



NATIONAL DEFENSE RESEARCH INSTITUTE

CHILDREN AND FAMILIES
EDUCATION AND THE ARTS
ENERGY AND ENVIRONMENT
HEALTH AND HEALTH CARE
INFRASTRUCTURE AND
TRANSPORTATION
INTERNATIONAL AFFAIRS
LAW AND BUSINESS
NATIONAL SECURITY
POPULATION AND AGING
PUBLIC SAFETY
SCIENCE AND TECHNOLOGY
TERRORISM AND
HOMELAND SECURITY

The RAND Corporation is a nonprofit institution that helps improve policy and decisionmaking through research and analysis.

This electronic document was made available from www.rand.org as a public service of the RAND Corporation.

Skip all front matter: [Jump to Page 1](#) ▼

Support RAND

[Purchase this document](#)

[Browse Reports & Bookstore](#)

[Make a charitable contribution](#)

For More Information

Visit RAND at www.rand.org

Explore the [RAND National Defense
Research Institute](#)

View [document details](#)

Limited Electronic Distribution Rights

This document and trademark(s) contained herein are protected by law as indicated in a notice appearing later in this work. This electronic representation of RAND intellectual property is provided for non-commercial use only. Unauthorized posting of RAND electronic documents to a non-RAND website is prohibited. RAND electronic documents are protected under copyright law. Permission is required from RAND to reproduce, or reuse in another form, any of our research documents for commercial use. For information on reprint and linking permissions, please see [RAND Permissions](#).

This report is part of the RAND Corporation research report series. RAND reports present research findings and objective analysis that address the challenges facing the public and private sectors. All RAND reports undergo rigorous peer review to ensure high standards for research quality and objectivity.



Analysis to Inform Defense Planning Despite Austerity

Paul K. Davis





NATIONAL DEFENSE RESEARCH INSTITUTE

Analysis to Inform Defense Planning Despite Austerity

Paul K. Davis

Prepared for the Office of the Secretary of Defense

Approved for public release; distribution unlimited

The research described in this report was prepared for the Office of the Secretary of Defense (OSD) and conducted within the International Security and Defense Policy Center of the RAND National Defense Research Institute, a federally funded research and development center sponsored by OSD, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community.

Library of Congress Cataloging-in-Publication Data is available for this publication.

ISBN: 978-0-8330-8507-8

The RAND Corporation is a nonprofit institution that helps improve policy and decisionmaking through research and analysis. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

Support RAND—make a tax-deductible charitable contribution at www.rand.org/giving/contribute.html

RAND® is a registered trademark

© Copyright 2014 RAND Corporation

This document and trademark(s) contained herein are protected by law. This representation of RAND intellectual property is provided for noncommercial use only. Unauthorized posting of RAND documents to a non-RAND website is prohibited. RAND documents are protected under copyright law. Permission is given to duplicate this document for personal use only, as long as it is unaltered and complete. Permission is required from RAND to reproduce, or reuse in another form, any of our research documents for commercial use. For information on reprint and linking permissions, please see the RAND permissions page (www.rand.org/pubs/permissions.html).

RAND OFFICES

SANTA MONICA, CA • WASHINGTON, DC

PITTSBURGH, PA • NEW ORLEANS, LA • JACKSON, MS • BOSTON, MA

CAMBRIDGE, UK • BRUSSELS, BE

www.rand.org

Preface

This monograph grew out of a presentation in May 2013 at a special meeting of the Military Operations Research Society. The meeting, “The Role of Analytics in Addressing the New Budget Environment,” discussed current challenges facing the U.S. Department of Defense and how analysis could assist such activities as the Quadrennial Defense Review. This longer document describes my view of how analysis can be more useful than it sometimes has been in the past by exploiting improvements in the state of the art and by rediscovering and supplementing classic principles. It reflects my experience over decades as an analyst at the Institute for Defense Analyses, an analyst and senior executive in the Office of the Secretary of Defense with responsibilities for both strategy and program analysis, and—for many years—an analyst and manager at the RAND Corporation.

The monograph’s primary intended audience includes defense analysts, their managers, and the policymakers who are consumers of defense analysis. That said, most of the principles outlined here apply to other government agencies and to strategic analysis generally. Comments are welcome (email: pdavis@rand.org).

The research for this monograph was conducted within the International Security and Defense Policy (ISDP) Center of the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community. For more information on the RAND ISDP Center, see

<http://www.rand.org/nsrd/ndri/centers/isdp.html> or contact the director (contact information is provided on the web page).

Contents

Preface iii

Figures ix

Tables xi

Summary xiii

Acknowledgments xxv

CHAPTER ONE

A Setting of Great National Security Challenges 1

Fiscal Constraints Are Only Part of the Problem 1

A Pollyannish Perspective on Tight Budgets?..... 3

Endnotes 4

CHAPTER TWO

Analysis to Aid Decisionmaking..... 5

Classic Tenets Remain Valid..... 5

Additional Tenets Are Needed 6

A New Principle and Implications for the Analysis Profession 8

 The FARness Principle 8

 Why FARness Is Neither Common Sense Nor Easily Obtained 9

 New Professional Responsibilities for Analysts..... 11

Endnotes 12

CHAPTER THREE

Concrete Suggestions for Analysis..... 15

The Concept of an Analysis Campaign..... 15

Supporting Policymakers: It Is Not Just Decision-Aiding 17

Depth: Balancing the Simple and Complex	18
Simplicity's Dominance in More Routine Analysis.....	18
Achieving Valid Simplicity	19
Simplicity and Complexity in Historical Studies	21
Breadth: Using Diverse Models and Tools.....	22
Recognizing Multiple Criteria.....	26
Multiple Objectives, Including Risk Management	26
Uncertainty and Disagreement.....	28
Measuring Qualities of an Option Under Uncertainty	31
Exploratory Analysis for Capabilities-Based Planning.....	38
Endnotes	41

CHAPTER FOUR

Creating Capability Models	47
Definitions and Examples	47
Definition	47
Examples.....	50
Illustrative Simple Models Used in Defense Studies.....	55
Building Capability Models	55
Low-Resolution Capability Models.....	55
Motivated Meta Models.....	58
Complex Models That Can Support Capability Analysis.....	60
The Special Issues of Social-Science and Other "Soft" Considerations.....	62
Models Relating to Terrorism and Insurgency	62
Soft Factors in Models Generally	64
Myths and Realities About Validation	65
Model Validation	65
Validity of Human Games, Historical Analysis.....	67
Analysis Validation	68
Endnotes	69

CHAPTER FIVE

Finding Suitable Options	73
Challenges in Finding Good Options.....	73
Recurring Issues	75
The Perennial Issue: How Much Is Enough?	75

Dependence on Assumptions.....	78
Dependence on Concepts of Operations.....	78
Special Implications for a Period of Austerity	81
Building-Block and Composite Options	81
A New Method for Developing Options.....	83
Endnotes	86

CHAPTER SIX

Integrating with Portfolio Analysis	89
Portfolio Analysis In Comparison with Other Approaches.....	89
Basic Concepts	89
A Simple Illustration.....	91
The Economics of Portfolio Analysis	94
Tailoring Portfolio Analysis to Classes of Decision	96
Endnotes	97

CHAPTER SEVEN

Conclusions	99
--------------------------	----

APPENDIX

A. Subjective Data on Past Studies	103
B. Capabilities-Based Planning	107
C. Other Approaches to Risk Management	129
D. Illustrative Threat-Based Analysis	139
E. A Model That Could Have Been “Simple”	143
F. An Example of Simplified Modeling: The Halt Problem	147

Bibliography	155
---------------------------	-----

Figures

- S.1. Generic Image of Decisionmaking xiii
- S.2. Capabilities Analysis to Inform Interim and Subsequent
Decisions..... xvii
- S.3. Cost-Effectiveness Landscape, by Strategic Perspective xxiii
 - 1.1. Problems Go Far Beyond Fiscal Constraints 2
 - 3.1. Decision-Aiding That Draws on an Analysis Campaign..... 16
 - 3.2. Generic Image of Decisionmaking 18
 - 3.3. Multiple Reasons for Simplicity..... 20
 - 3.4. Attributes of Some Past Studies..... 22
 - 3.5. Some of the Many Dimensions of Defense Planning 26
 - 3.6. Example: Critical Components of Interdiction Capability 28
 - 3.7. The Concept of Scenario Space 33
 - 3.8. Moving from a Scenario Space to a “Spanning Set of Test
Cases” 35
 - 3.9. Comparing Options Under Uncertainty (Point-Scenario
Analysis Versus Capability Analysis) 38
 - 4.1. Schematic of a Parametric Capability Model’s Output 48
 - 4.2. Types of “Simple Submodels” 50
 - 4.3. Selective Detail in a Simple Precision-Fires Model 53
 - 4.4. Qualitative Factor-Tree Model of Public Support for
Terrorism..... 54
 - 4.5. Computational Version of Factor Tree 56
 - 4.6. Empirical Model of Ground-Force Levels in Conflicts 57
 - 5.1. How Much Is Enough? 76
 - 5.2. A New Way to Construct Policy-Level Composite Options... 84
 - 5.3. Generalized Approach for Finding Options on the Efficient
Frontier..... 85

- 6.1. Zooming into Detail for Explanation.....93
- 6.2. Generalized Efficient-Frontier Depictions for Different Perspectives.....95
- C.1. Distinguishing Normal Risks and Those from Deep Uncertainty..... 132
- C.2. An Illustrative Taxonomy of Risks for Options in a Particular Study..... 135
- D.1. An Illustrative Build-Up Chart from the Cold War..... 139
- E.1. The Famous “Hairball” Graphic..... 144
- F.1. Results of Exploratory Analysis with Five Variables..... 152

Tables

S.1. Ballistic-Missile Defense Capabilities, by Threat and Objective (Notional) xix

1.1. U.S. Capabilities, Then and Now..... 3

3.1. Broad Scope of Analytical Capabilities to Support Decisionmaking..... 24

3.2. Ballistic-Missile Defense Capabilities, by Threat and Objective (Notional)39

5.1. Contributors to Strategic Options: A Few Examples of Synergy..... 74

6.1. What Makes Portfolio Analysis Different 90

6.2. Portfolio-Analysis Display from a Prompt Global Strike Study 92

7.1. Contrasts..... 101

A.1. Subjective Assessment of Attributes in Selected Past Studies..... 104

B.1. A Comparison of Planning Methods, Actual and Contrived 122

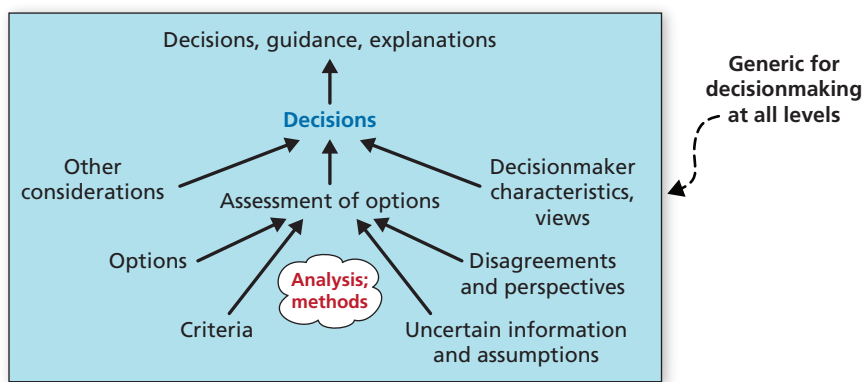
C.1. Distinguishing Normal and Deeper Risks 134

Summary

Overview

This monograph suggests ways for higher-level defense analysis to better serve the needs of policymakers, even in periods of austerity. The suggestions here may be especially significant because current defense planning also has many strategic challenges. A starting point is to see analysis as aiding decisions, as suggested in Figure S.1. Starting at the bottom of the figure, one sees that analysis is not just about evaluating options straightforwardly. Rather, it must (1) ensure that a good set of options are considered, (2) recognize multiple criteria for evaluating options, (3) confront uncertainty about the world, and (4) expect disagreements among policymakers. Despite this complexity, analysis

Figure S.1
Generic Image of Decisionmaking



RAND RR482-S.1

should frame and compare options *comprehensibly* with a premium on simplicity and a meaningful “story.” Simplifications, however, must be approximately valid. Simplicity is also a relative concept: It may mean describing, at a high level, how options deal with multiple components of a system problem or how they correspond to different ways to balance a portfolio across multiple objectives, including risk-control objectives. Thus, simple should not be simplistic.

The analysis framework should recognize that decisions often depend on considerations beyond what analysis provides. Once decisions are made, analysis should help policymakers to communicate, explain, and convince. It should also help shape implementation guidance with sharpened requirements, forcing functions, and metrics for monitoring, feedback, and adaptation.

To accomplish these aims in a study, *it is wise to plan an analysis campaign*. Experienced analysis managers already do so, but what follows is an enriched conception stemming from the perspective of capabilities-based planning.*

Capabilities-based planning is planning under uncertainty to provide capabilities for a wide range of modern-day challenges and circumstances while working within an economic framework that necessitates choice.

When done well, then, capabilities-based planning confronts uncertainty and the need to make choices within constrained budgets. Properly understood, it has always considered both generic possibilities and specific threats.

Some of the monograph’s guidelines on analysis campaigns will be familiar and even old-hat to readers; others will not be. The intent is to suggest best practices rather than introduce radical ideas, although some ideas were seen as radical not long ago and others may still be.

* What I describe in this monograph is sometimes referred to as “capabilities-based planning done right” because implementation of the concept has sometimes been troubled (e.g., with complex bureaucratic processes and, ironically, too little emphasis on dealing with uncertainty and making choices). Rather than invent yet a new term, I have opted simply to define my usage. See also Appendix B.

Seeking Flexibility, Adaptiveness, and Robustness

One core theme in an analysis campaign should be confronting “deep uncertainties” such as those spawning what some call “black swan” events. Another is dealing with multiple objectives. The result will inform decisions on how to balance and hedge when planning. Related to this, analysis should include comparing options for their “FARness,” i.e., for whether they provide capabilities allowing for

flexibility to take on new or changed missions, objectives, . . .
adaptiveness to new or changed circumstances
robustness to adverse shocks (or even highly positive shocks).

This sentiment goes by such varied names as robust decisionmaking, planning for adaptiveness, and planning for agility.

Regardless of the sticker name, this approach implies *a new professional responsibility for analysts*: Instead of merely listing analysis assumptions, analysts should

- routinely show how results vary with all key assumptions and disagreements—the opposite of focusing on a standardized case and perhaps running a few excursions
- routinely assess options for FARness, showing the value of affordable hedges even in periods of austerity when hedges may seem like luxuries
- do the above *comprehensibly* to aid policymakers in converging on decisions and actions.

The last point is crucial because policymakers need good summaries and will not tolerate hand-wringing about uncertainty or “paralysis by analysis.”

Simplicity Versus Depth

An analysis campaign will often need a mix of relatively simple and more complex models. Suitable low-resolution models are particularly

good for “capabilities analysis,” i.e., exploratory work varying parameters of the problem simultaneously to generate insights and tradeoffs. Such models also frame problems with the higher-level variables suitable for discussion with policymakers. That is, they provide a story. Higher-resolution models are necessary to understand issues thoroughly, to connect with real-world data and operational activities, and to reflect subtleties. Details often matter, and simplicity is, in a sense, only a necessary fiction along the way.

Breadth

The analysis campaign should provide for *breadth* with a mix of models, human gaming, historical analysis, trend analysis, and collaboration with experienced operators. It should reflect both technology-push and demand-pull. Such breadth can be seen as including—beyond “normal” analysis—lines of activity with features akin to work by the Office of Net Assessment in the Office of the Secretary of Defense (OSD), combatant-commander contingency planners, forward-looking planners seeking to exploit technology, and lessons-learned studies.

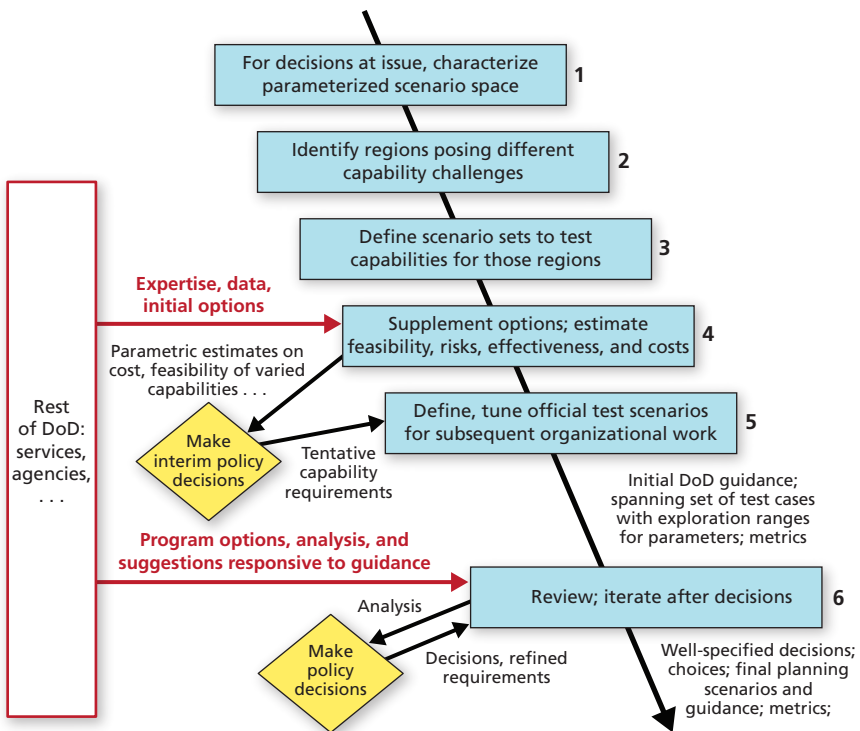
Multiobjective Assessments (Including Risk Management)

An analysis campaign should identify early the many dimensions that need to be considered in constructing and evaluating options. These correspond to multiple study-dependent objectives (including risk-management objectives) in approximate hierarchies of detail. A strategic-level study might have separate objectives for each regional and functional area, as well as such cross-cutting challenges as simultaneous conflicts. It might also have different objectives for the near, mid, and long term. A mission-level study (e.g., of the capability to improve air support of ground-force operations or to improve cyber defenses) might have different objectives for each mission-level scenario with objectives reconsidering military effects, collateral damage, and friendly losses.

Exploratory Capabilities Analysis

The campaign must, of course, include analysis itself. Although analysis organizations commonly focus on scenarios established by policy offices, an important analysis role is to help identify and design possible planning scenarios, discuss implications with policymakers, and subsequently tune the scenarios so that they accomplish what is intended in the rest of the planning process. Figure S.2 describes the desired process schematically, a process with good historical precedents in Department of Defense (DoD) planning over the years. Blue items are analysis tasks that should, however, be accomplished in an *integrated* partnership (not a sequential process) among OSD (Policy), OSD

Figure S.2
Capabilities Analysis to Inform Interim and Subsequent Decisions



(Cost Assessment and Program Evaluation), the Joint Staff, and OSD (Acquisition, Technology, and Logistics). These offices would have core responsibility, but many aspects of the process should be as open and collaborative as possible, something much valued by all DoD participants. The services would have major roles because of their expertise, knowledge of relevant data, and inherent interests.

Referring to numbered items in the figure, in this approach, analysts take a broad scenario-space view to recognize the many objectives, constraints, and uncertainties (Step 1). This stage of the analysis campaign confronts deep uncertainties. It involves “divergent thinking” that departs from standard thinking in recognizing issues often glossed over. It then discovers how the scenario space breaks the scenario space into regions posing different challenges (Step 2). Depending on the circumstances of a given region, the challenges might involve, e.g., response time, technical capabilities, force size, and plausible but unexpected adversary strategies. The challenges might also be political, economic, or social, as in “complex endeavors” in general or as illustrated in recent wars in particular. The next part of the analysis campaign should be convergent. Analysts can identify representative parameterized scenarios for each challenge region (Step 3). Given suitable models, they can then do first-cut capabilities analysis to estimate what is needed to meet the various challenges as a function of cost (Step 4). Since cost and feasibility depend on the stringency of challenges, parameterizing stringency (i.e., showing implications as a function of stringency) becomes part of the analysis.

The process in Figure S.2 next envisions going to policymakers (top yellow diamond) to discuss what capabilities they wish to pursue further given results of the first-cut analysis. Policymakers then make initial decisions, giving up on some capabilities but pursuing others. That is, they decide tentatively on “requirements.” This requirement-setting must be detailed enough to define intent. Thus, analysts translate qualitative desires (e.g., “deter,” “achieve an early halt,” or “achieve persistent surveillance”) into parameter settings within the test-case scenarios to be used subsequently (Step 5). Parameter settings may differ, for example, for evaluation of Program Objective Memorandum

issues, training and exercising, and suggestions to combatant commanders for operational planning.

In response to guidance, the services and defense agencies develop various proposals and evaluate them against the test cases and uncertainty ranges. The results are then reviewed and analyzed (Step 6) to aid decisionmakers in making “final” decisions on forces, weapon systems, and other matters. Given decisions, analysts then adjust prior guidance, test-case scenarios, metrics, and goals accordingly. The process continues and further iteration occurs in subsequent years (not shown).

Table S.1 illustrates capabilities analysis of the sort assumed throughout the process of Figure S.2. It uses a purely notional example of comparing two options for homeland ballistic-missile defense as discussed in Chapter Three, based on prior publications. The message for policymakers is that Option 2 would cost twice as much, but its value would be limited largely to weak threats (the bottom two rows). Given a tight budget, this analysis might suggest proceeding with Option 1 while continuing research and development on the capabilities asso-

Table S.1
Ballistic-Missile Defense Capabilities, by Threat and Objective (Notional)

Class of Threat	Option 1 (\$100B)			Option 2 (\$200B)		
	Minimum Defense	Moderate Defense	Near-Perfect Defense	Minimum Defense	Moderate Defense	Near-Perfect Defense
Objective						
Massive attack, near peer	R	R	R	R	R	R
Small attack, near peer; or multiple missiles, advanced rogue	O	O	R	Y	O	R
Multiple missiles; simple rogue	Y	Y	Y	G	G	LG
Single missile; simple rogue	LG	LG	LG	G	G	G

SOURCE: Davis, Shaver, and Beck, 2008.
NOTES: Red = very poor, orange = poor; yellow = medium, light green = good, and green = very good. These capabilities might be quantified in terms of the probability of intercepting a high fraction of attacking missiles.

ciated with Option 2 if they had enough upside potential. The story explaining such a decision would be straightforward from the table. Significantly, this analysis preemptively addresses the natural “what-if?” questions rather than focusing simply on a nominal threat. To some, the analysis would also suggest the need for additional (albeit more expensive) options with greater potential against advanced threats.

In earlier years, the proposed requirement to do such uncertainty-sensitive parametric analysis was resisted by those in analytic organizations, who argued that they were unable to develop and coordinate the massive databases allegedly needed. Their assertion, however, depended on the particular models used and the processes for coordinating data across all DoD stakeholders. The ponderousness of the models and process have not paid their way for higher-level decision-aiding, although they have great value for other purposes as described in the main text. Organizations should modify their analytic tools and processes to permit such capabilities analysis. No excuses should be permitted, since such analysis has long been demonstrated and underlay many of DoD’s major capability decisions over the decades.

Developing Capability Models

The “capability models” referred to above (used in Steps 4 and 6 of Figure S.2) can be defined as follows:

A capability model is a causal model that allows us to understand how the ability to accomplish a mission depends on system variables, circumstances, and goals expressed parametrically.

Such a model contrasts with, say, a large campaign model that describes developments over time in a single scenario with a single set of assumptions represented by scores of parameters and complex databases that are agreed upon but highly uncertain. A capability model can be developed from scratch by someone who understands the problem area, by generating “motivated metamodels” from a more detailed model (Chapter Four), or by using a “big model” (even certain campaign models) with modular, multiresolution features that allow it to be used

for exploration. All three approaches are well preceded. The requisite skills are less common than in earlier years, but there is no shortage of talent—even if some “reeducation” is needed.

A special challenge occurs when the model-building involves social-science considerations. In addition to applying traditional social-science methods (e.g., comparative case studies) to gain insight, several model-building approaches are worth mentioning, as discussed with references in Chapter Four. First, such qualitative models as factor trees and influence diagrams can be valuable in an analysis campaign. Second, some of these can be turned into capability models using recently developed methods. Third, campaign models can include political and economic considerations. If such a model is modular, transparent, vetted, and possessed of some multiresolution features, it would be a good candidate for certain kinds of parametric analysis of social-science issues.

Developing the Options

Evaluating options presupposes having options to evaluate. An analysis campaign should provide a suitable range of options as part of Step 4 in Figure S.2. For higher-level analysis (e.g., for the Secretary of Defense), this will include creating composite options from lower-level building blocks. The composite options should attend, to a greater or lesser degree, to all of the objectives that must be addressed. The effort to provide such options could include the structured use of independent experts, human gaming, and requests for information from industry. Some of this should be technology-push in nature and may call for major changes. Such efforts are especially important in periods of austerity when doing more with less will typically require a combination of using technology and changing both concepts of operation and organizations. The options arising in more usual ways may be less imaginative, call for unacceptable dropping of important missions, or have organizations clinging to as much of their legacy structure as possible, rather than cutting even more so as to leave room for innovation. This problem is familiar to DoD currently.

At a more technical-analytic level, Chapter Five describes a new analytic method that can generate a vast number of options and then filter for only the small subset that are potentially attractive in the multiobjective, uncertainty-laden context. The method generalizes classic “efficient-frontier” methods to deal with uncertainty and multiple objectives.

Putting It All Together: Portfolio Analysis for Integrative Decision Support

The last part of the analysis campaign should “put things together.” A natural mechanism is portfolio analysis of options that vary in how they use mixes of instruments to address multiple objectives while working within a budget. The analogy is to having alternative portfolios of such financial instruments as stocks and bonds to deal with such multiple objectives as long-term capital gain and reliable current income. For DoD, options may differ in the relative emphasis on ground, air, or naval forces, in the relative emphasis on different regional and functional theaters of operation, in the relative emphasis on short-term and longer-term problems, and so on. Striking the right balance (which does not imply evenness) is the challenge for the Secretary of Defense, President, and Congress.

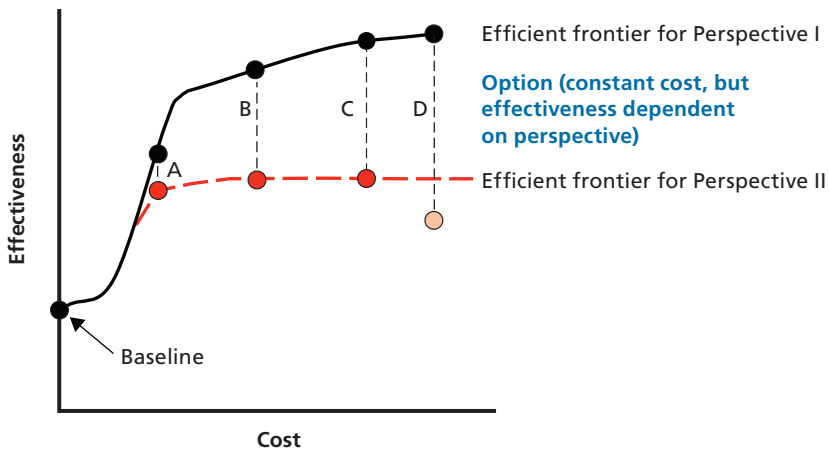
Analysis should therefore discuss strategic options so that policymakers can see how the options deal with the various objectives (including risk-control objectives) and how much they cost. This suggests the use of policy scorecards (even the sometimes-maligned stoplight charts) rather than the kinds of bar charts or graphs appropriate in other types of analysis. It is crucial, however, that policymakers *understand* why the options perform as shown in the scorecards. They must be allowed to ask, e.g., “Why is Option 2, which I like, performing so poorly against Objective D?” They should be able to zoom in—even within a briefing context—to see the underlying logic. The zoom may bring up another scorecard that allows visual explanation at a glance. For example, the evaluation may depend on several factors, most of which are favorable, but one of which is a “killer,” such as

excessive vulnerability to a countermeasure or excessive dependence on a notoriously unreliable ally. If the policymaker asks about changing an assumption (e.g., the weight given to a worst-case scenario), analysts should be able to draw on their previous capabilities analysis to show tradeoff curves or other responsive depictions.

Most top officials will use the zoom option only rarely, as in testing the mettle of staff or depth of analysis, or because of concerns about a particular issue. Deputies and staff, however, will often go into substantial detail. Further, experience shows that structuring the analysis campaign to generate material for such a layered presentation of results is an excellent way to ensure solid credible analysis.

