet Offensive, the North Vietnamese attacked multiple cities rather than massing on a particular city. Air Force doctrine of concentrating on a target-like acquisition radar during offensive counterair operations is another example of the kind of forces that may be generally characteristic in a low density battlefield.

An additional change in the battlefield has been caused by the range of systems. Airpower was one cause of the change, but in the past few years the capability to deliver fires at longer and longer ranges has come through such weapons as the Multiple-Launch Rocket System, the cruise missile, and conventionally armed ballistic missiles. Looking to the future, this is going to become

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[11]The most extensive development of these trends has been made by Trevor Dupuy, *Numbers, Predictions and War: The Use of History to Evaluate and Predict the Outcome of Armed Conflict* (Fairfax, VA: Hero Books, 1985). It is also well developed by Chris Bellamy, *The Future of Land Warfare* (New York: St. Martin's Press, 1987).

even more significant. The U.S. Army is thinking in terms of artillery systems that may have ranges of as much as 75 kilometers, and there are concepts for missiles that will be able to deliver submunitions at still longer ranges.[12]

There are a number of consequences of increasing ranges of weapon systems. One is that it will be more and more difficult to separate the missions of the Services by range or even by target. More and more weapons will be able to attack the same kinds of targets. The Services will have to do more and more joint coordination of targeting. In fact, one may raise the question whether the traditional division into three or four Services still makes sense, especially since the extended range will also change the nature of future theaters of operations. We have historically been able to think of theaters that were predominantly either ground or naval. In the future, these distinctions will blur. Europe, for example, with increased ranges of naval fires delivered by conventional cruise missiles, is becoming a littoral theater. In the future, all of the theaters will become more or less littoral.[13] Figure 8 illustrates the overlapping of ranges that is changing the nature of theaters of operations.

Consequences for Analysis and Modeling

Although most analysts recognized relatively early on that the world had changed and that our European-centered analysis had to change, the consequences of change must still be determined.

There are at least six major adjustments that analysts studying the changing battlefield must make. They relate to:

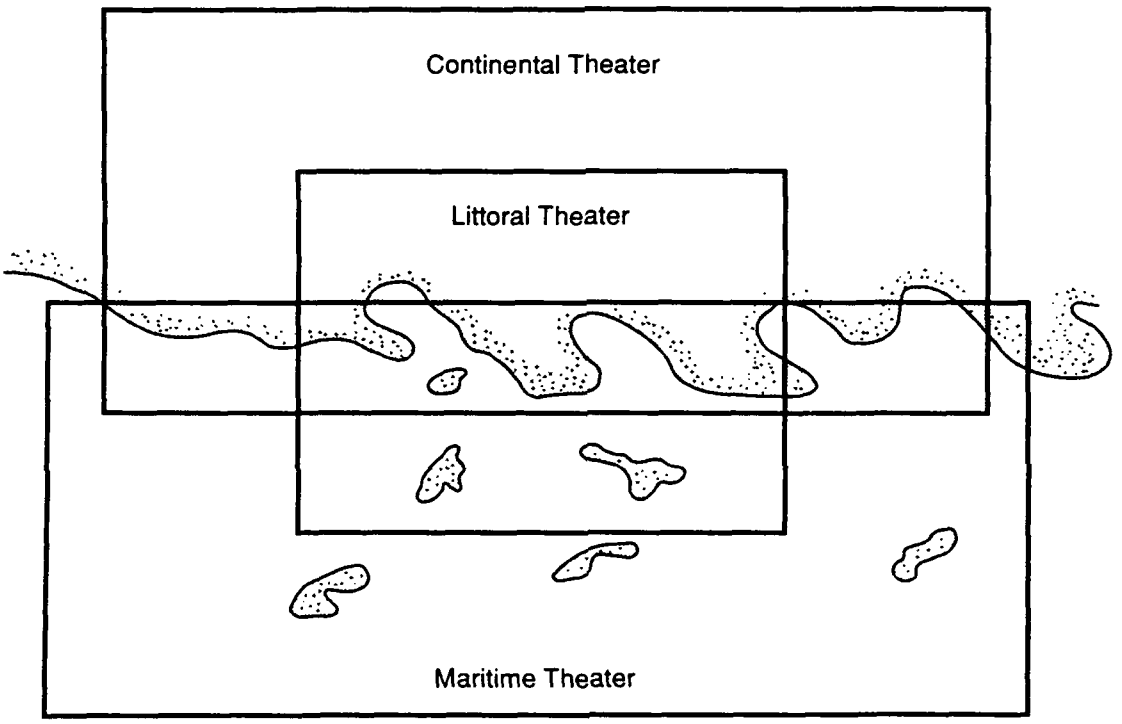
- The nature of modern war
- Modeling of units rather than equipment
- Nonhomogenous weapons
- Theater strategic bombing
- Campaign phasing

[12]There are some related implications of these increased ranges. One is the range limitation, 500 km, of the INF treaty. If the U.S. Army stays within this range limitation into the 21st Century, it will mean that the mission of delivering very-long-range conventional munitions with unmanned systems will have to be performed by the Navy, which is not bound by the treaty limitations. The recent public announcement of a common stealth cruise missile for both the Air Force and the Army may eliminate the issue.

[13]The notion of more theaters becoming littoral comes from work by Lieutenant General Phil Shutler, USMC (Ret.). Figure 8 is from the charts he uses in a briefing on the impact of technology on war.

– The integrated theater.

Nothing needs to be added to the above discussion of the nature of modern warfare to support the argument that the basic character of combat is changing. However, the requirement for modeling units rather than equipment needs to be elaborated.



SOURCE: Phil Shutler, *Thinking About Warfare*

Fig. 8—The Littoral Nature of Future Theaters of Operations

In the recent past, most of our combat analyses have had as their starting points the fundamental calculation of the results of weapons against weapon interactions. We have focused our combat models and analyses on equipment. One of the major conclusions of our work is that this will not be adequate in the future. Combat performance may, under certain circumstances, depend less on weapon performance and more on human factors such as combat experience and aggressiveness.

As the direction of combat information flow reverses and as that trend continues, units will become more subject to outside disruption. If a unit, for

example, is highly dependent on an outside flow of data for even its tactical targeting, the unit's operations can be stopped by destroying the command and control systems. The term being increasingly used is "mission kill." The analytic community needs to be able to deal with mission kills. Understanding mission kills means understanding how units function. This is more than weapon-against-weapon modeling, which implies a more or less autonomous operation of all elements. Ultimately, it means we must be able to describe the impact on unit effectiveness of degrading the command, control, communications, and intelligence system.

Much of the doctrinal groping that went on during the early period of the use of airplanes by the military came from not understanding that air power was a weapon that would influence the battle at the operational level. Air power was a tool of the operational commander. A number of other systems that need to be considered are in the same category. They include:

- Tactical ballistic missiles
- Barrier systems (minefields)
- Advanced interceptors
- Lethal chemicals
- Standoff weapons
- Unmanned battlefield weapons
- Nonlethal agents
- Tactical nuclear weapons.

The effect of these systems cannot be understood by simply thinking in terms of a marginal tactical contribution. These weapons will have a nonhomogeneous impact on outcomes[14] in the sense of force or effectiveness multipliers.

Given the high level of ready forces and the in-place logistics in the principal theater of operations as well as the nuclear deterrence doctrines of the past forty years, most conventional combat analysis has concentrated on about two weeks of

[14]The way in which the term nonhomogeneous is used here might cause some confusion. In our work, we have used the term to mean weapons that cannot be given a score and combined into an aggregate unit value, or otherwise treated as "homogeneous" with other battlefield systems. This is not intended to have the same meaning as the term "heterogeneous" forces found in classical operations research literature. The term heterogeneous force has been used in connection with combat between forces with unlike kinds of weapons.

combat. As demonstrated in the Gulf War, two weeks will not be enough for the future, and the consequence is that we will have to be able to deal with the analysis of "campaigns," including possible separate phases of an air campaign.

One of the elements of our work was to look at the Gulf War campaign and identify those phases that had been subject to major past analytical efforts.[15] In the past, we have concentrated more on the combat spasm, but we have not spent as much time dealing with operational movements and logistics buildup. Most important, we may not have spent enough time understanding the interaction of the phases of a campaign. We need to be better at campaign analysis, that is, we need to expand the scope of modeling and simulation.

The importance of theater strategic bombing (with conventional weapons) was demonstrated during the Gulf War. A strategic bombing campaign was undertaken to reduce nonmilitary communication, force generation, weapons production facilities, and storage of weapons of mass destruction. Furthermore, a significant effort was devoted to "scud busting" although the scuds had little significant *military* potential. The strategic campaign had to be integrated with the battlefield campaign and diverted resources from tactical operations.

The integrated theater must be considered in future analysis. Joint forces and coalition forces will be necessary in many possible contingencies. It has already been mentioned that the "deep battle" or "maneuver by fire" can be served by air- , sea- , and ground-launched assets, each with particular advantages and disadvantages.

There are many lessons that the traditionally Europe-focused analytical community may derive from the Gulf War, for the defense of Europe as well as for out-of-area force projections. The changes the analytical community has to face are not just political but involve the very nature of warfare itself.

The consequences of the changes in the nature of warfare, in the weaponry that will become available, in the doctrine and employment concepts, as well as in the possible types of conflict are significant. To deal with the consequences, we will have to work on issues not previously addressed. We will have to deal with some aspects of analysis we have done poorly in the past, if at all, and we will have to look backward as well as forward. We will have to have a vision.

"To prepare for war demands, then, exercise of the imagination..."

[15]The "100 Hour War" in the Gulf represented only a short part of the longer air/land campaign and an even smaller portion of the entire buildup process.

ANALYTIC SUPPORT FOR DESERT SHIELD/DESERT STORM

The material presented in the first part of this section provided a somewhat futuristic and speculative view of possible areas of combat, of improved military capabilities, and of some implications for future military analysis. By comparison, the recent conflict in Southwest Asia provided the workshop participants with the opportunity to hear about how analysis and models can contribute to a current and on-going military conflict. Four presentations were made by organizations participating in the Desert Shield and Desert Storm operations. These presentations provided the workshop attendees with a basis for including consideration of the real-time support of future military operations in their panel discussions.

The four presentations on analytic support for Desert Shield/Desert Storm were chaired by Vince Roske of JCS J-8 and were made by:

Colonel Gary Ware of U.S. Central Command
Major Frederic Case of U.S. Air Force Center for Studies and Analysis
Mr. Philip Louer of U.S. Army Concept and Analysis Agency
Mr. Geoff Hawkins of UK Defence Operations Analysis Establishment.

This section summarizes two of the presentations.[16]

USCENTCOM Analytic Support For Desert Shield/Desert Storm

The analyses were carried out in Saudi Arabia by the U.S. Central Command Combat Analysis Group, a special staff element subordinate to the Chief of Staff and located at MacDill Air Force Base, Florida.

