Effects-Based Operations

A Grand Challenge for the Analytical Community

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PREFACE

The impetus for this monograph was provided by a project on force transformation for the Commander in Chief, U.S. Joint Forces Command and his Director of Joint Experimentation (J-9) and a project on advanced modeling methods for the United States Air Force Research Laboratory. The monograph also drew on the research of a cross-cutting project on transformation concepts for the Office of the Secretary of Defense and Joint Staff. This study should be of interest to both civilian and military consumers of analysis and the analysts and modelers who seek to inform development of military forces and doctrine.

The work reported here was conducted in RAND's National Defense Research Institute (NDRI) and Project AIR FORCE. These organizations are federally funded research and development centers (FFRDCs) for the Office of the Secretary of Defense, Joint Staff, Unified Commands, and Defense Agencies; and for the United States Air Force, respectively. Comments are welcome and should be addressed to the author at RAND:

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SUMMARY

A GRAND CHALLENGE

Effects-based operations (EBO) are defined here as operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects—effects that may, with different degrees of probability, be achieved by the application of military, diplomatic, psychological, and economic instruments.

Current methods of analysis and modeling are inadequate for representing EBO, and this reality should be considered by the analytical community to pose a grand challenge. Addressing the challenge will require changes of mindset, new theories and methods, and a new empirical base. Fortunately, several research-and-development efforts toward this end are now under way, but it will take years for them to reach fruition. In the meantime, these efforts can benefit from some broad analytical considerations.

PRINCIPLES FOR AN APPROACH

The following principles are a useful guide for defining and conducting defense-planning analyses that take a broad view:

- Analysis in support of defense planning should embrace the paradigm of focusing on *mission-system capability*, which refers to the no-excuses ability to accomplish missions under a wide range of operational circumstances and to characterize the range of circumstances for which the capabilities are sufficient to provide different degrees of confidence. Addressing EBO-related issues should be an important part of such analysis.

- Analysis dealing with EBO should fully confront the scope and magnitude of uncertainty and should deal explicitly with probability and randomness. For summary purposes, assessments of capability should refer specifically to most-likely, best-case, and worst-case outcomes (with "best" and "worst" corresponding to something like 90 percent limits, judged subjectively).
- Dealing with uncertainty will require low-resolution *exploratory analysis* for breadth, as well as more-detailed modeling and gaming for both depth and insight into underlying phenomena. This suggests a *family-of-models-and-games* approach in which information obtained from different members of the family is used to inform and cross-calibrate the whole body of knowledge. To be meaningful, as distinct from being merely slide-show material, such work requires major investment and effort—in additional models, empirical knowledge, and the analysis necessary to actually accomplish the cross-calibration.
- A key element of analytical work should be *qualitative modeling*, including *cognitive modeling* of the decisionmaking and behavior of commanders, political leaders, and even societies. Such modeling should be undertaken in an uncertainty-sensitive framework and can greatly enrich analysis while breaking down the barriers between "rigorous analysis" (usually quantitative, but rigid) and human gaming (often more realistic and innovative, but fuzzy). Here, as elsewhere in EBO analysis, the objective should be to increase the *odds* of success and decrease the *odds* of troublesome side effects.
- Because much of EBO is tied to affecting decisions and behaviors of people and organizations or the operation of complex systems and organizations, much of the related modeling should be organized around adaptive systems for command and control and other matters, rather than around the mass and physical characteristics of forces. This implies emphasis on the concepts and technology of *agent-based modeling* (albeit in many variations), as well as on system engineering.
- Because the questions asked in EBO analysis are so different from traditional questions, analysts should vigorously pursue a

new base of *empirical information*—including information obtainable from history and from a combination of gaming, man-in-the-loop simulation, and experiments in battle laboratories and the field. This information should be collected and framed in ways that illuminate complex and subtle relationships and that support uncertainty analysis. The goal should *not* be merely to inform "best-estimate" databases, because in EBO work, uncertainty is often inherent and best-estimate analyses can be misleading and even dangerous.

EXAMPLES OF REFLECTING EBO IN COMBAT MODELING

Much discussion of EBO is relatively abstract or even philosophical. It is often difficult to see how the issues can be dealt with in rigorous analysis and supporting models, except when those issues are amenable to systems engineering, as in precision targeting to halt the functioning of a complex facility without excessive or permanent damage. It is therefore useful to have down-to-earth examples demonstrating that much can be done by embellishing traditional combat models and adding new features to them. Examples can also demonstrate that some of the alleged dichotomies between attrition-based operations and EBO are not dichotomies at all.

Example 1: Interdiction with Long-Range Fires

One example addresses the operational challenge of achieving an *early* halt through interdiction alone—i.e., of halting an invading army before it occupies critical territory, and doing so without the benefit of ground forces. The problem has been studied heavily over the past decade, but not within the framework of EBO. When the problem is studied in conventional ways with the usual models and assumptions, the mission appears to be extremely demanding. However, when the problem is viewed from an effects-based perspective as described above—with serious attention paid to uncertainties and to indirect effects on behavior and decisions—the conclusion reached may be quite different in both form and content. For example, instead of conservatively assuming a brave and motivated enemy, analysis from an effects-based perspective considers the possibility that the halt could be achieved much more quickly than is predicted by considering massive attrition alone—especially if the interdiction is focused. The analysis suggests that a particular force-employment strategy (e.g., a leading-edge strategy) is unlikely to be less effective than a baseline strategy and might instead be substantially *more* effective in bringing about a very early halt. That is, the strategy has a strong upside and only a modest downside.

To reach this conclusion, it is necessary to revise the models used to permit considering a range of plausible break points, building a qualitative model of what determines the break point, and recognizing that even with such a model (in the reductionist form of a table), the break point should be treated as a random variable. Further, the analysis requires modeling direct physical effects of the leading-edge strategy, which depend on the enemy's scheme of maneuver (number of axes, dispersion along the axes, etc.). Despite this apparent complexity, the analysis reproduces the reasoning of a hypothetical sensible commander interested in upside potential and downside risk, not just nominal predictions. In that context, such a commander would be quite willing to consider soft factors such as the enemy's apparent cohesion, morale, and motivation. Although break points are quintessential examples of soft factors resistant to precise assessment, they can be represented analytically. Further, the analysis demonstrates how an attrition-based model can be modified to reflect quite a range of softer effects and to become, in essence, a model for assessing EBO.

Example 2: Halting an Invasion with a Combination of Fires and Early-Intervention Ground Forces

A second example considers the combined use of long-range fires and early-intervention ground forces inserted nominally at a forward defense line. Estimating likely outcome, best-case outcome, and worst-case outcome now has a different flavor. In this instance, the downside risk of inserting ground forces would be very high: the lives of those being committed. In some circumstances, that risk might be tolerated; in others, it would not. An imperative would be to reduce the size of the downside risk, e.g., by considering a deeper defense line, delaying or slowing the advance through early and well-focused strikes, improving the capabilities of the ground force, slowing the enemy's rate of advance, or increasing the magnitude of the long-range fires and their assured ability to support the ground force. If such measures were not sufficient to greatly reduce the downside risk, ground forces would not be employed.

As part of this example, a simple cognitive model of the commander can be used to essentially formalize the logic described above in words. The commander's decision is whether or not to insert the ground forces. Although simple, this example demonstrates that building useful decision models is possible and that such models could be used to broaden and sharpen conclusions of human-conducted war games in which only one of many paths is taken, to represent plausible enemy behaviors in effects-based analysis, and to better characterize historical events. Computer programs embodying such models are examples of agent-based modeling.

CONNECTIONS TO FORCE PLANNING

The two examples above revolve around the problems of a hypothetical future commander, not the reasoning of a current-day force planner. Traditionally, operations planning and force planning are considered to be very dissimilar, with force planners providing only raw capabilities motivated by deliberately stereotyped scenarios. However, planners should consider the *customers* of today's defense planning to include tomorrow's President, Secretary of Defense, and military commanders. Thus, it is appropriate in today's force planning to evaluate capabilities in more-realistic frameworks. That does not mean adding greater detail to the scenarios, as though the relevant details are known. To the contrary, it means exploratory analysis over a *broader* range of assumptions, but a range that explicitly considers realistic variations in the qualitative factors that so dominate real conflicts. The consequences can, paradoxically, work in both directions. On the one hand, such exploratory analysis can highlight additional vulnerabilities and thereby raise "requirements" (e.g., for capability to cope with short-warning scenarios). On the other hand, it can demonstrate that capability sets that would be manifestly inadequate in highly conservative, stereotyped scenarios would be highly valuable in others—so much so as to merit investment. It should be remembered that airborne, air-assault, amphibious, and special-operations forces would never have been developed had they been evaluated only in stereotyped attrition scenarios underplaying the role of surprise and special tactics. Nor is the issue confined only to "special" capabilities. Consider the debate about two-MTW (major theater war) capability. By evaluating affordable force structure against inflated versions of a two-MTW conflict, and by using analytical methods focused on straightforward attrition warfare, one can conclude that two-MTW capability is not feasible and that the strategy should be relaxed—perhaps one threat is enough. Alternatively, one can do the exploratory analysis and conclude that two-MTW capability is feasible for quite a range of currently realistic threats and scenarios but is not feasible in other cases. In that analysis, the conclusion is not that the idea of two-MTW capability should be dropped, but that it should be defined better. Another step is to recognize the tradeoff between conducting other operations (including small-scale contingencies) and short-term *readiness* for (as distinct from *eventual capability* for) two concurrent MTWs.

NEXT STEPS

An important motivation for this monograph was the belief that analysis methods need to be improved so that they can be useful in studies and operations undertaken from an effects-based perspective. Such improvements appear to be quite feasible, but they will depend on new attitudes, principles, and norms—as well as on the use of modern modeling technology such as that for exploratory analysis under uncertainty and the development of agent-based models. Further, the improvements will depend on developing an expanded and enriched empirical base. The next steps should include in-depth application of the principles enumerated here in efforts to obtain insights and data from history, training, exercises, and experimentation (both in the "laboratory" and in the field).

ACKNOWLEDGMENTS

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ACRONYMS

AFV	armored fighting vehicle
ATACM	advanced tactical missile system
BAT	brilliant antitank submunition
C^4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAS	complex adaptive system
EBA	effects-based analysis
EBO	effects-based operations
EBP	effects-based planning
FFRDC	federally funded research and development center
IAD	integrated air defense
ISR	intelligence, surveillance, and reconnaissance
JAWP	Joint Analysis Warfighting Program (a division of the Institute for Defense Analyses)
JICM	Joint Integrated Contingency Model
JSF	joint strike force
JWAC	Joint Warfare Analysis Center
JWARS	joint warfare system
MSA	mission-system analysis
MSC	mission-system capability
MSP	mission-system planning

MTW	major theater war
RDO	rapid decisive operations
RMA	revolution in military affairs
RSAS	RAND Strategy Assessment System
SACEUR	Supreme Allied Commander, Europe
SAM	surface-to-air missile
SEAD	suppression of enemy air defenses
SSC	small-scale contingency
SWAT	special weapons and tactics
TACWAR	Tactical Warfare System
TNDM	Tactical Numerical Deterministic Model
TPFDL	time-phased force-deployment list
WMD	weapons of mass destruction

Chapter One

INTRODUCTION

OBJECTIVES

This monograph suggests principles for sharpening discussions of effects-based operations (EBO), for increasing the rigor of those discussions, and for building the key ideas of EBO into analysis for defense planning, experimentation, and operations planning. It then illustrates the principles with explicit models. Finally, it sketches a possible research program to enrich the base for studying and practicing EBO.

BACKGROUND

A New Movement Stressing EBO

One of the "new ideas" in military planning is operations that attack the adversary's capabilities and thinking, specifically to accomplish the commander's objectives efficiently and discriminately (as distinct from cruder operations that have only broad connections to specific objectives). The idea—i.e., EBO—is, in fact, not new,[1] and some EBO advocates have been accused of excessive enthusiasm, but it is undeniable that an EBO movement is well under way and is influential. Critiques of both terminology and concept are common, and I include my own suggestions here, but the purpose of this

[1]See Beagle (2000, ch. 3) for a discussion of EBO's roots in airpower theory and McCrabb (2001) for a thoughtful discussion of concepts and terminology.

monograph is constructive: to applaud the reasons for the EBO movement, to acknowledge shortcomings in the ability of current military analysis to represent EBO, and—most important—to suggest improvements in analysis and in the models that support it.[2]

A Way of Viewing the EBO Movement

The rise of interest in EBO can be readily understood if one views the movement as a *revolt of the war fighters*. This revolt has at least two components. The first is mostly outside the scope of this monograph, but it is important as background. The second is a motivation for this work.

Revolt Against Poor Force-Employment Strategies in Wartime. To a large extent, the EBO movement and the passion of its advocates stem from wartime experiences of young U.S. Air Force officers who were appalled by the frequently mindless and ineffective use of airpower in Vietnam.[3] When their turn to lead came, they were determined to do better. The Gulf War was their first great opportunity and, in fact, joint fires (not just Air Force fires) were applied with decisive effectiveness as the result of sound thinking about affecting *systems*, not just servicing targets. Operations were dramatically different from anything previously seen. At that moment in history, a great many concepts and capabilities came together after years of evolution.[4]

In stark contrast, long-range fires were used inefficiently and ineffectively through most of the Kosovo conflict (Operation Allied Force). Because of the way the air campaign had to be conducted, U.S. Air Force generals were particularly frustrated and were no more sanguine than others about the likelihood that it would force Milosevic to concede. But he did capitulate, creating the paradoxical

[2]In this monograph, the term *models* includes simulations. Models may be either closed, interactive, or a combination, as when a Blue team makes decisions and Red's decisions are made by a model. Analysis may be accomplished with a single model or a family of models, which in turn may be colocated or distributed. Thus, the models considered here go beyond what are ordinarily referred to as *constructive models.*

[3]Beagle (2000, ch. 5) includes a good review of the Air Force's Vietnam experience.

[4]Good references include Murray (1993), Watts and Keaney (1993), Deptula (2001), and Lambeth (1999).

problem that political leaders might see the conflict as a model—failing to learn the correct lessons, much less act upon them.[5] Proponents of EBO are determined that the lessons should be learned and heeded; they believe that EBO philosophy is a crucial element of doing so.

The EBO movement would probably not have much influence if it were restricted solely to airpower theorists, but its tenets have much in common with those of modern maneuver theory developed by the U.S. Army during the 1980s and embraced by the Navy and Marines. The great military accomplishments of Desert Storm were equally meaningful for all of the services and created a powerful image of what is now possible. This image can be seen in the basic vision documents (Joint Staff, 1996, 2000) and in the current emphasis—across service lines—on concepts such as achieving decision superiority and achieving capabilities for rapid, decisive operations (RDO). For example, such matters are now the centerpiece of transformation-related joint experiments by the U.S. Joint Forces Command (United States Joint Forces Command, 2000, 2001). More generally, EBO has become an important part of the vernacular used by today's innovative war fighters, even though outsiders may find the terminology puzzling.

Revolt Against Standard Models and Analysis. The part of the war fighters' revolt that is of most interest in this monograph is its connection with analysis and the models that support it. For many years, war fighters ("operators") and military historians have been convinced that there is a striking disconnect between themselves and what they see as "number-crunching" modelers and analysts. Their views on this have not been particularly fair, and, in fact, considerable strides have been made over the past two decades in having operators inform development of models and databases; but the results have been uneven, and operators have often felt that they were being asked to comment on inappropriately structured conceptions of warfare. Many operators merely tolerate modeling when forced to deal with it. To be sure, they acknowledge the need for lo-

[5]For an authoritative memoir of modern war's political-military complexities and lessons that should be learned, see Clark (2001, pp. 417ff). For a more analytical study focused primarily on airpower issues, see Lambeth (2001). A study focused on ground-force issues is in preparation (Nardulli and Perry, forthcoming).

gistical calculations, simulations to rehearse the orchestrated application of airpower, engineering calculations, and so on—even checking out aspects of war plans[6]—but they are more comfortable with human war gaming for purposes such as conceiving new operational concepts and actual military operations in war. Basically, whether they are right or wrong, they consider constructive models to be too limiting.

Ordinarily, model-averse operators have just gone their own way, but the Gulf War and the past decade's activities in connection with the revolution in military affairs (RMA) and military transformation have put a premium on rethinking the art and science of war. Human war games are useful but nowhere near sufficient. There is a critical need for systematic studies using a combination of models, war games, and field experiments.[7] This need is now appreciated, but it will take years for the process to evolve.[8]

Unfortunately, the pace of innovation and related human war gaming has exceeded the ability of models to keep up. Although analysts can trick legacy models into representing many complex phenomena, and some modern models can do a great deal,[9] it is nonetheless true that most modeling and analysis still encourages a mechanistic

[6]Such uses of models and simulations certainly paid their way in the Gulf War. Importantly, however, they were then used quite differently than they are in peacetime planning: with many variations, a great deal of direction and feedback from the war planners, an attempt to make realistic assumptions, and a good deal of "tricking the models" to make them represent what the war planners wanted to address. See, for example, Appleget (1995) and Case, Hines, and Satchwell (1995).

[7]For published discussions of how to use families of models and games, see Davis, Bigelow, and McEver (1999) and Defense Science Board (1998). These issues were also discussed at a special workshop on joint experimentation held by the Military Operations Research Society on March 8–11, 1999. For a book-length review of how high-resolution constructive modeling has been used at RAND, see Matsumura, Steeb, et al. (2000).

[8]United States Joint Forces Command (2000) describes the current campaign plan for joint experimentation—broadly construing *experimentation* to include work with models and games.

[9]For example, the Joint Integrated Contingency Model (JICM) has been used to explore maneuver-oriented and otherwise nonlinear joint concepts of operations at the theater and multitheater level. It also represents a variety of soft factors (see Chapter Five). It is weaker, however, with respect to intelligence, surveillance, and reconnaissance (ISR). Also, it is a relatively aggregate-level simulation (e.g., brigades or divisions for ground forces).

view of warfare that emphasizes firepower and attrition while ignoring other critical aspects of strategy, such as maneuver of forces and fires, command and control, and aspects that relate to each side's effort to attack its opponent's strategy, will, cohesion, and cognition—as in a drive for decision superiority.[10] Those pursuing concepts such as network-centric operations, RDO, decision superiority, and EBO often find that traditional models are simply inadequate.[11] At the same time, these new thinkers often discuss their concepts in ways that many analysts and modelers perceive as fuzzy or even vacuous. The differences in paradigm and problems of communication reflect the cognitive dissonance that occurs across a classic culture gap.[12]

Opportunity and a Grand Challenge

With this background, the point of departure for this monograph is as follows:

- The EBO movement is timely, interesting, and important; it poses a grand challenge to the analytical community.
- Responding to this grand challenge is definitely feasible, but new attitudes and methods are needed and a new research base must be laid. Much can be done now with methods developed over the past 20 years, but—as befits a grand challenge—a great deal is not yet well understood, nor is the requisite empirical information available (National Research Council, 1997).

It is appropriate, then, to review methods of analysis to determine what can be done better and what research should be pursued.

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[10]Decision superiority was emphasized in the recent *Report of the Transformation Panel to the Secretary of Defense* (McCarthy, 2001). Decision superiority has been a continuing theme of General Larry Welch (USAF, ret.), Ted Gold, and others in a series of recent Defense Science Board studies (Defense Science Board, 1996, 1998, 1999).

[11]Some recent models try to do better. See, for example, Herman (1998) and Booz Allen Hamilton (1999), which discuss an "entropy-based warfare system" that has been used in a number of recent war games. Such efforts are, however, still in their infancy.