Once policymakers have made choices, analysis can help to tidy and simplify. As one example, they can define a composite measure of effectiveness and generate cost-effectiveness charts as shown schematically in Figure S.3. This represents the aggregate significance of major uncertainties and disagreements as one compares investment Options A, B, C, and D. The effectiveness of each depends on underlying assumptions that are assumed to cluster in two “strategic perspectives.” Perhaps Perspective I reflects an emphasis on technology-push, the

Figure S.3
Cost-Effectiveness Landscape, by Strategic Perspective



future, and optimism that friendly developments will outpace counters. Perspective II might be more near-term oriented, might believe that the capabilities of Options B, C, and D could be readily countered, and might believe that Option D has a concept of operations that would be counterproductive. The perspectives agree only that Option A is well worth the investment. As a variant, even someone with Perspective I might agree, if funds were tight, to stop with Option B. The example is notional, but dramatic differences across perspective have been demonstrated in past studies as cited in the main text.

Next, we come to implementation. The same capabilities modeling discussed above identifies key parameters and metrics at different levels of detail. It should allow analysts to fine-tune the nominal parameter settings and ranges in the test-case scenarios and to define metrics for follow-up monitoring and adaptation. This is no small matter, since it is common for organizations to generate metrics in more ad hoc ways, which often creates confusion and counterproductive incentives.

To wrap up (see also Table 7.1 in the main text), the monograph describes an approach to dealing effectively with uncertainty. The approach envisions demanding more from higher-level analysis and analysts, particularly routine evaluation of options for flexibility, adaptiveness, and robustness, and also finding simple but credible ways to aid decisionmaking, explaining decisions to and convincing others, and defining implementation plans with metrics. All this will require new analytic methods with reduced dependence on detailed models and massive databases, although those should remain important for establishing the common base of knowledge and for integrative work. The approach urges streamlined processes in which select analysts from OSD (Policy), OSD (Cost Assessment and Program Evaluation), the Joint Staff, and OSD (Acquisition, Technology, and Logistics) work together rather than sequentially. They would, of course, continue to depend heavily on the services and combatant commands for expertise and suggestions.

Acknowledgments

This monograph is a personal review of analytic concepts. Shortcomings are my own, but I have benefited from collaboration over the years with Richard Hillestad, Russell Shaver, and many other RAND colleagues, including doctoral students of the Pardee RAND Graduate School. Individual points in the monograph were motivated by discussions with or work by George Akst (MCCDC), David Alberts (IDA), Tom Allen (Joint Staff J-8), Mike Bailey (MCCDC), Tripp Barber (Navy Staff), Justin Beck (Australia's DSTO), James Bexfield (previously of OSD [CAPE]), Daniel Chiu (OSD [Policy]), Mark Gallagher (Air Force A-9), Joel Predd (RAND), James Stevens (OSD [CAPE]), Ben Taylor (Canada's DRDC), and Rob Solly (the United Kingdom's DSTL). Some of the ideas stem from discussions over the years with Andrew Marshall (OSD Net Assessment) and with a number of other people who have previously been highly placed government officials: David Chu, Richard Danzig, David Gompert, Kenneth Krieg, Robert Soule, and Michael Wynne. None of these, however, bear any responsibility for what follows. Finally, I greatly appreciate the thorough and detailed formal reviews by James Bexfield and RAND colleague Ryan Henry.[†]

[†] MCCDC: Marine Corps Combat Development Center; DRDC: Canada's Defence Research and Development Canada; DSTL: United Kingdom's Defence Science and Technology Laboratory; DSTO: Australia's Defence Science and Technology Organisation; IDA: Institute for Defense Analyses.

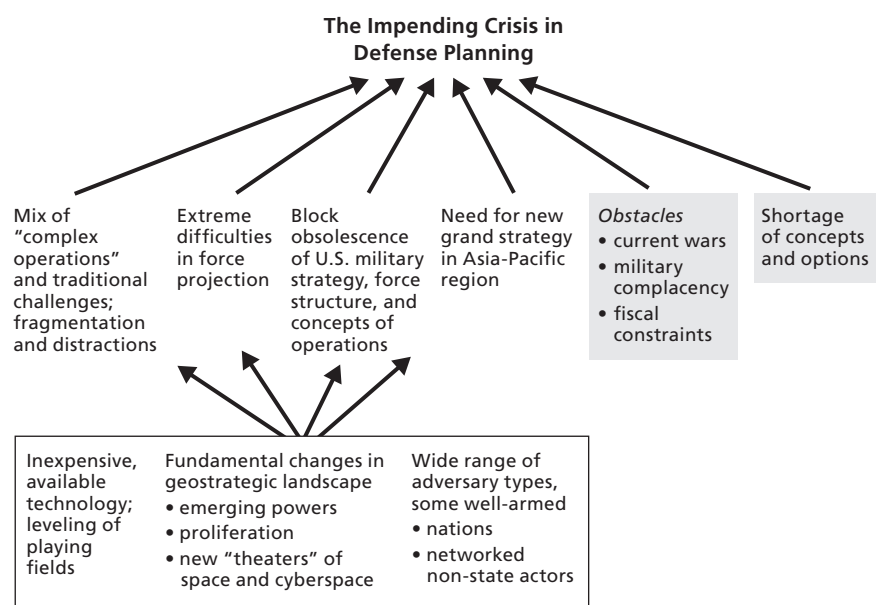
A Setting of Great National Security Challenges

Fiscal Constraints Are Only Part of the Problem

As of late 2013, the U.S. Department of Defense (DoD) was still struggling with severe budget cuts. Historically, a 10 percent cut in the DoD program has led to a 20 percent cut in force structure due to other expenses being difficult to understand, isolate, and trim.¹ Also, certain costs such as those associated with long-term medical benefits have risen markedly, and the inflation-corrected cost per member of the military continues to grow as it has for decades. These increases further complicate efforts to achieve desired force levels. Such problems have been exacerbated by sequestration and related uncertainty, although the sequestration problems were mitigated by congressional decisions in December 2013.

These facts are part of the context, but the United States has profound national security challenges of which the budget is only one. Figure 1.1 identifies challenges as described in an earlier publication with colleague Peter Wilson.² If our earlier work is largely correct, then the task of analysis will be even greater than otherwise because new options and difficult choices will be needed and their evaluation will be difficult. We argued that the United States faces a mix of complex and traditional military challenges; extreme difficulties in force projection; block obsolescence of U.S. military strategy, force structure, and concepts of operations; and the need for a new grand strategy in the Asia-Pacific region. Obstacles to dealing with these challenges include current wars and crises, complacency about obsolescence, and, of course, fiscal constraints. Another obstacle is striking: the absence of a coherent

Figure 1.1
Problems Go Far Beyond Fiscal Constraints



SOURCE: Davis and Wilson, 2011a.

RAND RR482-1.1

vision on the way ahead (despite many good ideas and initiatives). In the period 1996–2001, forward-leaning planners had concrete proposals to transform U.S. forces by exploiting precision fires, precision navigation, networking, and stealth technologies.³ Doing so would, it was argued, allow performing many missions better than before but with smaller military forces and corresponding reductions in cost. Many of these changes have since occurred and are now taken for granted. But no analogous and coherent proposals loom large in the current defense debates, although many ingredients are present. It will be an interesting period for defense analysis.

Changes in U.S. capability to project forces are particularly troublesome. Drawing again from the earlier publication, Table 1.1 elaborates for eight operations. Some are widely discussed under the rubric of anti-access and area denial; others are less appreciated. For example,

Table 1.1
U.S. Capabilities, Then and Now

Operation	Then: Assessment in Near Past	Now: Assessment Looking Forward
Forward presence	7	5
Large forward deployments	7	3
Broad naval supremacy	7	5
Air supremacy	7	5
Suppression of enemy air defenses	5	3
Offensive air operations	7	3
Ground-force entry	7	1
Later ground-force operations	7	3

NOTE: Red = very poor, orange = poor, yellow = medium, light green = good, and dark green = very good.

the United States may not be able to count on easy air supremacy due to mobile and man-portable surface-to-air missiles. Also, ground-force operations with traditional U.S. units will be more dangerous as even “rogue-level” adversaries gain some precision-guided weapons and area weapons. Interestingly, this shift from enjoying military overmatch to being faced with numerous difficult challenges has long been predicted. A 1998 paper looked forward to what it called Era A in which the U.S. military would benefit greatly from technological developments, but it also foresaw a very difficult Era B ahead starting in about 2012. By then, China would have arisen rather than be rising, some rogue states would have nuclear weapons rather than be working on them, and the fruits of technological developments would be more broadly disseminated.⁴ We are now in Era B.5.

A Pollyannish Perspective on Tight Budgets?

Ironically, this background of challenges may suggest that budget stringency could be helpful since the need for tough budget choices has

sometimes forced modernizations and organizational changes that otherwise would have been successfully resisted. Better that change come about by budget necessity than, say, by losing a war. Forward-looking choices are much easier, however, when good options are on the table and when an organization has latitude in how to spend its resources. These conditions do not apply today, with the result that many current discussions are primarily about how to take large cuts rather than how to solve the problems in Table 1.1.⁶ Nonetheless, I proceed as though the situation will improve and that analysis can help DoD make far-sighted choices. The question is how analysis can do so. The answer is that many elements of and process for analysis need to be rethought. What follows describes my own suggestions.

Endnotes

¹ The rule of thumb traces to the late Kevin Lewis (Lewis, 1994).

² Davis and Wilson, 2011a, 2011b.

³ Contemporaneous studies are available (Defense Science Board, 1996; Davis, Gompert, and Kugler, 1996; Joint Staff, 1996; Defense Science Board, 1998; National Defense Panel, 1997; National Research Council, 1997, 2000; Cebrowski and Garstka, 1998; Davis et al., 1998. The 1997 Quadrennial Defense Review (Cohen, 1997a) also had a chapter on Transformation (National Defense Panel, 1997).

⁴ Davis et al., 1998.

⁵ Other authors have addressed many of the same challenges (Flournoy and Brimley, 2008; Krepinevich, 2009; Flournoy, 2009; Glenn, 2012; Watts, 2013).

⁶ Blechman and Committee, 2012; O'Hanlon, 2013. As of August 2013, DoD has just completed Secretary Chuck Hagel's Strategic Choices and Management Review (Hagel, 2013), highlights of which are compared to some think-tank recommendations in a Center for Strategic and Budgetary Assessments paper (2013).

Analysis to Aid Decisionmaking

A starting point for discussion is to ask what policymakers should expect from analysis.

Classic Tenets Remain Valid

Defense analysts have benefited for decades from tenets expressed by Alain Enthoven, who founded the Office of Systems Analysis for Secretary of Defense Robert McNamara. The office evolved into the Office of Program Analysis and Evaluation and, most recently, Cost Assessment and Program Evaluation. Although systems analysis was extremely controversial in the early years,¹ and the Vietnam War tarnished the reputation of Secretary McNamara, a remarkable consensus developed about Enthoven's analysis tenets as listed below.² Indeed, chiefs of the military services, heads of other government agencies, and corporate managers often embrace variants tailored to their purposes.

1. Decisions should be based on explicit criteria of national interest, not on compromises among institutional forces.
2. Needs and costs should be considered simultaneously.
3. Major decisions should be made by choices among explicit, balanced, feasible alternatives.
4. The Secretary of Defense should have an active analytic staff to provide him with relevant data and unbiased perspectives.
5. A multiyear force and financial plan should project the consequences of present decisions into the future.

6. Open and explicit analysis (including transparent data and assumptions), available to all parties, should form the basis for major decisions.

Additional Tenets Are Needed

The classic tenets have held up well, but I believe that additional tenets are needed.

7. Decisions should confront “deep” uncertainty and disagreement.
8. The planning process should ensure creative and effective collaboration across strategy, operations, technology, programs, and budgets.
9. The planning process should provide for monitoring, feedback, and adaptation.

I will discuss each of these in turn and then focus on the first (Tenet 7).

Deep Uncertainty and Disagreement. Tenet 7 is important because organizations so often settle into routines that focus on alleged best estimates, official forecasts, official scenarios, and prevailing assumptions. The history of strategic planning, however, reveals the significance of uncertainties, many of which are “deep,” referring, for example, to how the future will unfold, how humans will behave, and other matters for which there are no reliable probability distributions.³ Actual developments are sometimes very different from those expected due to unplanned-for events or a misunderstanding of the problem. Such uncertainties are all too often poorly treated if addressed at all.⁴ This is now recognized even in books about “black swans” intended for airplane reading by managers.⁵ It has also been the reason that U.S. policymakers, including defense secretaries, are sometimes disappointed in the analysis they receive. This was reflected in 2006 with leadership complaints about how the analytic community was continuing to focus on old and familiar scenarios rather than assisting leadership with irregular warfare and exploring the effect of potential strategic

shocks.⁶ To be sure, exceptional efforts are sometimes made to compensate, as when OSD (Policy) conducted some “trends-and-shocks” studies between 2005 and 2008.⁷ Such efforts, however, are outside the mainstream of analysis.

Deep uncertainty underlies many current questions: Will China become increasingly aggressive and hegemonic? Will North Korea or Iran actually use nuclear weapons at some point despite that seeming to us irrational? Will violent Islamist Jihad fade away, grow, or remain a chronic threat? Will future special-operations-forces-centric counter-insurgency operations be successful or counterproductive? Will U.S. efforts to maintain a power balance in the Asia-Pacific region (e.g., the air-sea battle) be effective or counterproductive? The list of such unanswerable questions is long, but much can be done to inform decision-making amid such uncertainty.

Collaboration. One lesson from experience is that problem-solving often requires dynamic, stressful collaboration among those associated with strategy and policy, operations, technological developments, and resource-sensitive planning. Stovepiped organizations often mandate sequentially cooperative processes, but solutions can emerge faster and better if people work together simultaneously across stovepipes. To use language from command and control research, success is often enabled by collaboration and networking across hierarchical columns, rather than by occasional “deconfliction.”⁸ Unfortunately, some of DoD’s processes are stovepiped and sequential for historical and organizational reasons, as well as interpretations of law.⁹ Interestingly, many of the most important DoD program developments have occurred only by working around these processes (e.g., with highly classified “black” programs). This said, communication and collaboration do occur routinely on many matters, whether because of personal relationships among senior leaders, inclusive processes (at the expense of having large committees), or necessity.

Monitoring, Feedback, and Adaptation. The implementation of plans sometimes proceeds as though the plans are reasonably solid and enduring. Realistically, of course, initial plans are often flawed, poorly executed, or overtaken by events.¹⁰ Thus, feedback loops are essential. Their importance has been particularly evident to DoD in the

last decade as the result of continual wars with many unanticipated developments.¹¹ Fortunately, the U.S. military services are learning organizations that evolve and adapt—especially when circumstances necessitate doing so. Nonetheless, neither DoD nor other government agencies are good at routinely building into programs the means by which to monitor outcomes, reassess, and adapt. This is a work constantly in progress.¹²

Tenets 9 and 10 are large subjects better treated elsewhere, but Tenet 7 relating to planning is at the core of this monograph. It leads to a new principle and implications for analysts.

A New Principle and Implications for the Analysis Profession

The FARness Principle

The last two decades have spawned methods for dealing effectively with both normal and deep uncertainty. They suggest a new principle, which is to plan (whether for future force structure or operations) for flexibility, adaptiveness, and robustness. This is what I have called the FARness principle.¹³ It has an immediate implication for analysis.

- Analysis should help leaders find strategies that are flexible, adaptive, and robust:
 - *flexible* to accommodate changes of mission, objectives, and constraints
 - *adaptive* to circumstances
 - *robust* to events such as positive or negative shocks
- Leaders should demand analysis that does so.

This basic concept could have been embraced by any Secretary of Defense in memory.¹⁴ It has broad support among those who plan under uncertainty, although terminology varies. The principle overlaps with what has elsewhere been called planning for adaptiveness, robust adaptive planning, robust decisionmaking, and planning for agility.

A considerable literature documents applications of one or another variant.¹⁵

Why FARness Is Neither Common Sense Nor Easily Obtained

Elevating FARness to a principle might seem merely to glorify common sense: Who would *not* want to plan for FARness? The following examples may illustrate why the matter is nontrivial.

1. *Acquisition.* The norm in acquisition has been for industry to receive precise requirements (although requirement ranges are becoming more common), even though the future uses of what is being acquired and the capabilities that will be needed may be impossible to forecast accurately. Why does DoD not ask industry to write proposals that compete in the versatility of their offerings by providing parametric descriptions of what capabilities can be delivered as a function of cost and yet-to-be-decided requirements?¹⁶ The government would then better understand the tradeoffs, and industry would not need, when writing proposals, to “divine” the product and price tag that will eventually be acceptable. This approach, however, is unusual. As an example of non-FARness, consider the failure over decades to protect satellites, aircraft, and other systems with modern electronics against electromagnetic pulse effects, which created major vulnerabilities that could have been avoided affordably.¹⁷ A second well-known example is that initial development of the F-15 did not allow for air-to-ground capability—capability that was later recognized as necessary. Similar disputes have arisen in the history of the F-22 program.
2. *Tyranny of Priority Lists.* Establishing priorities is essential, but the common management tactic of establishing rank-ordered priority lists can lead to bad decisions inconsistent with FARness. In an austere budget environment, the result may be to fund items from the top down until the budget is exhausted. Since the most expensive items sometimes have the highest priorities, fully funding them may eliminate items for capability that will prove crucial. Yes, priority-setting is essential, but it

is best approached in the language of “balancing portfolios” as discussed in Chapter Six.

3. *Difficulties in Attaining Jointness.* DoD has been remarkably successful in promoting jointness over the last 25 years, but doing so has entailed substantial and sustained leadership effort and the goals are not yet fully implemented.¹⁸ For example, the military components continue to have command and control systems with interoperability problems that hinder flexibility, adaptiveness, and robustness in operations. Technical difficulties and specialized needs are an important root cause, but so also is the fact that the individual military services—when squeezed for budget and faster acquisition—conclude that it is more important to acquire their own systems than to ensure interoperability. Such decisions represent locally rational decisions “necessitated” by shortcomings in the complex overall planning system.

Despite these problems, DoD has generally avoided the most serious blunders that might have been made. Moreover, it has sometimes demonstrated flexibility, adaptivity, and agility. For example, after the attacks of September 11, 2001, it was able to employ both Army and Marine forces to landlocked Afghanistan without previously developed doctrine. Special operations forces on the ground innovated to find ways to direct precision strikes from the air. Ground forces were supported with aircraft rather than traditional heavy artillery.

DoD’s successes in this regard have been due significantly to the quality of its people and, on the planning front, its large budget, decentralized decisionmaking that has allowed advocates of new ideas to shop around for buyers, and a U.S. tradition of supporting research such as that conducted by the Defense Advanced Research Projects Agency.¹⁹ Unfortunately, current budget-tightening and sequester-related constraints are endangering all of these and the long-range consequences could be severe.

Despite this worrisome background, in what follows I assume that budgets and budget processes will allow reasonable decisions and return to implications for analysis and analysts.

New Professional Responsibilities for Analysts

The FARness principle implies a new concept of the analyst's professional responsibilities. To set the stage, we should recall that one of the most important accepted responsibilities of an analyst is to make the assumptions of analysis known to the leaders to whom the analysis is reported. The need to do so is taught routinely to young analysts and stressed by study leaders. It is an excellent principle—but nowhere near sufficient. The FARness principle suggests the following additional professional obligations:

- routinely identify and assess options for FARness, showing the value of affordable hedges to policymakers even in periods of austerity when hedges may seem like luxuries
- routinely show how results vary with the major assumptions on which there is or should be disagreement; it is not sufficient to show sensitivities to only one or a few issues while ignoring others that are also important.²⁰

A subtlety here is the difference between analysts who fight the policymaker's strategy and analysts who support the strategy but also identify hedges. Even strong-willed policymakers can appreciate the latter, so long as the hedging does not endanger the strategy. Many examples of possible hedges come to mind drawn from historical experience. These include (1) continuing research and development on a weapon system that has been ruled out for the present but has upside potential for the future, (2) preserving the ability to reopen an assembly line, (3) maintaining cadre-staffed reserve-component units rather than disbanding them, (4) mothballing ships rather than destroying them, (5) acquiring more drones for intelligence, surveillance, and reconnaissance than are currently thought to be needed, (6) maintaining infrastructure for recruiting, training, and equipping additional ground forces if in the future the Army and Navy need to be scaled up again, (7) accepting deliberate redundancy in programs or forces to reduce risks (e.g., by being able to employ either ground-based or sea-based air forces as a crisis arises) and foster competition, and (8) using

an economy-of-force strategy in a region rather than pulling forces out of the region and leaving a possible vacuum.

Hedges are not free, sometimes undercut strategy, and are sometimes counterproductive by delaying more decisive actions. Some hedges are wise; some are not. Analysts can help find the good ones and some analysts do so routinely. Often, however, doing so is not seen as an important function of analysis, especially if “requirements” are imagined to be fully adequate and solid.

With this background in objective-setting for analysis, the remainder of the monograph discusses what analysis should arguably look like and ideas for making that vision into a reality.

Endnotes

¹ Murdock, 1974.

² Enthoven and Smith, 1971. The second edition in 2005 has a new introduction by Kenneth J. Krieg and David S.C. Chu reendorsing the tenets across decades and political parties.

³ See a recent review of RAND work on the subject (Davis, 2012).

⁴ Mintzberg, 1994; Mintzberg, Lampel, and Ahlstrand, 2005. Related writings have focused on defense planning (Davis, 1994b; Davis, 2002; Gray, 2010).

⁵ Taleb, 2007. See also a volume on strategic surprise (Bracken, Bremer, and Gordon, 2008).

⁶ Rumsfeld, 2006, p. 19.

⁷ An edited volume reflects the spirit of these efforts (Arnas, 2009). Other elements of the activity are not in the public domain.

⁸ NATO panels have discussed command and control issues for “complex endeavors” (Alberts, 2007; NATO RTO SAS-065, 2010; Alberts, 2011). A report by NATO’s SAS-085 panel is in preparation.

⁹ An example is the Joint Capabilities Integration and Development System (JCIDS) in which understanding needs, developing requirements, developing alternatives, and making choices are addressed sequentially (Joint Chiefs of Staff, 2012), which may seem logical but is troublesome (see, e.g., Chapter Two in Davis, Shaver, and Beck, 2008, with excerpts appearing also in Davis et al., 2008).

¹⁰ Mintzberg (1994). Parts of the business world have moved on with attitudes consistent with those in this monograph (Grant, 2002, 2010).

¹¹ Examples have included the insurgency in Iraq, the effect of improvised explosive devices leading to rapid acquisition of the mine-resistant, ambush-protected vehicle (Rogers, 2012); the ineffectiveness of early U.S. counterinsurgency strategy and the overhaul of doctrine by General David Petraeus (Army) and General James Mattis (Marine Corps) (Petraeus and Amos, 2006); huge cost increases for weapon systems such as the F-22 and F-35; and technologically inspired innovations in direct-action operations with modern networking (McChrystal, 2011).

¹² This comment reflects ongoing work by colleague Jeff Drezner for DoD's Office of the Under Secretary for Acquisition and Technology, as well as such examples in homeland security work noting the need for programs to monitor and evaluate effectiveness (Jackson et al., 2012) and to have peer-reviewed assessments of the results (Davis et al., 2013). The U.S. Government Accountability Office has published a series of reports that describe its perspective on related DoD acquisition efforts to plan for important "knowledge points" at which decisions can be made (2013).

¹³ The terminology dates back to 1993–1994 with the terms having distinct classic meanings (Davis and Finch, 1993; Davis, 1994a, 1994b). In everyday speech, however, the terms are often synonyms. Some of the themes were repeated in a later collection (Johnson, Libicki, and Treverton, 2003).

¹⁴ Robert McNamara commissioned a 1963 study that looked at a wide range of possible conflict scenarios. Only afterward was it concluded that—for force-sizing purposes—simplification was possible in terms of worse-than-expected cases. Subsequent Secretaries have routinely requested analysis across scenarios, but organizations have resisted going beyond the canonical scenarios of the time.

¹⁵ A considerable policy-analysis literature exists from RAND (Davis, 1994b, 2012; Lempert, Schlesinger, and Bankes, 1996; Lempert et al., 2006) and Delft University in the Netherlands (van de Riet, 2003). See also defense-related discussion from the Hague Centre for Strategic Studies (De Spiegeleire, 2011) and NATO's command and control research (Alberts, 2011). See also a RAND website collecting publications using robust decisionmaking methods, mostly in social-policy contexts (<http://www.rand.org/topics/robust-decision-making.html>).

¹⁶ This discussion benefited from discussions with colleague Elliot Axelband.

¹⁷ Foster et al., 2008.

¹⁸ Harold Brown has recounted early history, noting roots to President Eisenhower (Brown and Winslow, 2012, p. 54 ff). Congress had a powerful role with passage of the Goldwater-Nichols legislation in 1986. General Colin Powell took an activist stance implementing the intent during his tenure as Chairman (Jaffe, 1993; Powell and Persico, 1995). Donald Rumsfeld's shift to capabilities-based planning was a

major step in institutionalizing change (Joint Defense Capabilities Study Team, 2004).

¹⁹ One notable example was JSTARS, the Joint Surveillance, Tracking, and Reconnaissance System platform, which might never have been acquired except that a Defense Advanced Research Projects Agency prototype was brought into operational use in the 1991 Gulf War, where it proved the concept's value (Dunn, Bingham, and Fowler, 2004).

²⁰ See also Dewar, 2003, including a discussion of hedges. More commonly, the emphasis is merely on listing the assumptions and perhaps doing some excursions. As merely one example, NATO's worthy code of best practice for command and control analysis mentions varying assumptions (p. 43), but more prominent portions of the text convey a sense more of the need merely to specify them (e.g., pp. 7, 64, 75, 101). Similarly, where the study admonishes varying assumptions (p. 115), the language used is with the word "may," as in "Sensitivity analysis may be applied. . . ."

Concrete Suggestions for Analysis

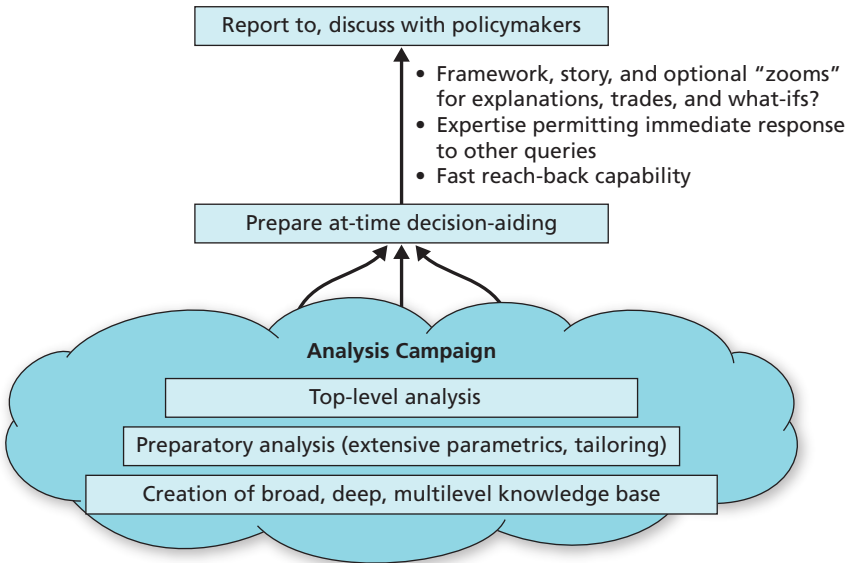
This and subsequent chapters address specific concepts and issues that arise in attempting to plan under uncertainty. The first is the concept of conceiving of an *analysis campaign* with many elements. This raises a number of issues that are discussed in terms of how to (1) think about analysis for decision-aiding, (2) balance the simple and complex, (3) broaden the character of analysis, (4) deal with uncertainties and disagreements, (5) recognize multiple objectives and criteria, including the need to manage risk, and (6) show analytic results as a function of major assumptions (exploratory analysis).

Such analysis often requires models and Chapter Four addresses how to develop “capability models” enabling the style of analysis called for in this monograph. Chapter Five then turns to the challenge of finding the appropriate options to assess. Chapter Six then describes portfolio-analysis techniques for comparing options. It includes a generalized, uncertainty-sensitive version of cost-effectiveness analysis that is especially salient for a period of austerity.

The Concept of an Analysis Campaign

Figure 3.1 suggests the concept of an analysis campaign schematically. Such a campaign might be tailored to a particular upcoming decision or to continuing analysis for a capability or mission area of continued interest and development (e.g., undersea warfare, defense suppression, ground-force maneuver). The campaign might have extensive original

Figure 3.1
Decision-Aiding That Draws on an Analysis Campaign



RAND RR482-3.1

work or might consist largely of distilling knowledge available from the services, industry, academia, and elsewhere.¹

When the time comes for analysts to discuss results with policymakers, what goes forth should seldom be “the answer”; it should instead be a combination of a well-framed and coherent story and the ability to zoom into detail to explain results and highlight uncertainties and to answer diverse and perhaps unstructured questions requiring in-depth knowledge. While most responses should be possible immediately by virtue of preparation, a fast reach-back capability will sometimes be necessary.