Early in the Desert operations a forward element of the group was set up in Riyadh, Saudi Arabia. The group deployed to the location with a military staff consisting of the Chief of the Group, Colonel Ware, seven 0-4 Operations Research (OR) specialists and a systems manager. Their equipment included a VAX 4000, SUN server, seven SUN sparc-stations, and power equipment. The staff used three

[16]The presentation by Geoff Hawkins covered analyses carried out by DOAE before and during operations in the Gulf, but is not included. The presentation by Major Case covered analysis carried out in Saudi Arabia by members of the Regional Forces Division of the USAF Center for Studies and Analysis.

major analysis models, TACtical WARfare (TACWAR), Theater Analysis Model (TAM), and a hybrid version of Joint Theater Level Simulation (JTLS). Other tools included a Master Simulation Data System, SCRIPTOR tool box, spreadsheets, and so forth.

The forward element was networked with its rear element at MacDill via a secure satellite link, where there was a duplicate set of hardware and software as well as several contractor teams.

The Group worked in close coordination with the J5 Special Planning Group, a compartmentalized element charged by the Commander in Chief (CINC) to develop the theater offensive campaign plan. The Group also performed studies for the J3, the J4, and the U.S. Army Forces, U.S. Central Command (ARCENT) and U.S. Marine Forces, U.S. Central Command (MARCENT) staffs.

Group members faced a number of challenges in moving, setting up, and carrying out the analyses. They had to be able to modify models expeditiously, face turnaround times of a matter of hours, handle limits in the data and in the communications between the forward element and MacDill, as well as in the compartmented nature of the planning. Considerable emphasis was placed on developing "simple" representations of some phenomena in order to meet the time constraints and the types of high-level questions that were asked. Focus was often on Measures of Comparison (MOCs) rather than on Measures of Effectiveness (MOEs), that is, what were the crucial issues or decisions identified by the analysis rather than what were the specific outcomes of the simulations.

The analyses of the Group covered major offensive and defensive courses of action, and considered force structure, logistical, and air interdiction requirements. Among the operational items were:

- The mix and positioning of the defensive forces
- Mission objectives of the Arab Corps
- Interdiction delay and force requirements
- Allocation of air
- Deployment and employment of VII Corps
- Composition of the main attack force
- Timing and sequencing of the attack forces
- Commitment of the reserve

- Attacks on Iraqi scud positions.

Among the logistics items covered in the analyses were:

- Locations of supply nodes and ports
- Logistics sustainability for offense and defense
- Transportation aspects.

Among the regional security items covered in the analyses were:

- Residual force options
- Prepositioned Overseas Materiel Configured in Unit Sets (POMCUS) issues.

From these efforts, a number of "lessons" emerged regarding the use of analysis in supporting military operations. They included the importance of timely, credible analysis, presented in a crisp, consistent, and objective manner, as well as the ability to tailor the data, the parameters, and the situations examined to keep pace with the changing conditions in the theater.

AFCSA Analytic Support for Desert Shield/Desert Storm

The analyses were carried out in Saudi Arabia by the members of the Regional Forces Division of the USAF Center for Studies and Analyses (SA), since renamed the Air Force Studies and Analyses Agency. SA's involvement began shortly after Iraq's August 2nd invasion of Kuwait when Major General Alexander, Air Force Director of Plans (AF/XOX), asked the Center commander, Major General Harrison (AF/SA), to provide attrition estimates for a proposed air campaign plan. Although SA provided a quick-look estimate within a few days and planned to provide, by use of the TAC THUNDER simulation model, attrition estimates for a thirty-day war scenario, the focus of SA's efforts eventually fell on a relatively new computer simulation model, C3ISIM. The following paragraphs describe the C3ISIM model, its use in the early stages of attrition analysis at the Pentagon, and its deployment and use in the CENTAF area of operations.

Prototype Development. SA tasked a team of four analysts led by Major F. T. Case to use C3ISIM to provide a detailed attrition analysis of the first 24 hours of the planned air campaign. C3ISIM is a hybrid Monte Carlo/deterministic simulation developed for the U.S. Army Missile Command by Teledyne Brown Engineering in

the late 1980s as a tool to study alternative command and control structures needed to defeat the tactical ballistic missile threat to Central Europe. The U.S. Army Strategic Defense Command in Huntsville, Alabama, currently manages the model. The model's ability to simulate command and control operations made it a desirable tool for assessing attacks against a Soviet-style integrated air defense system. Also, the model's high-resolution graphics output, which allows an analyst to replay a mission, is an attractive briefing feature. Unfortunately, the model requires many detailed inputs ranging from positions of air defense systems and waypoints of all aircraft down to the signal-to-noise ratios of each radar and probabilities of kill of every missile and bomb. At the time of tasking, necessary data were missing and the team had no experience building such a large scenario. The team was, in effect, forced to build a prototype scenario while attempting to provide attrition analysis.

During September and early October, the team conducted an extensive research and modeling effort, conferring with representatives from the Defense Intelligence Agency, Service intelligence agencies, Teledyne Brown and XOX to create a detailed and reasonable simulation of the campaign plan. Completion of the initial analysis did, however, require some simplifications. C3ISIM was incapable of simulating emissions control (EMCON), which meant that Iraqi radars would always radiate even in the presence of Wild Weasel aircraft. Second, the model did not allow missile kill probabilities to vary with distance, altitude, or target aspect angle. All kill probabilities of a missile against a particular aircraft type were single-valued. Third, the model could not simulate human elements of combat such as confusion and fear at command and control nodes, and finally, the team lacked some of the detailed campaign plan data and had to approximate ordnance loads, precise aircraft routes, and the Suppression of Enemy Air Defenses (SEAD) plan. Despite these limitations, the team completed its prototype and presented the results to Major General Alexander during the first week of October. The results indicated an approximate attrition rate of 4 percent for the allied forces, but the team stressed that a better knowledge of the attack plan would result in more reliable predictions. Major General Alexander, convinced that the model would be useful to CENTAF, offered the model and its analyst team to the chief CENTAF air campaign planner, Brigadier General Buster Glosson.

Desert Shield Analysis. The team arrived in Riyadh on 20 and 21 October and began operations in the CENTAF Special Projects Office on 26 October. With access to the most current air campaign plan and its planners, the team began loading the

new scenario into C3ISIM. This was more difficult than expected, because the Allied plan and Iraqi threat changed faster (almost daily) than the team could input the data. Brigadier General Glosson, therefore, requested a simulation of the 9 November version of the plan, thus eliminating effects of constant plan revisions. Although the attack plan consisted of waves of attacks with several hours between waves, the team decided to simulate only the first wave. Three factors led to this decision. First, Brigadier General Glosson was primarily interested in first-wave attrition. Second, C3ISIM had no algorithm allowing air defense sites to be degraded or repaired. The team would have to do this manually prior to programming each new wave. Finally, the input requirements for multiple waves would have exceeded the computer's processing and memory capacities. On 18 November, Major Case briefed Brigadier General Glosson on the results of the first-wave attack. Attrition was significantly lower than that of the prototype (less than 2 percent), a result probably due to more accurate modeling of the SEAD plan. The output also highlighted those areas, such as the scud sites in western Iraq, where aircraft were consistently shot down. Major Case also briefed Brigadier General Larry Henry, the chief electronic combat planner, on the effectiveness of the SEAD plan. Every planner could view the results via the playback feature, which proved to be a valuable aid for fine tuning the timing or composition of mission packages.

With experience gained from modeling the first wave, the team had little trouble programming the next two waves. Programming the threat, however, proved more difficult, for two reasons. First, the team had to assess which Iraqi threat systems would be inactive as a result of the first-wave attacks. Using results from earlier runs and expert advice from electronic combat planners, the team constructed an approximation of the surface defense threat that would have remained after the first-wave attack. Second, the later waves, since they attacked during daylight hours, were expected to face an air-to-air threat. The team had little experience modeling this threat and had to first test the model's air-to-air simulation capabilities. Problems with the computer flight algorithms and fuel use equations proved insurmountable and forced the team to abandon the idea of simulating the air-to-air threat. In retrospect, this limitation was basically irrelevant, since the Iraqi air force was reluctant to engage Allied aircraft. Major Case did perform a simple spreadsheet analysis, calculating attrition as a function of Iraqi and Allied air orders of battle, Iraqi air defense connectivity, and relative aircraft capabilities. His results predicted a small number of Allied losses versus huge losses for the Iraqis.

C3ISIM predicted practically no losses for these two waves, but through the playback feature did provide planners valuable mission timing information.

During the first two weeks of January, the team worked on two projects. In the first, the team programmed the air refueling plan to assess congestion in air refueling tracks. Based on the results of this analysis, the tanker planners determined that congestion was within acceptable limits. The team also began reprogramming the first-wave attack, this time based on the 13 January version of the campaign plan. Brigadier General Glosson requested the analysis to determine the effect of additional forces and targets on attrition. The beginning of the air war on 16 January precluded completion of this effort.

Desert Storm Analysis. As the air war began, changes to the campaign plan and subsequent air tasking orders were so rapid that the team, now led by Major Charley Allan, could not possibly hope to use the model as a means to estimate overall daily attrition. Instead, the team used C3ISIM for regional activities such as shootdown analyses and concept analyses.

During Desert Storm, the team modeled several packages of aircraft that had experienced a shootdown in an attempt to determine the most likely cause. The analyses examined an F-15E downed over western Iraq, an F-16 lost near Baghdad, an A-6 shot down in western Iraq, an F-14 lost in central Iraq, and an AC-130 downed in Kuwait. In each case, the team would conduct multiple simulations of a package to pinpoint the suspected threat system. To perform these analyses, the team had to make several assumptions due to lack of information or C3ISIM limitations. First, lack of real-time intelligence meant that threat laydowns could only be approximations. Second, to decrease computer run time, only the threat and warning systems in the region of the shootdown were modeled, eliminating early warning information from other regions. This assumption, given the degraded nature of Iraqi command and control, did not seem unreasonable. C3ISIM, as previously noted, cannot model human factors. The model assumes guided missiles are not fired in an unguided mode and that defenders will not shut down sites at the approach of an aircraft. The team could not account for these Iraqi actions in any of the analyses. Finally, the team could only model planned aircraft flight paths, not actual flight paths. C3ISIM cannot account for the possibility that a pilot might stray into the envelope of a threat system not on the planned route. As a result of these limitations, the team could only estimate which threat systems were more likely than others to be responsible for a shootdown.