[12]For a discussion of paradigm shifts and cognitive dissonance, including the early work of Kuhn and Popper and iterations thereof in the light of controversy, see Lakatos and Musgrave (1970).

ORGANIZATION OF THIS MONOGRAPH

The remainder of this monograph is organized as follows. Consistent with discussing the need for addressing changes of mindset, new theories and methods, and a new empirical base, Chapter Two defines EBO and discusses important dimensions and distinctions, highlighting what is different. Chapter Three itemizes key challenges in thinking about EBO and representing EBO in analysis and the models that support it. Chapter Four identifies numerous methods that could be brought to bear. Chapter Five provides concrete examples based on the familiar defense-planning problem of defeating an invasion. Finally, Chapter Six draws conclusions and sketches components of a possible research program.

Chapter Two

DEFINITIONS, DIMENSIONS, AND DISTINCTIONS

DEFINITIONAL ISSUES

A Suggested Definition

No definition of EBO has yet been agreed on, but the following suffices for present purposes:

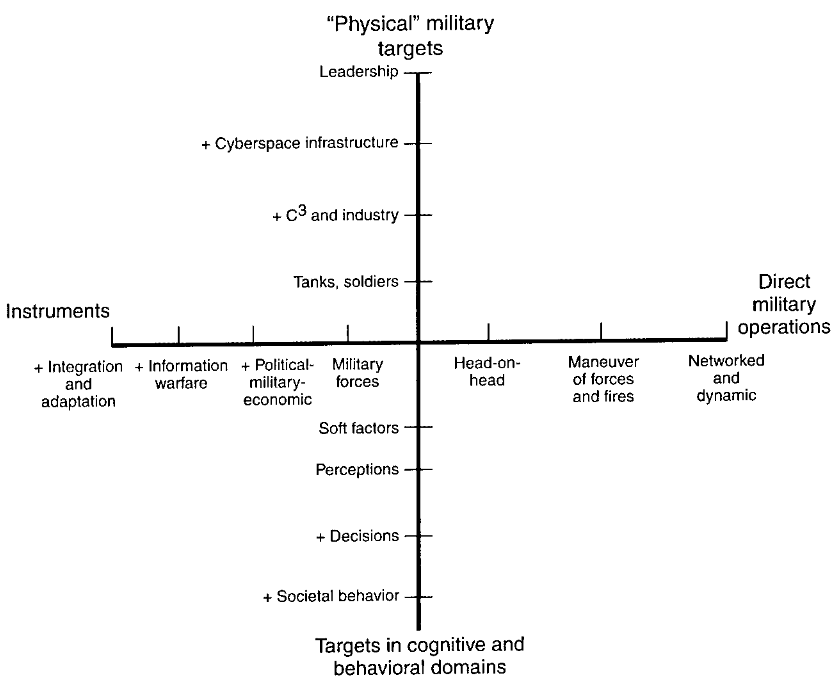
> Effects-based operations are operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects, which may—with different degrees of probability—be achieved by the application of military, diplomatic, psychological, and economic instruments.

This definition includes several features: the systems framework; the intent to address not only direct physical effects, but also a range of indirect effects, which may accumulate and reinforce each other; the potential use of all applicable instruments of influence; and the explicit mention of probability. Most of the definition is an attempt to reflect what others discussing EBO have had in mind.[1] I have added emphasis on probability, because explicitly including it enriches discussion and reveals common ground for people with different initial attitudes about EBO—people who often talk past each other because of cognitive disconnects.

[1]For thoughtful discussions, see McCrabb (2001), Murray (2001), and Forestier (2001).

Issues of Scope Implied by the Definition

If one merely reads the words "effects-based operations" and interprets them according to normal English usage, one might reasonably ask what is new. After all, good commanders have *always* kept their mind on objectives and related effects. Nonetheless, mainstream analysis has often addressed only a small part of what EBO entails. Figure 2.1 presents a structure for conveying the story. It shows four axes along which the quality of modeling and analysis can be assessed. Starting from the left and working clockwise, they are the instruments of force employed (the negative x axis), the scope of physical (and cyberspace) targets (the positive y axis), the nature of direct military operations (the positive x axis), and targets in the cognitive and behavioral domains (negative y axis). To characterize the state

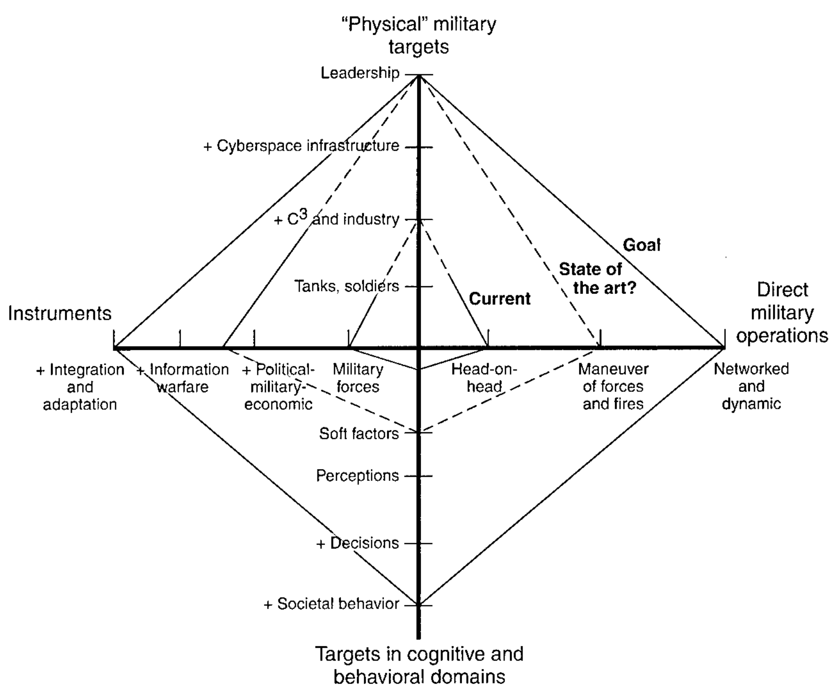


NOTE: The axis of physical targets relates to both direct physical and systemic effects.

Figure 2.1—Structure for Characterizing Current and Future Modeling

of modeling, we can mark points along each axis and then connect them, thereby creating a spider plot.

Figure 2.2 characterizes several states of modeling and analysis. The baseline—i.e., what is routinely treated by most current models and analyses—is shown by the small, nearly triangular shape in the center, labeled "Current." The claim here is that the baseline focuses on the employment of military forces; considers a variety of materiel targets involving military forces, C^3I, and infrastructure (such as powerplants); goes a bit beyond head-on-head attrition when considering direct military interactions; and does exceedingly little in the cognitive/behavioral domain. The dashed portions of the assessment indicate where the models and analysis tend to be quite thin with respect to indirect effects. For example, the baseline treatment



NOTE: The axis of physical targets relates to both direct physical and systemic effects; dashed lines indicate where current capabilities are poor in capturing indirect effects.

Figure 2.2—Characterizing the Baseline, Current State of the Art, and Goal

includes attacks on infrastructure and assessments of how many targets are damaged, but assessments of impact are often weak because many effects are indirect and uncaptured.[2]

The second (middle) assessment—denoted "State of the Art?"—acknowledges that methods that push modeling and analysis further already exist and are sometimes used. For the most part, the expansion is in the range of targets considered, sophisticated targeting of physical systems, adding more features of coalitional action and information warfare, and including more aspects of maneuver (e.g., breakthrough phenomena, networking rather than pistons, deep operations, and adaptive decisions on commitment of forces). At this level, it is unusual in peacetime combat modeling and related analysis even to see efforts to measure effects on cohesion and morale of forces,[3] much less effects on decisionmakers' decisions or the behavior of the enemy's population. For most of the analytical community, this level represents the state of the art; it is relatively weak in considering indirect effects.[4]

The goal, arguably, is indicated by the shape labeled "Goal" in Figure 2.2, which pushes the frontiers outward in all four dimensions. Al-

[2]As demonstrated by the operations-related work of the Joint Warfare Analysis Center (JWAC), many such effects of infrastructure attacks *can* be captured, with sufficient effort (Beagle, 2000, pp. 107–109).

[3]Exceptions here are the static Quantified Judgment Model (QJM), now called the Tactical Numerical Deterministic Model (TNDM) (see Dupuy, 1979, 1987, and www.dupuyinstitute.org), and the JICM, both of which contain "soft factors" to reflect issues of morale, cohesion, surprise, training time, recent combat history, and so on (Bennett, Jones, Bullock, and Davis, 1988; Davis, 1989a). The RAND Strategy Assessment System (RSAS)/JICM development reflected Dupuy's work as well as other considerations (Davis, 1999). The emerging Department of Defense (DoD) JWARS model has been designed to include many such factors as well, although users may end up turning them off (private communication, Chuck Burdick, June 2001). Finally, some very interesting current research is expanding the state of the art of predicting cognitive and behavioral effects through the use of influence nets informed by experts in war-game settings (Wagenhals and Levis, 2001).

[4]The word *most* applies here because much more detailed and ambitious targeting is sometimes employed in operational targeting work and because a number of research-and-development efforts are under way, under the sponsorship of the Air Force Research Laboratory and the Defense Advanced Research Projects Agency (DARPA) in particular (e.g., Wagenhals and Levis, 2001; Lofdahl, 2001). Such work is still in its infancy, however, except where the issues can be treated at an engineering level. Arkin (2000) is an unusual published discussion of more-sophisticated aspects of bombing in Kosovo. See also Hosmer (2001) and Lambeth (2001, pp. 148ff).

though it may at first seem unexceptionable to seek such a goal (why should we not, at least, *try*), we should ask what degree of success is *possible*—especially in the cognitive domain but also along the other dimensions. Many military operators (and historians) remain skeptical about representing such fuzzy considerations with computers, much less making interesting predictions. We shall return to this later.

Traditional analysts—especially those concerned with force planning or peacetime deliberate planning—might also answer pessimistically the question, How far can we go? with, "Not far. You can set any foolish goal you want in this regard, but get real: We're not going to be able to understand, much less predetermine, the decisions of the enemy leadership and population. In fact, it's not even a good idea to dwell on the cognition of the enemy's fighting forces, because that's extremely difficult to predict."

Proponents of EBO disagree, as well they should. History is a notoriously unreliable source of prescriptive guidance, although it is an excellent source for existence proofs. Because of historical experience, it should not be controversial to assert that effects-based planning—in one form or another—can be brought to bear far along all of the axes.[5] This said, both common sense and historical experience tell us that doing so is plagued with difficulties, and the effects obtained may not be those sought.

EBO as Expansion Rather than Substitution

Figures 2.1 and 2.2 suggest that the new or underrealized aspects of EBO should be used to *expand* the scope of operations and supporting analysis. This is in contrast to the frequently heard assertion that EBO is *different* from traditional practice and is to be understood largely in terms of what it is not. In particular, it is claimed, EBO is not about destruction or attrition of enemy forces (except incidentally), occupation of territory, or other classical considerations. Proponents of EBO sometimes stress images such as

[5]Numerous examples are given in Institute for Defense Analyses (2001). As the authors note, many efforts at effects-based planning failed or had little effect; others had negative side effects. EBO is difficult to plan and conduct.

- Collapsing the will and cohesion of the enemy.
- Defeating the enemy's strategy rather than his armies.
- Convincing the enemy's leader to make decisions favorable to our goals.

As for mechanisms, EBO proponents may emphasize speed, agility, parallel operations, decisiveness, creating shock and awe, and attacking the enemy's mindset and conceptual centers of gravity. Despite the merit in this and numerous precedents in war, such proponency can convey a mystical zealotry that raises the hackles of those charged with hard-nosed objective analysis. Even some of the natural allies of EBO can be put off. Critics are apt to argue that

- Operations intended to break the will and morale of populations have often done precisely the opposite (e.g., strategic bombing against Nazi Germany) (Pape, 1996).
- Nations whose initial strategies have been defeated have adapted, regrouped, and gone on to victory (e.g., the American colonies in the Revolutionary War).[6] In contrast, if an enemy's armies have been destroyed, they *cannot* regroup and come back.[7]
- Immediate deterrence and compellence have traditionally been exceedingly difficult to accomplish (Huth, 1998), in part because the psychological factors that determine the decisions of leaders are difficult to understand and even more difficult to control. The problem is not irrationality, but rather *limited rationality* (Davis and Arquilla, 1991a,b; National Research Council, 1997).[8]
- Rigorous thinkers may reasonably ask whether the classical concept of attacking *centers of gravity* has content. Is an enemy's

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[6]The response here might be that the patriots were not decisively defeated early on, but this begins to sound like a circular argument.

[7]Such considerations are reflected in Gompert (2001), the report of the conventional forces panel to Secretary of Defense Donald Rumsfeld. One operational objective recommended is to destroy the enemy's ability to fight and capacity to threaten again.

[8]Many of the psychological issues are discussed at greater length in Jervis, Stein, and Lebow (1985).

center of gravity physical or cognitive? Is it tangible or imagined? Is there an objective basis for identifying it?[9] And is the concept ultimately circular?[10]

The critics also observe that attrition, destruction, and the occupation of territory have been essential factors in some of the greatest victories that could be viewed as effects-based. The precipitous fall of France after the German Blitzkrieg was strongly affected by "shock and awe" (Ullman and Wade, 1996), but that shock and awe were in no little measure the result of stunning military victories that defeated forces, killed people, and occupied territory. General Sherman's march to the sea in 1864 avoided regular battles and killed few people, but it caused destruction that is resented a century and a half later.[11] Or, to raise a subject that is still painful, the North Vietnamese Tet offensive led to strategic victory for North Vietnam precisely by defeating American will, but that victory was bought at the price of huge numbers of casualties to both sides.[12] Finally, it

[9]Some advocates of strategic airpower are prone to associate centers of gravity with strategic command and control, leadership, and other natural targets of airpower (for a seminal piece, see Warden, 1989), while mentioning ground forces only grudgingly. Other military thinkers may focus immediately on defeat of the enemy's elite ground forces, which may be uniquely capable of serious maneuvering and which may also be critical to leadership survival. In the Gulf War, the debate was rendered moot because U.S. resources were so massive that virtually all targets were attacked.

[10]In discussions of centers of gravity, the operating definition used implicitly by speakers frequently seems to be that the center of gravity is that which, if successfully attacked, will bring down the adversary. With such circularity of argument, it is little wonder that analysts sometimes tune out. Another logical problem that arises is more subtle: In a future war, the adversary's capabilities may very well be highly distributed. There may not be any physical "thing" to be attacked: no critical nodes for an integrated air defense, no command headquarters, and no elite army formation. When this point is raised, the response often is to elevate the issue to a more mystical level by referring to the will and cohesion of the enemy. At that point, however, the metaphor has completely failed, and it is surely better to just talk directly about attacking the will and cohesion of the enemy.

[11]Sherman sliced his way through Georgia and captured Savannah—a "Christmas gift" for President Lincoln. His army, however, left in its wake devastation of crops, plantations, and war-supporting economy. See Dupuy and Dupuy (1991, pp. 986–987).

[12]North Vietnamese and Viet Cong combat casualties totaled about 2,500,000; South Vietnamese combat casualties totaled about 800,000; and American combat casualties totaled about 205,000 (Dupuy and Dupuy, 1991, p. 1333). About 50,000 North Vietnamese and Viet Cong participated in the Tet offensive, suffering high attrition.

should not be forgotten that one of the most dramatic instances of causing a favorable decision by national leaders was the American use of atomic bombs against Japan.

Proponents of EBO are well aware that past wars have typically emphasized death and destruction. They are convinced, however, that modern information technology and precision fires have dramatically altered the situation and made it unnecessary to destroy in order to save.[13] There is a great deal to be said for the argument, especially if its purpose is to force a reexamination of assumptions and strategies and to encourage more effective employment of forces than was done in Vietnam or Kosovo. Indeed, if the EBO movement should accomplish this, it will have accomplished a good deal indeed.

Nonetheless, this strong version of the argument for EBO is not persuasive as a general proposition. As they deem it necessary to avoid being defeated by precision and finesse, adversaries will adopt new tactics, such as operating in cities and urban sprawl and exploiting forests, jungles, and even mountains (where C^4ISR is often degraded by line-of-sight problems). They will adopt distributed logistical systems and systems of command and control. U.S. Marine and Army officers remain convinced from their experience and reading of trends that some operations—and perhaps the most decisive ones—will still have to be "up close and personal."

Definitions Need to Work for Both Sides

Another rejoinder to the strong argument for EBO is that a respectable definition of EBO must also apply to the adversary's actions. It is clear, however, that in conflicts such as those in Bosnia, Kosovo, and Rwanda, the purpose of ethnic-cleansing operations is often *precisely* attrition (or extermination)—not just collapsing centers of gravity. The effects sought are brutal. They can even include, for example, killing all male children who might otherwise grow up to

[13]For a clear and candid discussion of this, see Deptula (2001).

oppose the victors. To such nations or factions, then, EBO is very much about attrition and control of territory.[14,15]

Allowing Also for Virtual Wars

The next point to be made is that even if we wish to affect the decisions of the enemy's military or political leaders, and even if—in the event of real war—U.S. forces would likely be more constrained than they were in past decades, the time-honored way to affect an adversary's thinking is to convince him that his preferred course of action is infeasible and that he *must* bow to the greater power. That can sometimes be accomplished bloodlessly or by demonstrations of brutality, but the mental playing through of the *virtual war* is typically pivotal: The leader capitulates because he knows the consequences of not doing so. Modeling and analyzing that virtual war involve the old standbys of attrition, destruction, and occupation of territory.[16,17] No matter what we believe, we can hardly control the way in which our opponents conduct virtual wars.

Synthesis

As shown by the discussion above, attrition *versus* effects is a false dichotomy. EBO should be considered an expansion of, not a substitute for, operations that involve attrition, destruction, and occupation. Mindless attrition, destruction, and occupation are to be avoided, but even with the most sophisticated versions of effects-based planning, and even with the advent of precision weapons and

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[14]As one example, the Serbian police commander, Colonel-General Djordjevic, plaintively asked General Clark with respect to the Albanian KLA group, "We were within two weeks of killing them all, when you stopped us. Why did you stop us?" (Clark, 2001, p. 148).

[15]Tragically, the events of September 11, 2001, only underscore this point.

[16]The virtual-war concept was stressed by the late Albert Wohlstetter.

[17]One troublesome feature of operational concepts featuring nonlethal weapons is that they may actually undercut deterrence and compellence by suggesting to the would-be aggressor that the worst outcome will not be so terribly bad after all. A similar dilemma exists for large-city police forces. The *absence* of the nonlethal option was used to dissuade Milosevic from using allegedly civilian demonstrators to threaten U.S. troops (Clark, 2001, p. 89). See also Lambeth (2001) and Nardulli and Perry (forthcoming).

cyberwar, some traditional aspects of war will still be necessary. Moreover, independent of the attitudes of Americans, many nations will continue to pursue them ruthlessly. It requires a suspension of critical judgment to imagine that such nations (or factions within them) will be defeated by strategies optimized for flash and finesse in first operations—especially operations that avoid death and destruction.