Some of what is depicted in Figure 3.1 occurs routinely in analysis organizations. Other aspects do not. In particular, there has often been insufficient emphasis on the simple story, the optional zooms for explanation, uncertainty analysis, and related parametric tradeoffs. Also, analysis campaigns are sometimes overly tilted toward the kinds of

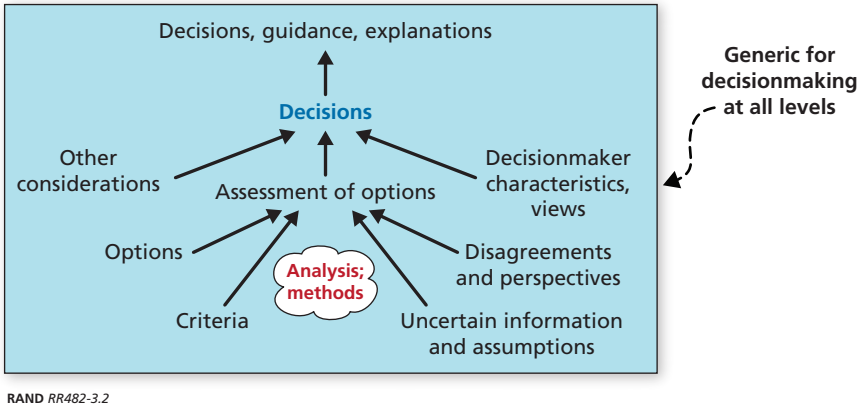
knowledge obtained from big computer models. And, as discussed in the next section, analysis campaigns are often construed too narrowly.

Supporting Policymakers: It Is Not Just Decision-Aiding

Countless textbooks describe tools and techniques for decision support but do not convey a sense of how decisions are made or how analysis can help. Figure 3.2 suggests that the outcomes of decisionmaking are not just the decisions themselves but also guidance and explanations—i.e., the story. The guidance is necessary for implementation and explanations are needed if the guidance is to be understood and the decisions accepted by the President, Congress, and diverse stakeholders.²

The generic model described in Figure 3.2, which applies specifically at the strategic and operational levels most relevant to this monograph, recognizes that decisionmakers are usually affected by considerations other than formal analysis (see the items on the left and right sides). These other factors reflect their own backgrounds, characteristics, and views and also such matters as concerns about the industrial base, pressures from lobbyists, or their administration's campaign promises.³ Thus, analysis informs but may or may not be decisive even if well done. This said, analysis can be more helpful if it considers a full range of appropriate options, considers multiple criteria relevant to the decisionmaker, confronts uncertainty, and deals well with the effects of disagreements by showing alternative perspectives. To elaborate on the latter, senior leaders often disagree about, say, the relative importance of modernization and current readiness or about the relative emphasis to be given to the Asia-Pacific or Mideast regions. Although it may be necessary for decisions to clearly favor one perspective or another, it is common—and consistent with the FARness principle—to achieve “balance” by finding options that account “adequately” for the full range of considerations (assumptions, uncertainties, and disagreements). This helps both to build consensus and to hedge against uncertainty. Overall, Figure 3.2 is saying that:

Figure 3.2
Generic Image of Decisionmaking



- Analysis and analysis methods should include diverse options and treat criteria, uncertain information, assumptions, and perspectives as *variables*—not as fixed assumptions.

Depth: Balancing the Simple and Complex

Most of what follows is about studies and analyses that require depth of inquiry. Before going down that path, however, it is important to recognize that only some analysis is of that character.

Simplicity's Dominance in More Routine Analysis

As those familiar with such organizations are quick to point out, supporting decisions in a high-level analysis shop such as OSD (Cost Assessment and Program Evaluation) or the related offices of the Joint Staff and services often requires only clear and logical thinking, arithmetic, algebra, and skills in chart-making and writing “one-pager” memos. There may even be a well-known formula that does a “good-enough” job. For example, Navy analysts do not need to do a full study to understand how losing some aircraft carrier battle groups in the budget wars would affect forward presence worldwide. Army, Marine

Corps, and Air Force analysts do not need a new study to estimate the consequences for force management of extending units' operational deployment periods. A great deal of analysis on the margin can be rather simple. Analysis often depends more on obtaining credible data (e.g., cost estimates or geographic information relevant to deploying forces or targeting adversaries) than on mathematical models.⁴

With this said, let us now return to the main thrust of the monograph, which is about issues for which analysis is more demanding.

Achieving Valid Simplicity

Figure 3.2 says nothing about the nature of the analysis itself, but it instead reflects a recurrent plea from policymakers that analysis be simple and transparent.⁵ After all, they must ultimately be able to reason about their choices, which requires intellectual simplifications (none of us can “reason” with too many variables simultaneously). Further, they must communicate to and convince others. And, finally, policymakers often know from experience that the most important issues are driven by relatively simple considerations—if one can merely frame the issues properly and see through the fog. Finding ways to see through the fog has long been a prized goal of system analysts and policy analysts.

It might seem that analysis and underlying models should therefore be simple. At the same time, however, even those arguing for simplicity want the “simple story” to be correct! And there, of course, lies the rub. Can these considerations be reconciled? The answer is yes, but it means that simplicity must be balanced with more in-depth work. It is wise to remember the last phrase of a good version of Occam's Razor:

Everything should be made as simple as possible, but not simpler.

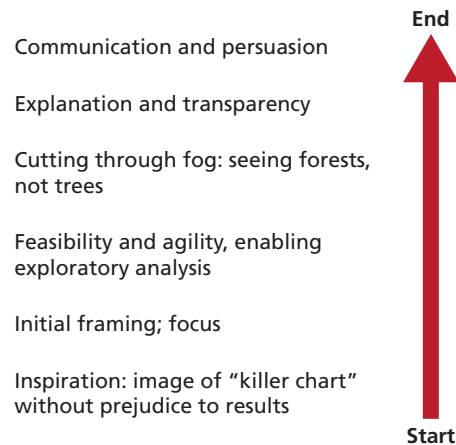
Often ascribed to Albert Einstein⁶

Ignoring sound but contradictory empirical evidence, then, is not acceptable. So also, it is not acceptable to disregard the implications of logic, experience, and credible theory extrapolating beyond what has been observed so far.

Reconciling simplicity and sufficiency of depth is easier to appreciate for those who have had the good fortune to move back and forth among levels of detail. A physicist or chemist is expected to understand phenomena at levels from quantum mechanics through thermodynamics or engineering formulas. Economists are expected to understand both micro and macro economics. System engineers work principally at higher levels but know that details matter when the system modules are connected.

As indicated in Figure 3.3, telling an understandable story is only one reason among several for using simple models. At the outset of the analysis campaign (the bottom of the figure), one may ask what seems to be the problem and what a “dynamite result” would look like, one that would be palpably interesting and important—whether to falsify initial notions or to confirm them. Such framing can focus analysis and, at the same time, motivate research with the depth and integrity to test competing possibilities. Moving upward in Figure 3.3, relative simplicity enables fast and agile modeling and enables “exploratory analysis” across the vast range of possibilities. That is, it enables parametric modeling, which allows one to see forests, not trees, and understand major tradeoffs. Such results can be explained clearly and

Figure 3.3
Multiple Reasons for Simplicity



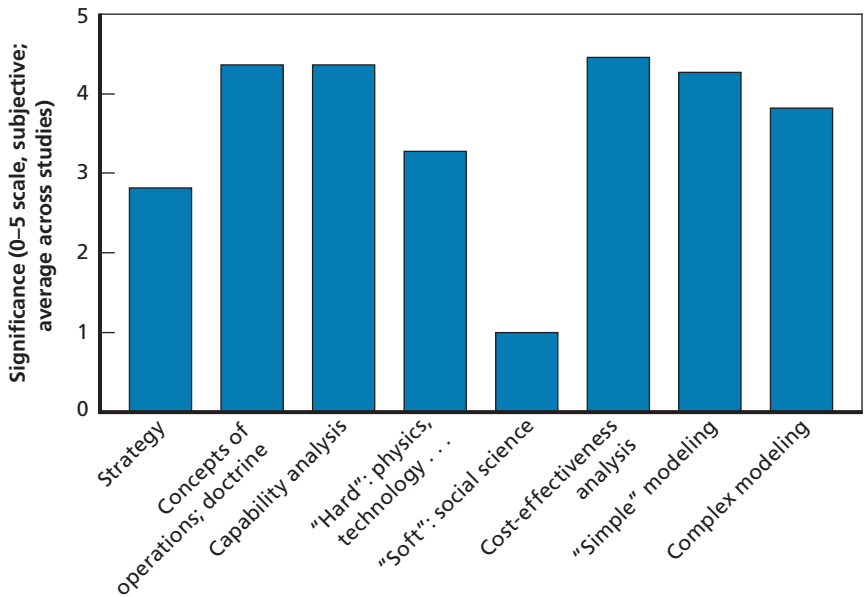
persuasively. Further, the key parameters of such work become natural metrics following logically from underlying considerations⁷ rather than being ad hoc and frequently counterproductive.

Simplicity and Complexity in Historical Studies

Arguing for a *combination* of simplicity and underlying depth may seem irregular, but a casual look at a dozen past studies suggests otherwise. I chose major studies from the early 1960s to 2010 with which I was at least casually familiar and in some cases involved. I then characterized the studies along a number of attributes with subjective scores of from 1 to 5, with 5 indicating a heavy dose of the attribute. (Appendix A lists the studies and my subjective characterizations.) For example, a study with a 5 in the “hard physics” category might have involved considerable analysis using concepts from physics and technology. On the other hand, it might not have required deep thinking about concepts of operations and would get a score of 1 or 2 in that category. Figure 3.4 summarizes results using average scores across the 12 studies and eight attribute categories. Readers could quarrel with the choice of studies, the attributes, and the scoring: The results are merely suggestive. Nonetheless, the studies rather consistently included a mix of simple and complex modeling, developing concepts of operations, doing parametric capabilities analysis, and performing cost-effectiveness analysis. That is, it seems that in relatively large studies, analysts have found it necessary to delve deeply into problems and also to find simplified ways to guide, understand, and communicate the work. Unfortunately, the trend over the last decades has been for DoD studies to become more focused on standard scenarios and big models. Restoring a better balance should be an imperative for those who manage or consume analysis.

Another trend in DoD research, but not yet in many analytic studies, has been recognition of social-science considerations, which were largely ignored in the earlier studies. In recent times, DoD has been experimenting with how to include social science in studies, especially for those relevant to interventions in troubled societies.⁸

Figure 3.4
Attributes of Some Past Studies



RAND RR482-3.4

Breadth: Using Diverse Models and Tools

Having discussed depth, a next issue is how to *broaden* analysis. The need to do so is even more evident now than a decade or so ago because social-science factors have been important in the wars in Iraq and Afghanistan.⁹ Good decision-aiding should draw on a mix of “hard” and “soft” information, and not just when dealing with human behavior. Furthermore, despite the emphasis on “rigor” and the common fallacy of associating rigor with “quantitative,” many important strategic-planning questions are not well informed by purely quantitative analysis. Examples include such questions as

1. How can the United States best deter a given adversary? To what extent should deterrence be based on the assumption of “rational” decisionmaking and how can we understand that rationality—in both peacetime and crisis?

2. Is deterrence even the appropriate focus or should attention be broadened to include other elements of influence, such as co-optation, dissuasion, and punishment now for recent actions so as to deter later aggression?
3. How well should we expect a particular strategy or related tactics to work when they interact in complex ways with entire societies, as in intervention operations with the intention of stabilization and reconstruction?
4. How should we expect our adversaries to respond and adapt to new strategies, capabilities, or actions on our part?
5. What does history tell us about the kinds of operation that we are currently considering?

Such questions suggest that diverse instruments are needed in an analysis campaign. Table 3.1 illustrates this with instruments in rows and columns showing their strengths and weaknesses.¹⁰ Although the ratings are subjective and depend on unspecified assumptions, the goodwilled reader will probably accept the rough validity of Table 3.1 and acknowledge that different insights come from varied models, human war-gaming, red-teaming, and historical studies. Some instruments are good for narrow decision aids, whereas others are needed for putting the pieces together. Campaign models, for example—when used with large negotiated databases for only some standard case—are poor decision aids but are excellent for integration, for understanding the many facets of a successful large operation, and for building analyst expertise that is valuable in answering specific questions quickly, often with simpler models.

Table 3.1 was constructed with strategic-level issues in mind, but the instruments (rows) would be different if the figure were for an analysis campaign at the mission or capability-class level (e.g., an analysis of next-generation armored fighting vehicles, unmanned submarine-launched vehicles, or new low-cost fighter aircraft intended for partner militaries). Also, the relative importance of attributes (columns) would change. There would be less interest in strategic integration (a strength of campaign models) and more interest in mission-level models and parameterized engineering-level models. Instead of human war-

Table 3.1
Broad Scope of Analytical Capabilities to Support Decisionmaking

Instrument	Resolution	Relative Strength						
		Strategic-Level Functionality					Physical Phenomena	Human Phenomena
		Agility	Breadth	Strategic Decision-Aiding	Strategic Integration			
Simple analytical ^a	Low	5	1	5	1	1	1	N.A.
Seminar-level human war-gaming	Low	5	4	3	1	1	4	3
Red-teaming on capabilities and operations	Varied	5	3	3	1	3	5	5
Qualitative factor trees	Low	5	5	5	5	1	3	
Human war-gaming	Medium	1	5	5	5	3	3	5
Campaign simulation (usual)	Medium	2	5	2	4	2	1	N.A.
+ agents, political-economic factors, and exploratory analysis ^b	Medium	3	5	4	5	2	3	N.A.
Mission-level adaptive models, exploratory analysis	Medium	3	3	3	1	5	3	N.A.
High-fidelity simulation ^c	High	1	1	1	1	5	1	3
Historical case studies	Varied	1	1	1	1	3	5	5
Historical data analysis	Low	1	1	1	1	1	1	5
Field experiments and war data	Varied	1	1	1	1	5	5	5

NOTES: Ratings are 1 (very poor) to 5 (very good), with red, orange, yellow, light green, and green corresponding to 1, 2, 3, 4, and 5, respectively. Scores depend on assumptions.

^aExamples include closed-form models and spreadsheet-level computer models.

^bExploratory analysis examines the effect of simultaneous variations of all important assumptions, not mere sensitivity analysis on the margin.

^cIn some instances, high-fidelity simulation can be a primary and reliable source of what can be considered to be empirical information. It is simply not feasible to obtain the equivalent information with physical testing.

gaming, an important instrument might be virtual simulation with human operators or field experiments.

Regardless of the level of the decision being made, the supporting analytic campaign should keep in mind a generic rule of thumb:

Analysts working primarily at a given level of detail should be familiar also with representations one notch deeper in resolution, to ensure an adequately deep understanding that will inform their assumptions, and a notch lower in resolution so as to appreciate the needs of decisionmakers.

Yet another reason for breadth is that it is often possible to discover a fruitful way ahead by examining a confusing uncertain-laden problem from multiple perspectives.¹¹

Why doesn't everyone use a range of instruments in their analysis? Efforts are sometimes made to do so in DoD.¹² Those, however, tend to be exceptions because of the influence of organizational structure, culture, experience, management, and budgets. People with different knowledge, skills, and tools tend to be in separate organizations with different perspectives on what constitutes an "analyst" or "analysis." This can be insidious when de facto organizational doctrine defines these terms narrowly and enforces specialization. The best analysts (and consumers of analysis) are often generalists with backgrounds in such subjects as the physical sciences, engineering, economics, or even political science, history, and law. They have often benefited greatly from applied experiences, to include commanding or planning military operations. Mathematics, including operations research, then, is only one of many possible backgrounds. This quickly becomes evident on reviewing the backgrounds of past giants, as conveyed, for example, by the oral histories of senior leaders developed by the Military Operations Research Society. The same message arises from discussions with senior industry managers about their hiring practices, even for modeling-intensive work.

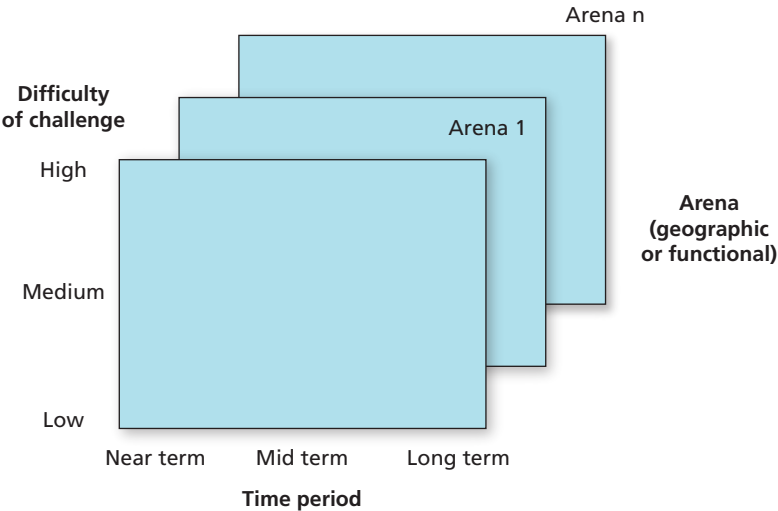
Recognizing Multiple Criteria

Good analysis, then, should balance depth and breadth and use appropriately diverse tools. But what should analysis *address*? One approach, taken in some DoD documents, is to organize around classes of risk (see Appendix C). In what follows, I take the more positive approach of organizing around objectives, in which case, *risk control is just another kind of objective*.

Multiple Objectives, Including Risk Management

One eternally challenging aspect of defense planning is that it is so multifaceted as Figure 3.5 suggests by noting that DoD’s planning must address different arenas worldwide (including the global arena and functional arenas such as intercontinental conflict, space, and cyberspace), different time periods, and different levels of challenge (e.g., the spectrum from, say, showing occasional military presence to being capable of long-duration conflict with a capable adversary). This implies multiple criteria for assessment of force-planning options—

Figure 3.5
Some of the Many Dimensions of Defense Planning

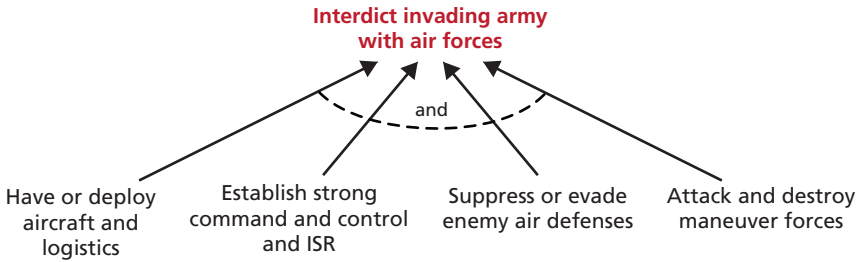


criteria that cannot sensibly be combined or measured on a single scale. After all, a robust plan for the long term and a woefully inadequate plan for the short term and mid term do not usefully “average” to “medium.” The Secretary of Defense must be concerned with the near term, mid term, and long term separately, for each of the various arenas and levels of challenge.¹³

Within any given time period and arena, DoD may have a number of objectives, each with subobjectives, sub-subobjectives . . . down to discrete tasks. Assessing how well the capabilities of an option are “expected” to accomplish each of these constitutes a set of evaluation criteria (e.g., how well would the option’s capabilities do in a best-estimate scenario?). A top-level force planner is concerned primarily with an aggregate-level description. Will an option be able to protect allies from invasion or coercion, whether by deterrence or military action if deterrence fails? Will it be able to keep the sea lanes open to commerce? Such higher-level objectives are routinely discussed in national planning documents.¹⁴ The next level of detail begins to address what tangible military capabilities are needed to achieve the various objectives and subobjectives. DoD uses “capabilities-based planning” to do so, as discussed below.

A relatively specific goal such as being able to defend South Korea from invasion or coercion by North Korea leads to an approximate hierarchy of objectives and capabilities. Narrowing the same example to U.S. and South Korean air forces interdicting an invading North Korean army, the capabilities needed include being able to (1) ensure presence of sufficient aircraft, (2) quickly achieve high-quality command and control (including intelligence, surveillance, and reconnaissance), (3) suppress or evade enemy air defenses, and (4) attack and destroy fixed and moving enemy targets. Such a “mission-system perspective” recognizes, as shown in Figure 3.6, that all four of these are critical components for success. It then measures the extent to which the defense program will provide all the capabilities necessary. Suppose, for example, that the program did everything except provide for suppression of air defenses. The effectiveness of air forces against an invading army with air defenses would then be very low during the time when they were most needed.¹⁵ That is, if a program component

Figure 3.6
Example: Critical Components of Interdiction Capability



NOTE: ISR is intelligence, surveillance, and reconnaissance.

is critical, then a program that ignores it is fatally flawed even if the option is “efficient” in procuring other components. Mathematically, it follows that the key metric for a related program would be nonlinear—in this case, more nearly multiplicative than linear, because the effectiveness of the program is proportional to the *product* of factors indicating whether each critical component is adequately present. More of one critical capability does not compensate for the lack of another.¹⁶

Analysts with this perspective will relate easily to and be seen as useful by commanders and other operators. With apologies to Moliere, we can imagine a commander responding to a briefing on such matters:

Ah, you mean that I routinely use nonlinear system models in my thinking? If only had I known!¹⁷

Uncertainty and Disagreement

If options are to be evaluated by numerous criteria, then what about uncertainty and related disagreements? What threats may materialize? Where? When? How much more capable might they be than expected? How far should planning go to hedge against the risk of a much-worse-than-expected threat? What program hedges might allow for cutbacks in the event that threats develop more slowly than expected?

Just as the basic evaluations above can be accomplished using test scenarios, so also can scenario variants represent different assumptions

about threat, circumstances, and the future generally. Before dealing with that matter more fully below, let us consider the problem of reasoning under uncertainty somewhat more abstractly. How much can be accomplished? Based on a combination of logic, experience, and historical review, the most feasible and productive approach (the “sweet spot”) is arguably as follows:

- In evaluating an option, assess (1) how well it is *expected* to perform, (2) the potential for it to do much better (upside potential), and (3) the risk¹⁸ that it will do much more poorly (downside).
- In each of these assessments, account heuristically for both approximate likelihoods and consequences.¹⁹

This may seem like mere common sense, but it is in contrast with common approaches. It is *not* mini-max thinking (planning for the worst case); it is *not* rosy-scenario planning; it is *not* thinking restricted to the best estimate. Nor is it overreaction to a negative shock or complacency after a long period of stability. It is, however, what leaders aspire to when they are working hard at rational, balanced decisionmaking.

Describing this analytic sweet spot does not say how to trade off best-estimate, most-favorable (upside), and downside (risky) possibilities in reaching a decision. Indeed, no such rule exists for the most consequential decisions. Yes, one can always refer blithely to maximizing expected subjective utility as though that can be meaningfully defined or accomplished.²⁰ However, even if an all-knowing god atop Mount Olympus could know everything needed, that would do little to help real people affected by uncertainties, misperceptions, cognitive biases, and idiosyncratic path-dependent preferences. Further, people know that they only live once, so that “expected value” (over many lifetimes in parallel universes?) may have little salience. Famous historical commanders have sometimes “gone for the gold” even when they were aware of the catastrophic consequences of failure.

It seems that we must be content to say that decisions should somehow “balance” the considerations, a term favored by Secretary Robert Gates²¹ and used heavily in RAND work on strategy.²² In prac-

tice, national leaders concerned about those for whom they are responsible will use a heuristic:

- Seek first to avoid disasters by not even considering unduly risky options.
- Within such constraints, try to be smart (i.e., do sensible things and, in some cases, optimize).

This may seem easy, but consider, for example, that—as in bargaining more generally—leaders may need to use bluff and bluster, suggesting a greater-than-actual willingness to take risks. The difficulty of doing so both credibly and responsibly is notoriously difficult, as became clear from Cold War discussion of nuclear matters²³ and the recent budget wars in Washington that led to sequestering that no one wanted.

Defining the terms of this sweet-spot approach is, then, by no means straightforward. Optimists may underestimate both the probability and the negative consequences of the “worst case” as did Saddam Hussein in both 1990 and 2003.²⁴ Our own leaders also make mistakes. The George W. Bush administration underestimated the downside risks of the 2003 war with Iraq—despite notable efforts by Secretary of Defense Donald Rumsfeld to identify what could go wrong and demand related contingent planning.²⁵

In other contexts, political leaders may miss upside opportunities. That was arguably the case at the end of the Cold War when the administration of George H.W. Bush was skeptical about developments in the Soviet Union. It soon recognized that changes were real and engaged effectively, but some histories refer to 1989 as the “Lost Year” and speculate about what might have been.²⁶ Some observers argue that the Bill Clinton administration and NATO missed an opportunity to intervene early in the Bosnian crisis and impose stability, which might have avoided the decade of misery that ended with the Kosovo operation. Clinton himself regarded failure to stop the genocide in Rwanda as a great error (a missed opportunity to stop massive killing). Another consequential example arose in the 2000 Arab-Israeli talks when, in the dominant narrative, it was proven again that “Arafat has never missed an opportunity to miss an opportunity.”²⁷ Although skepticism is war-

ranted, some accounts argue that the Bush administration failed in the early 2000s to recognize a window of opportunity for dealing with North Korean leaders.²⁸

Even though the sweet spot for analysis described above is anything but simple, it is a sound aspiration for framing issues and for aiding high-level decisionmakers. Analysis can help a great deal in doing so.

Measuring Qualities of an Option Under Uncertainty

Given distinctions among an option's expected performance, upside potential, and risk, how do we measure them? The most common way is to characterize options by static attributes thought to correlate with or determine both performance and risk. Examples include number of brigades, ships, or aircraft; number of people; network bandwidth; percentage of budget devoted to research and development (seen as reducing future risk); and quality of people. Another class of measures includes such items as number of carrier battle groups on station, number of wars that could be fought simultaneously or at least concurrently, and spin-up time for some functions.

In this monograph, I do not address such attribute-based measures. Instead, I focus on measures typically obtained from models of one sort or another, usually in connection with scenarios.

The scenario approach has been widely used since the work of Herman Kahn in the 1950s.²⁹ It may employ thought experiments or use models to estimate the performance of options in scenarios. One scenario might correspond to a somewhat worse-than-expected conflict (conservative, but not strongly so). Other scenarios might correspond to much more troublesome conflicts (e.g., short-warning attacks, wars in which allies are unwilling to cooperate, or wars that start with major degradation of U.S. networks or space systems). Still other scenarios might correspond to wars in which circumstances are especially favorable and the outcome could be a major, favorable change in a regional balance of power as in replacing a despotic regime with a well-supported democratically disposed government, as some envisaged in 2003.

Although scenario usage is ubiquitous, the art and science of how to *construct* suitable scenarios is not. This merits emphasis:

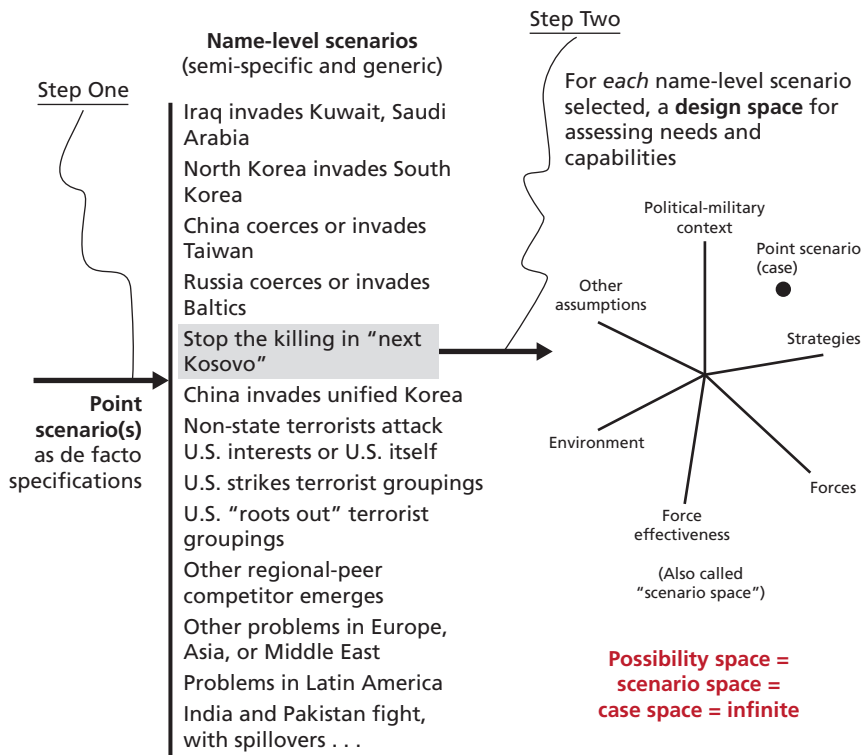
- A fundamental truth in analysis is that scenarios drive the answers. Thus, much effort should go into conceiving and tuning the scenarios used and specifying uncertainty ranges. This should be a deeply analytic affair rather than the result merely of creative people spinning stories that raise interesting issues.³⁰

Military staffs of the various services, of course, quickly recognize how parameter settings in DoD scenarios will affect their services' programs of record. They advocate accordingly. From a national perspective, such parameter-settings should be driven by explicit strategic considerations and joint analysis, rather than by de facto log-rolling in lower-level committees.