Concepts analyses consisted of modeling several proposed missions to assess effectiveness and risk. These missions included: (1) an F-111 attack on Shayka Mazhir airfield in which the aircraft ingressed at varying altitudes and time intervals; (2) an F-15E attack on Tallil airfield; (3) a B-52 attack against Republican Guard units in northern Kuwait, comparing results with and without EF-111 and F-4G support; (4) attacks by F-117s and RAF Tornados in the Baghdad area; and (5) B-52 attacks in and around Baghdad to determine which threat systems should be suppressed. Since the modeled air defenses, unlike the actual defenses, functioned in a rational manner, the team's conclusions were worst case and did not predict actual results.

Summary. The SA team began analysis of the Desert Shield campaign plan with an unproven computer simulation model set in a research environment and transferred it to a combat arena, where it became a useful contribution to actual war planning. C3ISIM was the only computer model used by the air campaign planning staff to assess and fine-tune operations. The team provided expertise in other areas as well, from spreadsheet analysis to production of computer graphics products. During this time, SA analysts developed a large database, gained valuable experience in war planning, and most important, transformed C3ISIM from a prototype air war model to an operational model. The SA experience in Desert Shield and Desert Storm leads to two primary conclusions:

- Combat simulation models do have potential for effective use in an operational environment; however, they must be equipped to perform in that environment. Such attributes as high-resolution graphic output and user-friendly windowed inputs are a must. Furthermore, automatic feeds from aircrew planning aids (MSS II) as well as intelligence fusion feeds that include position and connectivity data must be developed.
- An analysis team at the operational level of employment can provide mission-essential feedback to multiple levels of command, from the theater planning level to the unit employment level. Off-the-shelf tools exist today to support such a team; however, they must be modified to accommodate the environment in which the team will be employed. The analysts must be trained to produce real-time,

interactive analysis before hostilities begin. This training cannot be accomplished in an academic environment. Although schools can teach the fundamentals of analysis, analysts can only get this training in the field at exercises such as Blue Flag, Green Flag, Team Spirit, and Display Determination.

USACAA Analytic Support for Desert Shield/Desert Storm

The analyses were carried out by staff members of the Concepts Analysis Agency as an extension of their work with the Concepts Evaluation Model (CEM). This model, whose origins date back to 1968, was developed to simulate large-scale European combat between NATO and Warsaw Pact forces. It is a deterministic, theater-level model that uses weapon-on-weapon attrition data to evaluate force-on-force interactions.

CEM was used in analyses in the early 1980s to evaluate a series of combat situations in Iran and provided considerable learning background on the modeling of desert operations, discontinuous FEBAs (forward edges of the battle area), restricted maneuver, and amphibious operations, which CAA brought to bear in the Desert Shield/Desert Storm analyses.

In early August 1990, CAA used CEM in support of Desert Shield analyses for Office of the Deputy Chief of Staff for Operations (ODCOPS), Office of the Deputy Chief of Staff for Personnel (ODCSPER), and ARCENT on topics such as strategic deployment; developing requirements for forces, personnel, ammunition, and equipment; for assessing air defense and theater ballistic missile (TBM) defense; and the potential of Allied forces.

One aspect of the CAA efforts included modeling the air war separately as part of the analysis of the preparation stages of AirLand Battle Future combat operations in the Gulf. Several different approaches were used, including the use of "air boards" (an application similar to the use in CEM of ground combat boards), the use of a CEM/TAC THUNDER interface, and the use of parametric analysis.

From mid-August until the termination of the ground war, CEM was used for over 30 Quick Reaction Analyses (QRAs) involving over 500 CEM runs on the CRAY II Supercomputer with virtually no modifications of the model. The success of this effort depended heavily on highly dedicated analysts employing the model in a well-designed analytical process. The continually changing situation in the Gulf involved a continual change in the scope of the analyses being conducted. As these were

carried out, Central Command (CENTCOM), Forces Command (FORSCOM), the Joint Staff, and ARCENT were advised. Among the analysis topics were:

- Supportability of the campaign
- Refinements in the concept of operations
- Risk assessments
- Assessment of the sufficiency of selected ammunition stocks
- Effects of different levels of air attrition
- Changes in estimates of potential losses.

An example of a typical Quick Reaction Analysis was one which was completed in five days and examined four variants in U.S. force size, two Allied operational concepts, two threat response concepts, and three levels of inflicted air damage. The operational assessment covered the time to achieve the objectives, casualties and losses, and consumptions. The logistic supportability of selected combat systems support (CSS) units and logistic shortfalls were also considered.

The CAA simulation results had an impact on a number of areas, including force structure (combat forces, combat support, combat service support, replacements, war reserve stockage), force employment and the concepts of operations, and force modernization considerations.

Key Issues Raised in the Desert Presentations

Discussion during the three presentations and in the workshop panels covered a variety of related topics, including:

- The ability of capable and dedicated analysts to rapidly adapt existing models
- The utility of developing simple models (spreadsheets, PC-based, aggregated) to deal with specific phenomena or conditions
- The importance of the ability to "deploy" models and databases, to establish communication links for remote operations, and to support such operations
- The capability to use simulation tools designed for broader, longer-term analyses in a dynamic, time-sensitive environment

- The need to establish credibility in both the models and results, and to communicate effectively with the operational staffs in the on-going situation
- The values (and limitations) of having "real-life" situations as a basis for improving a simulation.

3. REPORT ON PANEL 1: ISSUES AND CONTEXT FOR FUTURE MILITARY ANALYSIS

Reiner K. Huber[1]

PANEL OBJECTIVE

The goal of panel 1 was to discuss issues and contexts for military analysis arising from recent events in Europe and Southwest Asia. To this end, the panel first identified the relevant changes brought about by these events as a basis for defining the new demands on military analysis and the significantly extended scope of its issues. In addition, the panel addressed the recent critique of military modeling as captured in *The Base of Sand Problem: A White Paper on the State of Military Combat Modeling, N-3148,* P. K. Davis and D. Blumenthal, 1991.

THE CHANGING GLOBAL ENVIRONMENT

For more than four decades, the global politico-military environment was dominated by the bipolar relationship between the two superpowers that had emerged in the wake of World War II. Military analysis was focused on Central Europe, where the Inner-German border marked the main demarcation line between the military forces of the Soviet-led Warsaw Pact (WP) and the U.S.-led NATO Alliance. As it evolved over the years, the basic military planning scenario was characterized by the assumptions of (1) a high density of ready forces in the Central Region, (2) NATO's flexible response strategy, (3) the fairly static layer-cake forward defense by national corps, and (4) a massive attack by the WP forces.

All of these assumptions have been rendered obsolete by the events following the 1989 "revolution" in Central/Eastern Europe and the conflict in the Persian Gulf in 1990/91. Today, military analysis is faced with the following facts:

- The conclusion of the Conventional Forces in Europe (CFE)1 treaty will bring about rough parity of the essential military equipment categories

[1]The author is grateful for the invaluable cooperation extended by Dr. Seth Bonder in compiling the briefing materials on the panel findings based on the judicious notes provided by the rapporteurs, Dr. John Friel, Lt. Col. Mary McCully, and Robert Howe.

between NATO and the (former) WP in the Atlantic-to-the-Urals (ATTU) area.

- The German unification extends NATO territory to the east, albeit at the price of the united Germany limiting its troop strength to 370,000. According to the Two-Plus-Four treaty setting the terms of German unification, the Soviets will remove their troops from East German territory "around" or "by" the end of 1994.
- Similarly, the Soviets have agreed to withdraw their military forces from the territories of their former Eastern European allies as well. Thus, by 1995 there will be no Soviet troops deployed outside the Soviet Union. In conjunction with the termination of the Warsaw Pact on 1 April 1991, the immediate military confrontation of the past decades has virtually disappeared.
- In their London Declaration of 6 July 1990, the heads of government of the NATO nations announced the development of a new military strategic concept for the Alliance as a policy guideline upon which to develop a new force posture and operational concepts, and taking into account the inter-relationships between defense capabilities, arms control, and the emerging European cooperative security structures.
- Major defense budget cuts will occur, reflecting the desire in Western societies to cash in the "peace dividend." These will result in a concomitant reduction in force sizes, a reshaping of their structures, considerably reduced funding for force modernization, and probable additional constraints on defense analyses.
- With the end of the Cold War, the world is expected to enter a period of increased instability in the Third World as well as in Eastern Europe. The Iraqi aggression against Kuwait is evidence of the disappearance of the restraint imposed on many of the former recipients of Soviet economic, technical, and military support. In addition, there is a proliferation of modern military technology to many Third World nations that tends to foster their inclinations for solving international conflicts by force. In Eastern Europe, national and ethnic conflicts, long suppressed by ideological dictum, are resurfacing and are exacerbated by the demise of the centrally planned economies.

NEW DEMANDS ON ANALYSIS

These facts and events have substantially changed the global politico-military environment and will continue to do so. As a consequence, analysis will have to address a host of new and frequently rather "soft" problems, in addition to many of the old ones in new domains.

Within the "boundary conditions" of the "immutable" scenario characteristics, the analysis issues of the past were confined mainly to weapon system cost-effectiveness comparisons, force requirements and deployment studies for the European Central Region, and—as probably the most demanding problem—to force mix and force structure optimizations under cost and personnel constraints. Compared to today's situation, which demands no less than a complete redesign of the European and other regional security systems, including the military forces required to ensure their stability, the analysis issues of the past involved rather marginal changes and required only a few variables to be considered. In addition, most of the problems were of a fairly long-term nature, requiring answers to questions arising in course of the well-organized and continuous process of defense planning and force modernization in response to the perceived evolution of the principal threat.

There are not only new problems but they are of much higher complexity and the conditions and assumptions underlying them change with high frequency. These changes are associated with the large degree of uncertainty in the new global environment. The swiftness associated with both the changes in Europe and the emergence of the Iraqi threat to Kuwait is an indication that the eruption of regional tensions with little or no warning may become a characteristic feature of the future international environment. Thus, analysis in support of decisionmakers must become much more responsive. Furthermore, the fact that the events in Europe and Southwest Asia were largely unexpected, even by the foremost experts, underlines that even fairly short-term issues may exhibit a high degree of uncertainty and variability. Some specific driving dimensions that place new demands on analysis are discussed below.

Time Constraints

In the future, severe time constraints for decision support analysis will be the rule rather than the exception. The situation is exacerbated by uncertainty and

variability that require the consideration of a large number of potential scenarios involving conflicts anywhere in the world, coalition in nature, and with a large political dimension. As a consequence, *Quick Response Analysis* (QRA) concepts must be developed that permit staffs (including analysis organizations) supporting decisionmakers to perform viable analyses within a period of days, weeks, or a few months while taking into account the nonmilitary (e.g., political, economic, cultural, ethnic) factors affecting the security relationship in the respective regions.