In summary, the valid essence of EBO is its emphasis on taking a systemic view when assessing how best to accomplish objectives (i.e., to achieve the desired effects). Rapid, well-designed parallel operations can sometimes lead to decisive victories and improving related capabilities. Seeking such capabilities is an excellent focal point for new operational concepts. The extent to which attrition and occupation of territory will be necessary, however, is another issue altogether and one that should not be allowed to muddy the water. Similarly, we should not *equate* EBO with RDO, because other types of operations will often be more effective—often for adversaries and sometimes even for the United States. Moreover, RDO will often not be feasible, either for military reasons or because of political constraints that are entirely legitimate, however frustrating to warriors.[18]

As a final thought, I offer the suggestion that a portion of the work on transformation and new concepts of operations should focus on how the United States and its allies can accomplish missions when RDO is simply not possible. How would the United States refight the Vietnam War? How would the United States suppress a guerrilla movement such as the one the British dealt with in Malaya? How would the United States operate in an extended stability operation in urban sprawl? One might hope that modern technology and networked operational concepts would be useful in these situations as well, but they tend to get less attention than is directed to major theater

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[18]See, particularly, Clark (2001). As Supreme Allied Commander, Europe (SACEUR), General Clark had more than his share of frustrations during the Kosovo conflict, but he also concludes that the constraints are an inherent part of modern war—especially when the United States fights as part of a coalition of democracies.

war (MTW) scenarios or even high-end small-scale contingencies (SSCs).[19]

Despite this observation, but with the irony recognized, the rest of this monograph will focus primarily on issues for MTWs and high-end SSCs.

A SIMPLE TAXONOMY AND SOME EXAMPLES OF EBO

The discussion so far has been broad and abstract. It is useful now to move increasingly toward specifics.

A Simple Taxonomy

A starting point is the simple taxonomy suggested in Figure 2.3. Effects-based operations may be considered to have two aspects:

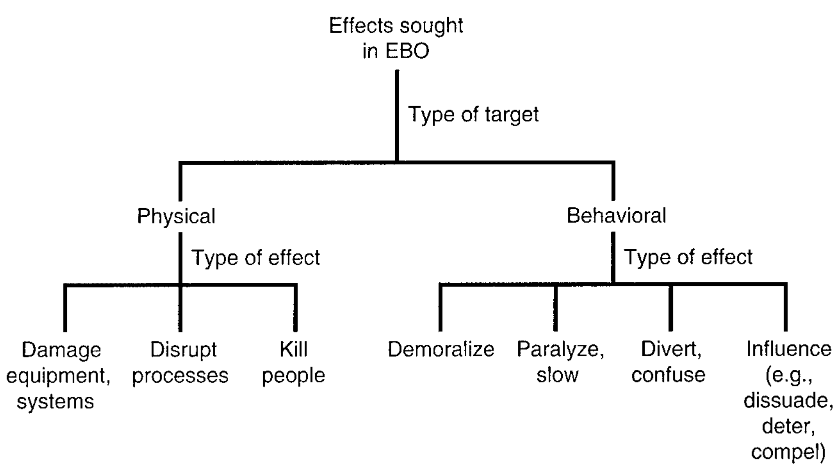

Figure 2.3—A Simple Taxonomy of Effects

[19]This was a continuing frustration of Assistant Secretary of Defense Edward Warner during the Clinton administration. He concluded that virtually all studies—regardless of how they started—tend to slip to a focus on war fighting, at the expense of learning more about how to deal with lesser contingencies (private communication, April 2001).

physical and behavioral. Physical effects sought may include disruption (e.g., delay of an army's maneuver by destroying a bridge), damage (e.g., kills of tanks or installations), and the killing of soldiers. Behavioral effects sought may be to demoralize and thereby reduce the fighting capability of military forces (or a population), to slow actions (perhaps to the point of paralysis), to confuse and deceive local and higher-level commanders (e.g., regarding the locus of an offensive), or to influence decisions—e.g., to convince, deter, or compel.

The taxonomy should be applied hierarchically. That is, the same issues and breakdown can be used when thinking at the strategic, operational, tactical, or engagement level.

Other Distinctions

Many other distinctions could be used in constructing taxonomies of various kinds. Figure 2.4 summarizes a number of them in six groups. Addressing the groups in order, the location of targets is particularly important. The most obvious distinction probably relates to networking. As has become increasingly evident in recent years—especially with the advent of ubiquitous computing, cyberwar, and terrorist organizations operating in loosely connected cells, attacking networks effectively can be very difficult if the networks lack critical nodes or if those nodes are difficult to find (Arquilla and Ronfeldt, 2001).

The second group distinguishes between open and closed target systems, according to the degree to which they are adaptive. Some systems have preprogrammed alternatives but no capacity to go beyond these. Other systems can be more creative. The third and fourth groups distinguish by time scale (both when effects occur and how long they persist). The fifth group distinguishes among levels of conflict. The last group distinguishes among the types of effects usually referred to in Air Force studies.

Examples

With this background of distinctions, what are some desired effects? Those working on such matters routinely have much more extensive

Target locations

- Colocated
  - Single
  - Multiple
    - Discrete
    - Hierarchical
    - Networked
      - Chain network
      - Star or hub network
      - All-channel network
- Separated
  - Discrete
  - Hierarchical
  - Networked
    - Chain network
    - Star or hub network
    - All-channel network

Nature of target system

- Static, closed*
  - With programmed adaptations
  - With creative adaptations
- Dynamic, open
  - With programmed adaptations
  - With creative adaptations

*A system is closed if it cannot effectively draw on outside resources to change.

Time and location of effects

- Instantaneous
  - Localized
  - Distributed
- Delayed
  - Localized
  - Distributed

Duration of effects	Level of effects	Type of effect
Permanent	Strategic	Direct physical
For course of war	Operational	Systemic
For course of operation	Tactical	Psychological and behavioral
For course of task	Engagement	

Figure 2.4—Illustrative Distinctions

lists of examples, but for the purposes of this monograph, the following serve to illuminate the scope and many of the key distinctions. These effects are concrete, real, and precedented, to emphasize that EBO is not about matters mystical:[20]

1. Destroy a functionality of a complex *facility* (e.g., the ability to generate electricity or to produce aviation fuel).

[20]Many examples are discussed in detail by Deptula (2001), Lambeth (1999), Murray (1993), Watts and Keaney (1993), Ullman and Wade (1996), Warden (1989), and Beagle (2000).

2. Reduce the functionality of a C^2 or C^4ISR *distributed network* or the crucial elements of an integrated air defense system (IADS) (as was done in the first hours of the air attack on Iraq in 1991).

3. Limit the functionality of a combat system by attacking one or more of its *critical components* (e.g., in World War II, a goal was to kill most of the Luftwaffe pilots, limiting Luftwaffe capability even if aircraft and aviation fuel were plentiful).

4. Limit combat mission capability by degrading *support operations* (e.g., destroy ammunition or POL stocks, sever lines of communication necessary for resupply, or prevent surveillance).

5. Degrade the effectiveness of enemy operations by *demoralizing* or tiring enemy personnel (e.g., soften defender infantry by massive artillery fire and bombing prior to one's own offensive into the infantry positions).

6. Degrade the effectiveness of enemy operations by *confusing and diverting enemy commanders* (e.g., with feints, such as the amphibious forces off the coast of Iraq during Desert Storm; rear-area operations, such as the partisan activities in World War II, civil war cavalry raids, or deep missions proposed for U.S. Marine and Army units; and higher-level disinformation, such as deception regarding the landing areas for Operation Overlord).

7. *Influence the decisions* of the enemy leader by making visible preparations for a large-scale ground offensive (as was arguably accomplished in the later days of the Kosovo campaign).

8. *Influence the decisions* of the enemy leader by providing him with a convenient way to protect some of his assets (e.g., as when the Iraqi Air Force flew to Iran, which served as a sanctuary during the remainder of the Gulf War, but which also removed the assets from the theater of operations).

9. *Influence the attitudes of the enemy population* to encourage a revolution or other change of power (as, for example, when Serbians removed Milosevic in the aftermath of the war over Kosovo, arguably as the result of seeing him as the one who had led the nation into ruin and who—in any case—was an obstacle to recovery from the bombing campaign and continued economic isolation).

Chapter Three

CHALLENGES IN ADDRESSING EBO

LESSONS IN HUMILITY

Thus far, I have suggested definitions and distinctions for EBO and provided a range of concrete examples. Before discussing the methods that can be brought to bear in EBO analysis, it seems appropriate to pause and ask again what is feasible and what experience tells us. This chapter reviews some relevant strategic and operational-level experiences, focusing on sobering experiences.

Strategic Misjudgments Related to Understanding and Influencing Adversaries

Some proponents of EBO establish high goals in the cognitive domain, seeking to influence the decisions of enemy political leaders, military commanders, or populations, sometimes in subtle ways. In considering these possibilities, it is well to look to everyday experience for some common-sense calibrations.

Do individuals consistently behave the same way in what appear to be the same circumstances? The answer is, No, and this appears to be a fundamental reality reproducible by psychologists (Ross and Nisbett, 1991).

Do individuals reason from a consistent mindset from one day to the next? The answer is, No, as can be seen in the detailed accounts of President Kennedy and his Executive Committee during the Cuban missile crisis (Blight and Welch, 1990; Fursenko and Naftali, 1997).

In that situation, streams of reasoning were affected by numerous factors such as the vividness of certain facts or images, the order of events, physical fatigue, and random events. Readers familiar with war games will also agree that even those artificial events can influence beliefs and leave images.

Can the best political pundits and political advisers consistently predict the effects of various tactics used by candidates? The answer is, No, as illustrated by the "invasive-of-personal-space" tactics used by presidential candidate Al Gore during the second presidential debate in 2000. Instead of coming across as being stronger, he apparently came across as being rudely aggressive (McCaleb, 2000).

Putting aside whether more detached analysts could have done better, were the highest officials of NATO, with all of their resources, able to predict correctly whether Milosevic would fold quickly after the start of bombing? The answer is, No. And according to most accounts, there was virtual consensus about the expectation that Milosevic would capitulate immediately.

Finally, the higher ambitions of EBO thinking require strategic intelligence, which is notoriously unreliable—and not for lack of effort or resources. Table 3.1 reviews some of the many failures of strategic intelligence over the past 60 years.

To add further to this catalog of misjudgments, a number of past academic studies have discussed attempts to "signal" opponents and affect their behavior. By and large, the results have been overwhelmingly negative. With the benefit of hindsight and access to primary-source materials, historians routinely discover how badly the sides in conflict have misunderstood each other and the meaning of signals (if the signals were even seen) (see, e.g., Cimbala, 1994; Jervis, Stein, and LeBow, 1985). Even in the exhaustively studied Cuban missile crisis, which featured powerful political leaders with strong supporting military and intelligence organizations, it is now believed that the favorable outcome was more tenuous than it was thought to be between 1962 and the end of the Cold War. The Soviet politburo had drawn up orders delegating authority to the military commander in Cuba to use nuclear weapons in defense if Cuba were invaded (an invasion strongly supported by some Executive Committee participants). Had the crisis not begun to defuse when it did, the Soviets

Table 3.1

Examples of Major Intelligence Failures

- The Japanese attack on Pearl Harbor[a]
- Hitler's attack of the Soviet Union[b]
- The Japanese assessment that the United States would tire of the war[c]
- Khrushchev's error in imagining that the installation of nuclear weapons in Cuba could be accomplished as a fait accompli[d]
- The light at the end of the tunnel in Vietnam
- The fall of the Shah of Iran[e]
- Saddam Hussein's invasion of Kuwait[f]
- Failure, until after the 1991 war, to detect—much less target—Saddam's extensive weapons-of-mass-destruction (WMD) program
- Ending the Gulf War with the expectation that Saddam would be toppled from within Iraq
- Slobodon Milosevic's failure to capitulate quickly

[a]With few exceptions, military and political leaders regarded such an attack as unthinkable until it occurred.

[b]Stalin had fundamentally misunderstood Hitler's intentions.

[c]The Japanese were under no illusions about their ability to defeat the United States in a long war. Their hope was to win by achieving major early victories and seeing a diminishing of American will.

[d]Khrushchev was probably correct in assuming that Kennedy would not tolerate an overt deployment, but he misjudged both the likelihood of a successful covert deployment and the consequences of the deception being uncovered.

[e]Experts believed that the Shah would retain power by unleashing naked force; as it happens, whether for reasons of failing health or other reasons, he did not do so.

[f]Official estimates completely misread Saddam's motivations and his likely reaction to the efforts that were made in the name of deterrence (Davis and Arquilla, 1991b).

would probably have delegated nuclear-use authority (which had already been agreed to), and if an invasion had been made, a large-scale nuclear war might have occurred.[1] Earlier in the crisis, it was a

[1]A detailed account of discussions on the Soviet side, including the nuclear-delegation decisions, is given in Fursenko and Naftali (1997, p. 246). For a brief time, Khrushchev was convinced that Kennedy was losing control of the government to the hardliners (p. 274), the mirror image of the U.S. concern.

close call that Kennedy chose to act on the basis of Khrushchev's first letter rather than focusing on the second letter, which was much tougher and which some interpreted as being the result of a coup.

Operational-Level Experiences: An EBO Scorecard for the Gulf War

Having demonstrated how difficult it has been in the past to understand or affect adversary leaders, let us now turn to lower-level matters more clearly in the military domain. Table 3.2 provides a scorecard for the Gulf War based largely on the Gulf War Airpower Survey (Murray, 1993; Watts and Keaney, 1993).

A fundamental problem in EBO is that in many conflicts there may be no vulnerable "centers of gravity" to attack. For example, much of the enemy's support may come from outside its own borders (as was the case in North Korea), which precludes destroying the relevant industrial base; in some wars, the enemy stocked so many supplies in forward areas that attacking its logistics structure would have been relatively ineffectual (e.g., in Iraq); in still other cases, the only targets for decisively changing the enemy's attitude were the citizens of the enemy country (e.g., in North Vietnam). Looking to the future, distributed operations will likely reduce many vulnerabilities a great deal further.[2]

WHY EBO IS DIFFICULT: IT'S THE CAS EFFECT, STUPID!

Why does the track record include so many failures or unintended consequences? The primary reason is fundamental:

- War, many contingency operations short of war, and even foreign affairs generally occur in a *complex adaptive system* (CAS), with that term to be understood in its technical sense.[3]

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[2]Similar observations were made by Watts and Keaney in the Gulf War Air Power Survey (GWAP) (Watts and Keaney, 1993, pp. 364–365).

[3]The best popular discussion of complex adaptive systems is given in Waldrop (1992), which conveys a sense of both substance and personalities. For an excellent technical discussion at the popular level, see Holland (1995). Czerwinski (1998) discusses relevance to military affairs. Lieutenant General Paul Van Riper (USMC, ret.) has described the relevance of CAS concepts widely and emphasized it in the curriculum at Quantico.

Table 3.2

Summary Effects of the Air Campaign in the Gulf War

Target Sets	Planned Effects	Results
Integrated air defenses (IADS) and airfields	Early air supremacy; suppress medium-high air defenses; contain or destroy air force.	IADS taken apart, but low-altitude antiaircraft batteries and surface-to-air missiles (SAMs) remained; Iraqi air force did not engage and eventually fled to Iran.
Naval	Attain sea control.	All Iraqi combatants neutralized, but Silkworm missiles remained active.
Leadership and C^3	Disrupt government functioning; isolate Saddam from people and troops in the Kuwait Theater of Operations (KTO).	Unknown disruption; no decapitation; telecommunications substantially reduced, but not cut.
Electricity and oil	Shut down national grid with minimal long-term damage; cut flow of fuels and lubricants to forces, with no long-term damage.	Rapid shutdown of grid; some unintended damage; degraded refining by 94%; destroyed 20% of fuels and lubricants.
WMD and SCUDs	Destroy nuclear, biological, and chemical weapons and production capability; destroy nuclear program for the long term; prevent/suppress use.	Only some chemical weapons destroyed, though use was deterred; nuclear program merely "inconvenienced"; firings of missiles somewhat suppressed.
Railroads and bridges	Cut supply lines to KTO.	All bridges destroyed, but workarounds were made; short-term effects.
Republican Guard and other ground forces in KTO	Destroy Republican Guard; reduce effectiveness by 50% before the counteroffensive (kill half the armored vehicles?).	Much less than intended effect on Republican Guard, although it was arguably "immobilized"; front-line units were either attrited to 50% or had morale severely reduced: they waited to surrender or be destroyed.

NOTE: Adapted from Watts and Keaney (1993, p. 349).

Unpredictability

A defining feature of CASs is that, at least in some domains of the variables that define their state, they behave in effectively unpredictable ways. Nevertheless, when one thinks about such systems, intuition—abetted by enthusiasm—often suggests that one's actions will "surely" have predictable, intended consequences. Perhaps this fact continues to be underappreciated, because few people routinely visit past assessments, predictions, and decisions. As a practical matter, such things may be much more useful for helping to understand systems and adapt as necessary when the time comes than for developing sound and accurate plans.

This is not a new insight. Much can be found in the writings of Clausewitz that amount to the same thing at a less technical level. It is nonetheless a lesson that must continually be relearned.

One among the many reasons for unpredictability is simply that the antagonists in war are human beings who are regularly making assessments and decisions and taking actions. The "system" that one is trying to affect is dynamic, and many of its changes are observable—if at all—only indirectly and after delays.

Mysteriousness

The developments in a CAS are often mysterious for a variety of reasons. As others have noted in this connection (e.g., McCrabb, 2001), even the very concept of cause and effect begins to break down because so much of what develops is affected not only by a particular action taken by a participant, but by numerous other factors as well. Effects, then, are often indirect and ambiguous. It may never be known, for example, precisely why Milosevic finally capitulated in the war over Kosovo.[4] More to the point, however, it is unlikely that he capitulated for any single reason. The air campaign was increasingly effective, ground forces were ominously preparing for invasion, political developments within Serbia were worrisome, and—just to highlight the role of effects we often ignore when intellectualizing and seeking rational cause-and-effect relationships—Milosevic may

[4]See Clark (2001), Hosmer (2001), and Lambeth (2001) for discussions.

have become mentally and physically fatigued after the great tensions of the prolonged affair.[5]

Another reason for the mysteriousness of developments in CASs is that they have no respect for hierarchy: Small events at a microscopic level may have major consequences at a macroscopic level. The reverse is also true, although sometimes overlooked in discussions of CAS: Words spoken by leaders and actions they take can have ripple-down effects on the behavior of individual soldiers inspired (or embittered) by the leaders and their cause. Everyone knows this, but in their yearning to discover cause-and-effect relationships, predictability, and stability, people often forget how special the circumstances are that generate such ripple-down or ripple-up effects.

As a final example to illustrate why developments are frequently mysterious, consider that the events associated with the potential playing out of a scenario may or may not occur, and even if they do, they may occur at a variety of times and in a variety of orders. Again, the phenomenon occurs at different levels of detail: The airborne unit reaches the bridge that it is to capture but arrives five minutes too late because winds came up earlier than expected and slowed the aircraft delivering it; or the order to cease combat arrives at General Andrew Jackson's headquarters, but not until after the Battle of New Orleans has already occurred; or Ambassador Primakoff convinces Saddam Hussein that U.S. airpower will be devastating, but it is now too late for Saddam to slip away.[6] In these instances, the significance of the order of events is easy to understand, but it is much less so when one considers decisionmaking. On the one hand, it is often said that once the decisionmaker reaches his decision, he can no longer be swayed by contrary argument (i.e., the first to speak to him persuasively wins). On the other hand, it is often said that decisionmakers are unreasonably affected by the last argument they hear (i.e., the *last* to speak to the decisionmaker has the better chance of winning). Finding consistent general principles is difficult.

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[5]Stress and fatigue are known to be significant contributors to behaviors in crisis and even to behaviors in everyday life, some of which appear quite out of character. George and Simmons (1994) discuss such matters in the context of deterrence.