Divergent Thinking and Scenario Space. Figure 3.7, drawn from work a decade or so ago, indicates the concept of a “scenario space” (or possibility space). The left side shows a number of name-level scenarios (i.e., scenarios defined only to the extent of giving them a name describing the particular operational challenge that they pose). The right side notes that specifying what any given name-level scenario means requires thinking about a multitude of variables ranging from political-military context to the various actors' strategies and objectives, their actual capabilities, and so on.³¹ To think about test-case scenarios, then, should mean thinking to some degree about the full dimensionality of scenario space.

A Process of Convergent Thinking with a Spanning Set of Test Cases. Musing about an entire scenario space is a heady, abstract business. For down-to-earth purposes such as systematizing analysis and managing change, it is desirable to draw insights from the broad scenario-space work to identify a smallish discrete set of test cases, which can be called a spanning set, such that a force able to handle the test cases should be able to handle real cases if they arise in parts of scenario space that are of interest. These are perhaps the parts that pose significant challenges for the future capabilities but that are also reasonably plausible (what Kahn sometimes referred to as “not incred-

Figure 3.7
The Concept of Scenario Space



SOURCE: Davis, 2002, with older antecedents (Davis and Winnefeld, 1983; Davis, 1994b).

RAND RR482-3.7

ible" to suggest the realm of 10 percent likelihood rather an 0.1 percent or 50 percent) *and* about which it is possible to do something. It is conceivable that the earth will be hit by a meteor, but defense planners can do nothing about that. The situation in a country with civil war may be deplorable, but perhaps the United States cannot do anything about it and might, in the course of trying, make things worse.

Although it has become common for analysis organizations to focus on scenarios established by policy offices, an important analysis role is to help identify and design possible planning scenarios, discuss

implications with policymakers, and subsequently tune the scenarios so that they accomplish what is intended in the rest of the planning process. My own conclusion is that

- This function should be accomplished ultimately in a partnership among Office of the Secretary of Defense (OSD) (Policy), OSD (Cost Assessment and Program Evaluation), the Joint Staff, and OSD (Acquisition, Technology, and Logistics).*
- This function should be accomplished with a small group of analysts from the four offices working together, rather than with divided responsibilities and sequential processes.³²

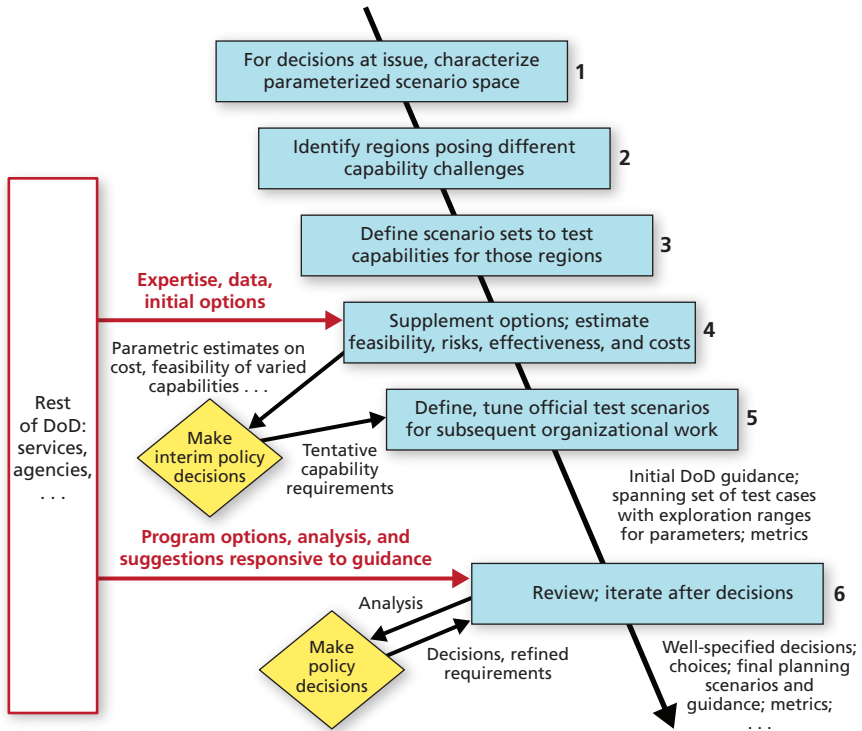
The concerns of the services, combatant commanders, and defense agencies would be represented through one or more of the above offices.

Figure 3.8 describes the process schematically. Referring to the numbered steps of the process of Figure 3.8, analysts first take a broad scenario-space view to recognize the many objectives, constraints, and uncertainties (Step 1). In doing so they confront deep uncertainties and discover how the scenario space breaks into regions posing different challenges (Step 2). For a given region, the challenges might include, e.g., response time, technical capabilities, force size, and troublesome adversary strategies. The challenges might also be political, economic, or social, as in “complex endeavors” generally or recent wars particularly. Next, analysts identify representative parameterized scenarios for each challenge region (Step 3). Given suitable models, they can do first-cut capabilities analysis, estimating what could be achieved to meet the various challenges as a function of cost (Step 4). Since cost and feasibility depend on the stringency of challenges, parameterizing stringency becomes part of the analysis.

The process next envisions going to policymakers to discuss what capabilities they wish to pursue further given results of the first-cut analysis (top yellow diamond). Policymakers then make initial decisions, giving up on some capabilities but pursuing others. That is, they

* These represent the perspectives of strategy and policy, program analysis and suggesting choices within a budget, the military “operators,” and those responsible for new technology and related acquisition (as well as logistics).

Figure 3.8
Moving from a Scenario Space to a “Spanning Set of Test Cases”



RAND RR482-3.8

decide tentatively on “requirements.” This requirement-setting must be detailed enough to define intent. Subsequently (Step 5), analysts translate qualitative desires (e.g., “deter,” “achieve an early halt,” or achieve “persistent surveillance”) into parameter settings within the test-case scenarios to be used subsequently. As discussed below, parameter settings may differ for different functions.

In response to guidance, the services and defense agencies develop proposals and evaluate them against the test cases and uncertainty ranges. The results are then reviewed and analyzed to aid decision-makers in making “final” decisions on forces, weapon systems, etc. (Step 6). Given decisions, analysts then adjust prior guidance, test-case

scenarios, metrics, and goals accordingly. The process continues with further iteration occurring in subsequent years.

The process shown would, in some respects, be more centralized in OSD and the Joint Staff than the current process. There would be fewer “seats at the table” in recognition that high-quality decision-aiding requires coherence and that the offices named are ultimately the ones responsible. That said, the services and defense agencies would be the source of much information and advice, the analysis could be as transparent to them as DoD found desirable, and the sharing of information and tools could be as extensive as it has been in recent years—something widely regarded as quite valuable, a period in which “open and collaborative” have been watchwords.

A key output of Figure 3.8’s process concept is that of the function of test-case scenarios (Step 5). These could fall into several classes with different functions in the overall management of DoD.³³

1. *Capability-development tests* or requirement-expressing tests should be stringent, demanding as much of the options as is reasonable given the nature of the challenge and the feasibility, under a budget, of developing requisite capabilities. The tests should be forcing functions of changes decided on by leadership.
2. *Representative tests* should test against what might be seen as reasonably typical or even “best-estimate” versions of the challenges. These might be the basis for education, training, normal exercises, and most public discussion.
3. *Communication-related tests* should be tailored for purposes of, say, summarizing key points for policymakers, convincing Congress why a capability is important, and explaining broad intended directions to the organization as a whole. These might be a subset of those in (1) or (2).
4. *Operational-planning tests*. At any given time, operations planners need to build plans dependent on numerous assumptions, although hedged where possible. Some of the assumptions are highly sensitive because they involve undisclosed and possibly fragile U.S. capabilities and tactics, intelligence on adversaries, or judgments about likely and possible behaviors of many coun-

tries, including allies. Such assumptions are often not suitable for use in (2) or (3) above. They may be reflected in (1) directly or indirectly. However, some may be ignored for good reason. For example, if the United States today has a highly secret and clever countermeasure against an air-defense system, capability development may nonetheless seek the ability to defeat the air-defense system without such cleverness because the special countermeasure is fragile.³⁴

The differences across classes of test case are not always as one might expect. Historically, operations plans have included assumptions that were more, less, or equivalent to those of corresponding force-development scenarios. Also, forcing functions of change (Class 1) have sometimes been very useful for communications to everyone from Congress to the broad DoD organization. (See Appendix D for a discussion of Cold War examples.)

Upon reflection, Figure 3.8 implies an iterative approach to analysis in which a small set of analysts does the first-order analysis to acquaint decisionmakers with the big choices, making it clear what capabilities can plausibly be achieved at what price, but only roughly. With such information, decisionmakers can expand or contract their appetites for improvement, after which analysts can sharpen the definition of test cases so that they become “requirements” for the organization to impose subsequently. This has often been the way that decisions have been reached. The notion that objective “requirements” are set by the combatant commanders with Congress and DoD then providing the necessary resources has always been nonsense. The real “requirements” are what the policymakers decide to demand after paying attention to strategy, needs, alternatives, feasibility, costs, and other considerations.

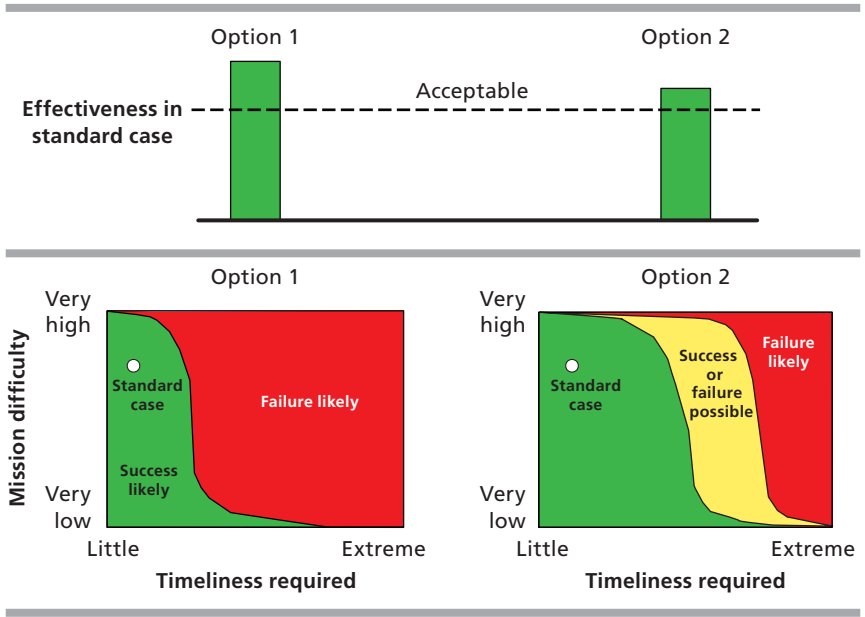
Superficially, it may seem to some readers that this is already the way DoD works, since senior policymakers discuss and agree on planning scenarios. In fact, the policymakers often do not understand the implications of the all-important parameter settings in these scenarios that emerge. Sometimes, they do, as when they decide to require ability for *near*-simultaneous conflicts with “near” including an offset of a

specified time. Sometimes they do not, as in early pronouncements of intent to acquire capabilities to halt an invasion that were ambiguous about how quickly that needed to be achieved. Similarly, early calls to achieve persistent surveillance were notoriously ambiguous about whether that meant continuous or with coverage updates of, say, minutes, hours, or days.³⁵

Exploratory Analysis for Capabilities-Based Planning

Whether for broad initial work or more pointed analysis, it is valuable to have capabilities analysis that shows results as a function of assumptions. Figure 3.9 illustrates this by contrasting ways to compare two options. At the top is a simple bar-chart summary comparing the options for a standard case. Option 1 appears somewhat better. The

Figure 3.9
Comparing Options Under Uncertainty (Point-Scenario Analysis Versus Capability Analysis)



bottom half of the figure is in the spirit of capabilities analysis, preemptively addressing What-if? questions by showing results as a function of timeliness and mission difficulty (X and Y axes, respectively). For this, the result is not shown on the Y axis, but rather by the location within the rectangular space. That space has an infinite number of dots, one for each scenario. Only one such dot is shown. Results for a given scenario are good, bad, or ambiguous depending on which colored region it sits in.

This depiction is consistent with the earlier comparison in that both Options 1 and 2 are in the success region (green) for the standard case. However, the lower display shows that Option 2 is superior overall because we should want capabilities that ensure good or at least potentially good results in as big a portion of the space as possible. In other analysis, results might depend sensitively on more than two key variables and such comparisons would be more difficult to plot. However, great advances have been made in such matters as discussed.³⁶

As a second example, Table 3.2 compares two notional options for a homeland ballistic-missile defense system. Option 2 costs twice as much as Option 1. Because ballistic-missile defense effectiveness

Table 3.2
Ballistic-Missile Defense Capabilities, by Threat and Objective (Notional)

Class of Threat	Option 1 (\$100B)			Option 2 (\$200B)		
	Minimum Defense	Moderate Defense	Near-Perfect Defense	Minimum Defense	Moderate Defense	Near-Perfect Defense
Objective						
Massive attack, near peer	R	R	R	R	R	R
Small attack, near peer; or multiple missiles, advanced rogue	O	O	R	Y	O	R
Multiple missiles; simple rogue	Y	Y	Y	G	G	LG
Single missile; simple rogue	LG	LG	LG	G	G	G

SOURCE: Davis, Shaver, and Beck, 2008.
NOTES: Red = very poor, orange = poor, yellow = medium, light green = good, and green = very good. These capabilities might be quantified in terms of the probability of intercepting a high fraction of attacking missiles.

depends on the nature of the future threat (size, simultaneity, technical sophistication), about which there is deep uncertainty, it makes little sense to assess only in terms of a standard case. Also, it is important to distinguish among several objectives as do policymakers themselves:³⁷ Having *some* defense (minimum defense) is very desirable to avoid coercion and potential self-deterrence—i.e., the possibility that if a rogue state were attacking a U.S. ally, the United States would be deterred from responding effectively because of the rogue’s ability to strike the United States with a nuclear weapon. Having a moderately effective defense that would intercept most of an attack would presumably further improve deterrence. A near-perfect defense would be valuable in improving deterrence and in limiting damage if deterrence failed. Overall, Option 2 provides better capabilities, but primarily for modest threats without advanced counter measures. If the “standard case” assumed a multiple-missile attack by a simple rogue (bottom row), then Option 2 would be superior. In the larger perspective, however, it would be a more difficult judgment call to choose between options. How much would policymakers be willing to pay for a system increasing capability only against a primitive threat? There might be interest in a better Option 3, even if considerably more expensive. But would that be technically feasible even with high costs?

Many examples might be given of capabilities-based analysis summarizing difficult issues comprehensibly over the relevant possibility space. (Appendix F describes exploratory analysis for the “halt problem,” circa 2000.) Modern displays help, as discussed in RAND work on robust decisionmaking and by analysts from the United Kingdom, Canada, and Australia at a recent meeting of the Military Operations Society³⁸

My own observation here is that

- Policymakers almost always prefer the kinds of uncertainty-conscious results that come from capabilities-based analysis—but only if it is comprehensible and helps with decisionmaking (hand-wringing about uncertainty is not helpful).

- Managers of analysis, however, have often not responded accordingly—bowing instead to pressures for consensus on scenarios, detailed instantiations thereof, and models.

A major reason for the lack of response by analysis managers has been the desire to respond to earlier policymaker complaints from when senior leaders were often exposed to competing analyses that could not be readily compared because of having been based on different scenarios, data, and models. This was frustrating to officials because they could not compare “apples with apples” and to the services because they feared that analysis was not a “level playing field.”³⁹ In theory, the solution was to require that analyses use standard cases as baselines, but then go on to provide additional information. Regrettably, the “additional information” provided has often been meager. This has long frustrated managers of analysis as well as policymakers.⁴⁰

Endnotes

¹ As one example, service representatives preparing for an analysis of alternatives draw on industry knowledge and analysis to understand what can actually be developed, with what risks. They and DoD may also reach out to independent groups, as in studies of prompt conventional global strike (National Academy of Sciences, 2008). As a second example, DoD recently had a comprehensive study done to review and synthesize social-science knowledge on counterterrorism (Davis and Cragin, 2009).

² This point was reinforced by the comments of Vice Admiral (USN, Retired) Stanley Szemborki at a May 2013 Military Operations Research Society meeting, based on his experiences as Deputy Director of OSD’s Cost Assessment and Program Evaluation office.

³ Analysts sometimes despair because it sometimes seems that “political” considerations dominate. Some considerations that seem “political,” however, are strategic, but in a larger arena (e.g., national economics or environmental policy). Others reflect legitimate public values, whether or not convenient for DoD. That said, other decisions are indeed purely “political.” Harold Brown describes his experiences and thoughts on such matters in a recent memoir (Brown and Winslow, 2012).

⁴ See two strategy-level examples (Johnson et al., 2012; Davis et al., 2008a).

⁵ Senior leaders distrust black-box simulations and seek improved analytical agility. This was discussed at some length in a Military Operations Research Society meeting on how to improve what was then called the Analytic Agenda (since renamed as Support for Strategic Analysis) (Sweetser, 2010).

⁶ Whether Einstein actually made this statement is uncertain. It is consistent with his documented statements, but more pithy. See, for example, <http://quoteinvestigator.com/2011/05/13/einstein-simple/>.

⁷ An example for the Air Force discussed improving capabilities for close-air support (Davis et al., 2010). Many other examples exist, such as the approximation for defendable radius show in the illustrations in Chapter Four, where a natural but nonintuitive metric depends on the $1/3$ power of the power-aperture product of a radar divided by the target's cross section. Such natural metrics are conceptually similar to the dimensionless parameters that play a big role in theoretical chemistry and physics.

⁸ At the research level, see, e.g., Davis and Cragin, 2009, and Fenstermacher et al., 2010. Recent work in support of operations has been led by the Marine Corps Combat Development Command. It has included substantial participation by social scientists and new qualitative methods of analysis.

⁹ See Petraeus and Amos, 2006, and McChrystal, 2013.

¹⁰ The depiction iterates on earlier depictions (National Research Council, 2006; Davis and Henninger, 2007).

¹¹ An insightful discussion of how it is important to look at problems from different perspectives is Akst, 2009, p. 418, who also discussed the fact that most analyses are not predictive in large part because the necessary data are lacking.

¹² Even if the paradigm of seeking such breadth in analysis campaigns has been absent, numerous examples of seeking greater breadth can be noted. For example, OSD (Cost Assessment and Program Evaluation) has used system-dynamic models, human gaming, and the human-in-the-loop simulation Peace Support Operations Model to investigate irregular-warfare issues (alluded to in Luman, 2008, p. 379), acknowledging the value of gaming also in Military Operations Research Society meetings (Sweetser, 2010). In work overseen by James Bexfield of OSD (Cost Assessment and Program Evaluation), DoD sponsored substantial research on the social science of counterterrorism and irregular warfare at RAND (Davis and Cragin, 2009). In recent times, the Marine Corps Combat Development Command has drawn on social scientists and social-science methods rather than traditional simulation in conducting illustrative analysis for complex political-military-economic operations (discussions with Michael Bailey and Yuna Wong). In earlier years, the Army's Concepts Analysis Agency under E. B. Vandiver sponsored numerous historical studies, including some by the late Trevor Dupuy. Many other examples will be found in the Military Operations Research Society oral history series of leaders in military operations research. They are available on its website: www.MORS.org.

¹³ See also discussion the of strategy and multiple objectives in Kugler, 2006.

¹⁴ Particularly relevant are the National Security Strategy (Obama, 2010), the strategic guidance for the Defense Department (Obama, 2012); Defense Planning Guidance, which may be classified; Quadrennial Defense Review (Gates, 2010); service-by-service documents; and the Chairman's National Military Strategy (Mullen, 2011).

¹⁵ Assuring that *all* critical capabilities are planned for is a key element of capabilities-based planning (Davis, 2002) and also strategies-to-tasks (better called objectives-to-tasks) planning (Kent and Simons, 1994).

¹⁶ Heeding the implications is difficult, as can be seen by instances of failed international interventions for which failure was likely because of problems of security, economics, governance, hatreds, or all of these critical factors (Davis, 2011). See also the discussion by Harold Brown, commenting on current issues (Brown and Winslow, 2012).

¹⁷ The allusion is to "Well, what do you know about that! These forty years now, I've been speaking prose without knowing it," a comment by Monsieur Jourdain in Moliere's "The Bourgeois Gentleman."

¹⁸ Here "risk" is negative as in natural language. In finance and some of the risk literature, "risk" is often seen as a variance usage tracing back to "Modern Portfolio Theory" (no longer modern), when computational and data limitations made doing better impractical. William Sharpe and others later made distinctions between the good and bad sides of variance (Sharpe, 2006), leading to "Post-Modern Portfolio Theory." Markowitz and Sharpe won Nobel Prizes.

¹⁹ See Davis, Kulick, and Egner, 2005, which discusses this model of decision and argues, based on unpublished research, that top decisionmakers, such as presidents, are doing well if they consider uncertainty even to the extent that the model describes. Often, upside opportunity, downside risk, or both are given short shrift.

²⁰ The inherent limits of "bounded rationality" have been discussed for more than a half century by such notables as Nobelist Herbert Simon (Simon, 1982).

²¹ Gates, 2010.

²² Davis et al., 2008a; Johnson et al., 2012.

²³ See Schelling, 1960, 1966, and Kahn, 1962, 1966.

²⁴ Saddam Hussein anticipated boycott and perhaps air strikes from the air and sea, far less than what ensued (Brands and Palkki, 2012). That is, he recognized but underestimated risks. After the earlier 2003 war, Saddam admitted having miscalculated President Bush and his intentions, thinking that the war would be more like the shortened air campaign of the Gulf War (60 Minutes, 2009). Some of Sad-

dam's decisions, particularly the decision to invade Kuwait in 1990, were driven by nonrational emotions and misperceptions (Woods and Stout, 2010).

²⁵ See Rumsfeld, 2006, and Feith, 2008, the latter of which documents many key deliberations. Rumsfeld's prewar interviews demonstrated concern about downside possibilities (Lehrer Hour, 2003). Actual military preparations fell short for Phase IV (stabilization) (Bensahel, Olikier, and Peterson, 2009, p. 14ff; Ricks, 2004). Considerable critical thinking went into early Phase IV planning, but it was not translated into a solid operations plan, appropriate staffing, and needed preparations. When the time came, there also were conflicts about who was in charge and about higher-level strategy (Bensahel, Olikier, and Peterson, 2009, p. 40). Overall, military preparations for Phase IV were driven by top-down assumptions that proved false: The "worst case" was much worse than planned for (Bensahel, Olikier, and Peterson, 2009, pp. 233ff).

²⁶ Hoffman, 2009.

²⁷ Ross, 2005. The expression about Arafat is credited to former prime minister Abba Eban.

²⁸ This argument is made cautiously in a little-known book (Chinoy, 2008) based on numerous interviews.

²⁹ Herman Kahn developed the methods at RAND in the 1950s and then his own Hudson Institute (Kahn and Schelling, 2009). Scenario methods have subsequently been used extensively in the commercial world,

³⁰ Davis and Winnefeld, 1983; Builder, 1983.

³¹ The scenario-space concept traces to the 1990s (Davis, 1994b, 2002).

³² Currently, OSD (Policy) has responsibility for writing the scenarios in a high-level description; the Joint Staff then develops associated concepts of operations and defines most of the details; OSD (Cost Assessment and Program Evaluation) in the past oversaw the detailed scenarios in simulations. OSD (Acquisition, Technology, and Logistics) has not participated extensively in this part of the process, which is part of the "Support for Strategic Analysis" effort.

³³ Readers with long memories will recall that distinctions were once taught to analysts regarding declaratory, programming, and employment policies. What policymakers said publicly was one thing; what was actually being budgeted for was another; and what was planned in the event of war was yet another.

³⁴ Whether to count on countermeasures' effectiveness has been debated for at least 50 years, as with debate about the B-1 manned bomber (Quanbeck, Wood, and Thoron, 1976). Analogous debates exist today.

³⁵ This reflects discussions in the mid-2000s with Kenneth Krieg, then Director of Program Analysis and Evaluation, and Michael Wynne, then Under Secretary of Defense for Acquisition, Technology, and Logistics.

³⁶ RAND work on uncertainty in national defense has been reviewed recently with extensive pointers to contributing literature (Davis, 2012). Another report illustrates how n-dimensional results “project” onto two-dimensional depictions (Davis, Bankes, and Egner, 2007). For a compilation of reports using robust decisionmaking methods, see <http://www.rand.org/topics/robust-decision-making.html>.

³⁷ The distinctions were recognized by an influential commission (Rumsfeld and Commission, 1998). Policymakers were quite aware of the limitations of the ground-based midcourse system as they began its deployment in the 2000s. They anticipated that improvements would occur only with experience and time. Even then, as discussed by independent scientists, capability might be limited because of countermeasures (Sessler et al., 2000).

³⁸ See Hoehl and Scales, 2011; Taylor, 2013; Solly, 2013, and a brief overview of the Military Operations Research Society conference (Leonard, Thomason, and Bexfield, 2013).

³⁹ Personal communications with David Chu describing issues that arose when he was OSD’s Director of Program Analysis and Evaluation.

⁴⁰ This lament has been made to me by numerous OSD senior executives who oversee analysis and by policymakers who are consumers of analysis.

Creating Capability Models

Given the desire for “capabilities analysis” as described in earlier chapters, how do we obtain the models necessary for such analysis? Although the best approach involves a range of analytic methods and models of varied resolution, as described in Chapter Three, providing the relatively simple models needed for capabilities analysis is a special challenge—apparently because the art and ethic of simple modeling has been lost to a considerable degree as newer generations of analysts have grown up using complicated computer models. Thus, this chapter deals largely with how to obtain the lower-resolution capability models.

Definitions and Examples

Definition

As a preface, it is appropriate to discuss what is meant by “capability model” in the context of this monograph.

- A capability model is a causal model that allows us to understand degree of mission success as a function of input variables expressed parametrically.

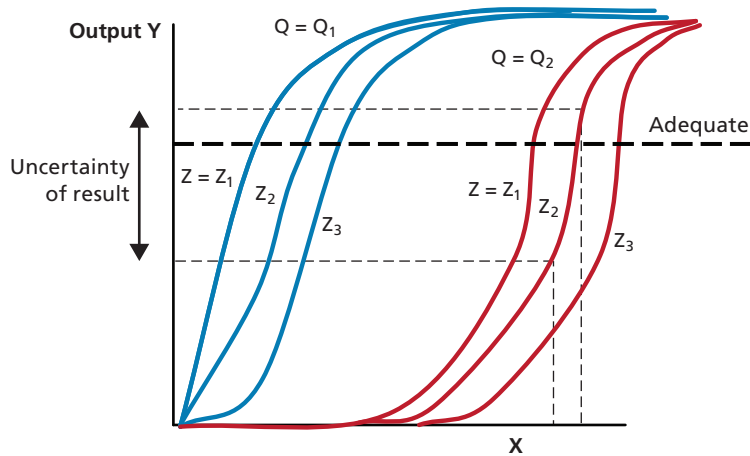
To simplify, suppose that we had a mission, the success of which was measured by Y . Suppose that Y depends on X , Y , Z , and Q . If we had a black-box model that allowed us to input the values of X , Y , Z , and Q , at which point it would return a value of Y , that model would be doing point-case analysis. What we want, however, is something

like Figure 4.1, which shows how degree of success changes as X, Y, Z, and Q are varied simultaneously. In some contexts, we could say that our capability to do the mission adequately depends on having a combination of X, Y, Z, and Q such that results are above the dashed line. Note how easy it is to gain insights from the graph. For example, observe that if $Q = Q_1$, then success can be achieved with much smaller values of X than if $Q = Q_2$, but success can be obtained for either value of Q.

This type of display, familiar to scientists and engineers, is ideal for discussing consequences of uncertainty. For the example, if we know that X is in the range shown by the dotted lines and Z's value is between Z_2 and Z_3 and that Q's value is Q_2 , then the uncertainty in Y (for $Z = Z_2$) is shown by the horizontal dotted lines: The mission is barely successful if $Z = Z_3$ and fails if $Z = Z_2$ or Z_1 . In contrast, if $Q = Q_1$, then a good result is ensured for any value of Z. Note that while this display is continuous, it is in the same spirit as the capabilities-analysis examples of the last chapter.