There was unanimous agreement among the panel members that QRA places a number of demands on the infrastructure of analysis organizations and the way in which analysis is performed:

1. First of all, QRA requires highly experienced and dedicated senior analysts with a good understanding of the problems and implications of the underlying issues, familiar with the decision environment, and capable of close interaction with the decisionmaker based on the latter's confidence in the competence and integrity of the analyst.
2. QRA models must be fast running, providing first-order approximations ("about right" answers) for large numbers of parameter variations in time. They must be transparent to ensure their credibility with the decisionmaker, and flexible to facilitate rapid (ad hoc) change and accommodation of new circumstances and scenarios.
3. QRA must be supported by a relevant knowledge base that incorporates the results of more detailed analyses in the respective subject areas. To this end, readily accessible "result bases" (as distinguished from databases) need to be developed and enhanced through a continuous study process fashioned in the manner of systematic research aimed at gaining insights on as broad a basis as possible.

Working with Uncertainty

There was agreement among the panel members that analysis must accommodate uncertainty in a manner that facilitates the selection of versatile and

robust solutions by the decisionmaker.[2] However, there was considerable discussion of the difficulty of presenting uncertainty to decisionmakers.

Some examples were reported in which the decisionmaker insisted on point estimates and was quite uninterested in the degree of uncertainty, mainly because he did not seem to understand its implications, or to attach any importance to them. The problem was viewed to be at least partially one of deficient relationships between the analyst and a decisionmaker who lacks confidence in the analyst's competence. The group agreed that it would be unethical not to point out the uncertainty in the results and recommended that:

- All studies must provide the sensitivity of results over the region of uncertainty, that is, show the response space to the (uncertain) issue and/or model assumptions, indicating, if possible, the regions of the uncertain parameters in which each of the available options of the decisionmaker would be preferred over the other ones;
- Attempts be made to find *minmax* and *maxmax* solutions for the issues at hand, to shed light on the implications of uncertainty attitudes for the selection of options and the associated costs.

Scenario Treatment

To address the uncertainty associated with scenarios in the emerging security environment, the panel agreed that scenarios should be as generic as possible and characterized by parameters that permit the analyst to adequately "span the space" of potential conflicts and their conditions. This involves the possibility to vary, among others, such aspects as geographic location, terrain, and threat characteristics, including force buildup.

The underlying objective is to support the design of forces and systems that, within given resource constraints, satisfy the requirements of as many scenarios as possible and to identify the so-called *windows of risk*. These encompass the time points in a military response within which the forces committed are not yet adequate to carry out their mission and are vulnerable to defeat if the enemy should attack.

[2] A *versatile* solution is one that performs adequately over many operating situations within the realm of uncertainty. A *robust* solution is (more or less) insensitive to a change of circumstances within a situation.

It was emphasized that, for most scenario applications, the threat should be treated as capable, that is, it should not be degraded by application of nationality or training factors but be considered fully capable of employing the equipment it has.[3] To span the range of possible outcomes, the threat might then be degraded parametrically to reflect possible nationality or training factors. But it should also be increased parametrically to reflect the possibility that advanced equipment, not now in its inventory, may be obtained at a later date and that that equipment might be used effectively.

Working with coalition partners should be an inherent part of any scenario since it is increasingly unlikely that any country will engage in future unilateral interventions. Both the number of partners and the size of coalition participation are candidates for parametric treatment. In addition, the operational concepts of both friendly and enemy forces need to be varied across the entire range of possible concepts, even the unlikely ones.

Two cautions were discussed but were not amenable to resolution. First was the inherent difficulty of dimensionality in this scenario approach. It is obviously impossible to vary all aspects of the scenarios across all possible values. Therefore, difficult choices are involved in limiting the scenario space to manageable dimensions. The second concern is that sponsors frequently are not only not interested in, but will actively oppose, treatment of the entire scenario space. Some see favorable potential outcomes as threatening to budgets or structure and have an interest in restricting results to those which show a need for more force, lift, or the like.

ISSUES

The panel attempted to categorize the key issues for future military analysis in a manner that reflects upon the scope of the issues as well as the requirement for responsiveness of analysis.

As regards Europe, and, with variations, other parts of the world, the post-1989 analysis issues fall into three broad hierarchical categories:

[3]Note: There was considerable discussion during the workshop about including soft factors representing differences in training, so called nationality factors, and the like, and there was some disagreement as to when and how they should be used. This represents one of the views.

1. The design of regional security systems in a manner that provides for internal and external military stability[4] by means of appropriate force structures and constraints (arms control), verification and warning systems, crisis management mechanisms, responsive coalitions, and others.
2. The redesign of NATO to cope with the requirements of the changing security environment involving, among other things, the development of a new strategy, new operational concepts for the defense of NATO (Forward Presence) and "out-of-area" operations, new force structures (multinational units), and command and control systems and procedures.
3. Determination of national capabilities and contributions to the Alliance and/or the European security system so that stability is assured, under the range of possible conflict scenarios, given the evolution of threat capabilities in the Soviet Union and elsewhere.

Each of these categories provides sets of assumptions for analyses at the next lower level and inputs for analyses at the next higher level. Thus, ideally these issues would be attacked in an iterative manner beginning top-down and repeated bottom-up. However, in reality many of the issues at the third level will, for domestic political and budgetary reasons, very likely have to be decided upon unilaterally before results of the higher level analyses become available. Thus, there is the risk that the degree of freedom in the redesign of NATO and, even more, the design of the European security system, will be severely limited unless QRA is employed in an imaginative manner to provide at least some approximate judgments on the impact of critical higher level issues that need to be resolved before decisions are made on the lower level.

For this very reason, the panel judged the demand for QRA to be quite high on the third level where the traditional (national) force planning issues (such as force

[4] *Internal military stability* of a regional security system requires that the military forces of all parties (nations, alliances) within the respective region are sized, structured, and equipped so that no party feels threatened by any one party or possible coalitions of the other parties or, vice versa, each party can credibly deter attacks by one or more of the other parties. The term *external military stability* refers to out-of-region areas vital to the security of a region. It implies the capability of a regional security system, or parts thereof, to project power by means of intervention forces, in order to deter the resolution of out-of-region conflicts by military means, as long as internal military stability is not warranted there.

design, materiel acquisition, logistics) are to be found, albeit in new domains. There appears only little room for QRA on the first level where the problems are largely new and, therefore, require some considerable in-depth background analysis on issues such as the causes of conflict; the military role in conflict containment and the associated risks; the role of nonproliferation, arms control constraints, and coalition capability in reducing the risk of aggression; the effects of nonmilitary factors (e.g., political, economic, social, cultural, ethnic) in carrying out both peace- and wartime military missions; appropriate use of military force in nonmilitary tasks; conflict termination and nation building.

The new or newly important issues at the third level reflect primarily the implications of the reduced levels of peacetime military forces and defense spending on one hand, and the requirements for "out-of-area" employment on the other. They include problems related to mobilization, training and readiness of active and reserve forces for warfighting and peacekeeping missions (as a function of region and coalition partners), maintaining the defense industrial base (while constraining weapon proliferation), and many others essential for the *reconstitution* of military capabilities should the need arise.

ON THE CRITIQUE OF MILITARY MODELING

The panel noted that in addition to the Base of Sand White Paper critique (N-3148), there are critical reviews of military modeling outside the United States. In fact, almost all of the defense operational analysis institutions within the NATO countries have been confronted with questions on the viability of their combat models for the analysis of the new issues. It comes as no surprise that most of the models developed during the Cold War period require extensive modifications to accommodate, for example, new operational concepts involving large-scale maneuvers for counter-concentration, counter-attacks into the enemy's flanks, and enveloping operations. After all, models are but a reflection of the analysis issues of the time. And during the past forty years, the military analysis issues were mostly concerned with the incremental improvements within a fairly static defense concept in response to one well-defined and slowly evolving threat.

For this reason, the majority of the panel felt that the critique is largely irrelevant on the lower tactical levels, and especially on the weapons level, at which the structure of the processes is well known and should remain by and large unchanged. In fact, the critique appears not to be directed at those levels where the

modeling base is considered to be comparatively solid with regard to both the theoretical foundation and empirical substantiation of the underlying elementary processes. However, the empirical base requires continuous review and modification in the light of new technologies.

Over the past 10 to 15 years, there have been a number of attempts to validate high level tactical and operational-level models and campaigns. Examples are CAA (Middle East, 1973; Ardennes, 1944; Falklands), Vector Research Institute (VRI) (Golan Heights, 1973), U.S. Army Materiel Systems Analysis Agency/Israeli Defense Forces (AMSA/IDF) (Golan Heights, 1973). The number of such studies (all ad hoc) is small relative to the importance placed upon simulation-based analyses in defense establishments. It would be nice, as suggested by the RAND critique, to have more studies conducted as part of an overall program of validation. However, there still is the open question as to the relevance of such efforts.

For example, what can be said about the validity of the results of simulations in European or Far Eastern scenarios with a combat model that has been calibrated to the experience in a Middle East campaign? From the British studies on the so-called nation factor, one would conclude that there is little reason for a positive answer. One might also ask about the applicability of historical observations of the combat performance of military units when considering the technological progress and social change in the period since.

Validation of operational-level combat models in the scientific sense of the word is inherently difficult.[5] As noted by Seth Bonder (*Military Review*, 9 February 1971, pp. 14-17), given the absence of sufficient data from actual wars, military modeling and analysis exhibit as many of the characteristics of structured intellectual activity as they do pure science.[6] For this very reason, publication and peer review of models as well as redundancy of analysis and comparison of results are considered essential for maintaining the integrity of analysis and its usefulness for decision support in defense and arms control.

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[5]Some difficulties and differences from a pure scientific validation process are described in "Summary of a Verification Study of Vector-2 with the Arab-Israeli War" by Seth Bonder published in *Systems Analysis and Modeling in Defense*, edited by Reiner K. Huber, Plenum Press, 1984, pp. 155-170.

[6]In the Base of Sand Paper, Paul Davis and Don Blumenthal express similar views by stating "that combat modeling should be regarded as to some extent part of a science (albeit a social science designed to improve decisionmaking under uncertainty, rather than a physical science)" (p.22).

SUMMARY

Summarizing the discussions, it was concluded that in the future military analysis will be characterized by shorter deadlines, a high degree of scenario uncertainty, and a host of increasingly "softer" problems.

To cope with these challenges, both a new analysis culture as well as an extension of the toolbox are needed. Analysis must become integrated into the decision processes using highly responsive tools (e.g., analytical models rather than simulation models) and readily available and up-to-date inputs. To this end, issues must be studied in an anticipative manner based on detailed simulation experiments performed on a continuous basis in the manner of basic research. To support this research, training games for military staffs at all levels should be designed so that their evaluation contributes to updating the knowledge base on the forces-in-being.

The respective simulation models must permit addressing any scenario in any region regarding the internal and external stability of regional security systems. For example, the internal stability of the European security system will depend on the military potential maintained by the USSR beyond the Urals to satisfy its Asian security requirements. Thus, analysis should be capable of testing the respective Soviet claims based on conflict simulation experiments in the regions of possible conflict.