[6]See Pape (1996) for a lengthy discussion of how compellence "almost" worked in the Gulf War.

Ultimately, students of such matters often conclude that when operating in CASs—such as the world we live in—salvation comes not so much in prediction as in adaptation.[7]

With these reminders of why one should proceed with humility, the next chapter addresses the challenges for analysis, modeling, and simulation.

[7]See Davis, Gompert, and Kugler (1996) for discussion of how this relates to higher-level defense planning.

Chapter Four

SUGGESTED PRINCIPLES FOR ANALYSIS IN THE CONTEXT OF EBO

SUGGESTED PRINCIPLES

Others are toiling on the many challenges created by interest in EBO, and I shall not attempt here to survey how they are going about planning for EBO or how they are attempting to analyze it. Nor could I do so, since some of the work is classified. Instead, my intention is to step backward from the problem and identify *principles* to guide the overall effort of adapting analysis and supporting models and simulation to the EBO challenge.

The following list of principles is not intended to be comprehensive. It is intended to highlight items that should be priority considerations but that are not as yet receiving adequate attention. For example, the list does not include the need for good information systems, good intelligence agencies, or dedicated targeting groups, since those requirements are well recognized. The principles I suggest are the following:

- Analysis in support of defense planning should embrace the paradigm of focusing on *mission-system capability.*
- Analysis dealing with EBO should confront the true extent of uncertainty and deal explicitly with probability and randomness. This is the domain of *exploratory analysis.* To do it well requires a *family of models and games.*

- Substantial effort should go into *qualitative modeling*, including cognitive modeling, but in an uncertainty-sensitive framework.
- *Empirical information*, including information obtainable from history and from a combination of gaming, man-in-the-loop simulation, and experiments in battle laboratories or the field, should be vigorously pursued.
- Modeling of military operations should be built around decisionmaking and related command and control, which essentially implies emphasis on the technology of *agent-based modeling*.

Before discussing these principles in more detail, let me note one more principle that should influence the application of nearly all the others. As highlighted in Institute for Defense Analyses (2001), it is necessary to design EBO with an emphasis on intra-operation adaptiveness and the related real-time monitoring of events. This is essential because, in practice, even the best analysis will have substantial residual uncertainties. The best way to deal with those uncertainties will be to plan for adaptation—the same principle, by the way, that should also be applied to modern defense planning[1] (Davis, Gompert, and Kugler, 1996).

MISSION-SYSTEM ANALYSIS

Characterization

Mission-system analysis (MSA) is undertaken to guide mission-system planning (MSP), the purpose of which is to develop mission-system capabilities (MSC). The first tenet of MSA is that one organizes thinking around output. Doing so in the context of military transformation means organizing around mission capabilities.[2] One can refer to aircraft, ships, and tanks as "capabilities," but the capabilities of most interest in defense planning are the capabilities to accomplish key missions—i.e., to successfully conduct operations such

[1]See Davis (1994, chs. 2–4) and Davis, Gompert, and Kugler (1996). The latter is an issue paper written to inform the 1997 Quadrennial Defense Review.

[2]I have discussed this elsewhere as planning around "operational challenges" (Davis, Gompert, Hillestad, and Johnson, 1998; Davis, 2001b). The theme also appeared in the report on conventional forces to the Secretary of Defense (Gompert, 2001).

as defeat an armored invasion, achieve control of the seas in a region, or defend against a ballistic-missile attack. Having large numbers of platforms and weapons, and even a lavish facilitating infrastructure, is not enough: What matters is whether the missions could be confidently accomplished. This is a system problem (Davis, Bigelow, and McEver, 1999).

MSA has much in common with other methods, notably the "strategies-to-tasks" approach of Glenn Kent and colleagues at RAND[3] and mission-capability packages urged by others (Alberts, Gartska, and Stein, 1999). I have chosen to introduce a new name, however, because MSA's character appears to me rather different in practice—even though the underlying philosophy is very similar. In any case, my concept of MSA construes the "system" quite broadly; emphasizes exploratory analysis under massive uncertainty with a family of models and games; and includes soft issues such as EBO, analysis of which, in my view, requires qualitative modeling (including cognitive modeling).

Overall, the purpose of MSA is to give meaning to the goal of achieving flexible, adaptive, and robust capabilities for the missions at issue. This means no-excuse, real-world capabilities, not just paper capabilities.

To elaborate, a future commander on the eve of battle will have little patience for being assured that the easily counted and measured factors are in good shape. He will be worried about *all* the factors that will determine the results of the next day's operations. Moving up the hierarchy, a future President will not be satisfied during a crisis by being told that the material factors are in line. Before deciding on a course of action, the President will want an assessment of whether the military operations being contemplated will be *successful*—with no hand-waving about the difficulty of knowing such matters. He will understand risks, and perhaps even the fog of war, but he will want assurance that the operations contemplated have been

[3]An early published reference is Warner and Kent (1984). A more recent summary is Pirnie (1996). As applied, strategies-to-tasks goes into much more detail than is indicated in the publications. Indeed, developing the hierarchies down to the task level is a substantial effort, but one that has been applied in work for the Air Force and the Army.

planned in such a way as to be very likely to succeed *despite* the problems and uncertainties. Moreover, although he may tolerate uncertainties (perhaps in the number of casualties and the extent of unintended consequences or so-called collateral damage), he will want bounds on them.

Figure 4.1 sketches the MSA process. Suppose that one wants to develop clear requirements for a particular mission and to then develop capabilities for it (shown at the left side of the figure). A variety of capability-set options are considered. The strengths and weaknesses of each option are assessed across a wide range of operating conditions (i.e., a scenario space, with *scenario* understood to include not just the political-military setting, but all of the key assumptions such

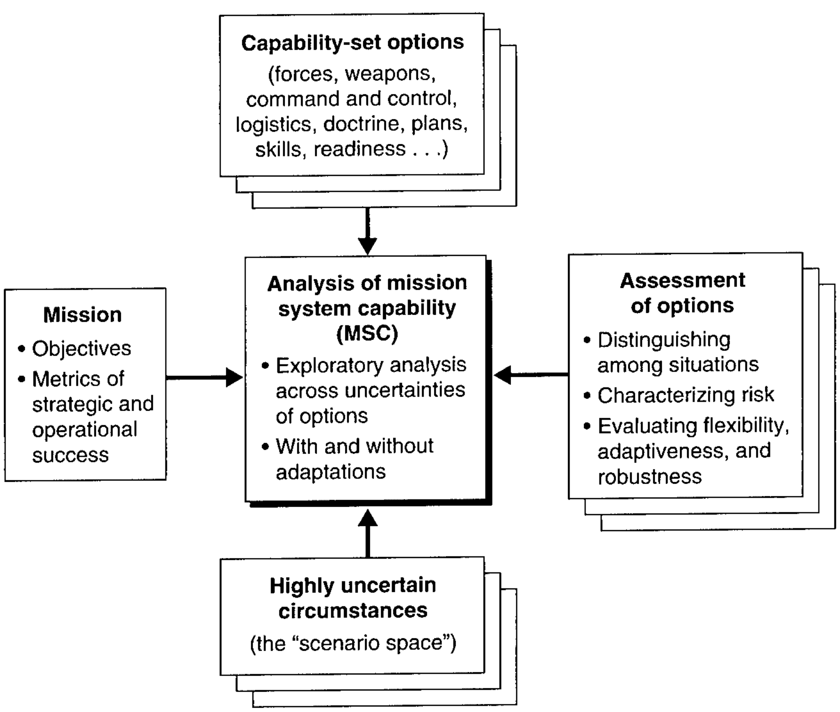


Figure 4.1—The Process of Analyzing Mission-System Capability

as warning times, force sizes, coalitions, and effectivenesses). This concept of exploratory analysis across a scenario space is fundamental to planning for adaptiveness, flexibility, and robustness. It dates back to the concept of multiscenario analysis developed in connection with the RAND Strategy Assessment System (RSAS) in the 1980s.[4]

Depicting Results of MSA

The result of MSA, then, is a characterization of how well the capability package for each option considered would fare throughout a scenario space. That is, the capabilities would be adequate in some circumstances and inadequate in others. Figure 4.2 illustrates this by summarizing the expected benefit of a new early-intervention force,

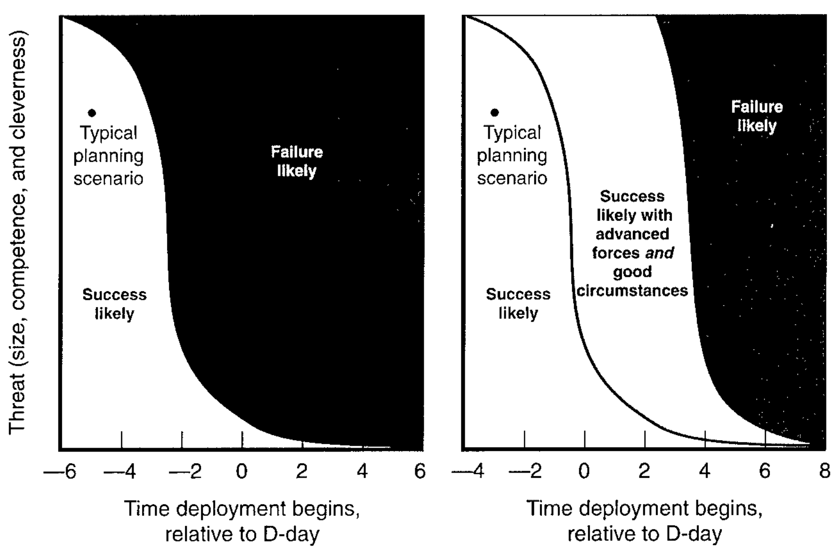


Figure 4.2—Illustrative Scenario-Space Depiction of How a Joint Strike Force Could Enhance U.S. Military Capabilities

[4]For more extensive discussions, see Davis (1994, ch. 4), Davis (2001a), and unpublished work by Davis and Hillestad (forthcoming).

sometimes called a joint strike force (JSF).[5] The benefit is not characterized as resulting in a somewhat reduced best-estimate halt distance or somewhat reduced casualties in a standard scenario, but rather as increasing substantially the range of operational circumstances in which the intervention would be successful in defeating an invasion. This is indicated visually by suggesting that much of the previously black portion of the scenario space (the portion in which an intervention would likely fail) can be turned white, or at least gray, if the United States develops the early-intervention force.

But How Much Is Enough?

Understanding the potential benefits of a new capability is one thing; deciding how much of the capability is needed is another. That is, how much of the scenario space does one wish to cover, given competing demands for available funds? Such questions should be discussed in a resource-allocation framework (Hillestad and Davis, 1998). They are outside the scope of the present monograph, except for the following observations. First, the capabilities-based planning view suggested by Figure 4.2 is very different from the one in which military forces are sized, configured, and postured around needs determined by a near-worst-case scenario and analytical methods and datasets with many built-in elements of conservatism. In the capabilities-based view, the planner wants to have a more explicit understanding—even if it is qualitative, subjective, and fuzzy—about the odds of success and the degree of risk. This view changes the way one looks at traditional issues such as the U.S. capability to fight and win two simultaneous MTWs. The strategic logic for a two-MTW capability is compelling, but it need not be translated into the requirement to maintain forces at constant readiness for an imagined version of a two-war scenario in which both enemies are substantially more powerful than they are today. Nor is it necessary to assume that the forces of those countries are as effective as the bean counts of their equipment might suggest, or that the United States would choose to fight those MTWs in a way paralleling the stereotyped attrition warfare favored in many major studies. Understanding alter-

[5]This is an adaptation of a figure in Gritton, Davis, Steeb, and Matsumura (2000). The graphs denote only a slice through scenario space, since a number of other parameters are being held constant.

natives, however, requires a style of analysis that at least *allows for* the consideration of EBO. Some examples of this are given in Chapter Five.

Highlighting the System Aspects

The "system" aspect of mission-system analysis becomes more evident with characterizations that indicate critical components of the overall capability, i.e., components whose failure will cause the system to fail (see Figure 4.3). This is *not* a standard decomposition into subordinate missions and tasks (although there may be considerable overlap); the breakdown in Figure 4.3 is organized by the purpose of the components, not by organizational considerations (i.e., Air Force, Navy, Army, and Marines), and by how critical the components are, not by a desire for logical completeness or a desire to cover all of the physical systems involved in the operation. Figure 4.3 is more like a success tree—the inverse of a fault tree (to use the terminology often associated with nuclear engineering studies).

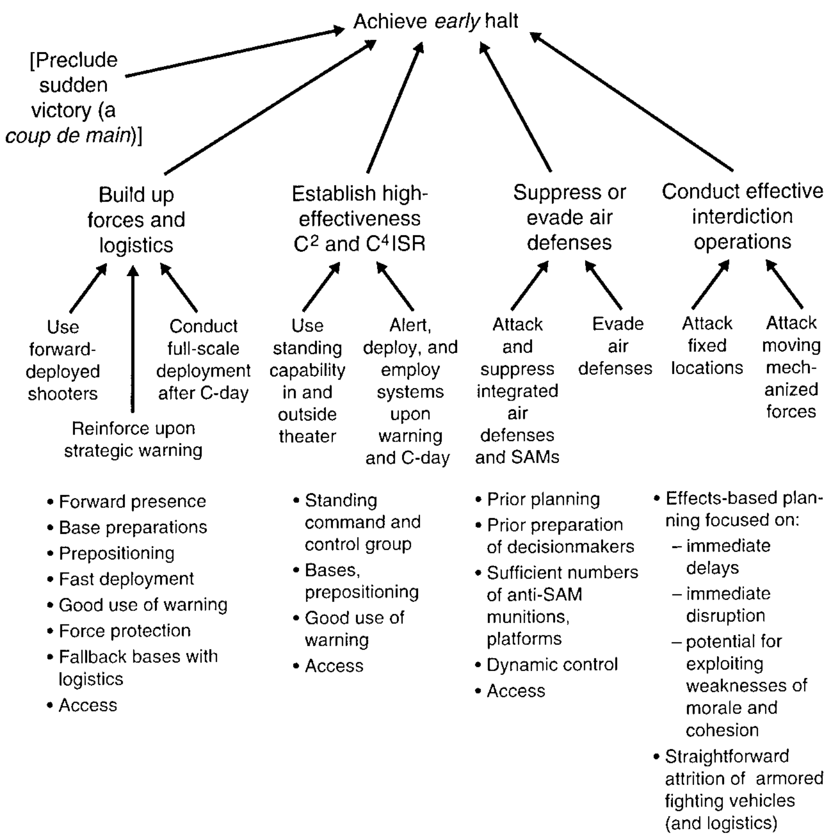
EXPLORATORY ANALYSIS TO CONFRONT UNCERTAINTY

Confronting Uncertainty

As mentioned above, exploratory analysis is a key element of MSA. Its purpose is to confront uncertainty head-on, rather than downplaying its magnitude. It is quite relevant to EBO because, however bitter the pill may be for those who ask their analysts to make predictions and cut out the complications, the uncertainty associated with EBO is fundamental and often massive. As indicated by the examples in Chapter Three, the results of an operation may even be the opposite of those intended.

Using a Family of Models and Games

Exploratory analysis requires relatively simple models with only a modest number of variables, i.e., models that have low resolution or are abstracted or aggregated. Such models are needed because more-detailed models bring the curse of dimensionality down upon



NOTE: Depicts interdiction-only case; preference is for integrated operations, including use of ground forces. Precluding a *coup de main* is not treated further here.

Figure 4.3—Critical Components of the System for the Early-Halt Mission

the analyst and prevent systematic exploration. This is not a computational issue, but something much deeper.

Simple models, however, are at best simple and at worst simplistic. MSA should therefore draw on a *family* of models, games, and empirical work to achieve a balance among breadth and depth, to assure that the phenomena at issue are understood, and to connect with the real world. Figure 4.4 indicates the strengths and weaknesses of the various members of such a family with simple analytical models indicated as being preferred for broad, agile, and flexible

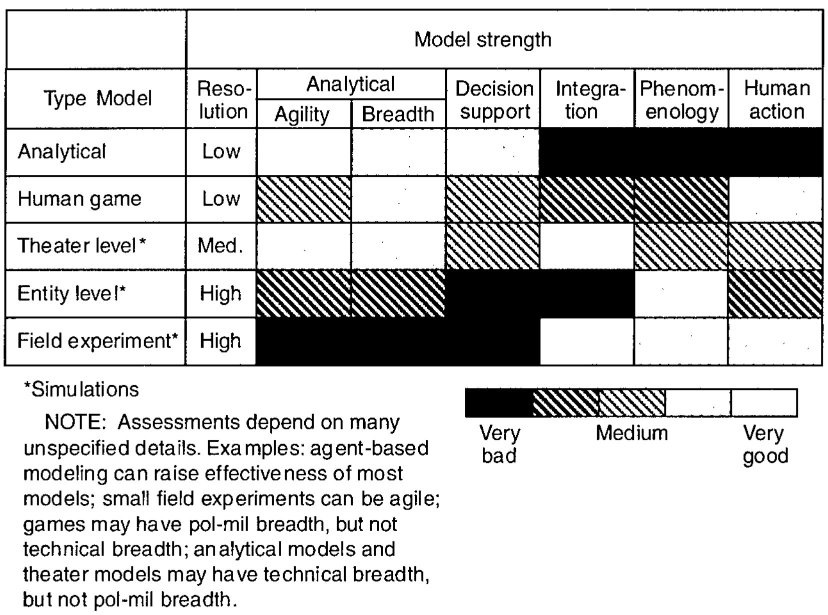


Figure 4.4—Strengths and Weaknesses of a Family of Models and Games

exploration. In contrast, human games and exercises are good for representing human actions and underlying phenomena (especially those related to command and control). How one builds and uses such a family is beyond the scope of this monograph, but work that used a combination of detailed simulation, midlevel simulation, and very simple simulation is described in Davis, Bigelow, and McEver (2001), a set of short papers. The following discussion focuses on exploratory analysis.

The Need to Address Probabilities

Fortunately, the theory and methods for exploratory analysis have advanced dramatically in recent years. They can help find ways to stack the odds favorably, although they can not *eliminate* uncertainty. Indeed, the proper language to use in discussing mission capabilities necessarily involves probabilistic considerations. An objective in planning should not be seen as assuring success, but rather as assuring as high a *likelihood* of success as possible given the circumstances.

This discussion of probabilities or odds is not as radical as it may at first appear. After all, ground-force commanders have long been taught that a 3:1 force ratio in the tactical-level attack of a prepared defense is essentially a break-even point and that to have a high probability of success with relatively small losses, something on the order of a 6:1 ratio is needed. Many attack elements—including configuration of forces, their physical capabilities, and their qualitative attributes—can be represented in some detail in a simulation.[6] A type of probabilistic reasoning was *implicitly* for many years the basis for the DoD's goal of assuring that the theater-level force ratio on NATO's central front did not exceed 1.25 (later compromised, with higher risk insured by nuclear weapons, to 1.5, and even then not achieved in the late 1970s).[7]

Discussing Probabilistic Matters Simply

Unfortunately, exploratory analysis under massive uncertainty is potentially open-ended and is inherently complex. An important challenge for analysts, then, is to reduce the fruits of such exploration to the essentials needed by decisionmakers. I shall return to this in the next section. Before that, however, it is necessary to address qualitative modeling.