This type of chart might be generated by running a “big model” many, many times while holding a number (perhaps hundreds) of vari-

Figure 4.1
Schematic of a Parametric Capability Model's Output



ables constant, but what if results depend also on those inputs—as in fact they often do? A good “capability model” should not have important hidden dependencies.

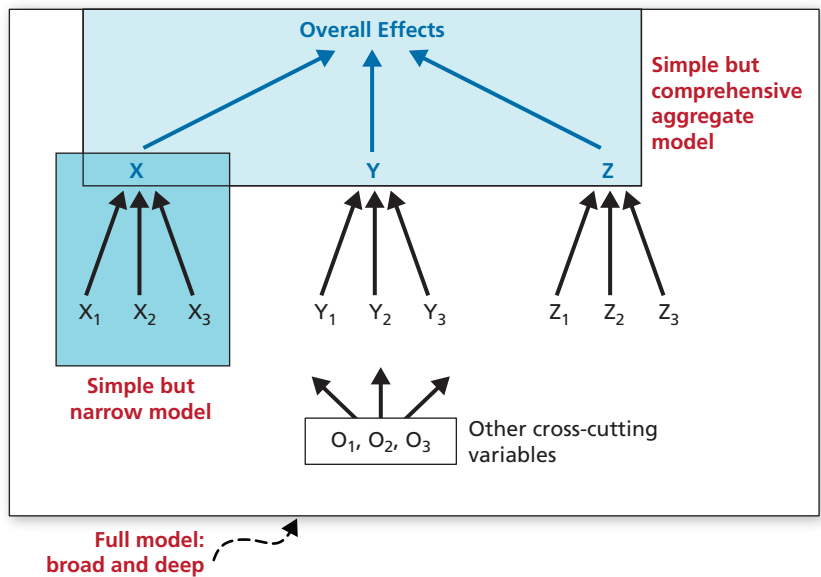
A capability model may take the shape of a formula, perhaps exploiting equilibrium, steady-state, or boundary conditions for success. Alternatively, it may take the shape of a time-dependent model (closed-form or, more typically, a computer simulation) that is structured like the operation necessary to accomplish the mission. It identifies the critical capabilities for success and represents their interaction, but in a relatively low-resolution way.¹

Defining the concept in more detail is not so simple because:

1. Not all “formula models” are simple, and most simple models of interest are not formula models.
2. “Simple” and “spreadsheet” are not synonyms: Many spreadsheet models are treacherous and many simple models are not implemented in spreadsheets.
3. Some simple models use only elementary physics, algebra, or economics, but others require some knowledge of calculus, differential equations, or linear algebra. How “simple” a model is depends in part on one’s background.
4. Some models are static or describe a steady-state, while others are structured like operations and lend themselves to simulation (e.g., as with successive steps of a kill-chain). These are simple as they are fairly aggregated (perhaps using “average shooters” or average probabilities of detection), but are complex enough to represent all critical components of an operation.²
5. Some models are simple by virtue of taking a very narrow view, while other models are comprehensive but use low-resolution variables.

Figure 4.2 illustrates the last point schematically. Suppose that the complete model (everything within the outer rectangle) has input variables $X_1, X_2, X_3, Y_1, Y_2, Y_3, Z_1, Z_2, Z_3, O_1, O_2, O_3$ intermediate variables X, Y , and Z ; and outputs, Overall Effects. One simple model would be the one shown in dark blue on the middle left. It would focus only

Figure 4.2
Types of “Simple Submodels”



RAND RR482-4.2

on understanding an intermediate variable X that might be one of the important effects. This simple model would have X_1 , X_2 , and X_3 inputs, and X as its output. It would ignore all other considerations. A different kind of simple model would be the one in the lighter blue region (top center). It would attempt to explain overall effects but would do so by using aggregate variables X , Y , and Z as inputs rather than the larger number of lower-level variables. This second model would be comprehensive, but not as detailed.

Examples

What, then, is simple? What matters primarily is the number of input variables (not counting data inputs that are constant and known accurately). Simple models will have perhaps three to ten, rather than dozens, hundreds, or thousands of inputs. To early system analysts and even to today’s design engineers and many hard scientists, such models

are familiar and routine. To some modeling and simulation shops, however, they may be rather foreign.

Below, I give diverse examples of simple models. As implemented, they may be part of relatively simple computer programs, but for discussion purposes key formulas are shown. Briefly, for each item:

1. *Lanchester equations* are widely used in classrooms and in some analysis, usually to illustrate certain concepts approximately. Closed-form solutions are possible when the coefficients are constant.³ I show them first because of their familiarity, but their importance is often exaggerated.

$$\frac{dA}{dt} = -K_d D; \frac{dD}{dt} = -K_a A$$

where A, D, and the Ks represent attacker and defender force levels and killing rates.

2. *Layering models of ballistic-missile defense* are widely used in studies of defense systems. If layers of defense are independent, multiple layers can greatly improve defense effectiveness.⁴

$$P_k = 1 - (1 - P_1)(1 - P_2)(1 - P_3)$$

where P_k is the probability of intercept given that P_1 , P_2 , and P_3 are independent probabilities for intercepts in successive layers.

3. *Defendable radius of a defense* estimates whether a defense system has the kinematic potential for being effective (deferring consideration of measure-countermeasure phenomena, interceptor and warhead quality, and so on). For such potential, the radar must detect the target far enough away so that it can launch an interceptor that will reach the incoming missile at a significant range from the target. The equation proved very useful in early arms-control analysis (could surface-to-air missiles be upgraded to have anti-ballistic-missile capability?) and subsequently in analysis of whether advanced radars later associated with Aegis and Patriot had at least some ballistic-missile defense poten-

tial.⁵ This does not describe dynamics, but rather the conditions under which intercept can occur.

$$R = \frac{V_i}{V_i + V_m} \left\{ \frac{C}{(PA\sigma)^{1/3}} - V_m \Delta \right\}$$

where R is the distance at which the missile is killed

V_i and V_m are the speeds of the interceptor and missile

P is radar power

A is radar aperture

C is an empirical constant for the radar

σ is the radar cross sections

Δ is the time delay between detection and launch of the interceptor.

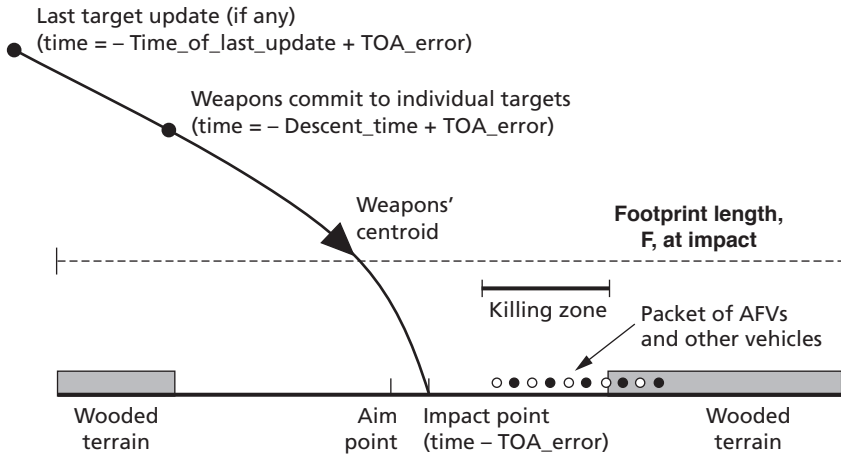
4. *Halt models* were used to understand the potential for long-range fires (whether from aircraft or artillery) to interdict and stop invasions of road-bound mechanized forces.⁶ Both closed-form and simulation models have been used.

$$T_h = \frac{-KSA_0 \pm \sqrt{(KSA_0)^2 + 2KSA_0}}{KSR}$$

The halt time is given as a function of kills per shot, shots per day, initial number of shooters, and the deployment rate of shooters. Halt distance is the product of halt time and the movement rate. See Appendix F.

5. *Multiresolution precision-fire modeling* have been used to understand how the effectiveness of precision fires against maneuver forces depends on not just weapon characteristics, but also characteristics of terrain; maneuver tactics; and intelligence, surveillance, and reconnaissance.⁷ Both closed-form and simulation models have been used with *selective* detail (Figure 4.3).

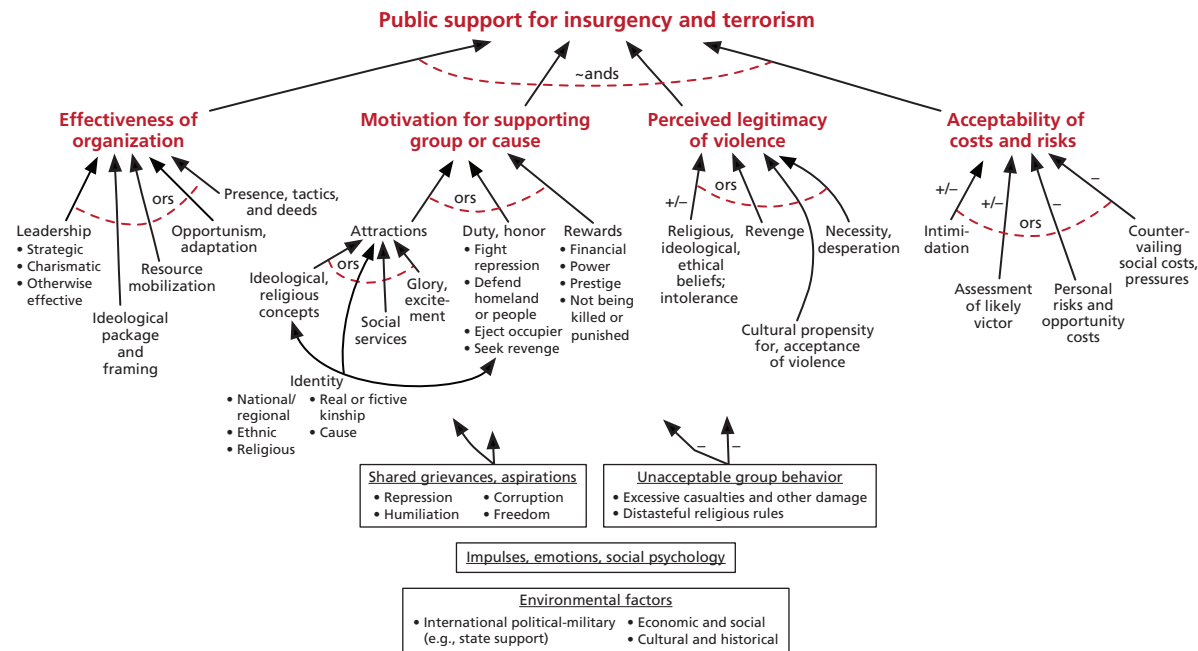
Figure 4.3
Selective Detail in a Simple Precision-Fires Model



The applicable equation is not aesthetic to read, but the diagram suggests its simplicity.

6. *Factor tree models* are qualitative models showing the factors causing an effect and which combinations of them are *necessary* for the effect to occur. Given social-science uncertainties and the shortcomings of data, such models can sometimes convey a sizable percentage of the available knowledge. They are valuable for integrative discussions, for identifying potential lines of action, and for noting where particular actions will likely fail because of substitution effects (e.g., enemy adaptation) (Figure 4.4).⁸

Figure 4.4
Qualitative Factor-Tree Model of Public Support for Terrorism



NOTES: Applies at a snapshot in time. Current factor values can affect future values of some or all other factors.

7. *Uncertainty sensitive computational versions of factor-tree models* make factor-trees quantitative but are used for exploratory analysis rather than point predictions. Visual programming can reveal structure and ensure that it matches that of the original factor tree (Figure 4.5).⁹
8. *Empirical models* (e.g., simple regressions inferred from experience) can sometimes dramatize the potential for failure unless, for some reason, this time truly is very different from previous times. The particular chart represents analysis before the Iraq war that warned about many more “boots on the ground” having been historically employed in successful stabilization operations (Figure 4.6).¹⁰

Illustrative Simple Models Used in Defense Studies

The intent of these examples, then, is to illustrate that the nature of “simple models” varies and that such models can provide comprehensible insights and valuable parametrics in a wide variety of problems. Those who focus exclusively on computations with large computer models might bear these in mind.

Building Capability Models

Low-Resolution Capability Models

The reader convinced by the virtues of simplicity and analysis under uncertainty may reasonably ask how to build suitable models. Unfortunately, there is no school solution. By and large, anyone with a solid education in the physical sciences or engineering is likely to have the core skills, if not necessarily the knack. The examples listed above convey common characteristics of such models. In particular, the key equations are small, with perhaps 2–12 parameters rather than dozens or hundreds. The key variables are represented as variable parameters rather than as fixed “data” (i.e., constants). The models may involve simple physics, less-simple physics or engineering, simple probability theory, and elementary differential and integral calculus. All can be implemented in spreadsheet programs, such as Microsoft Excel®,

Figure 4.5
Computational Version of the Factor Tree

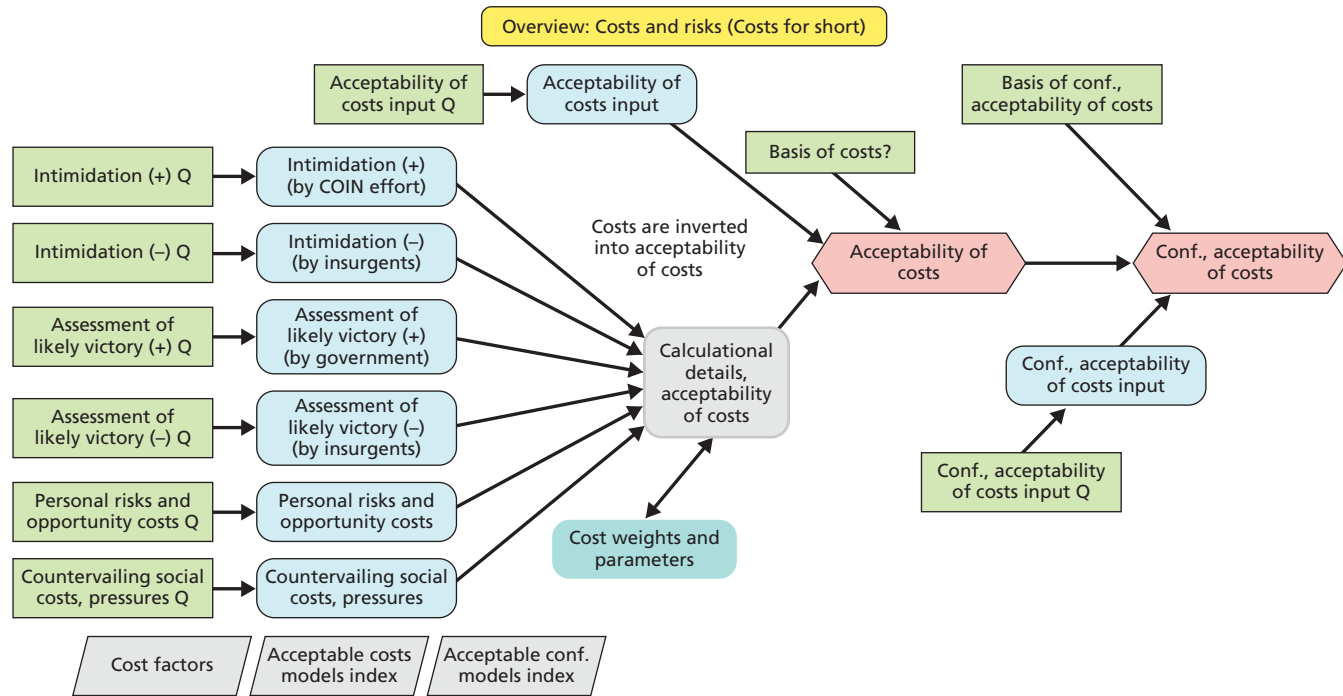
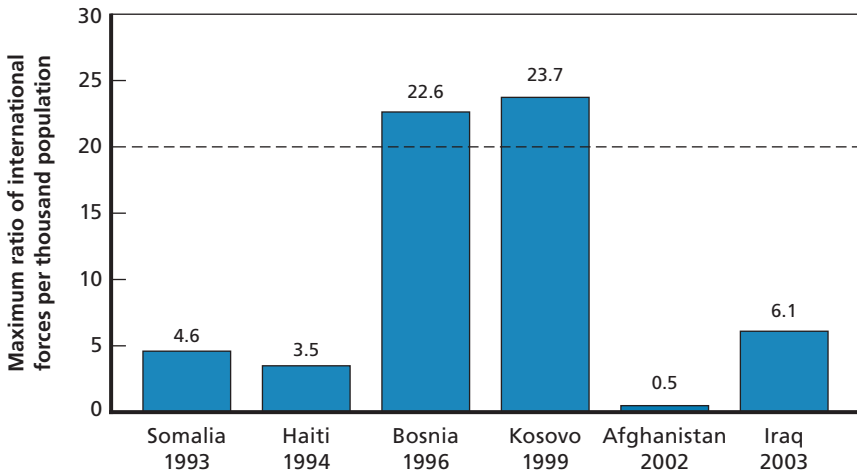


Figure 4.6
Empirical Model of Ground-Force Levels in Conflicts



RAND RR482-4.6

although other implementations are often superior for one reason or another.

As with analysis, some people are good at higher-level modeling; others are not.¹¹ Talent and background, for example, are necessary when modeling how concepts of operations should change as context and capabilities change.¹² Such automated adjustment is essential if one is going to use a model for exploratory analysis. Also, a good deal of judgment is necessary in deciding what to include and not include, how to express assumptions and uncertainties, and how to deal with diverse cases and avoid misuse. One example of misuse may suffice. Modern modeling software makes probabilistic and statistical calculations easy. Even someone with primitive knowledge can build a program to run calculations and produce seemingly impressive charts, referring pre-tentiously to having done “Monte Carlo calculations.” They may not even be aware that the software builds in the assumption that the variables are probabilistically independent. Nonetheless, they show results comparing the probabilities of success for different options to multiple significant figures. A more competent analyst/modeler might get dras-

tically different results by taking into account correlations. If an adversary achieves operational surprise, for example, he might cause damage to the U.S. network *and* disrupt some space-based surveillance, *and* strike when U.S. forces are preoccupied. These variables may be mathematically independent (legitimate independent variables), but their real-world values are not statistically independent.

Ultimately, then, the admonition is to put good people on the job, ensure that they have backgrounds in substantive modeling, not just mathematics, and ensure that the model designs and implementations are well reviewed. Such an admonition may seem banal, but experience suggests that it is not.

Motivated Meta Models

An alternative way to generate a simple parametric model is to run computational experiments with a well-validated computer model and a good experimental design. The trusted model can be run many times to generate a “metamodel” or “response surface” for subsequent parametric analysis. The most common version of this approach, as taught in classrooms, is to use standard statistical methods. The output is a regression equation that “explains” the results of the full-up simulation with only a handful of variables. If the correlations are strong enough, the regression might then be used to extrapolate to other cases.

This approach, regrettably, has what I see as fatal flaws. First, the result is not typically an intuitive physical model in terms of which to reason and debate, but rather a regression. Second, the response surface’s variables may not be the appropriate ones on which to focus. Third, the “dirty little secret” of supposedly theory-agnostic statistical analysis is that it is assuming one or another mathematical form, such as linear weighted sums, when the phenomenon may be manifestly nonlinear, in which case a linear metamodel may be downright counterproductive.¹³

A better approach is *motivated metamodeling* in which statistical apparatus is used to *test* a postulated simple model, rather than to find coefficients of a regression.¹⁴ Although I introduced the name “motivated metamodeling,” the concept is much the same as when physical scientists use experimental data to see if their best theoretic-

cal model does a good job or needs correction terms. If the postulated simple model is well conceived, then its variables will be the “right ones” for discussion and the form of the model will itself be explainable. Predictions of the motivated model can be discussed as intuitively understandable results plus some modest correction terms that reflect complicated details.¹⁵ Such a model has profound advantages for data analysis from computational experiments because it makes available to the computer the composite variables (aggregation fragments) that are more likely than lower-level variables to have clear causal significance. Suppose, for example, that an effect depends on the product of a speed V and a time T . If the computer uses linear regression to find a metamodel, it may find that the coefficients of V and T are large. It will not, however, discover that the product of V and T is crucial unless given the “hint” to look for that product.

Lest this seem too abstract, consider again the models shown above, which had several examples of formulas capturing essential features of the problems for which they were derived. Except for the Lanchester equations, which have a poor basis in theory, the simple models are all candidates to inform motivated modeling. In some analysis, such as effectiveness of precision fires for attacking columns moving through mixed terrain,¹⁶ interdiction of mechanized armies on roads,¹⁷ and epidemiological modeling of terrorism,¹⁸ my colleagues and I have had good success with motivated metamodeling. More important, something akin to this approach has been used for many years in the physical sciences.

The reader may at this point say “Ok, I’m convinced, send me the people who can do the simple modeling, whether for standalone modeling or the basis of a motivated metamodel. Where are they?” I have been told, by at least two directors of government analysis organizations, that their personnel are often not good as such things—especially if they are essentially mathematicians, computer scientists, or programmers. Nonetheless, many people—not just legends from bygone eras—have the requisite talents. Much of what one learns in the physical sciences, engineering, biophysics, and applied mathematics (especially if operations-oriented) amounts to how to think in terms

of relatively simple physical models. Finding the right people is a challenge for any organization, but supply should not be the problem.

I should emphasize that in some domains with complicated phenomena and abundant data, more inductive statistics-driven approaches can have great value and even be pragmatically superior to causal modeling.¹⁹ That said, mindless statistical analysis seems to me to be a big problem in military analysis.²⁰

Complex Models That Can Support Capability Analysis

A theme through much of this monograph is the virtue of simple models. Simplicity, however, is an elastic and subjective concept. Campaign models, for example, are often seen as large, complex, and opaque—but not by their developers and expert users. They are not necessarily opaque, and they can be made suitable for the kind of parametric exploratory analysis in support of higher-level decisionmaking described in this monograph. Experience suggests to me that this will typically not happen, and that analytic organizations would do better to build separate simple models if they need such work. However, that is a commentary on organizations, processes, and management, not a technical conclusion. In fact, “large” models can have many of the virtues of smaller models, and additional virtues as well. The keys are

- quality of design, to include
 - representation
 - modularity
 - selected multiresolution modeling, for the core model, displays, or both
- management.

The representation chosen determines whether the model relates well to the most important entities and processes. Modularity allows one to “turn off” aspects of the model that are unnecessary or inappropriately burdensome for a particular analysis. This also leads to a correspondingly simplified interface to work with. Multiresolution modeling refers to building in some alternative submodules with varied levels of detail so that, for example, one may “turn off details” and use a

simplified representation of some phenomenon, again with a suitably simplified interface. The word “selected” appears because such multi-resolution modeling features are practical for only some model functions. “Management” in this context refers to insisting on such features in the design phase, assuring that they are maintained subsequently, developing and maintaining simplified databases, exercising the capabilities, allowing competition by testing alternative modules as they are proposed, and resisting pressures to “enrich” the model in ways that make it less modular and more monolithic without preserving the fallback option of simpler representations.

As an example based on personal experience, the original Joint Integrated Contingency Model (part of the 1980s RAND Strategy Assessment System, RSAS) was modular. This permitted studies in which only the ground-combat model was used (sometimes with an overlay representing certain air-to-ground effects). Doing so was relatively easy and the user did not need to worry about the hundreds or thousands of other input variables. Modularity also paid off later when the original algorithms for assessing ground-combat attrition were optionally replaced by a killer-victim-scoreboard approach. The original model also had important multiresolution elements. For example, deployment of forces could be governed by a strategic-mobility model or by a simple mechanism in which the analyst essentially scripted arrival time of units. Such alternatives also existed for mobilization. In addition, it was possible to use “type units” and to scale their capabilities up or down with a few parameters, rather than specifying myriad named units and their many characteristics in a large database. It was also possible to scale the assumed “fighting capability” (due to morale, leadership, and the like) with a few parameters.²¹ As the model was used in later years, however, the optional simplicity fell into disuse as users focused on getting the detailed databases “right” (meaning agreed-upon) for running standardized case.²²

Analytic organizations with large investments in complicated models should consider this type of approach, but the considerable overhead involved in comprehending the workings of a large model and maintaining the expertise may instead suggest spinning off smaller, simpler models as discussed above.²³

The Special Issues of Social-Science and Other “Soft” Considerations

Models Relating to Terrorism and Insurgency

Most defense modeling focuses on what are loosely called “physics problems” in which results depend on, say, mass, momentum, accuracy, and time. In recent years, DoD has been sensitized to the overwhelming importance of softer factors and processes such as those studied by social scientists. The most tangible evidence of a changed view came from the operational commanders with the new Army-Marine Field Manual on counterinsurgency.²⁴ Today, any educated reader of newspapers knows that the United States shifted to a “population-centric” strategy that drastically altered tactics, rules of engagement, and measures of effectiveness in Iraq and Afghanistan.

The dominant models in DoD’s tool kit as of 2003 were unable to deal with such issues. A number of model developments proceeded, some of them using modern methods such as agent-based modeling. However, DoD officials came to realize that they had little visibility into what these models were doing, skepticism about their basis in social science, and doubts about whether they were useful for analysis. The officials took a step back and asked for research about what the social-science literature told us that *should* be represented in modeling and analysis. One result was an integrative science review; it started as a traditional critical review of the literature but ended up using qualitative models called factor trees to relate different strands of scholarly work and put the findings into what aspired to be a relatively comprehensive structure.²⁵ Factor trees are diagrams that arrange the factors contributing to a phenomenon in an approximate hierarchy of detail so that one can see a small set of top-level factors, but with these determined by many lower-level factors, sometimes at several layers of detail. They also indicate the directionality of influence and when certain factors are thought to be individually necessary to achieve a higher-level effect.

Although qualitative, the factor trees proved quite useful for summarizing much of the social-science knowledge in a structured way understandable even to large audiences with diverse backgrounds.

Such depictions are definitely simple models, not just cartoons. As with traditional models, they frame the problem, identify key factors, and support simple stories or narratives helpful in making decisions, such as identifying the “lines of approach” in planning. They do not, however, purport to provide quantitative information or make predictions. Factor trees have been used in a number of subsequent studies, most of them classified. One openly published stream of work, on public support for terrorism, describes empirical verification through use of case studies and includes a “primer” on the use of factor trees as an appendix.²⁶

Recently, a colleague and I took a next step by implementing the factor tree from the public-support study in a computational model, which required thinking much more rigorously about relationships.²⁷ By intent, the model (called PSOT) is designed to make it difficult to use as a black-box answer machine. Instead, the model generates multi-dimensional displays indicating what combinations of factor values are likely to lead to a good, bad, or indifferent result with respect to public support of terrorism. Despite the uncertainties built into the model (into the model’s algorithms, not just input data!), the model incorporates more of the available social-science knowledge than the purely qualitative factor tree. The nature of the computational model (full documentation in a visual-programming language, *Analytica*®) makes it easier for scholars to review and debate the substantive content of the model, to reproduce it in their own analytic laboratories, and to construct alternatives if need be. Such countermodeling has proven valuable in the long-established realm of MIT-style System Dynamics, as was first illustrated during a period of high controversy in the 1970s.²⁸

The Peace Operations Support Model Computer-Aided War Game. A second example of how social-science issues can be incorporated in models is PSOM, developed in the United Kingdom and used both there and by the U.S. Joint Staff to support operations planning in Afghanistan. In contrast to the PSOT model, which is in the spirit of capability modeling for a particular mission area (in this case, public support for terrorism and insurgency), PSOM is a campaign-level model that includes political and economic factors.²⁹ An important element, in my view, is that PSOM was designed to permit human

players to discuss and make higher-level decisions about, e.g., resource allocation and maneuver. Thus, PSOM provides the background structure for what can be essentially a higher-level war game with senior participants. My understanding is that this kind of structured gaming has proven to be quite informative. PSOM has also enjoyed considerable verification and validation. Although PSOM is hardly the kind of relatively simple “capabilities model” emphasized in this monograph, I mention it because it—like other campaign models—can be quite valuable as part of an analysis campaign. Like other campaign models, it may seem opaque to the casual observer but be amenable to explanation and even exploration by its expert users.

Soft Factors in Models Generally

Although the wars in Iraq and Afghanistan have dramatized the “soft” aspects of counterinsurgency and counterterrorism, it is less appreciated that soft factors are important—even crucial—in modeling and analysis of traditional warfare as well. This was explored in a Military Operations Research Society symposium decades ago.³⁰ The symposium included papers in several classes: human factors in decision issues, human performance models, human performance and availability in combat environments, combat as a data source, and representing human performance in combat models and simulators.