The critique of military modeling voiced here should not be taken as a rejection of modeling and analysis. The critique seems to be primarily directed at the style of military analysis as it has evolved in the rather static bipolar security environment of the past forty years and given the somewhat parochial military planning approaches. Because the focus has been on application models for immediate decision support, there has not been a concomittant emphasis on research on the theoretical and empirical fundamentals of military modeling, and little incentive has been provided for open publication and peer review. The panel agreed that the correction of these deficits must be an essential element of the future analysis culture.

4. REPORT ON PANEL 2: REPRESENTING MILITARY ACTIVITIES

Bruce W. Bennett

PANEL OBJECTIVE

The aim of panel 2 was to discuss the implications of the events in Europe and Southwest Asia for modeling military operations. To this end, the panel first compiled a list of the key phenomena that must be represented and defined the context within which they need to be modeled. The resulting implications were discussed as a basis for recommendations on an approach for improved modeling and analysis.

KEY PHENOMENA

Panel 2 spent much of its time discussing the key phenomena that should be considered in future modeling. These phenomena can be grouped into the following three categories, ranked in ascending order of our ability to model:

1. Qualitative (also referred to as soft or "fuzzy") factors (most difficult to model)
   - Doctrine, leadership, morale
   - Force performance, training, cohesiveness
2. Integrating elements
   - Objectives and means of accomplishing them
   - Acquisition detection, targeting
   - C3
   - Combined arms, maneuver
   - Logistics, support
3. Weapon system performance (least difficult to model)
   - Lethality
   - Mobility, maneuverability
   - Vulnerability

Historically, the community has focused on quantitative weapon system performance, and this focus has been best reflected in the model building process. In contrast, qualitative factors are both difficult to model and extremely uncertain in effect, and have often been ignored in our modeling and analysis.[1] Indeed, our panel argued that "military science" is still largely lacking in this area and is in need of development on the integrating elements.

At the same time, the context for military analysis needs to be considered. Today, a broad spectrum of potential opponents and combat environments must be addressable by the military analysis community. The analyst is forced to consider differences in objectives, strategy, doctrine, and force structure as an explicit part of the analysis. This places a heavy burden on the analyst and the modeler, as at the very least they must understand the spectrum of possible differences and look for robust solutions across them while at the extreme they must understand in considerable detail how one warfare situation might differ from another. Although we may be tempted to excuse the analyst from some of these demands, the Operation Desert Storm experience has shown that the policy audience understands the importance of qualitative and other factors, and that analyses that ignore these factors may well be discounted.

The discussion of qualitative factors also revealed a similar impact across ground, air, and naval forces. In particular, it seems clear that phenomena such as leadership, doctrine, and training may well dominate military performance, being sometimes more important than weapon systems, the traditional focus of military analysis. For example, the performance of the Iraqi ground forces in Operation Desert Storm was clearly quite different than would have been anticipated from the weapon systems alone. Similarly, a member of our panel indicated that one of the four U.S. F-15 squadrons in Operation Desert Storm had more than half the air-to-air kills of the operation, and that this pattern of performance could have been anticipated from the quality of manpower and leadership in this squadron. Another

[1]Because of the uncertainty in these factors, there is often a decision to ignore them in modeling and analysis. However, by so doing the modeler or analyst is implicitly assuming that these factors make no difference. For example, a decision to "ignore" Iraqi troop performance as an issue in an Operation Desert Storm analysis is the same as saying that it will be as good as the performance of all other troops, clearly a faulty assumption. Thus, rather than ignoring these factors, much of traditional modeling and analysis is assuming that they just do not matter.

member of our panel pointed to the role of personnel performance and training in the Vincennes incident several years ago.

A key conclusion of the panel was that military analysis and modeling need to be done from a "total system" context. Analysis needs to integrate consideration of key issues such as command, control, and communications, target acquisition, and combined arms operations, as well as issues such as support, supplies, and the ability to lift them to potential conflict areas.

Similarly, in examining opposing targets, we need to look at the overall target system. This involves attempting to find choke points and bottlenecks—relatively fragile aspects of the target system. It also means considering multiple alternatives both to guarantee redundant failures and to enhance the "shock effect" on the target system. These effects may be achievable with disabling weapons that cause "soft kills" and do not completely destroy all enemy targets.

IMPLICATIONS FOR MILITARY ANALYSIS

If the preceding considerations of the panel are correct, they have strong implications for military analysis. First of all, military analysis is increasingly complex, while at the same time many of the key phenomena are not (or are only poorly) represented in models. As a result, the burden is upon the analyst to make sure that the key phenomena are reflected in the analysis. Analysis must be done with a clear sense for military operations and warfare, and not be solely the result of computer model runs. The analyst must be prepared to integrate into the analysis the key phenomena, even when they are often only modestly understood. Because a single analyst or even a team of analysts may not have sufficient experience to cover all of the key phenomena, it is increasingly important that they "validate" their analysis, reviewing assumptions and findings in some detail with the intelligence, operations, and policy communities.[2]

We believe that some analysts are operating correctly and are producing worthwhile results to support policy decisions; however, we do not believe that this has yet become the community ethic, and it needs to be. Some analysis still depends upon the "model crank turner," a relatively junior staff member who runs models without a real sense for what ought to be examined or how the various factors ought to interact. This approach, while reducing the burdens on the true military analysis

[2]Indeed, we believe that it is more important to validate analysis and analysts than to validate models.

experts, increasingly endangers the military analysis community. As an alternative, senior military analysts need to take increased interest in the details of each analysis, working closely with "apprentice analysts" and supporting their training as part of the effort. These conditions and topics discussed below may have been true of past analyses, but they are of much greater importance for the future as analysis moves from the reasonably well understood situations of the European confrontation to the more complex and uncertain possibilities of the future.

Modeling of Phenomena

Because the list of key phenomena is quite long, there is a danger that our military models could increasingly become "black boxes" that preclude the analyst from understanding how results are produced. Analysts must understand the character of the calculations in the models, in part because they must be able to balance qualitative issues that may still be poorly captured in the models, and in part because model complexity implies a requirement for model verification and validation with each model run.[3] To balance complexity and breadth, we clearly have a need for more aggregated representations in many of our models; aggregation appears the only vehicle for controlling complexity. At the same time, this aggregation must be based upon more detailed modeling, analysis, historical experience, and exercises, else the model may turn out to be precisely wrong. There is an important role for balance in this regard, requiring more detailed modeling to develop an understanding of many military phenomena, and then capturing this understanding in aggregated representations that allow for more transparent tradeoffs with qualitative and other factors.

In the end, it is clear that uncertainty will increasingly dominate military analysis problems, because of the high degree of uncertainty in many of the qualitative factors and in how these factors interact with each other and affect

[3]Many military models today have more than 100,000 lines of computer code. Models of this size and complexity are difficult (if not impossible) for the modeler to thoroughly verify and validate. Instead, the modeler generally runs a series of tests designed to catch some of the more obvious errors in anticipated paths through the model. But as soon as an analyst follows any other path, he may well encounter errors or inadequate representations that the modeler was unable to identify. For example, The CENTCOM presentation at the conference indicated that some 200 changes were made to their theater-level model during the process of Operation Desert Storm. CENTCOM should be commended for such efforts, as should the modelers for responding to this demand.

military operations. Our recommendations for dealing with uncertainty are discussed below.

Aggregation Issues

The panel had several recommendations on the issue of model/analysis level of aggregation. As suggested above, we firmly believe that high-level models must be relatively simple to be understandable, which implies a requirement for aggregation. Aggregation has several implications. In particular, it means that in high-level models we are more interested in how a phenomenon affects military capabilities, rather than in how the phenomenon itself works. For example, high-level models need to be able to show that a failure in C3 at corps level and below prevents immediate close air support (CAS) from being effective, making defenses more fragile, as opposed to trying to model the flow of messages requesting immediate CAS. At this level, many factors may be captured as force multipliers. In other cases, it is important to be able to "stochastically" examine possible relationships within a range of uncertainty. For example, since we do not thoroughly understand the breakthrough process and what causes it, we need the ability to postulate breakthroughs and then to ask whether forces are able to recover from such events. However we proceed, we are better served by converting the analysis of phenomena into "data" of one form or another (whether a parameter value, a trigger invoking a phenomenon, or a trigger for an alternative model) in order to facilitate the sensitivity testing of the uncertainty range without having to make model changes.[4]

Although aggregation procedures clearly seem appropriate and appear to be practiced to at least some extent throughout the community, it was the sense of the panel that, too often, parameter values are "pulled out of the air," as opposed to being based upon historical, analytical, or other evidence. This practice tends to occur when the analyst does not understand the underlying phenomena being represented; this point strengthens the point that analysts must understand the area they are addressing from both an operational and analytic perspective. Historically, weapon system analyses have been performed based upon detailed models, exercises and system tests, and military judgment and operational experience. Even so, the community has still suffered from order of magnitude variations, all in the same theater environment, in parameters such as armored vehicles killed per CAS sortie.

[4]Note: This is another form and use of the result databases mentioned elsewhere in this workshop report.

As threats and environments vary, uncertainties may become even greater. In recognizing these kinds of problems, the panel encouraged further, systematic effort in approaches to aggregation that would benefit future military analysis.

Uncertainty and Variability

There was broad agreement in the panel that military analysis results will be even more uncertain in the future. In large part, this is because of the increasing recognition of the importance of qualitative factors and the variations in combat environment that we must be prepared to consider. Indeed, it is likely that in many cases uncertainty will dominate analytic outcomes. Whereas some analysts may feel paralyzed by such a development, we felt that the key to controlling uncertainties was to deal with them as an explicit element of military analysis. That is, the analyst should be trying to describe how robust the results of analysis are, and not what a result might be to many significant digits. Moreover, the analyst should be able to provide the policymaker with a sense for how he might control the uncertainties, including identifying the "regions" where uncertainties dominate, procedures to control uncertainties, and hedging strategies to minimize the risks of uncertainties. For example, if the performance of an enemy air defense in some future war is highly uncertain, an appropriate air strategy early on might involve a period of conservative testing of that defense, with alternative options available depending upon the test outcome. Analysts can provide policymakers a real service by helping them understand the risks they face in this manner, and in a sense "train" them to expect such information from future analysis.

Much of military analysis is performed with deterministic combat models that yield "expected value" outcomes. These results may not be valid, because the response space of many uncertain parameters is not linear. For example, we spent some time in our panel discussing an example in which battalion, brigade, and division-level combat simulations were run in a model using a deterministic option and then run as a group of stochastic cases, each showing a wide diversity of outcomes. The deterministic outcome was usually quite different than the average of the stochastic cases. The analysis considered only the variability in weapon effects (e.g., is a vehicle killed or not?) and the resulting decisionmaking, and not the substantial uncertainty in many of the underlying parameters, which would spread results further.