QUALITATIVE MODELING

Initial Observations

MIT Professor Jay Forrester once made the wise observation that when we ignore a factor or sweep it under the rug because we don't know its value accurately or consider it "squishy," we are implicitly

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[6]For those still interested in the theory of close-combat modeling, an interesting discussion that includes comparison of Soviet and Western models can be found in chapters by me, the late Wilbur Payne, John Hines, and Reiner Huber in Huber (1990). Discussion of how the 3:1 rule (or alternatives) relates to level of conflict and command-and-control issues is given in Davis (1995).

[7]The mathematical relationship between this rule of thumb and the famous 3:1 rule is discussed in Davis (1995). For a definitive account of how such planning was accomplished in the Office of the Secretary of Defense (OSD), see Office of the Secretary of Defense (1978), written by Richard Kugler.

assuming that the factor has zero effect.[8] Such an assumption is often absurd. In the military domain, it corresponds, for example, to ignoring effects of cohesion, morale, and training when modeling ground combat. If the Israeli Army had ignored such factors, it would have preemptively surrendered to the Arab armies in 1967 and 1973. Had the British ignored such factors, they would not have been nearly so audacious in their campaign to recover the Falklands in 1982 (Smith, 1989). Fortunately, many soft factors can be reflected—at least at an aggregate level.

Some of the many possibilities for reflecting soft factors are multipliers of capability, delay terms, spinup factors, frictional coefficients, credibility coefficients, and suppression factors (see Table 4.1).

Multipliers of Capability. Example: Treat the effective force ratio in close combat as having a multiplier that reflects the ratio of the sides' fighting effectiveness for a given level of materiel and personnel.[9]

Delay Terms. Example: Assume longer times for poorer forces when going through the cycle of observation, orientation, decision, and action (OODA).[10] Example: Explicitly distinguish between the delay times assumed for traditional multilayered command-and-control systems and systems designed around network-centric principles (Alberts, Garstka, and Stein, 1999; National Research Council, 2000).

Spinup Factors. Spinup factors can be used to adjust for the fact that people and units are often much less capable at the beginning of battle than they are after some minutes, hours, days, or weeks. Example: Reserve ground forces committed to assaults on prepared defenses might be only one-third as capable when first called up as they are after 100 days of training, but comparable forces might show

[8]See Forrester (1961) and subsequent work. Forrester originated the method of system dynamics.

[9]The late Trevor N. Dupuy argued that such multipliers could often be a factor of two or more. Related "hooks" are built into some models, such as the JICM.

[10]The OODA loop plays a large role in much current discussion of EBO and information warfare. See Institute for Defense Analyses (2001) and Allen and Demchak (2001). The OODA-loop concept was introduced by the late Colonel John Boyd (USAF), who applied the ideas at many levels, including assessing the maneuverability of fighter aircraft and understanding the key features of large-scale maneuver warfare.

Table 4.1

Illustrative Methods for Reflecting Soft Factors

Factor	Example	Illustrative Magnitudes
Multipliers of capability	Multiples of force ratio for ground forces in close combat	Factors of two across different nations' armies with comparable equipment
Delay terms	Times to execute the OODA loop in dog fights; sensor-to-shooter delays for use of precision fires	Multiple seconds; tens of minutes
Spinup factors	Improvement in efficiency of use of air-to-ground aircraft	Improvement from 50% to 100% over seven days
Frictional coefficients	Movement rates predicted to accord more closely to historical experience than to a nation's ambitious plans	Factors of two or more[a]
Credibility coefficients	Weapon effectivenesses much less than projected by developers, test-range results, and unconstrained simulations	Factors of three or more[b]
Suppression factors	Multipliers of ground-force capability reducing their effectiveness for some period after heavy suppressive fires	Factors of 0.75 to 0.25[c]

[a]Many of these are already reflected in large-scale models, which have been tuned—implicitly or explicitly—to be in at least rough accord with historical experience. In some cases, the frictions are also reflected in standard doctrine. For example, large ground forces are not expected to maneuver for hundreds of kilometers per day, even though that might seem plausible from the speeds of individual vehicles. Doctrine builds in large delays for rest, food, organization, and logistics.

[b]Such multipliers are applied routinely by the Joint Staff in large studies using the TACWAR model, particularly with respect to the effectiveness of interdiction. These coefficients are typically associated nominally with a named effect (e.g., difficulty in finding the target), but they appear to be indistinguishable in effect from merely tuning down effectiveness to levels considered—very subjectively—to be credible.

[c]David Rowland and other British researchers in the Defense Research Agency (DERA), previously the Defense Operational Analysis Establishment (DOAE), have studied such issues in detail, drawing upon a mixture of historical data and field trials. They concluded that suppression has sometimes been much more effective operationally than was ever observed in field trials, even trials with live fires (Rowland, 1989).

two-thirds of their potential if they are used initially in prepared defenses of their homeland.[11] Example: Joint command and control for precision fires against an invading mechanized army on multiple roads might on D-day be only half as capable as it should be, if the war began with little or no warning. It would improve in subsequent days and weeks as C^4ISR systems filled out and personnel became more efficient, both individually and as a team.[12]

Frictional Coefficients. Frictional coefficients can be introduced to adjust various calculations so that results are in closer accord to what has been experienced historically or in experiments, or to what experts expect on the basis of general background. This is done routinely when simulation models are tweaked to be in accord with doctrine, which is informed by experience and opinion. It is also done by "slowing down attrition" in models developed bottom-up. Although the predicted attrition rates at the battalion level may be realistic, those at higher levels may be much too high without such corrections—essentially because in real conflicts, commanders change behaviors as necessary to avoid catastrophic attrition, and the models do not allow for such behaviors.

Credibility Coefficients. Credibility coefficients are similar to frictional coefficients, but what I have in mind here is that when analyzing the potential value of a new weapon system, analysts quickly discover that the new system—which exists only in the mind of the program manager—is vastly more capable than current systems, just as current systems were once predicted to be vastly more capable than they turned out to be under operational conditions. As a result, analysts may—rather arbitrarily—reduce estimates of capability. Such reductions are often not readily defensible, but they are better than uncritically accepting the nominal estimates.

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[11]Such considerations can have a dramatic effect, as demonstrated in Davis (1988), a report developed in support of the negotiations on conventional forces in Europe.

[12]This speculative effect "rings true" to many officers who have served on ad hoc command-and-control teams, but there is an obvious need to replace these speculations with measurements—as based, for example, on joint experiments that might be conducted by the U.S. Joint Forces Command (USJFCOM). The spinup time would be much less, presumably, for standing command-and-control cells—even if they are augmented and filled out at the top at the time of crisis.

Suppression Factors. Suppression factors are also multipliers of unit (or individual) capability, but they have the special characteristic of applying only for some period of time after the application of heavy suppressive fires.[13]

Adding Sophistication: Situational Dependence and Time Dependence

A primary reason for soft-factor corrections not having caught on in general analysis is that they appear to critics as numbers based on nothing and therefore numbers that could be used for mischief. An advocate of a particular weapon, for example, could claim it to be worth a factor of two more than its calculated effectiveness because of its alleged scariness.

There is basis for such concerns. The solution, however, is not to ignore the issues, but rather to sharpen the definitions and distinctions among situations, and to recognize that the factors in question will vary with time. Compare, for example, a reserve-component ground force with an active-component ground force. What should its capability multiplier be? The answer is, It depends. Major factors include

- The level of the unit (squad, platoon, company, battalion, brigade, division, corps).
- The operation in which the unit is employed (e.g., assault on a determined enemy in prepared defenses, defense in favorable terrain of the homeland, rear-area security after a breakthrough, rear-area security in one's own territory).
- Context (operations by the unit "on its own" versus operations with higher-quality forces around it; operations with or without air superiority).
- The starting quality of the unit, which is a function of leadership, training, and various social factors such as commitment.

[13]An analog here is that special-weapons-and-tactics (SWAT) and Delta teams can use stun weapons to essentially paralyze adversaries for the brief time necessary to enter a room or a hijacked airplane.

And, of course, the multiplier would change with time, measured from when the unit is called up, reasonably filled, or put into "serious" training.[14]

The point of this example is not to suggest that estimating such factors is easy, but rather to show that such estimates are both possible and better than ignoring the factors altogether. A more detailed example is given in Chapter Five.

Cognitive Models

Cognitive modeling—defined here as the modeling of reasoning and decisionmaking, rather than brain research or computer-science efforts to represent the brain—is a special type of qualitative modeling.

If a major objective of EBO is to influence the decisions of national leaders and even the behavior of their societies, cognitive modeling would appear to be quite desirable. It is not, however, straightforward. There are substantial literatures in artificial intelligence, behavioral psychology, and agent-based modeling that bear on the subject.[15]

One conclusion of that earlier work is that the appropriate structure for a top-level, reductionist summary of how human decisionmakers consider options is the one suggested in Table 4.2. This is a framework comparing courses of action by their most-likely outcome, their best-case outcome, and their worst-case outcome. It is an analytical representation of how a high-level leader in any activity might summarize the situation to his cabinet or corporate officers in moving

[14]A subtlety here is the distinction between U.S. planning factors about when units could be used and reasonable estimates of capability if the units *were* used. It may be that the U.S. Army would refuse to use a brigade- or division-size unit without something like 100 days of training. However, if U.S. forces were to engage enemy reservists who had received only ten days of recent training, what should their effectiveness be assumed to be?

[15]See, e.g., National Research Council (1997, App. J) and, for predecessor work, Davis (1989b) and Davis and Arquilla (1991a,b). The recent work of Wagenhals and Levis (2001) is also relevant, having been used recently in the Naval War College's Global War Game.

Table 4.2

Format of an Outcome Table for EBO

Option (course of action)	Most-Likely Outcome	Best-Case Outcome (upside)	Worst-Case Outcome (downside)	Context (e.g., the criticality of what is being attempted)	Net Assessment (in words that refer to the ratio of upside opportunity to downside risk)

toward a decision. If the framework were filled in, a descriptive explanation might sound something like this:

> As you can see, the staff has compared a number of equal-cost options. It appears that the first option is best overall because—although it probably will do no better than several others—it has the great virtue of having a good upside potential and not much in the way of downside risks. That is, it is the most robust of our options. If you were to read the details of the analysis, Option Two's most likely outcome is actually a bit better than Option One's, but the robustness of Option One is worth a lot.

This framework is useful at many different levels of decisionmaking and for many different purposes. It has been shown to have substantial explanatory power in understanding the reasoning of Saddam Hussein in 1991–1992, to relate well to the way in which intelligent leaders actually reason, and to be quite workable in interactive group discussions.

To illustrate the concept, consider that in the Normandy invasion General Eisenhower was willing to commit airborne forces to operations with extreme risks because the stakes were cosmic and the upside potential of the operations was very high (e.g., capturing bridges that would preclude German reserves from moving quickly against the recently landed Allied forces). In contrast, at the outset of the war against Serbia over Kosovo, a combination of high casualty aversion and political considerations caused the use of NATO ground forces to be ruled out summarily (a decision that was revisited later and might well have been reversed had Milosevic not capitulated). That is, the downside risks of any strategy involving ground forces were considered unacceptable. In both of these examples, the decisions could be explained with the concepts of Table 4.2.

As a final example, consider a natural-language discussion between General Joseph Ralston, the Vice Chairman of the Joint Chiefs of Staff, and General Wesley Clark, the SACEUR, regarding General Clark's recommended strategy for deterring Milosevic from taking further actions in Kosovo (Clark, 2001, p. 119). The discussion occurred early in the Kosovo crisis, at which time the threatened use of force by NATO proved to be successful.

> Ralston: Wes, what are we going to do if the air threat doesn't deter him?
>
> Clark: Well, it will work. I know him as well as anyone. And it gets the diplomatic leverage they need.
>
> Ralston: O.K., but let's just say it doesn't . . .

The discussion continued, Clark explained what would be necessary if the threat didn't work, and Ralston was ultimately convinced. The point of the example is that the discussion was at the level of expected outcome, best case, and worst case. Probabilities *were* being addressed, but at an abstracted level.

It is the job of analysts to do exploratory analysis with enough depth and breadth so that they can give policymakers reasonable assessments at the level of Table 4.2—and back up their analysis when it is challenged (as it should be before the simplified version of the argument is accepted). This is nontrivial, because it is easy to misestimate the elements of Table 4.2. Saddam Hussein, for example, almost surely considered upsides and downsides before invading Kuwait, but it seems likely that he believed the downside to be no worse than the United States deploying to Saudi Arabia for awhile and then leaving after the fuss died down (Davis and Arquilla, 1991b).

PURSUIT OF EMPIRICAL INFORMATION

Without elaborating, let me simply note that a *principle* of EBO-related analysis must be the vigorous pursuit of empirical information, rather than reliance on concepts, notions, and war games. It continues to be the case that only a remarkably small amount of funding is allocated to the systematic exploitation of historical experience or the experience gained in training and exercises. Also, the magnitude and scope of experiments related to future concepts of operations continues to be much less than one might expect, given their importance. To make things worse, much of the effort that goes into such experimentation often ends up being focused on high-visibility demonstrations that "must not fail." This is a chronic lament of those charged with joint or service-level experimentation.[16]

STRUCTURING MODELS AROUND COMMAND AND CONTROL

In the United States, combat models have almost always been designed around forces and combat processes, with command and control being treated—along with logistics—as a support factor. The result is that command and control tends to be given short shrift and even trivialized. There are many ways to recognize this, but one is to observe the incredible emphasis given in DoD studies on getting the time-phased force-deployment list (TPFDL) "right." Doing so is treated as a matter of getting all the data to represent "the strategy" correctly, even though the plan tends to be the first casualty of war and the purpose of such studies is supposed to be to evaluate capabilities for a wide range of future wars and circumstances. Much more important than precision of the nominal TPFDL is representing how a strategy would be changed in the light of actual (or perceived) circumstances and diverse random factors. That, however, is precisely what is *not* modeled well. The TPFDL issue is only one example of the much larger generic problem.

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[16]See National Research Council (1997) for general arguments about the need to pursue empirical (and theoretical) information. The problems of having experiments slip into demonstrations are discussed in numerous Defense Science Board reports, among others.

Human war games are much more realistic in this respect. Because they are built around players, they tend to be organized around strategy and command and control. As a result, they are often more insightful and innovative than combat models and much better for preparing for adaptiveness. They have their own problems, of course.[17]

The prescription for this state of affairs has long been evident: Organize models and simulations (or at least some of them) around command and control, and represent strategies and decisionmaking explicitly. This was a theme in the development of the RSAS in the 1980s, and major successes were achieved between 1985 and 1988.[18] This, however, occurred just before the collapse of the Soviet Union and a temporary abandonment of interest in higher-level models; cognitive models and models representing strategy were of even less interest. Although the RSAS's combat-modeling features were retained and improved upon in the form of the JICM, which is used rather extensively, many other features disappeared.

Fortunately, a number of exciting related developments have occurred. The concepts and methods for agent-based modeling have blossomed, primarily as the result of work at the Sante Fe Institute in the early 1990s. Applications exist in numerous domains, including urban transportation,[19] speculative studies of societal instabilities (Epstein and Axtell, 1996), and—in the defense domain—space systems for C^4ISR (Gonzales et al., 2001), infantry tactics (Ilachinski, 1996), and the agent-based processing of C^4ISR data collected in the search for critical mobile targets.[20]

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[17]Decisions made in games are not reliable indicators of what top leaders would do in an actual crisis. Indeed, some actions taken in games, although serious, are experimental. Also, some of the adaptations made in games would be very difficult to execute in the real world.

[18]RSAS development was sponsored by Andrew Marshall, currently the Director of Net Assessment, for reasons quite analogous to today's interest in EBO. The same office has sponsored more recent work on modeling of network-centric effects (Booz Allen Hamilton, 1999).

[19]Chris Barrett and colleagues at the Los Alamos National Laboratory.

[20]Briefing by Lane Scheiber, Institute for Defense Analyses, June 2001.

Despite these many advances, agent-based modeling of the sort my colleagues and I demonstrated in the 1980s for discussing operational, theater-level, and even strategic-level crisis and conflict has not yet reemerged. A new initiative in this domain is warranted.

Chapter Five

EXAMPLES OF HOW EBO CAN BE REPRESENTED ANALYTICALLY

Much discussion of EBO is either philosophical or anecdotal, rather than analytic. This chapter, in contrast, presents examples showing how familiar types of models can be adapted and used for EBO. The examples have an operational flavor, but they relate directly to force planning and decisions about military strategy in a given region. My hope is that they are sufficiently concrete to leave the reader with no doubt that the ideas can be applied.

A BASELINE PROBLEM AND ANALYSIS

The Baseline Halt Problem

A well-studied problem in modern defense planning is that of stopping an invading army through the use of long-range fires and, if necessary, ground forces. The now-classic version of this is called the *halt problem*. It is usually addressed with a straightforward attrition model that assumes that the invader will halt when some fraction of its armored fighting vehicles are destroyed. That fraction is called the break point. This model is useful for capabilities analysis because it addresses generic issues rather than being caught up in the myriad details of a specific scenario. Further, it can reflect effects of forward presence, deployments, sortie rates, and per-sortie effectiveness (and it can do the same for missile parameters).[1] Much of

[1]The original reference is Bowie, Frostic, et al. (1993). See Ochmanek, Harshberger, Thaler, and Kent (1998) for a clear and more recent description.

the emphasis in recent work of this type is on assessing implications of an adversary's possible anti-access strategies—i.e., strategies designed to delay and limit U.S. projection forces and their effectiveness.[2] Limitations of long-range fires in mixed terrain, limitations due to command-and-control issues, maneuver tactics, weapon footprint, and other factors are discussed in detail elsewhere.[3]

This said, a serious problem with most of the analyses—especially official analyses—is that they ignore qualitative (i.e., soft) factors, which are often at the core of real-world operations. The impact of such omissions is pernicious. In particular, analyses often conclude that there is little or no hope for an early halt, and as a result, objectives are weakened. In many specific contexts, however, an early halt is definitely the appropriate objective, since it is the only achievable objective: Kuwait City is within 100 km of the Iraqi border; Seoul is even closer to the border with North Korea.

Analyses often end up focusing on halt distances of 300 km or more because the capabilities needed for a much earlier halt appear insurmountable in the usual models. It is a matter of simple arithmetic: Suppose the invader has 7,000 armored fighting vehicles (AFVs)—perhaps about ten divisions—and moves at 70 km/day until it reaches its objective or suffers 50 percent losses overall. Suppose the defender is unable to attack the invasion force for two days while air defenses are suppressed, but that it thereafter can bring 300 aircraft to bear, each flying two antiarmor sorties per day and killing two AFVs per sortie. It will then take about three days after air defenses are suppressed, or five days total, to bring about a halt (by killing about half of the 3,500 AFVs). The result is a halt distance of about 70×5, or 350 km.

Figure 5.1 shows results from such an analysis, but one that includes additional factors. Because of continuing deployments, if Blue has 300 shooters on D-day, it can bring about a halt at a distance of about 310 km (rather than the 350 calculated above).[4]

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[2]Davis, McEver, and Wilson (2001).

[3]Davis, Bigelow, and McEver (2001).

[4]Figure 5.1 and subsequent figures in this chapter are based on calculations using the EXHALT-CF model (Davis, McEver, and Wilson, 2001).