As an example from the theater level of modeling, for the decades during which U.S. defense analysis focused largely on the Soviet Union, most studies ignored such soft factors as morale, leadership, training, readiness, and even the effect of surprise on operational effectiveness. This seems to have been the result of modelers seeking to take a “scientific” approach that emphasized quantification, “rigor,” and reproducibility. It probably reflected also the view that World War II had ultimately been driven by the numbers and the belief that such large-scale war could be represented by mathematics such as Lanchester equations and more sophisticated computer models.

In any case, as analysis moves forward, analysts should be disabused of the notion that “good” analysis ignores soft factors. As I learned decades ago in a revelation when reading a book by MIT’s Jay Forrester, to ignore a soft factor is analytically equivalent to assuming

that its effect is zero. What kind of approximation is that when we know from history that such factors often have factor-of-two effects, or more?³¹

Soft factors can be easily included in models intended for parametric capabilities analysis. As merely one example, in characterizing the effective sizes of forces in an assessment of the military balance or making an estimate of likely war outcome, the effectiveness of low-readiness ground-force reserves can be represented by their nominal effectiveness times a multiplier varied from, say, 1/2 to 1. However crude that may be, it is better than ignoring the issue and assuming full effectiveness of ill-trained soldiers. More generally, the values of the various soft factors are just additional dimensions of uncertainty. To fail to address them in a misguided effort to be more “rigorous” is analytically unconscionable.³²

Myths and Realities About Validation

Whenever one discusses models in DoD, it becomes necessary at some point to deal with the dreary subject of verification, validation, and accreditation. Fortunately, extensive material is available on recommended practices due to efforts by a DoD office.³³ It is worthwhile, however, for me to confront some common myths that are sometimes raised to argue against simple modeling, efforts to represent soft or otherwise uncertain variables, use of human gaming, and other methods that I have suggested.

Model Validation

- Model “validation” must be understood in terms of both the model and the input assumptions.³⁴ The models themselves may be unable to represent some phenomena, and can thus be falsified in that respect, but if they can represent the phenomena, results are typically driven by uncertain input assumptions rather than model details.

- What sometimes passes for model validation is instead standardization of assumptions, which establishes useful base cases for comparisons but says nothing about accuracy.
- Empirical validation as in physics and engineering is not feasible for most higher-level analysis—or even for major components of the models. Controlled experiments are out of the question and historical results provide only ambiguous information. As a result, validation depends on indirect means such as expert reviews of structure and model behaviors.
- For exploratory analysis, it is feasible to review model structures (are the models able to represent the issues of interest and, if so, are the representations adequate even if parameter values are uncertain?) and to review the uncertainty *ranges* being used for exploration. Insights from exploration may then be valid even if precise prediction is impossible.
- As a practical matter, the quality of analysis (and of the underlying models and input data) depends on (1) the quality of the people and organizations involved, (2) the time available, and (3) the extent to which the analysis and results can be debated in peer review. Quality depends on the talents, education, and experience of people; the objectivity and practices of their organizations; and review practices. It must be possible for others to reproduce analysis and to conduct competing analyses with different models or input assumptions. Debate is very helpful. As the expression goes, “Sunlight is the best disinfectant.”
- Quality of models and analysis cannot be legislated or ensured by formalized and sometimes bureaucratic processes. Further, as with quality control in manufacturing, problems discovered late in the process are difficult and expensive to correct: Great care needs to be taken in the underlying design and foundational work.
- For higher-level work, the more detailed models are often *not* more accurate than well-conceived simpler ones—especially if only the simpler models represent effects of factors such as the sides’ command and control, fighting capabilities, motivation, and leadership. Further, regardless of their quality, if used only with standardized point-case assumptions, results from detailed

models are often quite unreliable—more so than relying on parametric analysis with simpler models to understand the range of possible results.

I would be remiss not to acknowledge controversies and organizational hurdles. In particular, anyone attempting to use relatively simple capability models and parametric analysis should not be surprised to find the work heavily criticized by those using detailed models and standardized data. Further, it may not be easy to gain consensus on the validity of the parameter ranges used for the exploratory analysis. Indeed, an admonition to managers is:

- Investment is needed in activities to develop well-vetted value ranges for key parameters so that exploratory capabilities analysis can be well informed and reviewed.

Such activities may require considerable work because so much of the more readily available information is very detailed (e.g., the sortie rates for each individual air force squadron and how that varies with the availability of maintenance facilities' additional crews). Also, many of the important "parameters" of capability models do not exist in the more detailed models except, perhaps, as outputs.

Validity of Human Games, Historical Analysis

- The purposes of human gaming, consultation with operators, drawing on historical cases, and the like are typically not "prediction" and are typically not an appropriate subject for "validation." The purposes include:
 - Identifying *factors* and relationships affecting the phenomena of interest, including factors such as trust across people and organizations that are supposed to operate effectively together, culture-specific perspectives and taboos, and ways in which misperceptions and misunderstandings arise. Many such factors and relationships may not even be represented in mathematical models.

- Discovering flaws in systems, such as defensive systems, by turning loose the creative minds of people who are good at finding such flaws. In defense work, this may involve “red-teaming.” In the commercial world, it may involve competition of “hackers” attempting to be the first to find ways to crack new software (such as Apple’s new fingerprint reader).

As noted by Thomas Schelling years ago in regard to nuclear war-gaming, insights are so valuable that we should be more than willing to tolerate the shortcomings of war-gaming if such gaming generates such insights. This said, the validity of the insights must then be assessed separately rather than assumed as a result of the game experience.³⁵

Similar observations apply when drawing on personal testimonies and anecdotes, or even when interviewing experienced operators. It is not as if such data can be assumed generally valid, but they add to the body of knowledge, may highlight important insights, and may provide more accurate estimates than those stemming from idealized models. As I write this, I find it incongruous that using such information needs to be defended. The fact is, however, that analysts are often taught to focus only on information characterized as rigorous, quantifiable, reproducible, and objective. This often translates into prejudice against softer information.

Analysis Validation

As nearly everyone has concluded after looking into verification and validation issues, what is most important is to ensure the quality of the specific analysis rather than attempt some broad validation of all the underlying models, data, and other tools.³⁶ Many of the same methods apply, such as using competitive methods, assuring transparency, reproducing results, debating, and so on.

- Validating an *analysis* is increasingly feasible to the extent that a campaign-analysis approach has been taken that draws on different types of models, tools, and expert views, and if the validation effort deals effectively with uncertainty and disagreement.

- The “validity” of an analysis should probably be judged based on whether it provides decisionmakers the information that analysis can reasonably provide and does so comprehensibly and usefully.

This last point is intended to reinforce the observation made at the monograph’s outset, that decisions draw on analysis, but also on other considerations. Sometimes, analysis can provide answers, as with Option X will not work, but many other times the choice among options will depend, and should depend, on the subjective judgments of policymakers who are informed by analysis but should also take into account matters outside what analysis can provide.

Endnotes

¹ Aspects of a capability model may be fine-grained, as with the large linear-program models that have been used in OSD (CAPE), the Joint Staff, and U.S. Strategic Command for 40–50 years to characterize capabilities of strategic-nuclear forces. The databases are large, the targeting strategy complicated, and the algorithms sophisticated. However, results are driven by a modest number of parameters such as the accuracy of a class of weapons, the scenario (e.g., who goes first), and crude aspects of targeting strategy.

² Understanding the essential elements of missions and operations has long been a core of “strategies-to-tasks” thinking (Kent, 2002, Kent et al., 2008). It is also reflected in success-tree, fault-tree, and mission-system-analysis methods in my own work (Davis, 1994a, 2002). I became convinced that success trees are a stronger form of communication than equivalent fault trees after discussions with General Larry Welch (USAF, retired) in the late 1990s.

³ Publications exist on the mathematics of Lanchester equations (Taylor, 1983), application to fleet tactics (Hughes, 2000), understanding the mysteries of ground-combat aggregation and disaggregation (Davis, 1995), and the potential value of intelligence, surveillance, and reconnaissance for ground combat (Darilek et al., 2001). Constant-coefficient Lanchester equations are used but seldom useful in ground-combat applications because forces and conditions change and losing commanders break off battle rather than allowing their forces to be annihilated. Such effects can be accounted for in campaign models. The equations have often been used in attempts to fit historical-empirical data, but—after countless papers—it is now clear that they provide a poor basis for doing so (Lucas and Turkes, 2003). This is hardly surprising since they have a poor basis in underlying theory for reasons that include not distinguishing between distinctly different phases of combat, misrepresenting the likely “statistical mechanics” of dynamic battle, and not recognizing the

inherent heterogeneity due to different attrition mechanisms. Some of this has been discussed in the literature (Davis, Blumenthal, and Gaver, 1996).

⁴ Layering models are used extensively in ballistic-missile defense studies (Kent, 1963; Wilkening, 1999; Wilkening et al., 1989) and also in homeland defense studies, which included discussion of subtleties (Jackson et al., 2012).

⁵ I learned this approximation in the 1970s from the late Christopher Nolen of the Institute for Defense Analyses, one of the most respected systems analysts of the time. The exponent of $1/3$ assumes processing of weak signals that can shorten detection range (Toomay and Hannen, 2004). I thank colleague David Vaughan for pointing me to this reference to refresh my memories.

⁶ Numerous halt studies were done in the late 1990s and early 2000s (Davis and Carrillo, 1997; Ochmanek et al., 1998; Davis, Bigelow, and McEver, 2001; Davis, McEver, and Wilson, 2002; McEver, Davis, and Bigelow, 2000). The influential Ochmanek et al. study used a simple spreadsheet simulation.

⁷ Davis, Bigelow, and McEver 2001.

⁸ Davis et al., 2012.

⁹ Davis and O'Mahony, 2013.

¹⁰ See Quinlivan, 2003, or the earlier Quinlivan, 1995. The caution that such work suggested about how many "boots on the ground" might be needed in Iraq was discussed with policymakers before the Iraq war (Bremer, 2006).

¹¹ This discussion is reminiscent of a 1950s comment about systems analysis by Herman Kahn. He noted that competence and honesty, while desirable, were not enough (Kahn and Mann, 1957).

¹² Even in relatively simple or mid-level capability models, it may, for example, be necessary to represent command and control that adjusts the concept of operations to suit the context of a given model run. This may involve local optimization, a more ambitious game-theoretic algorithm, heuristic rules, or a combination. Such aspects of modeling are unfamiliar to those using large and complex models in which concepts of operations and tactics are embedded in data provided from external sources.

¹³ Two examples may suffice. If $F(X)$ is bimodal, but fitted to a straight line, the straight-line approximation might be good "on average" but much too low or much too high for many values of X . If $F(X, Y)$ were $X*Y$, then using a linear-fit approximation would mean that increasing X or increasing Y would have the same effect when, in reality, if X or Y is 0, the result is 0 no matter how large the other variable is.

¹⁴ Davis and Bigelow, 2002.

¹⁵ See Bigelow and Davis, 2003, for the motivated metamodel approach, which has been used in numerous studies. It remains unusual, although its philosophy of using theory-informed statistical analysis to test theory rather than to induce principles from data has precedent from the hard sciences, as noted by the famous statistician George Box (Box, 1979, 2000).

¹⁶ Davis, Bigelow, and McEver, 2001.

¹⁷ McEver, Davis, and Bigelow, 2000; Davis, Bigelow, and McEver, 2001

¹⁸ Davis, Bankes, and Egner, 2007.

¹⁹ The strengths and weaknesses of theory-driven and data-driven approaches are discussed in Davis, 2009, a shortened and improved version of similar discussion in Davis and Cragin, 2009.

²⁰ As an example, one can gather time-series data from a theater of combat operations and, without thinking about the operations, strategy, or changes in either, look for correlations with, say, the number of friendly forces. But why? Why would a commander or other consumer of analysis permit analysis that ignores such first-order considerations?

²¹ Wild, Howe, and Davis, 1989. For a fuller description of the original Joint Integrated Contingency Model (then referred to as the Main-Theater Combat model) see Bennett et al., 1988.

²² This is discussed in a white paper done for OSD (Program Analysis and Evaluation) (Davis and Henninger, 2007).

²³ RAND's Excel-based START model, developed by Barry Wilson, was a spinoff of the Joint Integrated Contingency Model incorporating certain particular algorithms.

²⁴ Petraeus and Amos, 2006.

²⁵ Davis and Cragin, 2009.

²⁶ Davis and O'Mahony, 2013.

²⁷ Davis and O'Mahony, 2013.

²⁸ Greenberger, Crenson, and Crissey, 1976.

²⁹ Body and Marston, 2011, is part of a special issue of *The Journal of Defense Modeling* (<http://dms.sagepub.com/content/8/2.toc>) devoted to the Peace Support Operations Model with chapters by Noel Wilde, Howard Body and Colin Marston, Nathan Hanley and Helen Gaffney, Paul Strong, Gemma Warren and Patric Rose, Helen Gaffney and Alastair Vincent, and Oliver Talbot and Noel Wilde on model

philosophy, modeling, the strategic-integration process, strategic communication, stabilization, and security-sector reform.

³⁰ Military Operations Research Society, 1989.

³¹ This was documented by the late historian Trevor N. Dupuy. See, particularly, Dupuy, 1987, a polished version of an earlier book that was criticized by some in the operations research community who obsessed on his overusing data (which he did) while ignoring the power of his contributions. The United Kingdom has also done considerable historical research on related matters, as illustrated in a book by David Rowland on the role of stress in battle (Rowland, 2006).

³² The original Joint Integrated Contingency Model included many such soft factors, which enabled analysis of such matters as the plausibility of a rapid victory by the Warsaw Pact and the value in conventional arms control of constraints on the readiness of reserve forces (Davis, 1988b).

³³ Over the years, the office has been named the Defense Modeling and Simulation Office, the Modeling and Simulation Coordination Office, and the Modeling and Simulation Technology Office. The weblink for “Verification, Validation, and Accreditation: Recommended Practices Guide (RPG)” is currently http://www.msco.mil/VVA_RPG.html. Early efforts producing this material were led by Simone Youngblood and had a number of respected contributors (<http://vva.msco.mil/Background/Credits.htm>). The guide does not deal much with validating exploratory analysis as emphasized in this paper, and says little about social-science modeling, but some literature on that issue is available (McNamara, Trucano, and Gieseler, 2011; Bigelow and Davis, 2003; Bankes and Gillogly, 1994; McNamara, 2010).

³⁴ This is recognized in DoD’s work, which defines validation as “The process of determining the degree to which a model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.”

³⁵ Schelling, 1987.

³⁶ In DoD’s parlance, the key is Accreditation, defined as the “official certification that a model, simulation, or federation of models and simulations and its associated data is acceptable for use for a specific purpose.” This information is online, but with websites that change. As of January 20, 2014, see http://www.msco.mil/VVA_RPG.html.

Finding Suitable Options

Challenges in Finding Good Options

Previous chapters have discussed analysis and analysis tools but another issue is finding the options to be compared. Frustrated policymakers frequently grumble about less-than-impressive options—options that perhaps are mere extrapolations of what their organizations have been doing in the past. They seek options that solve problems, perhaps with new ways of thinking. What can analysis do? Although the etymology of “analysis” may suggest otherwise,¹ I assume in this monograph that:

- Analysis should involve not just decomposition, but also integration and synthesis for a complex world. Such analysis requires creativity and a sense of strategy.

Analysts may help find good options in many ways. During a period of austerity, for example, a cost-sensitive analyst might suggest efficiencies; an operator or a policy analyst might suggest reducing objectives. However, a technologist might suggest new ways of doing things, in which case the operator might suggest a new concept of operations to exploit the technology, and the policy analyst might then see it as possible to maintain objectives but accomplish them with a new strategy based on the new concept of operations. The creative tension of working across stovepipes of policy, operations, technology, and force-building should be evident. This, indeed, has been crucial in the past. Table 5.1 sketches some of the relationships over time, although the reader is cautioned to remember that the technologies typically

Table 5.1
Contributors to Strategic Options: A Few Examples of Synergy

High Strategy	Concepts of Operation	Programs	Technologies
Nuclear			
Assured-retaliation nuclear theory (1960s–present)	Nuclear targeting from postures permitting assured response	Triad of nuclear forces	Inertial guidance systems; multi-reentry vehicles, compact nuclear weapons; strategic command and control
Second-strike counterforce (1970s)	Threaten adversary’s nuclear systems primarily with invulnerable or second-strike systems	Air-launched cruise missiles, Trident II missiles	+ Even better inertial guidance systems and terrain contour matching
Countervailing strategy (1972–present)	Deny any plausible adversary leader a plausible theory of victory; demonstrate technological superiority	Mobile intercontinental ballistic missiles (never deployed); stealth	+ Earth-penetrating warheads + Stealth technology
Global Military Strategy			
Backstop deterrence in Europe with credible nuclear forces (1950s–1970s)	Initial conventional defense in Europe’s Central Region; limited nuclear options	Limited conventional forces, Pershing II, ground-launched cruise missiles	Advanced guidance systems
Strengthen conventional deterrence (1970s, 1980s)	Rapid reinforcement; move toward ability to interdict Soviet forces via air-land battle	Prepositioning of Materiel Configured to Unit Sets (POMCUS) program; Multiple Rocket Launching System; long-range precision fires (Air Force, Army)	Global Positioning System; command, control, computers, surveillance, and reconnaissance; laser-guided bombs; precision-guided munitions
Horizontal escalation (1980s)	Threaten Soviet bastions	Nuclear attack submarines	Reduced acoustic signatures
Broaden deterrence concept in East Asia (2013–?)	Air-sea battle	Conventional prompt global strike; new long-range bomber	Miniature weapons, extreme accuracy; intelligence, surveillance, and reconnaissance; stealth
Counterterrorism and Counterinsurgency			
Population-centric counterinsurgency + attack of leadership	New counterinsurgency manual; Special Operations Command direct action	Predators, Reapers,...	Unmanned aerial vehicles and combat air vehicles

evolved over decades and were not necessarily driven by the anticipation of strategic changes years in the future.

Recurring Issues

In this brief discussion, let me touch on three recurring issues in defining and selecting among options: (1) how much capability is needed, (2) how the attractiveness of options depends on assumptions, and (3) what concepts of operations are used in conceiving and evaluating the options. The examples are primarily at the strategic rather than operational or tactical level.

The Perennial Issue: How Much Is Enough?

You cannot make decisions simply by asking yourself whether something might be nice to have. You have to make a judgment on how much is enough.

Robert S. McNamara, April 20, 1963

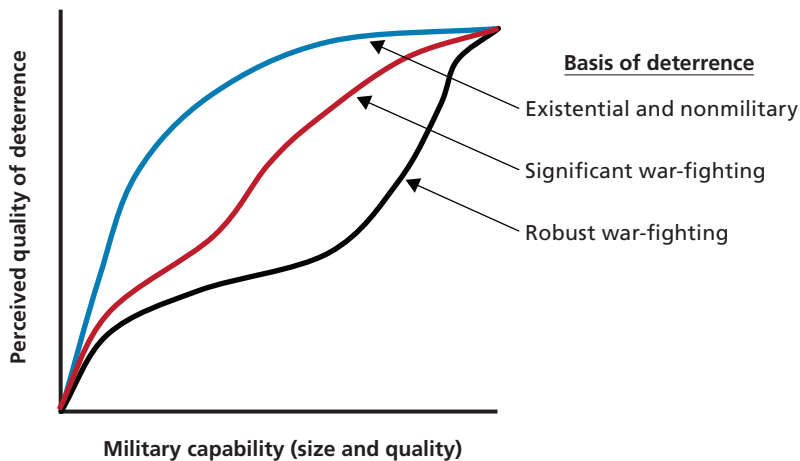
The question of “How much is enough?” has a different character in each capability area. For strategic planning, however, it often amounts to assessing what is needed to favorably affect the behavior of some potential adversary or competitor. Frequently, this is discussed in the language of deterrence. Suppose that the United States has some concern about a potential adversary in a particular region. In deciding how much capability is needed, the United States might consider at least the following strategies:

1. *Presence*: Maintain enough military presence to show that the United States has interests in the region—even though it is not postured for immediate defense.
2. *Tripwire*: Maintain and position forces sufficient to assure that aggression would very likely mean military confrontation with U.S. forces.

3. *Initial defense*: Maintain enough military capability to permit significant defense, at least temporarily. A purpose here would be to preclude quick and simple aggression, something that may be quite valuable because conventional aggression has often been undertaken with the expectation of quick and easy victory.²
4. *Substantial defense*: Maintain enough military capability to permit potentially effective and successful defense—enough so that the adversary would have serious doubts about his ability to prevail even if his “best estimate” was favorable. This capability might be sized, for example, for a first campaign lasting weeks.³
5. *Robust defense*: Maintain enough military capability to decisively defeat aggression with confidence. This might be called “Deter by Denial.”

Figure 5.1 indicates a fairly generic how-much-is-enough? curve of diminishing returns for such problems. To illustrate how the figure is to be read, suppose that one wants to evaluate deterrence skeptically, in the belief that robust war-fighting capability is ultimately important (bottom curve). With that perspective, there is surely some deterrence

Figure 5.1
How Much Is Enough?



from having modest capability, but to have a high level of deterrence requires much more capability. In contrast, someone who believes that deterrence is existential may believe that the quality of deterrence improves quickly with capability and then reaches the point of diminishing returns.

It is often important to have options suited for each of the several judgments about what is needed for deterrence. Policymakers must decide the nature of the deterrence being attempted and will draw on nonmilitary considerations such as past relations with the country in question, plausible incentives or disincentives for war, and the degree to which deterrence is driven by economics, international relations, or some other nonmilitary factors.

Robust defense based on war-fighting capability might seem to be the obvious preference, but countervailing considerations sometimes exist. First, improving one's "defensive" capabilities typically is seen by the adversary as posing an increasingly worrisome threat. This is the famous security dilemma of political science.⁴ Second, the cost of robust defense can be extremely high and the need is questionable if conflict seems sufficiently unlikely, especially if it were possible to scale up the defense in the future when necessary. Finally, it can be argued that preparing for war (no matter how much emphasis is given to the purpose of pure defense) may make war more likely because it is attended by the hardening of attitudes, suspicions, hatreds, and paranoia. This is a potential concern as the United States evolves its strategy with respect to China, which is a competitor but one that may never become an adversary.⁵ A related perennial issue is what fraction of the necessary military capability can realistically be provided by regional allies.

The next layer of sophistication in considering options is to take a broader strategic view. It may be, for example, that the adversary would "really" be deterred not by the local military balance, but by broader factors. War might have disastrous economic or political consequences. If so, then less military capability might well be enough. Most important, perhaps, is "existential deterrence." If an adversary believed that conflict would escalate to general war, even general nuclear war, then he would be deterred even if he were confident of his ability to win an

initial conflict. Unfortunately, it is not evident that all plausible adversary leaders would have this existential view. In particular, he might not deem the threat of nuclear escalation to be credible—the primary challenge in attempting to extend conventional deterrence by threatening use of nuclear forces.

Dependence on Assumptions

Even if we have decided functionally on the necessary level of military capability, which option will appear superior may depend sensitively on a number of assumptions. Consider some examples:

- Would conflict be preceded by strategic warning and mobilization?
- How much capability and determination would be provided by regional partners?

To illustrate how consequential these are, the United States postured its nuclear forces in the Cold War to assure the ability to massively retaliate against the Soviet Union even if the Soviets attacked first without warning (the “bolt from the blue”). The Soviet Union, in contrast, planned with the expectation that any conflict would come out of a crisis that would permit alerting forces. Historically, China has also not exhibited much concern about a bolt-from-the-blue attack. Was the United States being overly conservative and economically wasteful? Or was it being wise?

As a second example, consider how apparent force requirements for counterinsurgency operations have changed as the United States has decided to plan for the bulk of effort to be done by regional partners.

The point, of course, is not that one or another strategy is right, but that the notion of capability “requirements” is intimately associated with assumptions and strategies. Thus, option development should recognize the different ways that policymakers may choose to proceed.

Dependence on Concepts of Operations

Another pivotal factor in answering the how-much-is-enough question is the concept of operations assumed in evaluating an option’s capabilities. This is not a theoretical subtlety enjoyed by ivory-tower scholars,

but a core issue in practical planning—especially in periods of austerity when it becomes essential to be creative lest our capabilities be savaged by budget cuts.

Some principles apply here as well, principles based on historical experience:

- When new technologies are introduced, existing organizations (and budgeteers) often evaluate them by estimating how much more efficiently the technologies would allow the organizations to operate using current organization and practices. The result is often to underestimate the significance of the new capabilities.⁶
- If new concepts of operations and new organizations are created to exploit the new technologies, it is *frequently* possible to do much more with much less—i.e., to be far more effective (in at least some dimensions) while using many fewer people and machines.
- In periods of economic cutback, failure to introduce such innovations may have seriously disproportionate effects on operational capabilities. As mentioned above, a 10 percent cutback may mean a 20 percent cutback in the number of employable force units.

To be less abstract, consider some examples:

- Precision weapons have drastically reduced the number of aircraft needed for devastating attacks, whether by fighters or bombers.
- High-technology networking and command and control, coupled with new special-operations tactics, have had a major impact on counterinsurgency operations in Afghanistan, where U.S. ground forces have been far fewer in number than what has been traditionally needed for these type of operations.
- U.S. Army operations are now “brigade centric” rather than division centric.
- The future of ground-force operations is likely to be increasingly special-operations centric.
- The United Kingdom’s army, which has been suffering severely from budget cutbacks, is restructuring to change fundamentally

how it uses reserves and what assumptions it makes about the kinds of operations in which the its army will participate.⁷

In our day-to-day world, there are numerous examples of “revolutions,” such as the ones we associate with Federal Express, Walmart, and Amazon. A common feature of these and the military items above is that technology, concepts of operations, and organizations all had to change.

The reason for discussing these matters is to highlight the necessity in analysis of going beyond current ways of doing business.

We can confidently assume here that many good ideas exist for discrete matters, such as modernizing an aircraft’s avionics, reducing the rate of growth of personnel benefits, and improving logistical efficiencies. What follows is about how these “building blocks” might be put together. For higher-level decisionmaking, after all, the options to be considered are normally composites, as with a proposed defense program with innumerable facets but an overall “tilt” on the margin toward a particular strategic direction.⁸ Sometimes, top leaders must decide on something more narrow, such as which capabilities to acquire for a particular mission or whether to proceed with a particularly expensive system. Even there, however, they deal with composite options. For example, going ahead with a particular program such as a space-based surveillance system implies going ahead with numerous component programs involving, e.g., the platform, sensors, launchers, and support structure.

How composite options come to be created in DoD is more of an art than a science. It often depends on the knowledge, context-sensitive intuition, and skill of the staff in OSD (Cost Assessment and Program Evaluation), the services’ analytic organizations, and the Joint Staff’s J-8. The composite options are often rather crudely defined. One option, for example, might call for a relative tilt toward the Asia-Pacific region and away from manpower-intensive counterinsurgency and, at the same time, prioritizing acquisition programs accordingly. Many other features might be part of that option, but would not be explicit in the title or short-form description of the option.

Special Implications for a Period of Austerity

The admonitions of this section are especially important in periods of austerity and competition among services. In such periods, organizations often try to hold onto as much of their current status as possible, limiting cuts in personnel and equipment and planning to continue with the same approaches as in the past to the maximum extent possible. When budget cuts are significant, they may call for reducing their responsibilities—i.e., eliminating some missions or lowering expectations of performance. In defense planning as in other domains, it is sometimes possible instead to go about missions differently with an infusion of technology, new concepts of operation, and new organizational approaches. In some cases, it is even possible to do more with less. Where this is possible, however, there must be new investments and the ability to pay for the processes of change. That, in turn, typically implies making even larger cuts in personnel expenses and current equipment.

Without prejudice as to whether such options make sense at the present time, examples in the current defense world include (1) further reducing the size of ground-force building blocks to something more battalion-like in size (or even smaller) and efficient use of new technology,⁹ (2) further reducing the size of air forces' building blocks to reflect the greater capability of new systems and the absence of formidable air-force threats, (3) moving more drastically toward crew-rotation approaches, and, as in the United Kingdom, and (4) reconceiving the use of reserve-component forces, as in more fully integrating them rather than seeing them as a strategic reserve.¹⁰ All of these have been suggested; all have evident or potential shortcomings, as well as virtues. The point here is merely that—in times such as the present—the options under consideration should go well beyond scaling down current structure.

Building-Block and Composite Options

In discussing option development for capability options, level of analysis matters. The U.S. Joint Staff has carefully built an elaborate taxonomy

of joint capability areas with multiple layers of detail.¹¹ Within each capability area, at whatever level of detail, there is a need to understand the challenges, identify the capabilities that may be needed, develop options, and choose among options. For relatively detailed joint capability areas, such as offensive subsurface warfare, the options will also be relatively detailed—perhaps well below the interest level of the Secretary of Defense or Chairman of the Joint Chiefs of Staff.