Variability becomes most important when one side is able to gain an advantage in initiative. For example, consider a case in which the defending forces along a line vary significantly in quality. If these variations are understood by the attacker, and the attacker is able to maintain the initiative, he may focus his attack against the weaker defenders and exploit breakthroughs as they develop; in the end, the attacker is facing something less than the average strength of the defense, although our deterministic models often assume that he has no such leverage. Similarly, reserve forces capable of regaining the initiative in such circumstances have a value often beyond what our models currently reflect. In the end, variability in performance and control of the initiative may convey a large force multiplier.[5]

AN APPROACH FOR IMPROVED MODELING AND ANALYSIS

Before advancing recommendations on military analysis and modeling, we thought it important to diagnose why a problem exists. The panel generally felt that the problem lies in military analysis and modeling being more an art form than a science. In this regard, military models, as opposed to an organized body of literature, have become much of our "knowledge base" on how military phenomena should be represented. Because of the competitiveness of the military modeling community, modelers and analysts often feel proprietary about their models and the resulting knowledge base, and are not anxious to share information. As a result, military operations research conferences often focus on model or analysis sales pitches, as opposed to how military phenomena ought to be represented. We were particularly struck by the contrasts between the military modeling and analysis community and the physical science community in these and other comparisons.

Panel 2 strongly felt that to make substantial improvements, the military modeling and analysis community needed to adopt a stronger scientific framework. This need derives from coming changes in available funding, from the difficulty of problems now being faced, and to maintain credibility in an evolving environment.

Assuming our diagnosis is correct, we believe that a major change should be in building a true military modeling and analysis knowledge base. Modelers can aid

[5]In his examination of historical combat, Trevor Dupuy identifies a factor reflecting the effect of surprise; we speculated on the extent to which this factor might actually reflect the value of initiative and momentum, which in the historical cases were not examined separately from surprise. See, for example, Colonel T. N. Dupuy (ret.), *Numbers, Predictions, and War: Using History to Evaluate Combat Factors and Predict the Outcome of Battles* (New York: the Bobbs-Merrill Company, Inc., 1977), especially pp. 63-67 and 200-201.

this process by developing top-down documentation of their models from a military operations perspective. Our experience with model documentation suggests that, in contrast, it is mainly bottom-up in character, explaining specific equations or lines of code without a sense for the operational implication thereof. Analysts can aid this process by explicitly recording the analytic framework they adopt, including the role accorded to the analysis model, changes made in the model, and how factors were handled that were not directly represented in the model. With these efforts, the professional discussions in our community should increasingly focus on building a military science knowledge base. Early efforts might be in the preparation of basic primers on military analysis, both as a vehicle for recording the basic theoretical concepts of military analysis and as a training vehicle for apprentice analysts.

To make this process work, incentives must encourage such behavior. The community needs to rethink its approach, rewarding modeling, reviewing, and analytic efforts.[6] Such incentives should be geared to making the community operate in a scientific framework, including describing and advancing basic military science.

Other vehicles to use to begin this process from within the community include electronic mail and documentation exchanges on ideas, purposeful review of ideas by the operations and intelligence elements of the community, and the establishment of standards on military modeling and analysis. We might try competitions in which several organizations and models are brought together to evaluate a given problem, with the results compared in some detail.

All of this will be easier if models and data are kept unclassified. Although order-of-battle information and other data must be classified for some studies, other data, metrics, and performance parameters should be broadly available to encourage broad critical review in the analytic community. To this end, the community needs to work closely with the intelligence community to keep classification requirements to a minimum and to develop means of declassifying analysis results through aggregation or removal of context.

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[6]Peer review, comparative analysis, analysis review boards, and refereed journals are among the suggestions made at the workshop.

5. REPORT ON PANEL 3: TOOLS AND TECHNIQUES FOR FUTURE MILITARY ANALYSIS

Vincent P. Roske

PANEL OBJECTIVE

The objective of this panel was to identify and characterize those tools and techniques that would find increased value in support of future military analysis.

The panel considered "tools" in a generic sense, concentrating on requirements for tool technologies that provide the basic building blocks, such as software and data, from which application tools are constructed. The panel also addressed management tools and cultural tools that could improve future military analysis.

CHARACTERISTICS OF FUTURE MILITARY ANALYSIS

As indicated in the other panel reports, new issues of higher complexity, fewer resources, greater uncertainty, and an expanded set of decisionmakers requiring analysis support are the key characteristics expected to influence the behavior of analysts and decisionmakers in the future. They are already beginning to place new demands on the way analysis is performed and the role it plays in military decisionmaking.

New Issues

In addition to changes in the "threat" that was dominated for many years by the military capabilities of the Soviet Union, the infusion of technology and the military budget are undergoing rapid change. Technology such as stealth and "smart" munitions is changing military doctrine while introducing discontinuities into the homogeneous process of armed conflict as it has become understood and codified in the major models and simulations of warfare traditionally used by our analysts. The military budget, reacting to trends in threat perception and technology, and facing increased competition from pressing domestic issues such as a decaying transportation system, housing shortages, and other health and human services needs, is in a decline that is anticipated to continue over the next three to five years and to take the resources available for analysis support to record low levels.

As a result of these wide swings in threat, technology, and the budget, the military analyst is facing a barrage of new, interrelated issues involving force design and cost. Not only are the issues facing the analyst new, they are much more complex.

Increased Complexity of Issues

Decisionmakers are already demanding that analyses and assessments address more scenarios, a broader range of alternatives, and more thorough consideration of the important impacts. For example, the Illustrative Planning Scenario against which the warfighting capabilities of past military force programs were assessed has recently been replaced by a suite of six scenarios covering a broad range of possible conflicts.

In addition, the classic measures of effectiveness of attrition, consumption, and movement are being expanded to address a greatly expanded domain of decision perspectives. The Joint Military Net Assessment considers the current and programmed forces not only from the past perspective of warfighting capability, but also from trends in technology, industry, and demographics.

Fewer Resources

We expect that the number of analysts will decrease over the next five years as the size of the armed forces and the Defense Civil Service is reduced. Military headquarters, in which a great deal of military analysis is performed, have been reduced over the last year. Further reductions are expected, bringing military and civilian force levels down across the board.

Budget reductions are expected to be spread disproportionately to analysis activities that are not universally perceived as providing mission-essential contributions. For example, much of the operating budget of the headquarters staffs is for "nondiscretionary" expenses such as rents, utilities, and guard services. A 10-percent reduction in O&M funding to these staffs results in a higher percentage reduction in those "discretionary" items such as studies and analysis, computer system software, travel, and professional and management services.

Time is another precious resource of which analysts will have less in the future. There will be less time available between the expression of an issue and the implementation of decisions to cope with that issue. For example, force capability

assessments that used to be done at the Joint Staff on a one-year cycle are now being made for multiple scenarios in months or weeks.

Greater Uncertainty

Uncertainty will take on expanded dimensions. Analysts and the tools they have traditionally used have been accommodating a relatively fixed set of uncertainties, usually minor excursions in the size and capability of a fairly well understood threat, in U.S. force levels, and in the execution alternatives for fairly well understood conflict scenarios. The classic Euro-SWA-Korea theater conflicts had not changed dramatically in years, nor had the role of the military in those scenarios.

New uncertainties abound in the definitions of the new scenarios and the issues that spring from them. The lesser regional conflicts dramatically increase the variety of missions available for U.S. and allied forces. Time-honored concepts such as prepositioned supplies and lift take on new dynamics—"Preposition What? Where? For whose use? To do what with?" Political-military considerations become increasingly important to the decisionmaker. The care of indigenous populations and preservation of the economic infrastructure introduce new constraints and opportunities for waging war. The form of the combat is not at all clear. "Will the conflict be primarily an air campaign, a ground campaign, both simultaneously, both sequentially, low intensity, what?" Which considerations will dominate a decision? The amount of attrition to allied forces, enemy forces, or local populations? The duration of the campaign? The demographic cost in terms of reserve activations or draft? We expect that the expanded dimensions of uncertainty confronting the analyst will be a continuing factor in future analyses, because uncertainty is inherent in the new scenarios.

Expanded Set of Decisionmakers

The number and variety of decisionmakers who rely on modeling and simulation support are expanding. Three major categories of users of modeling and simulation technology are beginning to emerge--Operational Applications, Force Design and Cost Analysis, and Test & Evaluation (T&E) and Research & Development (R&D).

The operational community is greatly expanding its reliance on automated decision aids to improve operations planning, training and exercising, and real-time decisionmaking. Simulation of joint combat operations is becoming a primary tool for

exploring alternative courses of action in planning military operations. The continued reduction in operating funds coupled with a concern for protecting the environment and the quality of life of civil populations around military installations is steadily constraining the ability to exercise and train troops in the field. In response, simulation is an increasingly effective method for providing realistic decisionmaking experiences to weapon systems operators and to the staffs.

The Force Design and Cost Analysis communities are using modeling and simulation as an aid to assessing force capability and cost alternatives in complex combinations of conflict scenarios and potential future defense budget levels.

The R&D and T&E communities are using modeling and simulation to augment their ability to collect data from physical testing. Modeling and simulation offer the ability to "fill in the gaps" where testing is not a feasible alternative. Modeling and simulation also offer the tester and the developer the opportunity to assess the attributes of a weapon system in various combat scenarios.

EVOLVING TRENDS IN ANALYSIS METHODS

Analysts are beginning to respond to the new conditions. The old reliance on large, institutional simulations of theater-level warfare is being put aside in favor of more general and more flexible tools. There is a growing appreciation for effective front-end thinking before the "number crunching" begins.

Front-end "gaming" is increasingly being used by analysis teams to gain insight into the underlying issues and the subjective relationships that may dominate a thorough investigation of a question, particularly those questions regarding the force design and force employment challenges.

After gaming an issue—discovering the latent issues and associated measures of effectiveness—analysts frequently conclude that the institutional models available to them are not capable of providing the needed quantitative insights. Consequently, there has been a recent increase in the building of analysis tools "on the fly." These "on-the-fly" tools and techniques generally attempt to capture a more general treatment of relationships. They offer new perspectives on the issues and generally expand the number of influences contributing to the perceived system. There has been a resurgence of the use of optimization methods and sensitivity analysis to

explore relationships among variables. "Faster and more flexible" seems to be the effectiveness measure of these new analytic tools.[1]

There is also a renewed interest in the basic ability to access and assess current information. The need for fast, comprehensive, flexible database support has been articulated by many analytic organizations. The types of data required to deal with the new issues include not only current input information of the classical form (weapons, performance, units, terrain, etc.) but also the results of previous analyses stored so as to facilitate the presentation of any combination of variable relationships.