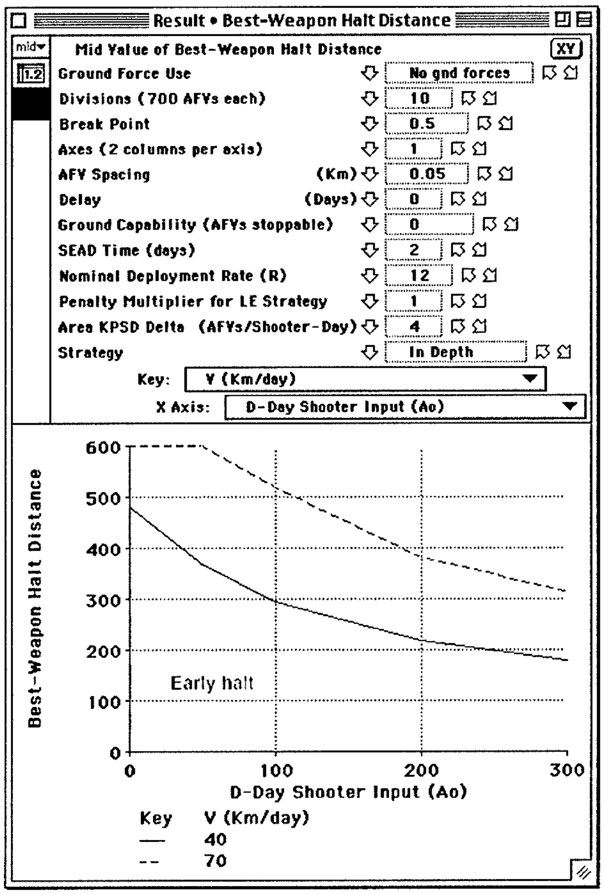

Figure 5.1—Baseline Halt Distances Tend to Be Large

Where did these inputs come from? They are merely illustrative, but the threat might be a projection of what Iraq could pose if sanctions were lifted and it rebuilt its army. The break point of 0.5 and the movement rate of 70 km/day are commonly used in theater-level models, although not because anyone believes they are accurate or reliable.[5]

An Innovative Operational Concept

A few years ago it was suggested that better results for interdiction could be obtained with an innovative operational concept in which the defender used a "leading-edge strategy," with all of the interdictors focusing on the nose of the advancing column.[6] This would reduce the daily advance by a distance equal to the length of the column killed by the interdictors. The consequences could be substantial. Figure 5.2 shows the effect of reducing halt distance by 150 to 300 km, depending on the number of D-day shooters.

To understand this result, assume that the attack moves unabated for 140 km during the two-day suppression-of-enemy-air-defenses (SEAD) period. On the next day, however, because the attacker has a large spacing between his AFVs, Blue has 324 shooters killing only two AFVs each.[7] If units on the nose collapse when the break point of 0.5 is reached, then Blue effectively kills roughly 1,300 AFVs per day. To attack the entire nose of the advance, Blue must spread its attack across two columns because they are essentially independent. Thus, taking into account the separation of AFVs and the break point, Blue will disable roughly 1,300 × 0.1 × 0.5 kilometers of column each day. The result is that Blue slows Red by about 65 km/day, to 5 km/day. Blue will achieve 50 percent overall attrition in roughly 3,500/1,300, or 2.7, days, in which case Red will advance about 15 km more after SEAD is complete, for a total of about 160 km, as shown in Figure 5.2.

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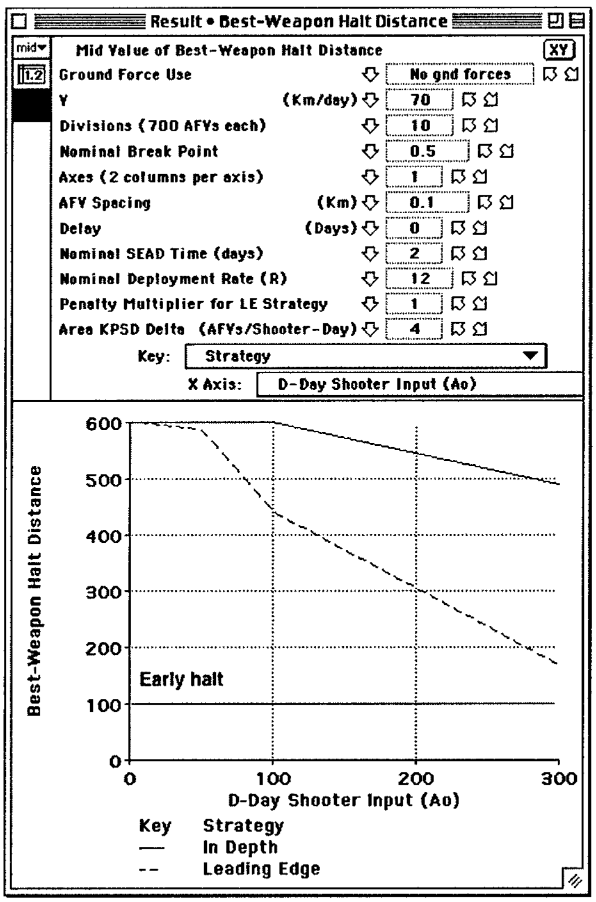
[5]See, for example, Bennett et al. (1988), and Ochmanek, Harshberger, Thaler, and Kent (1998).

[6]This was suggested by Lieutenant General Glenn Kent (USAF, ret.). See Ochmanek et al. (1998).

[7]The variable indicated in Figure 5.2 and subsequent figures as Area KPSD Delta is the *nominal* kills per shooter day for area weapons. That is input. However, if the attacker's AFVs are more widely separated than nominal, the model adjusts the actual kill in proportion to the ratio of a nominal spacing, 0.050 km, and the actual spacing.

Enemy Counteractions

Unfortunately, the outcome of the postulated leading-edge strategy depends on the enemy's maneuver choices (Davis and Carrillo, 1997; Ochmanek, Harshberger, Thaler, and Kent, 1998). This can be seen more clearly if the above logic is written out mathematically.



Note: Area KPSD Delta is the nominal value; the actual value is scaled as 0.050/AFV spacing

Figure 5.2—Effects of a Leading-Edge Strategy (First Look)

The leading-edge strategy creates a slowing effect proportional to the daily column-killing potential of the interdictors divided by the number of independent invading columns. The net speed is then given by

$$V_{net} = V_0 - \frac{KP}{(Axes)(Columns\ per\ axis)},$$

with the slowing effect (the second term) diluted as the attacker increases the number of axes of approach and the number of columns per axis.

This could be embellished by considering the dispersion along the line of advance—i.e., the distance between AFVs, L—and by recognizing that area weapons such as Skeets might kill AFVs in proportion to the density of vehicles (i.e., as 1/L), whereas point weapons such as Mavericks would be unaffected by L. If L_0 represents the spacing assumed in the baseline estimate of kill potential, then

$$V_{net} = V_0 - \frac{(KP_{base})}{(Axes)(Columns\ per\ axis)} \quad \text{for area weapons}$$

$$V_{net} = V_0 - \frac{(KP_{base})(L/L_0)}{(Axes)(Columns\ per\ axis)} \quad \text{for point weapons}$$

That is, if the interdictor is using area weapons, as the attacker disperses, the kills per sortie drops but the length of the column killed per AFV killed rises. The effects on slowing cancel each other. In contrast, for point weapons, increased dispersion has the net effect of increasing kill potential.

The kill potential can be estimated as

$$KP = \frac{(A)(S)(K)(L)}{(H)},$$

where A is the number of equivalent aircraft, S is the number of sorties per day, K is the number of AFVs killed per sortie, L is the distance between AFVs, and H is the break point—i.e., the fractional attrition at which a unit at the head of the march is assumed to collapse.

Putting these things together, for area weapons

$$V_{net} = V_0 - \frac{(A)(S)(K)L}{(Axes)(Columns\ per\ axis)L_0H}$$

Finally, the leading-edge strategy might be less efficient in terms of kills per sortie—perhaps because of problems related to deconfliction of aircraft (and missiles) in a relatively limited battle space or because of greater problems with air defenses due to the increased predictability of where shooters would appear. That could be treated as a multiplier, M, resulting in

$$V_{net} = V_0 - \frac{(A)(S)(M)(K)L}{(Axes)(Columns\ per\ axis)L_0H}$$

Figure 5.3 illustrates the implications for attacks occurring on 1, 2, or 4 axes of advance, each with two columns. In this case, the advantage of the leading-edge strategy largely goes away. The result for four axes is only a bit better than that achieved by the in-depth strategy shown in Figure 5.1. If a penalty for the leading-edge strategy is assumed, the advantage disappears entirely.

Over the past several years, considerations such as this have diminished substantially the credibility of the leading-edge strategy, at least in theaters where multiple axes of advance are plausible.[8] It appears that an apparently good idea has just not proved out.

RETHINKING FROM AN EFFECTS-BASED PERSPECTIVE

Questioning the Assumptions

Suppose that we now reexamine the issue from the imagined perspective of a commander stubbornly using an effects-based philoso-

[8]It was argued that advancing on multiple axes would mean using secondary roads and a major reduction of average speed (Ochmanek, Harshberger, Thaler, and Kent, 1998), but these arguments are not persuasive, at least not in the case of the Persian Gulf. Related arguments will be used later in this chapter, however.

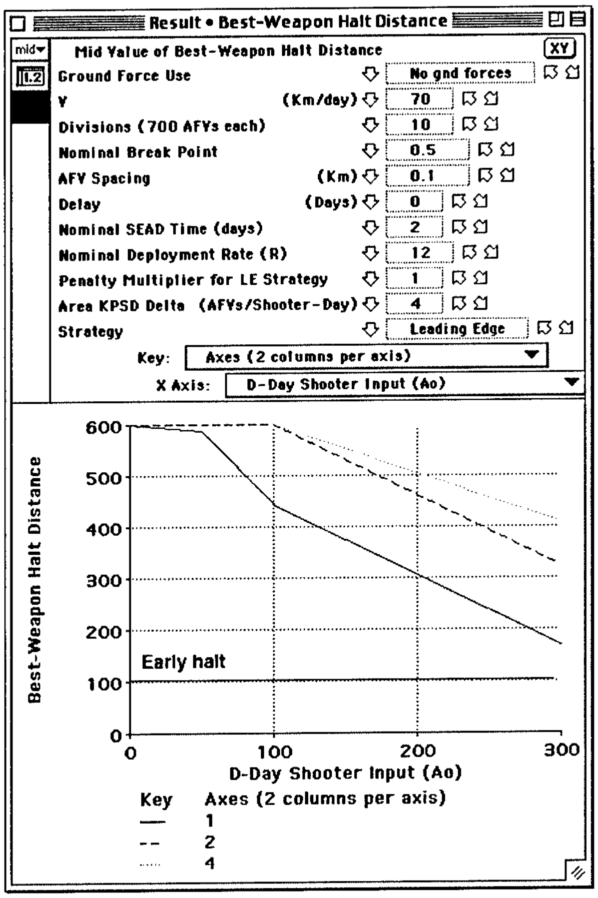


Figure 5.3—The Leading-Edge Strategy Appears to Fail if the Enemy Attacks on Multiple Axes

phy (as commanders are wont to do). Such a commander might drastically alter the analysis. In particular, he might ask:

> Where did the crazy number of 0.5 for break point come from? We're not fighting a highly motivated, cohesive, first-rate army defending its homeland; we're attacking columns of poorly motivated and mediocre forces, including a good

> many reservists, who have been ordered to invade another country in the teeth of opposition by the United States. Remember what Iraqi tank crews learned in Desert Storm: that it was suicide to stay in the tanks!
>
> And besides, why should there be a penalty for the leading-edge attack? Forces at the front of the advance ought to be particularly easy to find and track. As for air defenses, it's not evident to me that they would be able to keep up and cover the forward forces as well as those in the rear. Besides, we will be using standoff weapons, and in any case, we could focus our anti-SAM assets on a smaller area.

Some of us have asked similar questions over the years in analysis undertaken for defense planning, but the weight of official opinion has been that conservative assumptions should be used. The price of that hidden conservatism is illustrated below.

Figure 5.4 shows the results of assuming a break point half of that in the baseline and of assuming no penalty for use of the leading-edge strategy. Results are appreciably improved over those in Figure 5.3—by about 100 to 200 km—for both strategies. The results are still not good enough to achieve an early halt, however.

The Potential for Early Strikes Imposing Delays

The skeptical commander thinking about EBO might also ask what could be accomplished with strikes focused on disrupting the movement. This could be manifested in a reduced overall movement rate, delays at the outset of movement, or both. Suppose that strikes are assumed to cause a delay in initial movement. For example, strikes on bridges, tunnels, or other choke points might be able to buy some time. Or, in an ideal situation, interdiction might begin early enough to catch the attacker in assembly areas. Figure 5.5 shows the benefits of a two-day delay caused by some combination of such effects. The goal of an early halt has now become plausible—assuming a substantial number of D-day shooters.[9]

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[9]Here it is assumed that the strikes could be made even before air defenses had been suppressed. This might be accomplished, for example, by long-range missiles or stealthy bombers with minimal accompaniment.

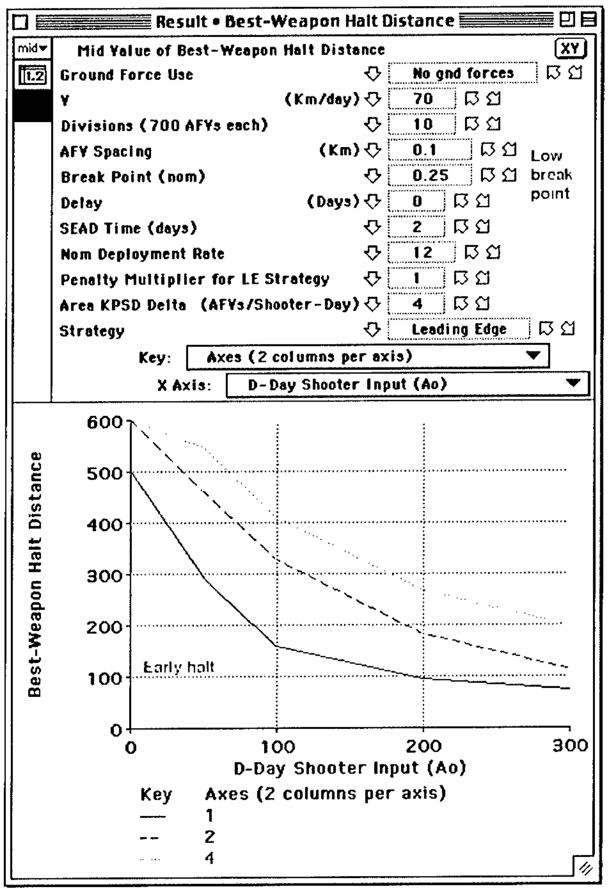

Figure 5.4—Effects of a More Modest Break Point

Roughly speaking, these results come about because (1) the postulated delay compensates for the time required for initial SEAD operations and (2) the reduced break point drastically changes the stopping requirement. Slowing the movement rate would have similar effects. Even better results can be obtained by assuming a higher per-sortie effectiveness, slower movement rate, smaller attacking force, or shorter SEAD time. In a fuller exploratory analysis, all of this

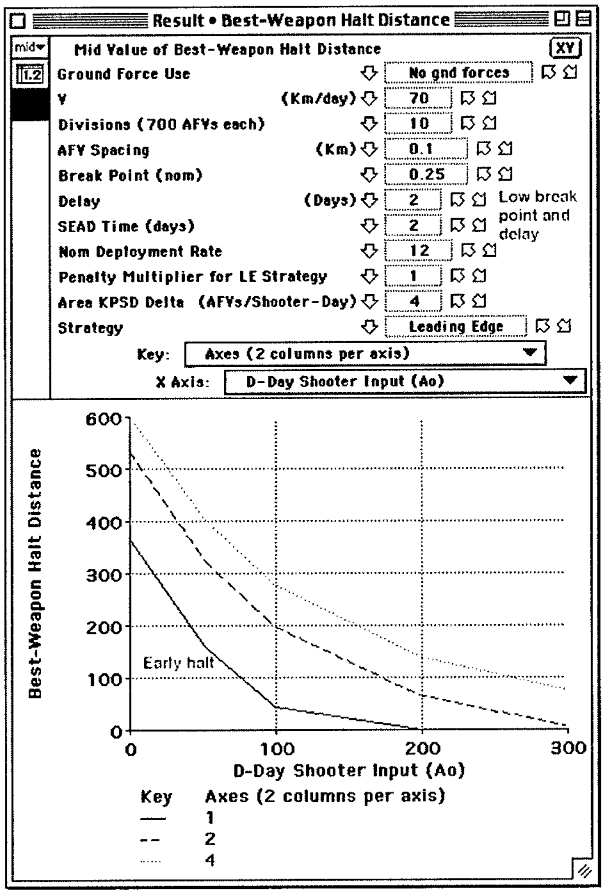

Figure 5.5—Achieving an Early Halt Is Possible with More-Realistic Assumptions

would be displayed, but it is unnecessary to go into such detail here. Figure 5.6, however, does show one more element of the story: If the attacker is unable to maintain the 100-m spacing between AFVs—especially toward the head of columns—results improve further and an early halt becomes feasible even with relatively few D-day shooters.

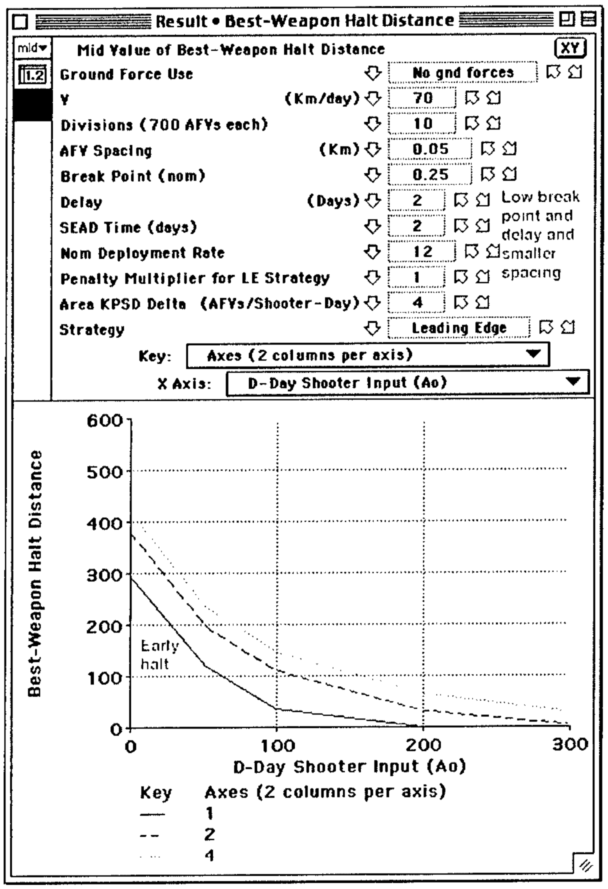

Figure 5.6—Outcomes with a Lower Break Point, a Two-Day Delay, and Smaller AFV Spacing

Defeating the Enemy Piecemeal

The results in Figures 5.5 and 5.6 are good, but they could be better yet. The commander might also take the view that if the attacker were to proceed along multiple axes of advance, some of them would likely be more circuitous (and perhaps also slower because of the need to use secondary or tertiary roads). Thus, in an effects-based perspective, he might choose to attack the most important axis or axes of advance first, achieve a halt, and then move on to the others. Mathematically, this might not seem to make sense because the forces on the first axes would then be given a free ride and could start up again. The commander, however, might reason that once they were stopped due to massive interdiction, those forces would not be able to pull themselves together quickly and charge ahead—especially since they would not know whether they would again be placed under fire.