An interesting role for analysts arises because, when decisions are made at a given level, the options considered are usually *composites* of the lower-level building-block options. For example, in making decisions about a program for undersea warfare, the options would probably all be composites of building-block options for antisubmarine warfare, subsurface warfare, and mine warfare. These composite options would differ in the relative resources allocated to each, and perhaps in the character of the solutions. If there was a uniquely best building-block option for each of the lower-level categories, then the options would differ *only* in the relative resource allocation. In reality, however, there may be ways to achieve *joint* capabilities that are not just a matter of assembling the building blocks offered up by the services.

For each capability area, regardless of detail, certain information is needed. The mission has to be understood and characterized analytically. The effectiveness of an option for accomplishing that mission (as measured perhaps by a number of separate metrics) needs to be understood as a function of the investment made in the relevant program(s). In some cases, “requirements” will be relatively fixed and objective, but in other cases requirements will be decided based on looking at what can be accomplished as a function of investment and deciding how much is enough.

Although the joint system for capabilities assessment and development is highly organized,¹² no rule book can specify how to conceive options, much less decide what is “best.” Some recurring themes and principles, however, bear mention. Because the United States is in a period of austerity for defense planning, it is essential to make choices. One criticism of capabilities-based planning has been that too often its practitioners have been eager to identify shortfalls and ask for more

money without adequately making tough choices. During the 2000s, it sometimes was referred to as a blank-check approach.

A New Method for Developing Options

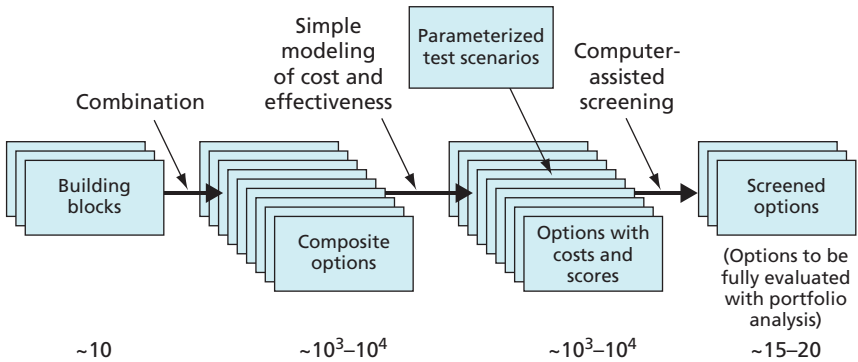
The one contribution to option development that I intend for this monograph is to suggest a new method for developing composite options.¹³ In a sense, the method seeks to formalize analysis for what has long been done ad hoc by creative staff. The methodology can be applied literally for some problems, whether for attention at the Secretary of Defense level in choosing strategy or at the Under Secretary of Defense (Acquisition, Technology, and Logistics)/Vice Chairman level in deciding on how to proceed in achieving a desired mission capability. In other cases (probably most cases), the concepts behind the approach represent a paradigm that may be useful even if the analytic machinery is not used.

The underlying analytic concepts are these, as sketched in Figure 5.2:¹⁴

1. Consider initially a vast range of possible composite options (i.e., the many possibilities inherent in a Chinese menu), thereby going beyond conventional wisdom and prejudice as to what might be considered.
2. Filter out the vast bulk of such composite options because they are distinctly inconsistent with any of the strategies under consideration with respect to multicriteria effectiveness, cost, or both.
3. Identify the small subset of composite options that are potentially the best in cost-effectiveness for the various cost levels under consideration when uncertainties are accounted for.
4. Plan to examine these surviving options in much more detail as discussed in Chapter Six.

The new features are (1) using computer methods to generate more possibilities, (2) filtering by multicriteria effectiveness measures

Figure 5.2
A New Way to Construct Policy-Level Composite Options



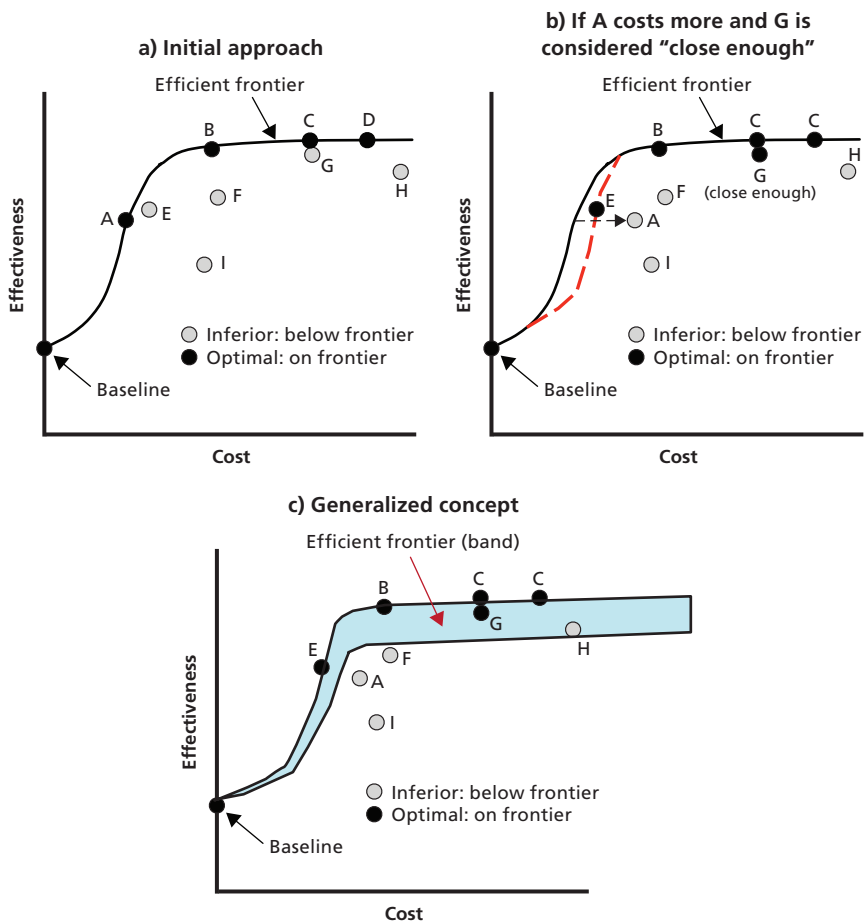
RAND RR482-5.2

suggested by the range of strategies still being considered, and (3) recognizing that uncertainties on which there are disagreements affect estimates of multicriteria effectivenesses and cost.

The classic approach is as suggested in the left pane of Figure 5.3. After plotting points against their effectiveness (vertical axis) and cost (horizontal axis), one draws the Pareto-Optimum curve, often called the “efficient frontier.” All options on that frontier are optimal: For any given cost level, the options on the frontier have highest effectiveness. And, at any given effectiveness level, the options on the frontier are least costly.¹⁵ This classic approach has many practical shortcomings. Estimates of both effectiveness and cost are likely to be squishy and even relative estimates may be significantly wrong. As shown in the right pane, suppose that the cost of Option A turns out to be a bit higher. That means that the previously inferior Option E is now on the efficient frontier and Option A should be discarded. Further, the frontier curve itself shifts. The right pane also shows what happens if one decides that Option G is so close to Option C that we do not want to discard it.

The first generalization is to keep options that are “close” to the efficient frontier, as suggested in the bottom pane of Figure 5.3. This means that the frontier becomes a fuzzy region with some thickness

Figure 5.3
Generalized Approach for Finding Options on the Efficient Frontier



RAND RR482-5.3

(perhaps 10 percent or so along both the effectiveness and cost dimensions, although the drawing is just notional). This has considerable effects on analysis. A further generalization, given in Chapter Six, has an even more dramatic effect.

A first tangible illustration of this method was in a study prototyping the approach for two Under Secretaries of Defense (Acquisition, Technology, and Logistics) (Michael Wynne and his successor Ken-

neth Krieg). The prototype problem was prompt conventional global strike for which a variety of different mission acquisition strategies were being considered.¹⁶ That example will be discussed further in Chapter Six.

With these suggestions on option development, let us now turn to the important subject of portfolio analysis.

Endnotes

¹ In scholarly work, “analysis” typically is defined as “resolution of anything complex into simple elements,” and is contrasted with synthesis. This meaning traces back to Medieval Latin and Greek. Merriam-Webster, however, recognizes as its fourth definition: “an examination of a complex, its elements, and their relations,” which is more consistent with the broad meaning in policy analysis. I discuss this because critics of “analysts,” particularly of system analysts and program and budget analysts, often accuse analysts—sometimes with justification—of being hopelessly reductionist with no sense of strategy.

² Mearsheimer, 1983.

³ With regard to NATO’s Central Region, an often-discussed goal was being able to defeat the Soviet first and second strategic echelons over the course of a month or so of combat. For strategic-nuclear planning, proponents of the Strategic Defense Initiative during President Reagan’s tenure often argued that such a defense, while imperfect, would greatly raise Soviet uncertainties about the ability to prevail. Others argued that the Soviet uncertainties were already extremely high and that an imperfect strategic defense initiative would accomplish little if anything except support the economy. The same people, however, often supported having substantial survivable counterforce capability because that, in their view, did indeed raise uncertainties.

⁴ Jervis, 1976.

⁵ See the discussion in two recent studies led by David Gompert, written soon after he served as Acting Director of National Intelligence (Gompert, 2013; Gompert and Saunders, 2011).

⁶ Early computers were evaluated for cost-effectiveness relative to typewriters and hand calculators with no recognition that work practices would change drastically. When aircraft carriers first entered the fleet, they were seen as able to improve scouting, with battleships continuing to be the core capability.

⁷ Carr-Smith, 2013.

⁸ Informing portfolio balance with strategy is illustrated in Johnson et al., 2012, and Davis et al., 2008a.

⁹ Arquilla, 2008.

¹⁰ Carr-Smith, 2013.

¹¹ See <http://www.dtic.mil/futurejointwarfare/jca.htm> for information on joint capability assessment, including the taxonomy.

¹² Joint Chiefs of Staff, 2011.

¹³ See Davis et al., 2008b; Davis, Shaver, and Beck, 2008, for the analytic method and an application.

¹⁴ The ideas were developed collaboratively with colleague Russell Shaver.

¹⁵ Markowitz, 1952; Markowitz, Sharpe, and Miller, 1991.

¹⁶ See Davis et al., 2008b; Davis, Shaver, and Beck, 2008; and related discussion from a larger workshop held by OSD (Acquisition, Technology, and Logistics) (Porter, Bracken, and Kneece, 2007).

Integrating with Portfolio Analysis

Portfolio Analysis In Comparison with Other Approaches

Even if one has a strong base of underlying analysis, the issue remains of how to evaluate the options and choose among them. Historically, a variety of methods have been used to compare options. These include equal-effectiveness comparisons (often with optimization), equal-cost comparisons, and mixed comparisons. The kind of portfolio analysis described here falls into the third class. It is especially suitable for strategic and other high-level decisions in which decisionmakers have to deal with multiple objectives, uncertainties and disagreements about “everything”—including the criteria, alleged “requirements” for each, costs, and risks. Often, the solution “emerges” as the result of process, rather than being the solution to a well-posed mathematics problem. Optimization methods can be highly valuable along the way,¹ but the most important matters are decided more subjectively, especially at the top levels.

Basic Concepts

The approach to portfolio analysis described here is well developed and documentation exists.² It is motivated by recognition that strategic decisionmakers have multiple responsibilities and multiple classes of capability to consider. Their challenge, at budget time, is to “balance” their program so that they are attending adequately to all of their responsibilities while giving special emphasis in one way or another to

some. This requires a form of multicriterion analysis. Table 6.1 summarizes ways in which this seemingly straightforward way of looking at things differs from narrowly construed decision analysis in which one constructs a common scale of utility across objectives, uses linear weighting but with constraints to keep results within acceptable bounds, emphasizes “hard” or “objective” evaluations, and optimizes cost-effectiveness for a base case, perhaps doing some sensitivity testing (e.g., varying weights). In portfolio analysis, the style is to recognize multiple incommensurate objectives without attempting to combine them; to be on the watch for nonlinear relationships such as in systems with multiple critical components; to use both objective and subjective evaluations with unabashed judgments playing a big role; to seek merely to “balance” rather than optimize (the meaning of which is doubtful here), with the intent being to address all of the multiple criteria “adequately”; and to confront uncertainty from the outset.

Table 6.1
What Makes Portfolio Analysis Different

	Simple Decision Analysis	Portfolio Analysis
Objectives	Single, overarching aggregate objective	Multiple, incommensurate objectives
Relative emphasis of objectives	Linear weights; constraints	Sometimes, complex nonlinear relationships to be discovered rather than understood a priori
Evaluations and emphasis	“Objective” evaluations and, often, a sense of once-and-for-all evaluation	A mix of objective and subjective evaluations with judgments and relationships evolving over time
Governing ideal	Optimizing for cost-effectiveness, often minimizing cost for equal-effectiveness options	Balancing to achieve good-enough effectiveness by all criteria, while remaining within a top-line budget but reconsidering component budgets
Treatment of uncertainty	Base case treated as authoritative design point; limited sensitivity analysis; reporting of assumptions	Exploratory analysis over all major dimensions of uncertainty; encourage, aid-hedging for FARness

A Simple Illustration

Table 6.2 illustrates the concept with a simplified example drawn from a study on prompt conventional global strike—a study that had high-level DoD interest because of its strategic consequences. Although the values are contrived, the display claims that the baseline capability for prompt conventional global strike is poor (red), that it can be improved markedly for attacking terrorist leaders in a short-duration meeting about which the United States gains intelligence, but is subject to the terrorists having shorter meetings or even greater secrecy about where they are held. The bomber option has some capability to attack weapons of mass destruction facilities given adequate intelligence, but not without that intelligence. Sensors, by themselves, do nothing, but in combination with the missile or bomber option provide some ability to attack mobile intercontinental ballistic missiles, although certain countermeasures would eliminate that capability.

Table 6.2 could be the basis for a substantive discussion of the options' nominal cost and effectiveness. Such spotlight charts, however, are notorious for often having no underlying basis. An important feature of the portfolio analysis approach is that it should be possible to zoom into detail, as illustrated schematically in Figure 6.1 if a recipient of the briefing asks questions. Although not shown here, the zooms can provide a visual explanation of results. For example, if someone asks why his favorite option shows up as red in Table 6.2, a zoom to the next level will show what that result depends on. The explanation may be that while several of the necessary conditions are met (green), at least one of the critical conditions is not (red). Thus, the option is ineffective. For example, an option with a great delivery platform and weapon will do no good if it lacks the intelligence, surveillance, and reconnaissance to find the target. Or, an option may work well unless the adversary adopts a countermeasure that intelligence now credits him as having already deployed.

Often, senior leaders have too little time to delve into details, but they will ask selective questions because of curiosity, prior knowledge, the importance of some particular judgment, or a desire to test the staff's mettle. Deputies and senior staff, however, often demand a deep

Table 6.2
Portfolio-Analysis Display from a Prompt Global Strike Study

Mission Option	Attack Mobile ICBMs		Attack Terrorist Leadership Meeting		Attack Hardened WMD Facilities		Program Risk	Employability Risk	Cost (\$B)
	Mobile Missiles A	Mobile Missiles B	Terrorist Leadership A	Terrorist Leadership B	WMD Facilities A	WMD Facilities B			
Base							N.A.	Low	0
Missile							Low	Low	10
Bomber							Low	Low	50
Sensors							Medium	Low	30
Missile + bomber							Low	Low	60
Missile + sensors							Medium	Low	40
Missile + sensors + bomber							High	Low	90

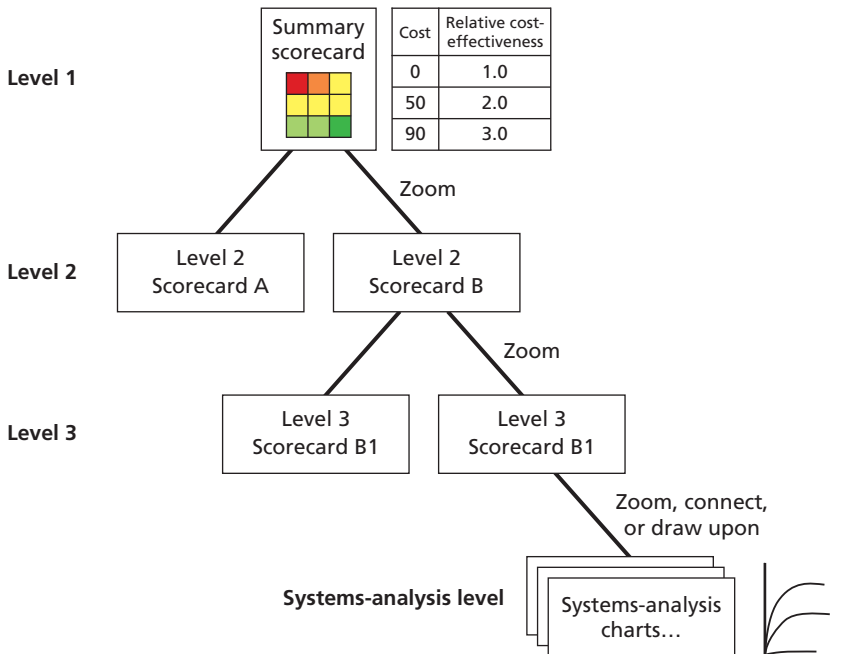
SOURCE: Adapted from Davis et al., 2008b.

understanding of the analysis: It is their responsibility to “scrub” the work.

At the bottom of Figure 6.1, the schematic indicates that scorecards only go so far. At some point, addressing issues requires using the kinds of charts more familiar in systems analysis—e.g., tradeoff curves.

Significantly, designing analysis to permit displays such as Table 6.2 and zooming leads to highly disciplined work and a sense of where the analysis is and should be going. Further, if the form of presentation is discussion with a few graphics, rather than a full-up briefing, the presenter will be able to answer questions verbally drawing on background knowledge.

Figure 6.1
Zooming into Detail for Explanation



The Economics of Portfolio Analysis

My recommended approach to portfolio analysis emphasizes discussing issues at the policy-scorecard level, as in the section above. There should be no early attempt to consolidate in some notional overall “effectiveness” because the measures are incommensurate³ and one seldom has a good understanding in advance of their relative weights (a linear concept), much less more subtle relationships. Rather, one “discovers” those relationships in the process of viewing the multicriterion results and contemplating how better options can be constructed by adjustments to improve results for some objectives, even while accepting lesser results than intended by others. For example, a policymaker might come into a discussion believing that certain goals for particular criteria are hard and fast, but might then realize that giving no attention to another objective is unacceptable. To do better may require “paying for it” by reducing goals under other objectives. The same kind of iterative “discovery” of values should be familiar to the reader from long experience with consumer-level rating systems. We do not usually want to just accept an overall judgment of some consumer magazine; instead, we want to know how the options fare by different criteria.

Discussions with policymakers at the scorecard level can be both efficient and profound, leading to better articulation of what will be acceptable. At that point, analysts can do some “neatening up,” which is particularly helpful when refining the economic analysis. That is, analysts can construct overall effectiveness in terms of the effectiveness of the top-level criteria, doing so in a way that reflects policymaker intent and values (which were not well understood, much less articulated, previously). The basis is then laid for cost-effectiveness calculations.

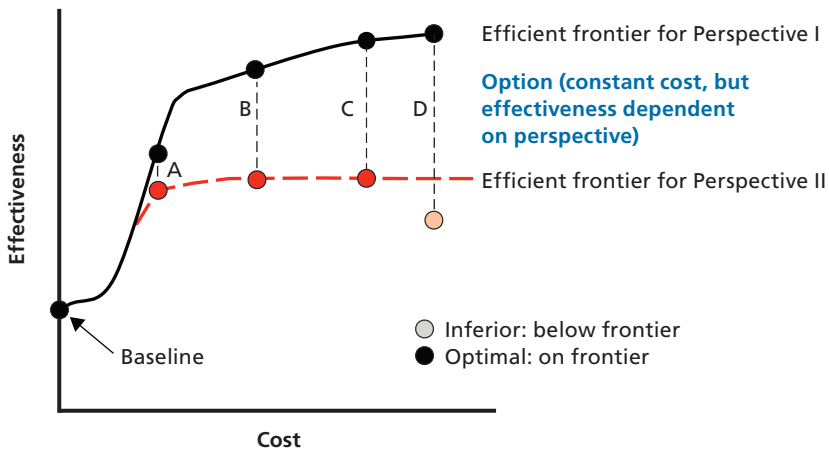
Since the effectiveness of options depends on numerous uncertain assumptions and judgments on which there may be disagreement among policymakers, however, it follows that cost-effectiveness needs to be interpreted with some sophistication. If important assumptions and disagreements cluster, then it is possible to exploit this by defining alternative “strategic perspectives,” one for each major cluster of assumptions, values, and judgments. In a debate about force structure, an example would be that some policymakers might cluster around

a forward-leaning military posture in the Asia-Pacific region, with investments in various forces and weapon systems associated with the air-sea battle and large-scale deployment of prompt long-range strike systems. Others might cluster around a strategy focused more on controlling sea lanes broadly and having what they saw as less-provocative military capabilities while maintaining an acceptable military balance. Still others might cluster around a strategy giving much more weight to continued counterinsurgency and counterterrorism operations in the Middle East, Africa, and perhaps elsewhere.

Figure 6.2 illustrates the idea notionally using just two perspectives. The two curves are efficient frontiers for Perspectives I and II (i.e., there are no options on the table that are more effective at a given cost or less expensive at a given effectiveness). Each perspective looks at the range of increasingly expensive force building options, but evaluates them differently.

Those holding Perspective I might see all the options on the table as desirable with Option A, B, C, and D having significantly better effectiveness (but at an increasing cost). In contrast, those with Perspective II might see little or no value for going beyond Option B.

Figure 6.2
Generalized Efficient-Frontier Depictions for Different Perspectives



Moreover, they might believe that Option D, although more expensive, would be downright counterproductive. To use the examples above, Perspective I might be calling for a relatively vigorous buildup of offensive options in the Asia-Pacific region, while Perspective II might be doubtful of their value and quite negative about the most ambitious option (D) because of concerns about stimulating arms competition and escalating peacetime tensions.

The example is contrived, but the methodological points being made are valid:

- Analysis should recognize that cost-effectiveness comparisons can be sensitive to strategic assumptions on which there exists substantial deep uncertainty, disagreement, or both.
- Cost-effectiveness comparisons should routinely highlight the implications of both uncertainty in the usual sense (the need for more information) and strategic disagreement.
- Finally, as discussed in Chapter Five, when selecting candidate options as a function of budget to be allocated, it is important to keep options that are “near” the efficient frontier under any of the salient strategic perspectives. Otherwise, potentially attractive options will be eliminated prematurely based on questionable assumptions.

Tailoring Portfolio Analysis to Classes of Decision

The discussion above suggests that portfolio analysis can be presented so as to be relatively simple and understandable to policymakers “at a glance,” to include providing visual explanation of underlying assumptions via the zooming described above. Experienced analysts, however, will suspect that this is too good to be true because the issues are truly complicated. The resolution of this apparent contradiction is simple enough, but important:

- Portfolio analysis must be structured differently for different policymaking contexts.

In some cases, this can simply mean tailoring displays, but in other cases it will mean structuring the underlying analysis differently. More specifically, policymakers worrying about future force structure, future force capabilities, how best to balance active and reserve components, or how best to deal with the immediate and short-term budgets, are working different problems. They need to see different “top-level factors” and different “explanations” of why one or another option looks attractive or unattractive. Ideally, an analysis organization will have an integrated understanding of how these different “views of the elephant” relate to each other and will ensure that they are ultimately consistent. However, that does not lend itself well to “simple” models, “simple” calculations, and “simple” displays. One virtue of campaign models is that building and using them establishes expertise that can in principle be harnessed for a variety of simpler and more focused efforts. As discussed in Chapters Three and Four, however, this often does not happen and managers or consumers of analysis need to insist that greater priority be given to the simpler and more focused efforts. This has many implications for investment, staffing, and terms or reference for the “analysis campaigns” that I have discussed.

Endnotes

¹ The more useful methods are sometimes referred to as robust optimization because they consider the consequences of relaxing alleged requirements and constraints. They are often used iteratively within an evolving decision process. For some examples of optimization as part of strategic planning, see Helms, 2012, Hoehl and Scales, 2011, and Davis et al., 2008b, which were discussed at a May 2013 Military Operations Research Society meeting. For a discussion of good modern practice in optimization, including robustness methods, see Brown and Rosenthal, 2008. See also recent work specifically addressing uncertainty (Chow, 2013).

² The methods began in research with strategic-level support of the first Quadrennial Defense Review (Davis, Kugler, and Hillestad, 1997). Years later, the methods were substantially enhanced in work for the Director of the Missile Defense Agency and two Under Secretaries of Defense for Acquisition, Technology, and Logistics. Some documents are in the public domain (Davis et al., 2008a, 2008b; Davis and Dreyer, 2009).

³ James Schlesinger made similar observations decades ago (Schlesinger, 1974). To be sure, many very useful studies have combined criteria into a single scale (Hammond, Keeney, and Raiffa, 2002; Keeney and Raiffa, 1976; Keeney, 1992).

Conclusions

In this monograph, I have tried to sketch ways in which defense analysis can better serve the needs of policymakers, especially in the current period of austerity. I have not discussed the substantive issues of the day, but rather paradigms and methods for the management of analysis. The emphasis has been on the subset of analysis for strategic planning that requires more than collecting data, thinking clearly, and creating good charts and point papers.

The claim of the monograph is that “big studies” should be conceived in terms of analysis campaigns. Analysts should worry from the outset about what analytic information policymakers need and what final summary conclusions might look like—but without presupposing a particular answer or slant. They should be sensitive to uncertainties and determined to distill the implications of those uncertainties usefully. This will often mean identifying affordable hedges that allow for later adaptations. Helping the organization plan for flexibility, adaptiveness, and robustness is part of the analyst’s job, as is demonstrating that it is possible to achieve objectives while keeping within budget constraints (assuming that it is indeed possible).

The campaign should be constructed to provide the underpinnings for the answer (actually many answers, in different levels of detail). The campaign may include a mix of simple and not-so-simple analysis, drawing systematically on models of different types, gaming, operations planning and insights from operators, historical data, and other sources of information. It includes technology-push and demand-pull contrasts. The options considered should go beyond those offered

up by the various advocates or programs. Further, the options should often include “paying” for additions with subtractions. And, especially in the present period, options should seek substantial cost savings—for their own sake given budget constraints, and also to make room for initiatives important to the future. This may require new technology, new concepts of organization, and new organizational structures—suggestions for which may not be forthcoming through usual channels.

Analysts should often construct composite options suitable to the policy decisions at issue, using a joint perspective with combinations for which there may be no initial advocates. Preliminary screening should identify composite options that are potentially cost-effective when viewed from a variety of perspectives and over the range of uncertainties. They should then use portfolio-analysis methods to structure discussion of options according to multiple measures of merit corresponding to the various relevant objectives, including forms of risk reduction. Analysts should be prepared immediately to explain results analytically in more detail than summary depictions. Even summary depictions should preemptively show how results depend on combinations of major assumptions and on one’s “strategic perspective.”

Finally, Table 7.1 contrasts what this monograph suggests (right column) to what sometimes occurs in current analysis. The word “sometimes” applies because analysis and analysis organizations vary substantially. Many past studies are consistent with the attributes shown. Managers of analysis will recognize many of the admonitions and note their attempts to do something similar. Nonetheless, in aggregate, the table is intended to point a way forward that is significantly at odds with much current practice.

Table 7.1
Contrasts

Attribute	To Be Avoided	To Be Encouraged
Interaction with policymakers	Initial tasking; final briefing and report	Structured discussion, iteration, discussion, . . . ; policymakers are part of the analysis; follow-up report
Character of output	Answers	Information, framework, explanation, and story to aid choice and subsequent communication, persuasion, and implementation
Explanation	Reference to underlying model runs	An understandable top-level story with understandable zooms into layers of detail as needed
Uncertainties	Identification of assumptions	Preemptively showing consequences of all major assumptions or decisions, depending on simpler analysis methods to do parametric work; emphasis on hedging
Origin of test cases	High-level committees for big-picture; lower-level staff work on critical parameters, sometimes with log-rolling	Analyst-designed candidate scenarios and parametrics followed by iterative discussions with policymakers to tune scenarios and uncertainty ranges, resulting in better policymaker understanding of implications; result: establishing meaningful requirements with good test cases
Assessment of options	Optimization of some overall "utility"	Multiobjective scorecards, with zooms for explanation; emphasis on assessing results in terms of flexibility, adaptiveness, and robustness (what others call support for robust decisionmaking or planning for agility)
Reports to policymakers	Capability shortfalls and requests for additional funds to fill them Consequences of budget cuts	Options and evaluations providing different portfolio balances, for each of several budget levels; tradeoff curves; etc. Options that include major future-leaning changes exploiting technology, new concepts of operation, and new organizational approaches
Response to "what-if?"	Requests for more time	Presentation of "capabilities analysis," which preemptively addresses the what-ifs, perhaps with real-time "zooming" routine quick-turn analysis when needed
Nature of tools used	Standardized complex models, standardized precise scenarios and data	Mix of simple and complex models with the simple ones providing structure of story and natural metrics; routine parametrics that treat standard cases merely as points of comparison; also, use of gaming, historical analysis, expert judgment from operators, etc.