As stated earlier, three types of tools (technical, management, and cultural) were suggested in the panel's deliberations.

TECHNICAL TOOLS

Graphics was recognized as a valuable future analysis tool, primarily because of its potential to facilitate rapid validation of simulations assembled "on-the-fly." The emerging ability to use graphics as a means of entering the simulation as it is running and, at will, visually assess the enigmatic behavior of the entities in the simulation could greatly increase confidence in new simulations and facilitate their rapid construction and acceptance.

The steady improvement of graphics as a presentation medium was recognized by the panel as important and valuable progress.

Communications, not so much among models and simulations as among analysis organizations, was identified as a needed and important technology for overcoming funding and personnel resource constraints. It can bring to bear the disparate talent and expertise needed for complex issues. Simultaneous multiparty videoteleconferencing, along with interactive graphics and basic data transfer capabilities, were considered to be technologies that could support effective remote gaming and cooperative analysis among analytic organizations.

Software languages need to be self-documenting to facilitate insight and understanding of algorithms and how algorithms interact in new models and simulations. More than modularity, the demand for "openness" is increasing. A

[1]Note: The faster and more flexible argument is used also for the QRA tools suggested in panel 1. The important danger in this trend is that without an experience base of analysts and data generated by a longer-term program of disciplined research, the fast reaction models and analysis can be wrong and misleading.

technique increasingly being used by analysts is the borrowing and assembly of algorithms from various sources into "on-the-fly" tools for investigating new issues. Analysts are going to need to be able to quickly understand how existing tools work and to be able to quickly and appropriately dissect needed algorithms. Self-documenting languages offer an additional benefit of reducing the overhead cost associated with documenting models and simulations and facilitating the verification, validation, and accreditation of a new tool.

Accompanying the demand for openness and the use of self-documenting languages is the need to reduce the amount of contractor proprietary code being used in our tools. The demand for flexibility and transportability of algorithms requires the removal of all imbedded data from the algorithms.

Database support should favor relational and object-oriented design concepts. The demand for fast, flexible access to a wide range of data and the ability to assemble those data in ways meaningful for the issues at hand are already increasing, accompanied by the need to increase understanding of what the data mean and where they currently find use. The use of thorough data dictionaries must accompany the expanded use of relational and object-oriented databases. These data dictionaries should also include the range of values for which selected algorithms will remain valid.

MANAGEMENT TOOLS

Accreditation will become an increasingly important management practice in the future. The flexibility and innovation demanded of future analysts and their tools will shift the accreditation focus onto the analysis process. An analysis process that employs front-end gaming, a peer review, multiple agencies, and openness in its tools and methods increases confidence in its results and facilitates an accreditation of the analysis. When accreditation needs to provide an institutional blessing on specific tools, the accreditation may be effectively focused on the algorithms, as the building blocks of future tools, rather than on the appropriate representation of systems and entities.

Cataloging of algorithms will provide a valuable reference for future analysts. More than specific models, analysts are finding increasing value in the basic algorithms that compose the models. It is these algorithms that analysts need in their assembly of new tools.

The panel recommends that the Joint Technical Coordinating Group (JTCG) be requested to catalog the dominant algorithms in use in military models and simulations today. These algorithms might include those in the categories of attrition, human factors, movement, terrain, C3, and others. In addition to cataloging algorithms, the JTCG should include an explanation of the various assembly and aggregation techniques used to relate the results of one algorithm to the input needs of others.

CULTURAL TOOLS

Education of analysts on the techniques and roles of analysis in the decision process is extremely important. Future analysts need to be taught not only the algorithms of analysis (queuing theory, linear programming, Markov processes, etc.), but also the techniques for designing and performing complete, effective analyses. Analysts need a better understanding of how to dissect and assess issues, of the role of front-end gaming, and of techniques for building simple, germane tools and simulations. The analysts also need increased education in the science of presentation of concepts and results, including a better understanding of what other diverse factors might bear on a defense decision and how presentation methods influence defense decisionmakers.

Education of decisionmakers is also extremely important. One recent trend is that the visibility of the basic quantitative analysis is becoming submerged in the soup of staffing results and recommendations to the senior decisionmakers. The new complexity of the issues is introducing a broader and more subjective flavor to the process of assessments. Although this tends to produce a healthier analysis product, a negative consideration is that senior decisionmakers may lose their familiarity with the issues confronting quantitative analysis, its limitation, proper role, and perhaps most important, the resources needed to sustain effective analysis support.[2]

Cooperation among analytic agencies will take on increased importance. The issues are becoming too complex for single agencies to harbor all the needed

[2]Note: It was pointed out during the workshop that the tendency to avoid redundancy and competing views should be avoided because of the large uncertainties involved in future military analysis. A decisionmaker who receives two competing views and who then makes the effort to understand the differences is likely to learn more about his problem and its sensitivities than the decisionmaker who accepts a single analysis or, even worse, receives only a point estimate of results.

expertise. As resources continue to shrink, analysis agencies can be expected to become increasingly specialized in narrower subject areas. Cooperative analyses, involving active participation from multiple organizations with specialized skills, will be necessary to provide effective, comprehensive analyses.

6. WRAP-UP, CONCLUSIONS, AND RECOMMENDATIONS[1]

The preceding panel summaries indicate that the majority of workshop participants agreed that the issues, required approaches to analysis, representation of military phenomenology, and tools either have changed or are likely to change in dramatic ways. Indeed, Secs. 2 through 5 tell the same story but with different emphasis and viewpoints. The degree of change is likely to be largest for analysis of large-scale military operations and smallest for detailed weapon analysis which, at the engineering level, is context and scenario independent.

The opening address suggested that the basic character of combat is changing because of decreased battlefield force density, information technologies, long-range weapons, and increased lethality of modern weapons. The discussions of military operations in the Gulf conflict supported this proposition. Operations analysis in support of Operation Desert Shield and Desert Storm (ODS) showed that analysis took on a different form because of time pressures and the critical life-or-death decisions depending on it. Much of the early ODS analysis was devoted to estimation of air and ground casualties, which in turn directly affected decisions about the timing of operations, duration of the air campaign, and basic operational strategy.

The workshop members also considered many of the other influences that would affect the military analysis community, including the collapse of the Warsaw Pact threat, possibilities and opportunities for conflict elsewhere in the world, reduction in defense outlays in most European countries and in the United States, implications of new military technologies, and the opportunities for analysis provided by new computer technology and software.

What then are the common themes and actionable items that have resulted from this workshop? Certainly a three-day meeting cannot solve all of the problems or completely define the future of military analysis. However, the panels were surprisingly consistent in identifying important themes and directions of analysis.

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[1]The conclusions include observations made in the wrap-up session by Paul Davis and others.

The important themes are:

1. We appear to be at a turning point in military analysis and the problems, requirements, and tools for future military analysis are likely to be changing faster than in the past 40 years.

2. Uncertainty of scenario and threat will be much larger than in the past because of the changes in the world political-military situation.

3. The context for military analysis is likely to be significantly broadened by the need to take greater account of both political and policy considerations.

4. The nature of military operations to be analyzed is likely to be dramatically different, not only because of changes in threat but because of new technologies being exploited by the military: information systems, long-range precision-guided weapons, etc.

5. A broader set of decisions and decisionmakers will require military analysis, but the time available for analysis in support of decisions will shrink.

6. The issues and resulting analyses will be more complex, at times requiring mechanisms such as aggregation to reduce complexity but at the same time teaching decisionmakers to deal with complexity.

7. New software and hardware tools can be used to accommodate these new analysis requirements, but management and cultural "tools" should be exploited as well.

Specific workshop recommendations to the military analysis community and its sponsors are:

1. Continue to discuss military analysis issues in open forums. NATO and MORS meetings provide additional opportunities, but have limitations in that they are not open to as broad an audience and are generally too large to have the type of focused discussions allowed in the workshop. Future workshops should have specific themes and continue this focus. Several organizations volunteered to sponsor the next workshop.

2. Develop a "quick reaction analysis" (QRA) approach to military analysis and supporting tools to enable quick turnaround and high-level decision support. This approach requires the development and support of results databases generated through a program of forward-looking basic research.

3. Reinstitute basic principles of systems analysis, which may have atrophied because of the relatively stable planning scenario of past decades. These principles include attention to uncertainty, multiple scenario analysis, parametric analysis, and comparative analysis.[2] It also requires peer review of models and analysis fostered by incentives to publish and otherwise disseminate information.

4. Promote basic research founded in scientific principles on complex phenomena such as the qualitative factors affecting military performance (training, morale, leadership), behavior of complex military systems (C3I), and new types of conflict, and encourage their inclusion into military analysis.

[2]Similar principles have been emphasized for some years on work sponsored by Mr. Andrew Marshall, the Director of Net Assessment in the office of the Secretary of Defense. See Paul K. Davis, *The Role of Uncertainty in Assessing the NATO-Pact Central Region Balance*, RAND, N-2839-RC, 1988.

5. Promote multi-organization analysis of complex issues and multiple analyses of the same issues. At the same time, encourage efficient use of analysis resources by cataloging and disseminating information on algorithms, approaches, databases, and "results bases."

6. Recognize that training and education are the key to quality in future military analysis. Promote the education of junior analysts in the synthesis and solution of defense problems. Promote the education of decisionmakers in the use and limitations of analysis.

An important class of issues that the workshop addressed only peripherally is fundamental institutional obstacles to implementing some of the panel's conclusions. These obstacles include parochial uses and views of analysis, classification of results for security purposes, and bureaucratic dislike of redundancy and competing views. The first is fostered by competition among the services and organizations supplying the various services. Because military analysis is used frequently to sell a weapon or capability, or support a doctrinal concept, advocates tend to use models and analysis that support their position and choose parameters or make assumptions to generate supporting results. Such analysis corrupts the scientific method and can be avoided by enlightened decisionmakers and broader peer review of analysis (not models). Security classification is a necessity, but it precludes adequate peer review and discourages publication. A long-term program should attempt to declassify results by various means—providing parametric results, generalizing results, and creating reasonable unclassified databases. Last, the tendency to avoid redundancy and competing views should be avoided simply because of the large uncertainties involved in future military analysis. A decisionmaker who receives two competing views of a problem and who then makes the effort to understand the differences is likely to learn more about his problem and its sensitivities than the decisionmaker who accepts a single analysis, or even worse, receives only a point estimate of results.

Participants in the workshop repeatedly mentioned the value of political-military or "pol-mil" gaming at the early stages of an analysis. It is possible that with emphasis on structuring, logic, and qualitative arguments, this work could be made more "analytic." In fact, there is a literature on how to address such issues

that may not be well understood by many military operations researchers. The important disciplines include political science, economics, and cognitive psychology.[3]

Finally, it was observed by several workshop participants that this type of opportunity for a broad cross section of members of the military analysis community to come together, to discuss common problems and approaches, and to get to know one another is likely to foster and enhance future communication, thereby in its own way increasing both the quality and efficiency of future defense analysis. In addition to following up on specific actions, certain participants have agreed to talks regarding the workshop recommendations. We are planning in the near future a series of workshops, to be held at several of the represented organizations, organized around issues raised in the workshop.