If the commander's concept were followed, even a four-axis attack might well be stopped within a few days. If a delay had been accomplished comparable to the SEAD time, the advance might be halted within a day or so of its beginning. Without belaboring the details, since they would be highly context-dependent anyway, the results shown in Figure 5.6 for two axes of advance might be rather descriptive if the four-axis attack could be dealt with in two phases.

Considering the Upside and the Downside

This is all very fine, the skeptic might say, but suppose the break points or movement rates were *higher* than expected? Or suppose the initial SEAD operations take longer than the two days indicated. And so on. The preceding discussion has focused on the positive, but uncertainties work in both directions.

The answer to the skeptic is that *if* the leading-edge strategy (and possibly a sequential strategy) could be adopted without significantly reducing the performance of interdictors, the commander would be in the situation of having a very good upside potential and only a modest downside potential. If the approach does not pay off, so be it; but the outcome will not be much or any worse than it would be with the baseline. On the contrary, if the invaders are not heroes, and if the word gets around quickly about what is happening to the lead units, the victory might be quick and decisive, with the enemy advancing only a short distance.

The generic principle—for both commanders and analysts assessing capabilities—is that focusing on the "best estimate" assumptions is a serious mistake. One should, at a minimum, consider both the upside and downside potentials of different strategies. That is, one should view the problem probabilistically before making decisions. Doing so does not require stochastic models, although having them could be useful. It merely requires addressing different sets of assumptions characterized by nonstandard assumptions about soft factors and indirect effects. Historically, commanders have often done this, but analysts and—more important—the bureaucratic organizations of which they are a part have generally refused to do so out of a misguided sense about what constitutes prudent conservatism. It is *not* conservative to abandon a potentially winning strategy because it "might" not work. One *must* consider upside and downside.

Another aspect of this principle is that those promoting EBO must understand that the effects they speculate about can seldom be counted upon. Related operational concepts will often not do well when competing on the basis of conservative analyses alone. Thus, proponents need to emphasize the uncertainty analysis.

The ideal situation, then, is to do the EBO-related analysis and discover that there is a very high upside, not much of a downside risk, and every reason, therefore, to make the effort to achieve the rapid and decisive results.

The Non-Ideal Case: Thinking About Early Use of Ground Forces

Let us next consider a more difficult case in which choices are not so easy. The original problem can be embellished by assuming that the commander has the option of employing an elite group of ground forces, which will take up positions at a defense line (and perhaps engage in a number of deeper operations to harass and disrupt the attacker's movement). These might be part of a rapidly employable joint task force, i.e., a JSF. The equivalent of one or two brigades of such Marine and Army forces could be employed within the first week after a decision is made, using a combination of airlift, amphibious ships, and prepositioning ships.[10] The application might be

[10]See Gritton, Davis, Steeb, and Matsumura (2000) and Defense Science Board (1998). McCarthy (2001) includes a recommendation for something quite similar to the early-intervention force described here.

any of a number of conflicts, including a Kosovo-type crisis, but with authorities willing to use ground forces to stop the killing quickly; or it might be to a defend-Kuwait scenario in the future, after sanctions have been lifted.

Being able to employ such a JSF could have major advantages. First and foremost, deployment of a JSF with its ground forces would likely have a very strong deterrent effect in many crises: Hopes of a fait accompli would be dashed, and invasion would mean the certainty of war with the United States. A second major advantage is that such ground forces might be able to (1) materially improve the effectiveness of allied ground forces, (2) provide deep reconnaissance to assist long-range fires, (3) harass invading forces enough to greatly slow their movement rate, and (4) hold a defense line forward of the most important objectives. All of this, however, would depend upon the attacker's numbers being substantially reduced by long-range fires before being able to engage the outnumbered ground forces directly.

The first problem, of course, is that the deterrent action may fail. Trip wires do get tripped and the result can be catastrophic for those who have been exposed. No commander would commit small ground forces without deep soul-searching.

A second problem is that commanders do not *know* when D-day will occur. War games and studies often have a well-defined time line associated with strategic warning, unambiguous warning, the decision for full-scale deployment, and the start of war itself. However, if an invasion occurs sooner than expected, deploying forces may be engaged before they are properly prepared. In what follows, it is assumed that warning is sufficient so that this is not a problem (if warning were short, the United States would also be much less likely to have many shooters present and ready on D-day).

The third problem is the one relevant to the present discussion: How confident could the commander be that long-range fires would provide the requisite effects to enable a small and badly outnumbered ground force to succeed?

Analysis can help considerably, but at this point it becomes essential to deal more explicitly with uncertainties and probabilities. Let us now rework the previous analysis, but with several changes. First, we assume that ground forces can be prepared at a defense line by D-day. Second, we treat SEAD time, kills per sortie (or shot), and break point as highly uncertain by representing them in the models with probability distributions. For simplicity, we use triangular distributions, such as that illustrated in Figure 5.7 for the break point. For the case in which the nominal break point is 0.25, break points from 0.125 to 0.375 are considered to be plausible—with probability densities as indicated in between.

The result is that we can now estimate the odds of different outcomes.[11] Figure 5.8 illustrates this by showing the cumulative probability distribution of halt distances. The graph on the left-hand side assumes ten divisions as in the earlier examples, but only 100 D-day shooters. Even though a delay of two days is assumed, along with the break point having a most likely value of 0.25, the results are not encouraging when viewed probabilistically. Although the halt would occur at the defense line about half of the time, the ground

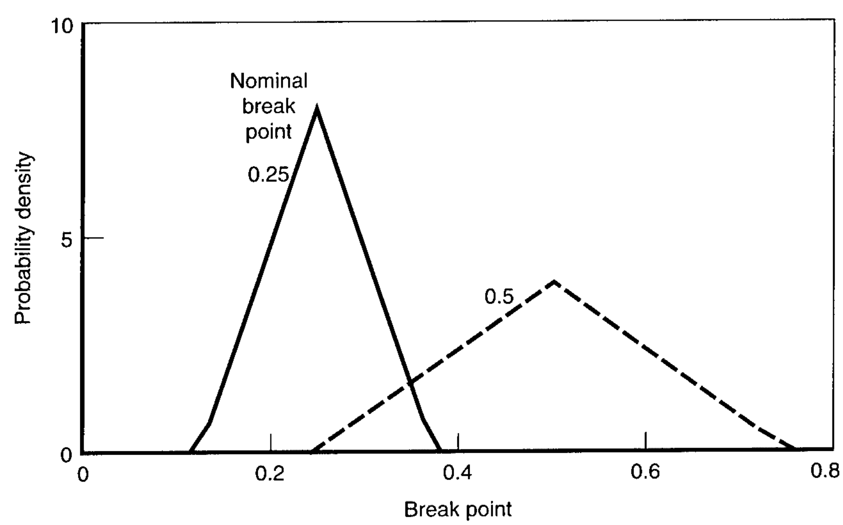

Figure 5.7—Distribution Function for the Break Point

[11]This is accomplished in the stochastic version of the model by using Monte Carlo methods to sample the distributions.

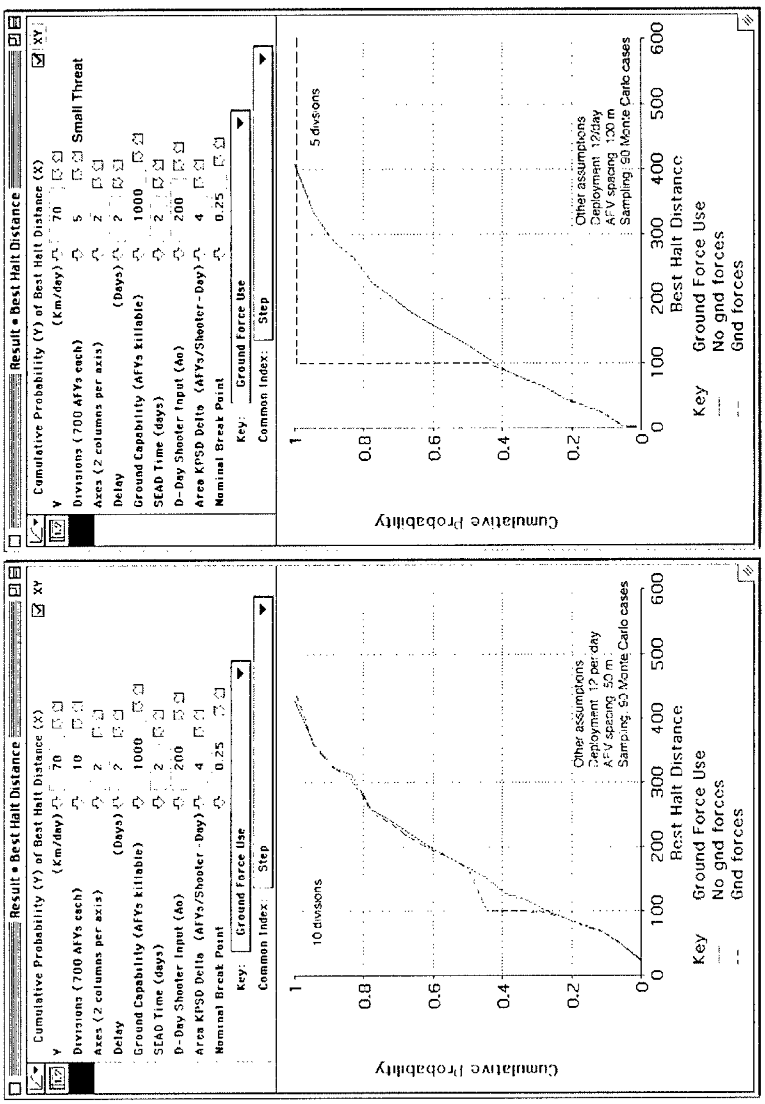

Figure 5.8—Cumulative Probabilities of Different Halt Distances

forces would be used the other half of the time. The precise numbers are unimportant here. What matters is that—in contrast to the earlier example—our imagined commander would be in a quandary. By taking an aggressive effects-based approach that includes ground forces, he might well succeed, but the risks would be very high. That is, both upside potential and downside risks are high. Unless the mission of defending forward were extremely important, he might decide to rely on interdiction alone. Alternatively, he might consider a deeper defense line with larger ground forces or various ways to further improve the effectiveness of interdiction. Actually, there are many possibilities, since it is plausible that the number of shooters in the theater on D-day would be much larger (e.g., 300 rather than 100) and that the kills per sortie (or missile shot) could be much higher than is assumed in our examples. Further, the most critical aspects of SEAD might be accomplished on the first day if appropriate capabilities are in place. And, of course, it is possible that allied ground forces could further delay the attacker's advance.

Perhaps more relevant to the defense-planning problem, however, is the situation depicted by the graph on the right-hand side of Figure 5.8. Here it is assumed that the threat consists of only five, rather than ten, divisions. Although that might appear to be an outrageously optimistic assumption to those familiar with defense planning focused on greater-than-expected threats or even worst-case threats, it is actually a very interesting case for the purpose of evaluating a small, special-purpose capability such as a JSF. It might apply to today's Iraq, to a future Kosovo, or to a number of other circumstances.

Such small-threat cases also are quite interesting when the problem is considered not as a classic halt problem conceived for the purpose of force sizing, but rather as a countermaneuver problem such as might occur in smaller-scale contingencies in a variety of theaters and circumstances. In any case, the odds look very different in this case. If the commander uses ground forces, bringing about a halt at the defense line of 100 km is very likely, whereas if he does not use ground forces, the advance may be significantly greater. More important (especially since such calculations can be considered as no more than approximate), it appears that the ground forces could be used with very reasonable risks. The upside here would be not the halt distance per se, but rather the ability to avoid war altogether by inserting the ground forces to deter the invasion and strengthen the defender.

QUALITATIVE MODELING

Some Speculations Based on History

To complete this example, let us now look more deeply at how we might reason about the break point itself. This was a critical factor in the foregoing analysis, but break point was treated merely as a parameter. Can we do better? The answer is, Yes.

Despite the central role they play in combat models, break points have not been discussed much, either theoretically or empirically. One relatively recent reference is Lawrence (1997), which was based on work by Trevor N. Dupuy for the Army's Concepts Analysis Agency.[12] In an extensive study of battles from World War II and the Arab-Israeli wars, Dupuy found the results shown in Table 5.1 for when a side quit battle, expressed as a level of casualties.[13] The median battle studied involved 22,000 versus 12,000 personnel, and about 360 versus 260 armored vehicles (McQuie, 1987, p. 32).

Table 5.1

Historical Casualty Levels at the Time a Side Quit Battle (percentage)

Cases	Median	Range
World War II defender quits	9	1–100
Arab-Israeli wars defender quits	6	0–33
WW II attacker quits	4	1–23
Arab-Israeli wars attacker quits	3	2–7

[12]Lawrence cites Dupuy's book *Understanding Defeat*, p. 210.

[13]The Lawrence article is ambiguous as to which numbers pertain to attackers and which pertain to defenders (the text appears to contradict a figure). I have used the data in his figure, which agrees with numbers cited in McQuie (1987). McQuie worked with Dupuy on these matters at the Concepts Analysis Agency.

Casualty rates do not translate readily into equipment loss rates, especially for infantry battles. For the Arab-Israeli wars, however, loss rates for armored vehicles were about five times times greater than casualty rates (Dupuy, 1979). Thus, the median break point was about a 15 percent loss rate for an attacker. The range of casualty rates was enormous, however, so the median by itself is not necessarily very significant. Still, considering the attacker in the Arab-Israeli wars and again applying the factor-of-five correction to map casualty rates into equipment loss rates, the upper limit becomes 35 percent—far below the 50 percent commonly assumed in models and war games.

The actual reasons for a side to terminate battle were seldom the extent of attrition or losses suffered (Dupuy, 1979, 1987).[14] The dominant factor was maneuver—as when a defender found himself seriously outflanked and therefore withdrew—tightening his lines in the process. It might reasonably be argued, however, that such decisions to withdraw were based on the mental projection of grievous losses in the absence of withdrawal. That is, the *prospect* of attrition was probably an important factor, even if an indirect one. Here again, we encounter the role of analyzing the virtual battle or virtual war. Even those advocates of EBO who abhor quantitative model-based analysis should realize that such analyses of virtual battles are highly relevant to understanding the cognitive processes of adversaries.

What Might a Qualitative Model Look Like?

We now move from mere data collection, as in Table 5.1, to developing a qualitative model of break points. Doing so is beyond the scope of this monograph, but the form such a model might take in the context of combat modeling can at least be illustrated.[15] Table 5.2 presents a simple version that might be used in a summary for decisionmakers.

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[14]See also Speight and Rowland (1999).

[15]Qualitative factors can be captured in other ways, each with its own advantages. As examples, Lofdahl (2001) uses systems dynamics; Bennett (1995) uses hyper games; Howard (1999) uses drama theory; and Wagenhals and Levis (2001) uses influence nets.

Table 5.2

A Simple Qualitative Model for Estimating Break Points Probabilistically

			Predicted Break Point[c]		
Quality of Attacking Units[a]	Motivation	Perceived Logic of Continuing[b]	Min.	Most Likely	Max.
Very good	Very good (to point of zealotry)	Irrelevant	0.5	0.75	1
Very good	**Good**	**>=Marginal**	**0.25**	**0.5**	**0.75**
Very good	Good	Bad or very bad	0.125	0.25	0.375
Very good	<Good	<=Bad	0.05	0.1	0.2
Continued, for many other cases not treated explicitly here					

[a]Values of very bad, bad, marginal, good, and very good, treated in ascending order of goodness.

[b]A >X sign indicates that the value in question can be anything larger (better) than X.

[c]Fractional losses of AFVs at which the unit will disintegrate, as represented by a triangular probability distribution function with minimum, most-likely (modal), and maximum values as shown.

The table focuses on three key variables, which theory might suggest would dominate the determination of break point: the quality of the attacking units, their motivation, and the degree to which they see (or sense) their prospects for survival being better if they break off combat—either by delaying operations, deserting, or putting up only a token fight and surrendering at the first opportunity. These variables are not arbitrary; rather, they are the top-level considerations that might be used by a commander. As is often the case, history helps in identifying such considerations. Real-world commanders have paid close attention to intelligence reports on the quality of the enemy forces and their apparent morale. Moreover, they have frequently paid implicit attention to the possibility that the enemy might decide to break off combat. In maneuver warfare, for example, the commander's objective may be to outflank the enemy so that the enemy commander will see no alternative but to break off battle and strike a retreat, giving up territory. Alternatively, the attacking commander's objective may be to encircle the enemy to prevent such a retreat and place the enemy commander in an untenable situation that will likely motivate surrender. These are surely EBO. Attrition is important, but it is the virtual attrition (in the battles that need not be fought) that drives the decisions.

From the perspective of lower-level officers and personnel, this assessment variable would be interpreted somewhat differently, but again there are many historical precedents. Interviews of prisoners after the Gulf War, for example, revealed that some Iraqi officers chose not to use chemical weapons because they saw any such use as suicidal; and it is known that units did indeed choose to surrender at the first opportunity. When deserters were interviewed prior to the ground counteroffensive, they reported that they had fled despite the risk of being executed. In effect, they saw that risk as being less than the risk of continuing in battle. They predicted that the units they had left would surrender as soon as they had a chance to do so. They were correct (Hosmer, 1996).

This modest theoretical framework, if applied, can result in an "outcome table" like that illustrated by Table 5.2. The first three columns show unit quality, motivation, and relative prospects for survival (continuing or not). The last three columns show a fuzzy, probabilistic prediction of break point.

One reads the table as follows: The first line (below the headers) amounts to *if unit quality is very high and motivation is very high, then—regardless of the enemies' assessment—the break point will be considered to be somewhere in the range of 0.5 to 1, as represented by a triangular probability distribution with peak value of 0.75.*

If the first line's conditions are not met, then the second line applies. It says that *if unit quality is very high and motivation is good and assessment is marginal, the break point will be more moderate, as represented by a triangular probability distribution in the range 0.25 to 0.75, with peak value of 0.5.*

If that line's conditions are not met either, the reader goes on to the third line, and so on. In computer programs, this corresponds to writing if-then-else logic. The only tricky feature of this is that the rule described by any given line of Table 5.2 applies only if the earlier conditions were not met. Thus, one must not judge the model by reading an intermediate line alone. That would make no sense.

Table 5.2 is severely truncated, because it is intended to represent a reductionist summary amounting to the following:

We've done our estimates of the course of action, using what we believe are realistic and reasonably hedged values of the enemy's break point. These drive our conclusions, so it's important to go over what we've done. There have been some historical cases when units have fought like tigers and suffered enormously high losses before being broken. Typically, however, that happens with high-quality units that are well led and disciplined and that also have a very unusual level of motivation. Perhaps they are protecting their homeland; perhaps they are ideologically committed, even zealously so. But they're not normal in this regard. If we merely take out the assumption of super-high motivation (zealotry), experience tells us that units who know that continuing will be suicidal (whereas something less than that, even if it's a quick surrender, will be better) will break sooner. There's a lot of uncertainty, but a range of 0.25 to 0.75 seems to us to still be conservative. If the units are less capable, less motivated, etc., then the break point will almost surely be lower yet. Typical break points have been much lower. Anyway, we used the third-highest range of break points in our model, and that was enough to conclude that we should go through them tomorrow like a knife through butter. And if we don't, we'll still win with acceptable losses.

The Dimensions of a Fuller Theory

For many purposes, this kind of truncated model and reductionist summary might be quite enough to inform development of EBO and decisions about them. It is far short of a true theory or a complete model, however. Table 5.3 suggests this with a speculative, partial filling-out of the table.

Developing such outcome tables is hard work when it is important to go beyond cream-skimming, as in the earlier discussion with the truncated table. All of the terms used and their scales of values must be defined. Further, rules must be established for systematically evaluating the variables. One person's notion of a very good unit might correspond to another's notion of good (but not very good). When working with such inherently qualitative and subjective issues, examples become crucial to de facto definition. As an example, one might imagine that unit quality would be defined as having values of very bad, bad, marginal, good, and very good. But how would one

Table 5.3

An Illustrative Outcome Table for Break Points

		Unit's Assessment of Its Prospects[a]		
Unit Quality	Unit's Motivation[a]	If Fight	If Quit/Desert	Outcome (Value of Break Point)[b]
High or very high	Very high (zealotry)	—	—	Triangular (0.5, 0.75, 1)
High or very high	High	—	Very bad	Triangular (0.5, 0.75, 1)
High or very high	High	Very bad	>=Bad	Triangular (0.25, 0.5, 0.75)
High or very high	High	Very bad	Bad	Triangular (0.1, 0.35, 0.6)
High	Moderate	Very bad	Very bad	Triangular (0.1, 0.35, 0.6)
High	Moderate	Very bad	>=Bad	Triangular (0.1, 0.25, 0.5)
High	Moderate	Bad or very bad	>=Marginal	Triangular (0.1, 0.25, 0.5)
High	Moderate	>=Marginal	—	Triangular (0.1, 0.25, 0.5)
High	Low or very low	Bad or very bad	>=Marginal	Triangular (0.1, 0.25, 0.4)
High	Low or very low	>=Marginal	—	Triangular (0.1, 0.25, 0.5)
Moderate	Very high (zealotry)	—	—	Triangular (0.5, 0.75,1)
Moderate	High	Very bad	Very bad	Triangular (0.1, 0.25, 0.5)
Moderate	High	Very bad	>=Bad	Triangular (0.1, 0.2, 0.4)
Moderate	High	Bad	Bad	Triangular (0.1, 0.25, 0.5)
Moderate	High	>=Marginal	—	Triangular (0.1, 0.25, 0.5)
Moderate	Marginal	Very bad	Very bad	Triangular (0.1, 0.2, 0.3)
Others	Very high (zealotry)	—	—	Triangular (0.1, 0.25, 0.5)
Others	<=High	—	—	Triangular (0.1, 0.2, 0.3)

[a]A >X sign indicates that the value in question can be anything larger (better) than X. This exploits ordered sets such as {very bad, bad, marginal, good, very good}.

[b]The notation *Triangular (a,b,c)* means that one should use a triangular probability distribution with minimum, modal (most-probable), and maximum values at a, b, c. That is, the probability distribution is 0 for values less than a or greater than c. The distribution rises linearly from 0 at a to a maximum value at b; it then drops to 0 at point c.

estimate the quality of an enemy force? Part of the definition would involve specifying, for example, that units as good as precounter-offensive Iraqi Republican Guards in 1991 would be rated as very good on the defense and marginal on the offense, whereas U.S. forces were very good for both offense and defense.

In evaluating motivation, one might reserve "very good" for zealous defenders of homelands or zealous troops inflamed by ideological fervor. One Israeli brigade was virtually decimated in 1973 while defending the critical Golan Heights. The Japanese defending Pacific islands sometimes fought to the death.

In evaluating the perceived wisdom of continuing, one would take into account not just the likelihood of surviving if the operation is pursued as directed, but also the alternatives. Deserters, after all, are commonly shot, and there may or may not be easy opportunities for desertion. More relevant would be the alternative of putting up a token fight but surrendering quickly. This is highly precedented historically.

Simplifying the Theory, if It Has Been Formulated

Let us now imagine that reasonable agreement had been reached on a qualitative model such as that described above. This might come about after extensive study of historical battles, memoirs, interviews, and theorizing. Group discussions would also be quite helpful.

At that point, a simpler mathematical equivalent could probably be constructed. We could translate the qualitative variables of quality, motivation, and assessment of the enemy (Q, M, and A) into numbers from 1 to 5: very low would map to 1, and so on. We could then associate the mean value of $\overline{B}$ with a weighted sum. If, for example, quality and motivation were considered twice as important as the enemy's assessment, then the weighting factors for M, A, and Q would be 0.4, 0.4, and 0.2, respectively. We could then represent the variability of B by defining the random variable $\tilde{B}$, given by a triangular distribution function between 0.5 and 1.5 times the mean value of B. We would have

$$\overline{B} = W_{qual}Q + W_{mot}M + W_{assess}A$$

$$\tilde{B} = Triangular(0.5\overline{B}, \overline{B}, 1.5\overline{B})$$

Why not just start with the mathematical approach? Actually, one could reasonably do so in many cases of qualitative modeling (perhaps including this one). Further, it is an effective way to accomplish something quickly that is at least roughly correct. However, it is often helpful to defer pushing things into a mathematical form until the issues have been discussed extensively in their natural, fuzzy language. Discussion can be useful for identifying all the factors and understanding how to evaluate them. It can also help in understanding their interactions—i.e., the ways in which the underlying theory should be nonlinear. This is sometimes subtle because it reflects the fact that real human beings do not reason in the manner preferred by advocates of utility theory. People use heuristics, which are sometimes illogical in dealing with unusual situations; they also interpret factors in ways that anticipate indirect effects that a mathematician would prefer to ignore. For example, people sometimes make economically irrational decisions as part of an ethic that apparently helps protect them in the long run from patterns of imprudent behavior.[16] To make things worse, people sometimes use different heuristics and can reach different conclusions depending on the order in which they process information and consider options.

Particularly important in this regard is recognizing that the heuristics used by some individuals (e.g., Alexander the Great, Napoleon) are not well represented by utility calculations. Conquerors (and also revolutionaries) think differently. A conqueror, for example, may reason, "I only live once and it's time to go for the gold." That is, he

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[16]As an example, someone arriving at the opera without his tickets may decide to forgo seeing the performance rather than shell out the money for new tickets, even though this might appear to be an example of the sunk-cost fallacy. In a sense, his decision might be to "punish himself," so as to deter himself from being so careless in the future. Is that irrational, or does it reflect an attribute that has evolved because of its value for long-term survival?

may be trying to maximize the likelihood of his glorious success, rather than maximize the expected value of the outcome more generally (Davis and Arquilla, 1991b).[17]

The point here is not to recommend this process in detail, but merely to illustrate the process of working with qualitative models, based on considerable experience in other, relevant efforts.[18]

A Cognitive Model of a Commander

Let us now consider what a cognitive model of a commander might look like in simplest terms. Suppose the commander reasons in terms similar to those discussed above. And suppose that his staff had worked exhaustively to evaluate the odds of success in two cases: a defense line at 100 km and a defense line at 150 km (not an early halt, according to the terms of the present discussion, but close). A model of his decision on whether to use ground forces might then look something like Table 5.4 (the numbers in the table are invented to support the discussion).

Before hearing the staff's assessment, the commander has already thought out the cases. If the political masters insist that the use of ground forces is absolutely essential for deterrence and if they essentially order its use, then so be it—under protest. However, if the commander has any choice in the matter, he will use ground forces

[17]The psychological literature on conquerors is very limited, but it emphasizes a concept called prospect theory, which has been well demonstrated experimentally. People make different decisions depending on whether their view of the status quo (or, more properly, their projection of the baseline) is positive or negative. Middle-class homeowners do not actually bet their farm even if offered good terms for such bets. On the other hand, revolutionaries often make great sacrifices because they consider the baseline totally unacceptable. The literature on these matters includes Jervis, Stein, and LeBow (1985), Davis and Arquilla (1991a,b), and the original psychological research of Daniel Kahnemann, Amos Tversky, and others (cited in other references).

[18]Such qualitative models played an important role in the decision models of the RSAS and even in the adjudication models used for representing small-scale contingencies in which factors such as surprise and motivation loomed large. For discussion of some such cognitive models, see Davis and Arquilla (1991a,b); for a summary, see the relevant appendices of National Research Council (1997).

Table 5.4

Decision Model on the Commitment of Ground Forces

Case	Defense Line (km)	Most-Likely Outcome	Best Case	Worst Case	Value of Having Ground Forces at the Defense Line[a]	Decision on Whether to Use Ground Forces
1	100	90	50	120	Extremely high	Yes, under protest
2	**100**	**90**	**50**	**120**	**<=Very high**	**No**
3	**150**	**90**	**50**	**120**	**>=High**	**Yes**
4	150	90	50	120	<=Marginal	No

[a]For deterrence, bolstering allies, etc.

only if the analysis concludes that even in the worst case (conceived of as roughly a probability of 10 percent), the halt will occur at or short of the defense line. That is, he wants to be 90 percent certain of success. Even then, he will not risk the ground forces unless he himself thinks the criticality of inserting them is high. Regardless of the staff analysis, he doesn't trust the estimate of the worst-case odds well enough to risk so many lives unless there are strong reasons to do so.

The staff now reports. They tell him that a defense line at 100 km may not succeed, but a defense line at 150 km almost certainly will. If the commander believes that the value of using ground forces is high, but not extremely so, then for the analysis results assumed in the table, his decision will be to insert ground forces at a defense line of 150 km.

This discussion is a reductionist description of what could be a very complex and soul-searching decision. The point of the example is simply that logical tables such as Table 5.4 can hope to capture the essence of reasoning such as that observed in serious human war games. If this overly simple treatment seems inadequate, the analysis can be embellished somewhat. At the very least, such cognitive models could go far in capturing the reasoning of players in war games and allowing a "rigorous" discussion of the many cases not played because of the detailed events of the game. That in itself would be quite useful.

Going Deeper

If one accepts the potential value of such cognitive models, a good deal more is necessary to implement them. My colleagues and I have used a wide variety of methods. For example, we have used simple influence diagrams such as Figure 5.9 to encapsulate reasoning about indirect effects.

We have also used more extensive cognitive maps and attribute lists to characterize the reasoning pattern we would anticipate for a particular individual. And we have insisted on developing *alternative* models (Davis and Arquilla, 1991a,b).

I have also found many of the ideas in the literature on hyper games and drama theory[19] to be insightful and useful, although I have not applied them formally.

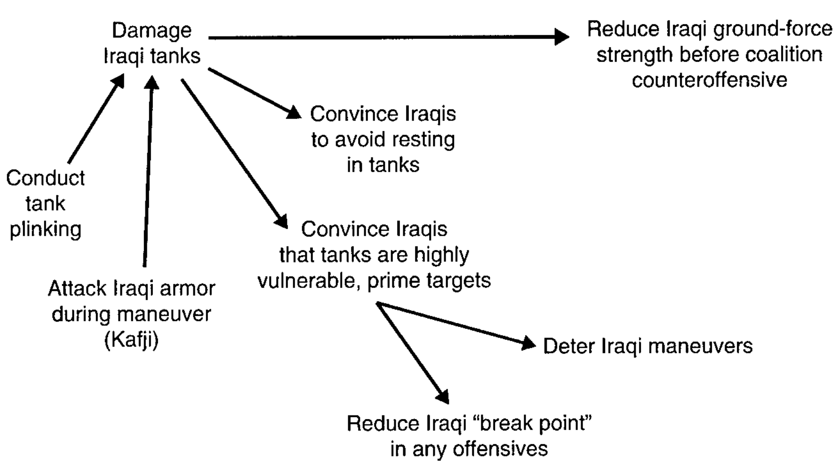

Figure 5.9—A Simple Influence Diagram

[19]Hyper games are relatively qualitative games in which the adversaries have different conceptions of what "the game" is. As a result, the usual mathematics of game theory doesn't apply and the sides may take apparently paradoxical actions. Arguably, this is often a more apt description of the real world than that provided by normal game theory (Bennett, 1995). Drama theory, as the name suggests, applies lessons from the field of drama to understand and reason about courses of action (Howard, 1999).

DISTINCTIONS BETWEEN OPERATIONS PLANNING AND DEFENSE PLANNING

Much of the discussion in this monograph appears to be more relevant to operations planning than to defense planning. At the same time, some of the key lessons to be learned about how analysis can be improved to reflect EBO philosophy carry over into defense planning as well. After all, if the United States evaluates programs for innovative use of forces, the options will likely include small, prototypical forces that would be far too small to prevail in anything like a standard MTW scenario. Recent suggestions about small rapid-intervention forces fall into this category (McCarthy, 2001; Gritton, Davis, Steeb, and Matsumura, 2000; Defense Science Board, 1998). If such JSF concepts are evaluated too conservatively, they will not fare well. And if similarly narrow analyses had been dominant, we would not today have Rangers, Special Forces, or Marines trained for amphibious operations and vertical envelopment. Indeed, the United States would not even have had aircraft carriers in time for World War II, since the prevailing view in the 1920s and 1930s was that, at best, carriers could merely support battleships.

It follows, then, that the methods of exploratory analysis should be used widely in defense planning—not only for examining classic big-war scenarios, but also for evaluating the potential value of new forces and operational concepts. Moreover, in conducting such analyses it will be important to account reasonably—albeit with serious representation of uncertainty—for the many ways in which new capabilities could have effects that transcend those expected from traditional analysis. Only then will it be possible to judge whether the potential is worth the cost in comparison with other uses of the available resources.

Chapter Six

CONCLUSIONS

A GRAND CHALLENGE

Effects-based operations (EBO) can be considered to be operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects—effects that may, with different degrees of probability, be achieved by the application of military, diplomatic, psychological, and economic instruments.

Current methods of analysis and modeling are inadequate for representing EBO, and this reality should be considered by the analytical community to pose a grand challenge. Addressing the challenge will require changes of mindset, new theories and methods, and a new empirical base. Fortunately, several research-and-development efforts toward this end are now under way, but it will take years for them to reach fruition. In the meantime, these efforts can benefit from some broad analytical considerations.

PRINCIPLES FOR AN APPROACH

The following principles appear to be a useful guide for defining and conducting defense-planning analyses that take a broad view:

- Analysis in support of defense planning should embrace the paradigm of focusing on *mission-system capability*, which refers to the no-excuses ability to accomplish missions under a wide range of operational circumstances and to characterize the range of circumstances for which the capabilities are sufficient to provide different degrees of confidence. Addressing EBO-related issues should be an important part of such analysis.

- Analysis dealing with EBO should fully confront the scope and magnitude of uncertainty and should deal explicitly with probability and randomness. For summary purposes, assessments of capability should refer specifically to most-likely, best-case, and worst-case outcomes (with "best" and "worst" corresponding to something like 90 percent limits).
- Dealing with uncertainty will require low-resolution *exploratory analysis* for breadth, as well as more-detailed modeling and gaming for both depth and insight into underlying phenomena. This suggests a *family-of-models-and-games* approach in which information obtained from different members of the family is used to inform and cross-calibrate the whole body of knowledge. To be meaningful, as distinct from being merely slide-show material, such work requires major investment and effort.
- A key element of analytical work should be *qualitative modeling,* including *cognitive modeling* of the decisionmaking and behavior of commanders, political leaders, and even societies. Such modeling should be undertaken in an uncertainty-sensitive framework and can greatly enrich analysis while breaking down the barriers between "rigorous analysis" (usually quantitative, but rigid) and human gaming (often more realistic and innovative, but fuzzy). Here, as elsewhere in EBO analysis, the objective should be to increase the *odds* of success and decrease the *odds* of troublesome side effects.
- Because much of EBO is tied to affecting decisions and behaviors of people and organizations or the operation of complex systems and organizations, much of the related modeling should be organized around adaptive systems for command and control and other matters, rather than around the mass and physical characteristics of forces. This implies emphasis on the concepts and technology of *agent-based modeling* (albeit in many variations), as well as on system engineering.
- Because the questions asked in EBO analysis are so different from traditional questions, analysts should vigorously pursue a new base of *empirical information*—including information

obtainable from history and from a combination of gaming, man-in-the-loop simulation, and experiments in battle laboratories or the field. This information should be collected and framed in ways that illuminate complex and subtle relationships and that support uncertainty analysis. The goal should *not* be merely to inform "best-estimate" databases, because in EBO work, uncertainty is often inherent and best-estimate analyses can be misleading and even dangerous.

NEXT STEPS

An important motivation for this monograph was the belief that analysis methods must be improved in order to be useful in studies and operations undertaken from an effects-based perspective. Such improvements appear to be quite feasible, but they will depend on new attitudes, principles, and norms—as well as on the use of modern modeling technology such as that for exploratory analysis under uncertainty and the development of agent-based models. Further, the improvements will depend on developing an expanded and enriched empirical base. The next steps should include in-depth applications of some guiding principles and efforts to obtain insights and data from history, training, exercises, and experimentation (both in the laboratory and in the field). Merely as examples to indicate what might constitute a research program, I offer the following researchable questions:

- What would constitute reasonable qualitative models for issues such as the break point of adversaries, the direct and indirect effects of strategic bombing, and the value of relatively parallel operations?
- What does history tell about break points when the cases are studied with a combination of simulation (using a model capable of representing maneuver, terrain, and soft effects), qualitative modeling, and statistics, rather than either pure statistics or statistics plus a more primitive combat model? In this approach, the objective would be to inform and help calibrate a qualitative model, rather than merely to present highly aggregated statistical information.

- What does history tell about the compellent effectiveness of strategic bombing when interpreted through the lens of an appropriate qualitative model?
- What does history tell about long-term effects of strategic bombing on the attitude of populations who have been subjected, even if collaterally, to that bombing when interpreted through the lens of a qualitative model?[1]
- What could relatively large-scale field tests, with both U.S. ground forces and those of allies, tell about modern march speeds—with and without systematic interdiction and with and without "modest" opposition in the form of, say, special-operations forces creating ambushes or laying obstacles, or very small but moderately competent defensive forces with attack helicopters conducting "continuous" delay operations?
- As above, but with the interdictor having the capacity to generate *surprise* obstacles, e.g., from air-delivered mines.
- What can a combination of simulation and field tests with real maneuver units of varied sophistication tell about the *distribution* of per-sortie effectiveness (or per-shot effectiveness, in the case of missiles such as advanced tactical missile systems (ATACMs) with brilliant antitank (BAT) submunitions), when the "random factors" that determine how many targets will be detected and attackable by a particular set of shooters for a particular sortie (or in a particular volley) are considered? If the cases were studied with real units subject to imperfection but capable of prudent and sometimes clever maneuver tactics, the result might well be quite different from the usual planning factors. Whether they would be better or worse is hard to predict.
- What "special capabilities" might be most valuable for the commander of a brigade-size intervention force attempting an RDO in something like a replay of the Kosovo conflict, but one that included early-entry forces charged with stopping the killing?

[1]Predicting the effects does not appear to be straightforward and may relate to a nation's history and culture.

How should such special capabilities be analyzed and their worthiness for investment be assessed?[2]

[2]It would be interesting to review, for example, how the special capabilities of SWAT teams, the Delta force, and other unconventional units were conceived, analyzed, and procured. Much might be learned from that experience that would be helpful to analysts attempting to address EBO who are familiar only with either physics-level models (e.g., radar detections) or theater-level models built for attrition battles in force-sizing studies.

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Effects-Based Operations

A Grand Challenge for the Analytical Community

Paul K. Davis

Effects-based operations (EBO) are defined for this book as operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects—effects that may, with different degrees of probability, be achieved by the application of military, diplomatic, psychological, and economic instruments. This book suggests principles for sharpening discussions of EBO, for increasing the rigor of those discussions, and for building the key ideas of EBO into analysis for defense planning, experimentation, and operations planning. It then illustrates the principles with explicit models. Finally, it sketches a possible research program to enrich the base for studying and practicing EBO.

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