[3]See both discussion and bibliography in Paul K. Davis and John Arquilla, *Thinking About Opponent Behavior in Crisis and Conflict: A Generic Model for Analysis and Group Discussion*, RAND, N-3322-JS, 1991.

Appendix A

POINT PAPERS SUBMITTED TO THE WORKSHOP[1]

TITLE	AUTHOR	ORGANIZATION
RAND Workshop, Panel 2 Discussion Paper: Representing Military Activities	Robert J. Atwell	Institute for Defense Analyses
Military Analysis at the Institute for Defense Analyses	Robert J. Atwell Stephen D. Biddle Neale Cosby Jesse Orlansky	Institute for Defense Analyses
The Scientific Method of Choosing Model Fidelity	Dr. Michael P. Bailey	Naval Postgraduate School
Requirements on the Analysis Community in the Post CFE Environment	Dr. Seth Bonder	Vector Research, Inc.
Panel 1: The Issues and Context for Future Military Analysis—"Reaction" Panel 2: Representing Military Activities—"Reaction" Panel 3: Tools and Techniques for Future Military Analysis	W. C. Borawitz	Netherlands Organization for Applied Scientific Research
Family of Models	Edmund Bitinas	The BDM Corporation
The Need for a Joint Tactical Engagement Simulation System	Neale Cosby	Institute for Defense Analyses
Long-Term Planning: Future Views of the Armed Forces	Captain Herman Faltstrom	Swedish Naval Staff
Tools and Techniques for Future Military Analysis: Research Issues and Tools	Dr. Bruce W. Fowler	U.S. Army Missile Command, Redstone Arsenal

[1]For further information or a copy of a paper, please contact the author.

A Point Paper on Panels at RAND Workshop	Dr. Donald P. Gaver	Naval Postgraduate School
Historical Analysis Research Areas	Geoff Hawkins	Defence Operational Analysis Establishment
Significant Combat Environment Factors	Martin E. Lee	U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range
Combat Modeling and AirLand Battle - Future	Philip Louer	U.S. Army Concepts Analysis Agency
Future U.S. Naval Operations	Professor Kneale T. Marshall	Naval Postgraduate School
Planning, Executing, and Analyzing Hyperwar	Major Mark Matthews	HQ U.S. Air Force Assessment Division
Issues for Future Military Analysis	Jesse Orlansky	Insitute for Defense Analyses
Army Use of Models and Simulations in Support of Test and Evaluation	Pete Reid	U.S. Army Materiel Systems Analysis Activity
U.S. Army Analysis Issues and Tools: ODCSOPS Perspective on Potential Discussion Topics for RAND Military Analysis Workshop	John A. Riente	HQDA ODCSOPS
Recent Trends in Joint Military Analysis	Vicent P. Roske, Jr.	Joint Staff
RAND Workshop Panel 1: The Issues and Context for Future Military Analysis	Dr. Shen Y. Shey	Massachusetts Institute of Technology
SHAPE Technical Centre	Dr. L. R. Speight	SHAPE Technical Centre

Appendix B

CONFERENCE ATTENDEES LISTED BY PRIMARY PANEL ASSIGNMENT

Panel 1

Chairperson: Prof. Reiner Huber	Universitat der Bundeswehr, Munchen, Germany
Dr. Mike Bailey	Naval Postgraduate School, USA
Dr. Seth Bonder	Vector Research, USA
Major Paul Butalla	CADRE/Maxwell Air Force Base, USA
Mr. Monti Callero	RAND, USA
Dr. Paul Davis	RAND, USA
Major Scott Dorff	United States Air Force, USA
Capt. Herman Faltstrom	Swedish Naval Staff, Sweden
Dr. John Friel	RAND, USA
Mr. Fred Frostic	RAND, USA
Mr. Geoff Hawkins	Defence Operational Analysis Establishment, UK
Colonel Robert Howe, USA, Ret.	RAND, USA
Mr. Philip Louer	U.S. Army Concepts Analysis Agency, USA
Prof. Kneale Marshall	Naval Postgraduate School, USA
Lt.Col. Mary McCully	The Joint Staff (J-5/Strategy), USA
Mr. Jesse Orlansky	Strategy Forces and Resources Division, Institute for Defense Analyses, USA
Mr. Jim Platt	British Embassy, UK
Wing Commander Ian Prior	Allied Air Force Central Europe, USA
Mr. John A. Riente	HQDA ODCSOPS, USA

Mr. John Shephard	U.S. Army Concepts Analysis Agency, USA
Dr. Shen Y. Shey	Massachusetts Institute of Technology, USA
Mr. Olof Soderqvist	National Defence Research Establishment, Sweden
Dr. L. R. Speight	SHAPE Technical Centre, Netherlands
Mr. Ralph Toms	Lawrence Livermore National Labatory, USA

Panel 2

Chairperson: Dr. Bruce Bennett	RAND, USA
Mr. Bengt Andersson	National Defence Research Establishment, Sweden
Mr. Robert Atwell	Institute for Defense Analyses, USA
Mr. Neale Cosby	Institute for Defense Analyses, USA
Lt. Col. Stephen Ellertson	CADRE/Maxwell Air Force Base, USA
Prof. Donald Gaver	Naval Post Graduate School, USA
Dr. Richard Hillestad	RAND, USA
Prof. Hans Hofmann	Universitat der Bundeswehr, Munchen, Germany
Mr. Martin Lee	U.S. Army, USA
Mr. Brian Leverich	RAND, USA
Major Mark Matthews	United States Air Force, USA
Mr. Klaus Niemeyer	Industrieanlagen-Betriebsgesellschaft (IABG), Germany
Miss Susanne Odar	National Defence Research Establishment, Sweden

Mr. Arend Reid	U.S. Army System Analysis Activity, USA
Dr. William Whelan	RAND, USA

Panel 3

Chairperson: Mr. Vince Roske	The Joint Staff (J-8), USA
Dr. Bart Bennett	RAND, USA
Mr. Steve Biddle	Institute for Defense Analyses, USA
Mr. Edmund Bitinas	BDM Corporation, USA
Mr. W. C. Borawitz	Netherlands Organization for Applied Scientific Research (TNO), The Netherlands
Col. Gilbert Brauch	U.S. Army, USA
Major Frederic Case	USAF/CSA, USA
Mr. Jack Craigie	RAND, USA
Dr. Bruce Fowler	USA/MICOM, USA
Mr. Dan Fox	RAND, USA
Capt. Leonard Heavner	United States Air Force, USA
Mr. Paul Herman	Lawrence Livermore National Laboratory, USA
Mr. Tore Isacson	National Defence Research Establishment, Sweden
Mr. Kenneth Lavoie	CADRE/Maxwell Air Force Base, USA
Dr. Lou Moore	RAND, USA
Mr. Mike Neighbour	Defence Operational Analysis Establishment, England
Mr. Kent Pickett	U. S. Army, USA
Col. Gary R. Ware	Headquarters Central Command, USA
Dr. Milton Weiner	RAND, USA

Appendix C

WORKSHOP ON FUTURE MILITARY ANALYSIS: AGENDA MAY 8-10, 1991

WEDNESDAY, MAY 8, 1991

- Welcome to RAND — Dick Hillestad and Paul Davis
- Introduction — "Future Military Analysis: New Issues" Sam Gardiner
- Short presentations by organizations represented; one person per organization (5-10 minutes each -- brief descriptions of organization, key issues, and approaches to analysis)
- Analysis in Desert Shield/Desert Storm

Vince Roske	Joint Staff/J8
Colonel Gary Ware	CENTCOM
Major Frederic Case	USAF Studies and Analysis
Philip Louer	USA Concepts Analysis Agency
Geoffrey Hawkins	UK Defence Operations Analysis Establishment

THURSDAY, MAY 9 1991

- PANEL MEETINGS

Panel 1: *Issues and Contexts for Future Military Analysis*
Main Conference Room — Reiner Huber, Chair

Panel 2: *Representing Military Activities*
Room 2309 — Bruce Bennett, Chair

Panel 3: *Tools and Techniques for Future Military Analysis*
Administration Conference Room — Vince Roske, Chair

FRIDAY, MAY 10 1991

- Panel report preparation, individual discussions as desired
- Panel reports and discussion in the Main Conference Room
- Workshop assessment and discussion of future activities

Appendix D

WORKSHOP PANEL TERMS OF REFERENCE

Panel 1 will discuss the major analysis issues arising from the events in Europe and Southwest Asia as well as the general trend toward reducing military forces. Discussions will focus on how and what types of scenarios should drive analyses, what are the important force procurement, force structure, and force employment issues for the future, and the role of models in such future analyses. Possible outputs of this panel include:

- Important issues for analysis during the next decade
- Roles and limitations of models in analyses of these issues
- How to best serve the decisionmakers while coping with time constraints and uncertainty in analysis
- The role of scenarios in future analysis--dealing with threat, regional, force, political, and effectiveness uncertainty.

Panel 2 will discuss the implications of recent changes in Europe and the conflict in Southwest Asia on models of deployment and combat operations. Discussions will focus on possible new combat environments, new combat phenomenology and insights regarding air/land and sea combat operations, new operational concepts, and possible new force structures. The panel will consider how these phenomena might be represented in models and what factors appear to be the most important to represent. It will consider steps the military analysis community might take to improve its analysis capability given the importance of these factors. It will also discuss methods of achieving confidence in analyses and models and dealing with uncertainties in predictions about military phenomenology. Possible outputs of this panel include:

- Key phenomena that should be included or better represented in models and future analysis
- A coordinated approach to improved modeling and analysis of military phenomena by the military analysis community
- Aggregation/disaggregation issues in modeling military phenomena
- Issues in using and presenting results from models when there is considerable uncertainty in data and/or phenomenology representation.

Panel 3 will discuss the opportunities and utilities of different tools and techniques for military analysis. Panel members will draw on the experience of recent analysis of Southwest Asia operations, conventional arms control in Europe, and force cutbacks to discuss the advantages and limitations of simple versus complex models, analytic versus simulation models, and supporting tools such as spreadsheets, graphic user interfaces, and database management systems. It will also discuss approaches and tools for enhancing the understanding and presentation of results of analysis. Possible outputs of this panel include:

- A listing of the advantages and disadvantages of various tools and techniques for modeling military activities with respect to uses and users of the analysis
- Possible new directions for military analysis given the emergence of new tools and techniques
- How new requirements have changed the types of tools needed and used
- Tools needed by the community.