Subjective Data on Past Studies

Table A.1 characterizes subjectively a number of past studies by using scores from 1 to 5 to indicate how strongly attributes in the top row were present. The cases included the damage-limiting study¹ and STRAT X study from the 1960s,² the surface-to-air missile upgrade studies from the period 1967–1972,³ the POMCUS study of the early 1970s,⁴ unpublished studies (1978–1981) leading to the Rapid Deployment Joint Task Force that became U.S. Central Command,⁵ some Star Wars studies of the 1980s,⁶ studies of conventional forces in Europe (1985–1993),⁷ the Deep-Attack Weapon Mix Study (1990s),⁸ various Halt studies (1996–2002),⁹ a detailed evaluation of the Comanche weapon system (1990s),¹⁰ a recent tanker study (2000s),¹¹ and social-science-intensive studies of the 2010s.¹²

Table A.1
Subjective Assessment of Attributes in Selected Past Studies

Case	Strategy	Concepts of Operations, Doctrine	Capability Analysis	"Hard": Physics, Technology	"Soft": Social Science	Cost-Effectiveness Analysis	"Simple" Modeling	Complex Modeling
Damage-limiting (1960s)	3	3	5	3	1	5	5	3
STRAT-X (1960s)	5	5	5	5	1	5	5	4
Surface-to-air missile upgrade (1967–1972)	1	5	5	5	1	2	5	5
POMCUS (1970s)	2	3	3	2	1	5	5	2
Rapid Deployment Joint Task Force (1979–1981)	5	5	3	2	1	3	5	3
Star Wars, arms control (1980s)	3	5	5	5	1	5	3	5
Conventional forces in Europe (1985–1993)	3	5	3	2	1	5	5	5
Deep-attack mix (1990s)	2	5	5	3	1	5	2	5
Halt studies (1996–2002)	3	3	5	2	1	5	5	4
Comanche simulation study (1990s)	1	5	5	5	1	2	1	5
Tanker study (2000s)	1	5	3	2	1	5	1	5
Qualitative counterterrorism modeling (2010s)	3	1	1	1	5	1	5	1

Endnotes

¹ The study has apparently not been released, but is described in a memoir (Kent et al., 2008) and an earlier paper (Kent, 2002), which notes “these computations were made on slide rules and Friden calculators and that the allocations were determined by measuring the slope of lines, by triangles and rulers, on utility plots fastened to a large table.”

² Fragments of the STRAT-X study have been released and some broad discussion is available (Grier, 2010).

³ See an excellent account by a retired Central Intelligence Agency official (Stevens, 2013).

⁴ The unpublished POMCUS studies were done by OSD (Program Analysis and Evaluation), but key elements are described in Congressional Budget Office documents and a book by Richard Kugler (2006, p. 564).

⁵ These studies began with the now-declassified “Wolfowitz study” (OSD [PA&E], 1979), the completion of which I led under Paul D. Wolfowitz. That was followed by informal, unpublished analyses in 1980–1981 that relied on qualitative considerations, facts, logic, and hand calculations, supplemented by sophisticated strategic-mobility models (OSD [PA&E], 1981) and insights from computer-assisted war-gaming in the Joint Staff.

⁶ This refers to separate classified RAND studies on the Strategic Defense Initiative accomplished by James A. Thomson, Russell D. Shaver, Maurice Eisenstein, Richard Darilek, and others. Some of the most important analysis required mathematical prowess, but not large computer models. Other parts required complex computerized kinematic modeling led by Michael Miller. See, e.g., Wilkening et al., 1989.

⁷ There were many studies on the conventional balance in Europe and related arms control. One of the most influential highlighted a simple story (Thomson and Gantz, 1987). Others went well beyond that but also sought to be readily understood without mathematics (Davis, 1988a, 1988b; Thomson, 1988). Underlying this work, however, was substantial research using the Joint Integrated Contingency Model.

⁸ The Deep Attack Weapons Mix Study was led by George Kolezar, James Bexfield (analysis), and Richard Nelson (cost) of the Institute for Defense Analyses and a DoD committee with representatives from numerous offices. The work was based on the tactical warfare campaign model and an optimization model. The study’s methodology is described in a published case study (Bexfield, 2001).

⁹ A number of interdiction or “halt” studies were accomplished at RAND and elsewhere, some with the Joint Integrated Contingency Model or comparable campaign models and some with much simpler models. See also Appendix F.

¹⁰ The RAND work on Comanche was led by Monti Callero in a classified study that used entity-level simulation of both ground forces and air forces.

¹¹ Michael Kennedy led several tanker-related studies, some with intense congressional interest. In part because of controversy, they were extraordinarily rigorous and relied on detailed computer models, sharply defined scenarios and databases, careful cost analysis, and optimization (Kennedy et al., 2006).

¹² A number of such studies have been conducted in recent years by colleagues. Some, led by Kim Cragin, Todd Helmus, and Brian Jackson have been classified. They involved significant data collection and analysis for the war zones, but did not use computer modeling. Much of the work used qualitative factor-tree models (Downes-Martin, 2013). Recent work has demonstrated how such qualitative models can be implemented as uncertainty-sensitive computational models (Davis and O'Mahony, 2013). Such models are not for point predictions but rather for exploratory analysis to see what combinations of factors need to be favorable for success to be reasonably plausible.

Capabilities-Based Planning

This appendix describes analytical aspects of the history of capabilities-based planning and discusses the confusion that has often arisen about how it compares to threat-based planning (ultimately, a non-issue as discussed at the end). What is described is what I see as the “good” kind of capabilities-based planning, which is rather different from the way it is sometimes perceived because of implementation issues (e.g., with complex bureaucratic processes and, ironically, with overuse of point scenarios).

History

The Early Period, 1961–1980

The planning methods of the 1960s and 1970s are often said to have been based on threat-based planning.¹ That label, however, conflated to very different issues: (1) highlighting a particular named adversary and (2) how analysis and planning dealt with scenario uncertainties and how-much-is-enough issues. Cold War defense budgets benefited from the United States having the Soviet Union as a known, formidable, and dangerous adversary. Highlighting this “capital-T threat” was a main feature of how defense programs were presented and discussed. However, as illustrated below, the stronger elements of defense planning were capabilities-based, even if that is not widely recognized.

Strategic Nuclear Forces. Since 1961, force planning for long-range nuclear forces has used constructs that help in planning under uncertainty. By the mid-1970s, when I was immersed in such work as

part of OSD (Program Analysis and Evaluation)'s strategic forces division, analysts varied whether U.S. and Soviet forces were on day-to-day alert or on generated alert, which side would attack first, and whether the sides would use launch under attack. We considered counterforce, countermilitary, and countervalue attack options for both sides.* We varied such technical assumptions as the projected accuracy of future Soviet missiles, whether the sides would try to limit civilian deaths with air bursts rather than ground bursts, and weapon-system reliabilities. Overall, we used *dozens of* scenarios/cases, none being regarded as a meaningful best estimate or base case. Rather, force planning depended on understanding the totality. We certainly had in mind a specific adversary, a capital-T threat, but in other respects this was capabilities-based planning. To be sure, public debate often revolved around a specific scenario, such as a surprise Soviet counterforce first strike followed by U.S. response in kind. That was useful as one bounding case. Other scenarios, however, were essential for net assessment, understanding the military balance, or understanding a more plausible play-out of nuclear war.

Strategic Mobility. Another important class of force-planning analysis involved strategic mobility—long-range airlift, sealift, and the use of prepositioned material. DoD's analysis and advocacy was crucial because mobility forces lacked the natural champions enjoyed by new fighter aircraft, carrier battle groups, or tanks. The analysis used standard scenarios as test cases and for presentations, but policymakers always valued the flexibility of strategic mobility forces demonstrated by working scenarios requiring deployments to various theaters under varied conditions. Again, then, much of the underlying analysis was capabilities-based even though external discussion was typically oriented toward the massive Soviet threat and goals were set accordingly. The conclusion of a major study from this period was expressed in capability terms: a requirement for airlift capability of 66 million ton miles per day.² This "requirement" was just a reasonable judgment based on considering numerous plausible scenarios seen as test cases.³

* Counterforce, countermilitary, and countervalue targeting refer to attacking just the adversary's nuclear forces, its broader military forces, or its urban-industrial base.

Conventional Forces. Conventional force planning was seemingly more threat-based. The primary adversary (the Warsaw Pact) was specified and force planning in the 1960s and 1970s used stylized idealizations of threat buildups to estimate force needs. This said, higher-level planning was more capabilities-oriented if one went beyond superficialities. Even as early as McNamara's first years, OSD looked at a wide range of possible conflicts and what capabilities would be needed to deter or deal with them. As it happened, it proved possible to focus *force-sizing* on a combination of the Soviet threat, the North Korean threat, and a possible "miscellaneous" smaller war. Higher-level analysis over the next 20 years often referred to planning for 2-1/2, 2, or 1-1/2 wars. The higher-level analysis was often quite simple (even simplistic), counting major formations (divisions, wings, aircraft carrier groups, Marine amphibious groups) and using rules-of-thumb to estimate force needs.⁴

Planning in the services and combatant commands was more detailed—not only for current operations planning, but also for building service programs (Program Objective Memoranda). One unfortunate aspect of this was a tendency over time to focus on rather precise notions of how war would be conducted. It sometimes seemed as though the memoranda were being developed to optimize against the official war scenario. This style of planning identified the Soviets as threat *and* used well-specified scenarios (e.g., scenarios indicating the time lines, focus of attacks, and duration of war). It was probably what people mean when thinking about classic threat-based planning.

Even so, *some strategic analysis considered nonstandard cases*. The examples with which I am most personally familiar involved Central Region scenarios with creative Soviet strategies and Southwest Asia scenarios.⁵ Perhaps the most influential example was the "Wolfowitz study" of 1979, aptly titled *Capabilities for Limited Contingencies in the Persian Gulf*.⁶ The study had been commissioned by Presidential Directive 18 (August 24, 1977) because of concerns about possible U.S. military weakness in the Persian Gulf region. The study had an inauspicious reception, but follow-on work led, in 1980–1983, to the strategy, force-building programs, and command changes associated with the Rapid Deployment Joint Task Force, which evolved in 1983

into U.S. Central Command.⁷ Remarkably, programs initiated in the Carter administration were embraced and expanded in the Reagan administration.

Although clearly “capabilities analysis,” this work looked closely at the most obvious big threats to the Persian Gulf region, notably the prospect that Iraq would invade or coerce Kuwait and the prospect that the Soviet Union might invade Iran and, subsequently, the entire region. These were not regarded as likely, but as worrisome possibilities to deter by assuring that the United States had suitable military capabilities. Other possible contingencies were considered in lesser detail. Overall, the emphasis was on viewing the whole and understanding what military capabilities would be especially valuable and affordable.

The Late Cold War Period, 1981–1992

DoD-level force-planning work did not change greatly between 1981 and 1990—even though the primary force-building scenario written in 1980–1981 made no sense by the mid to late 1980s.⁸ One change that did occur, however, was that related analysis in both OSD and the Joint Staff came to depend more on large campaign models, detailed specification of the scenarios, and related databases. The campaign models allowed richer and more subtle analysis of some issues and the standardization enabled better joint analysis, since those in the various services could use the same information and indeed had to do so when advocating for programs. However, the ascendance of this approach correlated with reduced nimbleness and a trees-rather-than-forest perspective. It was during this time that threat-based planning began to be increasingly associated with standardized models, standardized scenarios, complicated databases, lengthy coordination processes, and everything *except* broad assumption-varying analysis.

As of 1990 and the fading of the Soviet Union, planning changed, as exhibited by the 1990 “Base Force” discussion of the George H.W. Bush administration.⁹ General Colin Powell, Chairman of the Joint Chiefs, recognized that it was important to base force levels on general U.S. interests and conflict possibilities rather than on highly specific threats and threat scenarios.¹⁰ Referring to a change from a threat-based force to a threat- and capability-based force, Powell argued:

We might not face the old threat from the Soviet Union, I said, but we had to maintain certain fundamental capabilities. For example, we might no longer have a specific airlift requirement to move X million tons of materiel to Europe to meet a potential Soviet invasion. But we still needed the capability to move huge stores to unpredictable troubles spots around the world. We might no longer face the 8th Guards Army across the Fulda Gap, but we still needed the capability to project power elsewhere. I proposed forces capable of performing four basic missions: one to fight across the Atlantic; a second to fight across the Pacific; a contingency force at home to be deployed rapidly to hot spots, as we did in Panama; and a reduced but still vital nuclear force to deter nuclear adversaries.

Powell's claim was understandably not convincing to everyone. He did not include a compelling reason for *why* the United States needed the capabilities he referred to. It was obvious to him after a career of unexpected military events, but not to skeptics (especially those from a different political party than the then-current administration). Even if one accepted the argument that the United States still needed these capabilities, the question of how much was needed remained. Surely, it must be less without the Soviet Union. This criticism was unfair because, at Powell's urging, the Base Force was to be a good 25 percent smaller than the previous force. That said, by Powell's own description of his personally drafted "Strategic Overview 1994," his figures for the Base Force as of 1989 were intuitively driven estimates.¹¹ They were not obviously rooted in analysis, although—behind the scenes—his J-8 organization did a good deal of forward-thinking analysis.

Powell and his deputies, then, were attempting to institutionalize capabilities-based planning, to include dealing with uncertainty and making difficult choices under budget constraints. This approach was consistent with the preference of the Under Secretary of Defense for Policy, Paul Wolfowitz. The approach also included explicit hedging, such as the ability to reverse trends if need be¹²—very much in the spirit of this monograph. It was only when convinced of the plan's reversibility that Secretary Dick Cheney came to support it.

This moving away from threat-based planning did not mean ignoring the Soviet Union or thinking *only* in generic terms. Rather, it had to do with recognizing that many possible sources of crisis or conflict existed, including the Soviet Union, *and* that how crisis would arise and what U.S. forces would need to do was inherently uncertain—not unbounded, but uncertain. The specificity of what had become known as threat-based planning was inappropriate. Also, had threat-based planning been used, the logic would have called for even larger force reductions because the primary threat was falling apart, not just becoming a bit weaker.

Post-Cold War Period, 1993–2000

In 1993, the newly elected President Bill Clinton appointed Les Aspin as Secretary of Defense. Aspin had been Chairman of the House Armed Services Committee and was on record as opposed to capabilities-based planning, insisting that threat-based planning was necessary. One of his statements was widely publicized:

It is critical to identify threats to U.S. interests that are sufficiently important that Americans would consider the use of force to secure them.¹³

Much has been made of this, but Aspin did not mean what many have claimed. Aspin was making a judgment about what was necessary to sell the defense program to Congress and the public, rather than commenting on what concepts should underlie the program. By dint of long experience on the committee, Aspin understood the need for capabilities. He was aware of uncertainties and emphasized in his study called the Bottom-Up Review (similar to the Quadrennial Defense Review) that the planning scenarios were for force sizing: How forces would actually be used was another matter. The Bottom-Up Review¹⁴ also took a building-block approach to force planning with the intent of being prepared for diverse challenges, as emphasized in capabilities-based planning. In a section on “Scenarios as Planning Tools,” the Bottom-Up Review observed:¹⁵

History suggests that we most often deter the conflicts that we plan for and actually fight the ones that we do not anticipate.

For planning and assessment purposes, we have selected two illustrative scenarios that are both plausible and posit demands characteristic of those that could be posed by conflicts with other adversaries. Figure 4 [not shown] displays the scenarios and their relationship to planning for force employment across a range of potential conflicts. While a number of scenarios were examined, the two that we focused on most closely . . . envisioned aggression by a remilitarized Iraq . . . and by North Korea. . . .

Despite the scrapping about planning-method labels, then, the Bottom-Up Review actually built on and was largely consistent with the Base Force concept of the Bush administration although it went 10–15 percent further in force reductions.¹⁶ As I wrote at the time, the Bottom-Up Review framework had problems, such as its reliance on old-fashioned building-block forces (divisions, wings, and aircraft carrier groups) dating back to World War II, relying excessively on the North Korean and Iraqi threats for force sizing, and not being forward-leaning,¹⁷ but it was not nearly so “threat-based” as it seemed casually. Moreover, by the mid-1990s, DoD began expanding substantially the number and classes of scenario that inside-the-Pentagon planning was to address—i.e., it was moving even further toward capabilities-based planning, whether or not the term was in vogue.

The next Quadrennial Defense Review under Secretary William Cohen introduced a new strategic framework for planning (*Shape, Respond, Prepare Now*).¹⁸ It also had a chapter on “Transformation,” although not mandating changes in forces. It preserved the force-sizing requirement to be able to fight two major theater wars simultaneously, but Secretary Cohen was adamant about distinguishing between the strategic framework and that force-sizing consideration. That is, the capability to fight and win two overlapping wars was considered necessary *for* the strategy, but was not itself the strategy. He emphasized having forces that could respond quickly and decisively to the full spec-

trum of crises, and to be prepared for “wild card” scenarios.¹⁹ At the same time, he directed a number of additional cost-cutting measures.

By the late 1980s, there was recognition that the requirement to be able to fight two major theater wars, although explicitly intended to be only for force sizing, was being misinterpreted as though it were specifically about Iraq and North Korea, and thereby causing problems. A change of criterion was arguably needed to rebroaden thinking as had been intended in 1997.²⁰

The Early New-Century Period, 2001–2010

In 2001, Secretary Donald Rumsfeld established the capabilities-based approach as a new management framework, seeing it as a way to manage strategic risks in a highly uncertain world.²¹ He built on de facto developments from the Clinton administration such as assessing more diverse threats, but was much more vigorous in pursuing transformation and bringing about management change. He is often quoted for saying that a capabilities-based model is one that

focuses more on how an adversary might fight rather than specifically whom the adversary might be or where a war might occur.

Unfortunately, many people reading parts of the 2002 Quadrennial Defense Review believed that the Secretary was precluding discussion of specific potential adversaries. For a time, officials within DoD literally insisted that briefings not refer to named threats. Perhaps this misimpression was exacerbated by a more colloquial article in which Rumsfeld said

It’s like dealing with burglars: You cannot possibly know who wants to break into your home, or when. But you do know how they might try to get in. You know they might try to pick your lock, so you need a good, solid, dead bolt on your front door. You know they might try breaking through a window, so you need a good alarm. You know it is better to stop them before they get in, so you need a police force to patrol the neighborhood and keep bad guys off the streets. And you know that a big German Shepherd doesn’t hurt, either.

To head off confusion, he might have added an aside after the “You cannot possibly know” sentence: “Well, perhaps you have *some* idea; you might worry about a particular suspicious neighbor. However, you still don’t know the when or how; you can’t simply schedule a time to be at home sitting with a gun at the window you expect him to enter.” Does anyone doubt that Rumsfeld would have said something like this if his rhetorical language “You cannot possibly know” had been challenged?

If one goes back to the original document, it turns out that Rumsfeld’s language in the Quadrennial Defense Review did not actually have the narrow interpretation that would reject considering particular threats. On the very first page (p. iii) he says (referring to the attack of September 11 as backdrop):

the attack . . . highlights a fundamental condition of our circumstances; we cannot and will not know precisely where and when America’s interests will be threatened, when America will come under attack, or when Americans might die as the result of aggression. We can be clear about trends, but uncertain about events. We can identify threats, but cannot know when or where America or its friends will be attacked. We should try mightily to avoid surprise, but we must also learn to expect it. . . . Adapting to surprise—adapting quickly and decisively—must therefore be a condition of planning.

Also, when describing the capabilities-based approach in more detail, he says (p. 13):

That concept [the capabilities-based approach] reflects the fact that the United States cannot know with confidence what nation, combination of nations, or non-state actor will pose threats. . . . It is possible, however, to anticipate the capabilities that an adversary might employ to coerce its neighbors, deter the United States from acting in defense of its allies and friends, or directly attack the United States or its deployed forces. A capabilities-based model—one that focuses more on how an adversary might fight than who the adversary might be and where a war might occur—broadens the strategic perspective. It requires identifying

capabilities that U.S. military forces will need to deter and defeat adversaries who will rely on surprise, deception, and asymmetric warfare to achieve their objectives. . . .

These longer passages certainly include worrying about particular adversaries (how could anyone imagine otherwise?). Rumsfeld, however, was correctly asserting that all details of scenario were uncertain (recall the scenario-space depiction of Figure 3.7), thereby implying that specific threat scenarios should not be the focus of planning even if their concreteness makes them compelling.²²

When introducing capabilities-based planning, Rumsfeld also had strong ideas relating to organization and management. He was quite troubled about how jointness in planning was attempted only after the services had put together their programs independently. He recognized that concepts and capabilities should be conceived and developed in joint terms from the outset. This emphasis on joint thinking was reflected in a major implementation study (the “Aldridge study”)²³ that led to substantial reorganization of processes—mostly for good but with some stumbles as well (especially overly burdensome processes). In ongoing work, officials created an analytic agenda that was to emphasize, slightly paraphrased, “deeper understanding, collaborative development of data, more robust treatment of uncertainty, responsiveness, an understanding of differences among competing studies, support for Combatant Commander planning activities, and support of future-force development.”²⁴

The Recent Period, 2009–

The 2010 Quadrennial Defense Review issued under Secretary of Defense Robert Gates further embellished the risk-management structure introduced in 2001 but was largely seen as a continuation of policy. It continued the emphasis on capabilities-based thinking²⁵:

In short, U.S. forces today . . . can be plausibly challenged by a range of threats that extend far beyond the familiar “major regional conflicts” that have dominated U.S. planning since the end of the Cold War. . . . the wars we fight are seldom the wars that we would have planned . . . it is no longer appropriate to

speak of “major regional conflicts” as the sole or even the primary template for sizing, shaping, and evaluating U.S. forces. Rather, U.S. forces must be prepared to conduct a wide variety of missions under a range of different circumstances. . . . The QDR thus employed several scenario combinations to represent the range of likely and/or significant challenges anticipated in the future and tested its force capacity against them.

The entire section is well worth reading for those interested in the issue of capabilities-based planning versus threat-based planning, and in defense analysis generally. The discussion is clearly intended to be “analytic.” The scenarios used for the Quadrennial Defense Review were not just “reasonable,” but rather were chosen to be “test cases.” There was no intent to forecast. The authors of the Review were exploring the landscape of challenges. At some point, DoD would issue planning scenarios to serve as “requirements,” but not because the scenarios were thought to be correct.

Somewhat later, the administration of President Barack Obama announced major changes of strategy that included a pivot toward Asia, better described as a matter of rebalancing—reducing emphasis on large-scale counterinsurgency operations and giving renewed attention to the Asia-Pacific region. Not much is publicly available about what new planning scenarios will be like, but it can be assumed that those will be changed to match the times. As discussed in a 2011 report, attention should shift more to worrying about balance-of-power issues, deterring small-scale aggression, avoiding crises, and managing them if they arise, than about building forces for a particular scenario such as the battle over the Taiwan Straits.²⁶ With respect to North Korea, it now seems more important—given South Korea’s substantial military capability—to worry about specific issues such as potential coercion attempts or missile attacks than about all-out classic invasion.

Definitions and Contrasts: Real and Imagined

Early Connotations

The 2002 Quadrennial Defense Review did not include definitions of capabilities-based or threat-based planning, or describe consequences for analysis. At the time, the best summary of what people probably believed the terms meant was in a balanced article by John Troxell of the Army War College, who addressed the period from the 1950s to 2001 and pointed out overlaps and misunderstandings related to both terms.²⁷ He summarized comparisons as follows:

Threat-based planning:

This methodology is preeminent when threats to U.S. interests are easily recognized and identified. The task for the planner is to postulate a reasonable scenario, or a specific military contingency, then determine the amount of force needed to prevail in that scenario. The approach lends itself to dynamic and static modeling and provides quantifiable rationale for the recommended force structure. . . . The logic . . . is very compelling and greatly facilitates accomplishing the planner's third task—convincing the public and Congress.²⁸

Capabilities-based planning:

Capabilities-based planning is most in vogue when threats to U.S. interests are multifaceted and uncertain, and do not lend themselves to single point scenario-based analysis. Instead of focusing on one or more specific opponents, the planner applies a liberal dose of military judgment to determine the approximate mix of required military capabilities. Capabilities-based planners claim to focus on objectives rather than scenarios. A major problem planners have with this approach is convincing Congress that military judgment has established the proper linkage between the recommended force and the uncertain geostrategic environment.²⁹

Tightening Up Concepts

My own definition was published in a 2002 monograph (Davis, 2002, p. xi), but stemmed from a decade of previous work.³⁰

Capabilities-based planning is planning under uncertainty to provide capabilities for a wide range of modern-day challenges and circumstances while working within an economic framework that necessitates choice.

The intent was to convey in plain language the common-sense nature of the approach. Planning should confront uncertainty and, recognizing the inability to forecast accurately what challenges will arise or, significantly, the detailed circumstances, should provide “capabilities” able to deal with what does arise. Capabilities, however, do not come free and choices must be made so as to live within a budget. In many ways, the intent was to refocus analysis on enduring principles such as described in Chapter Two.

Although never adopted formally, this definition, or minor variants, has been used and cited widely in DoD work,³¹ including in a white paper from the Joint Staff.³² Other agencies such as the Government Accountability Office, Federal Emergency Management Agency, and the Department of Homeland Security have used it or a variant.³³ It has also been cited prominently by the National Academy (National Research Council, 2005); an international defense planning group from the United States, United Kingdom, Australia, and New Zealand³⁴; and the scholarly literature.³⁵

The definitional issues run deeper. What does “capability” mean? In day-to-day language, the word has two different meanings.³⁶ One refers to “general wherewithal” (as in, “we haven’t actually planned for that, but we could deal with it because we have the requisite general capabilities”). In a variant, a Secretary of Defense or Chairman may refer to capability as being measured by force structure, modernization, readiness, and sustainability.³⁷ The other connotation has to do with being able *truly* to accomplish a specified mission.³⁸ If the President asks a commander, “Do you have the capability to do this mission?” a positive answer should mean that the mission can actually be accom-

plished successfully, implying adequacy of physical equipment, personnel, training, plans, support forces, etc. This meaning is what led to the sometimes-cited but unfortunate DoD definition:³⁹

Capability: the ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks

One commenter wryly observed, “For an effort aimed at clarification, this must be the lexicographical equivalent of destroying a village to save it.”⁴⁰ Still, the definition’s motivation is understandable. If DoD establishes a requirement for a capability, the services and combatant commands can promise to achieve it only if they know for what they are responsible. That is, there is a contract involved. Unfortunately, this definition is easily misread to undercut the core concept of capabilities-based planning. The solution is straightforward:

- The apparent contradiction can be reconciled by interpreting “under specified standards and conditions” to mean “under a specified *range* of standards and conditions.”

An analogy would be for an aircraft designer to promise capability to operate within a flight envelope. Commanders and other “operators” are intuitively inclined to this interpretation, but contractors building a piece of equipment might have an incentive to interpret matters more narrowly. More insidiously, that is often so as well for analysts who work with big models and painfully coordinated databases. In my view, analysis organizations have often undercut the kind of capabilities-based planning that was intended by DoD leadership.

Comparisons

What about the definition of threat-based planning? How do they relate? My answer is as it was a decade ago:⁴¹

Capabilities-based planning is often contrasted in discussion and articles with “threat-based planning,” which is confusing because capabilities-based planning is also very much concerned

about threats. No one seriously proposes that the Department of Defense should spend nearly \$400 billion per year for general insurance against the abstract possibility that some threat might conceivably arise somewhere, sometime—especially when threats currently exist and other potential challenges can be seen on the horizon.

It follows that the correct contrast is not with “threat-based planning” as that phrase is interpreted literally, but rather with dependence on a specific bounding threat as represented by one or a very few point scenarios.

To elaborate, Table B.1 characterizes variants of capabilities-based and threat-based planning by various attributes. It includes extreme and more reasonable versions, the latter being in the middle rows, particularly those shaded in blue. TBP+ corresponds with what is favored by people who say they prefer threat-based planning or a hybrid of TBD and CBP. Such people *do* value what I have called FARness and they *do* make clear distinctions between analytic threats for the sake of power balances, for example, and capital-T threats that are to be greatly feared. They see planning scenarios as useful instruments, not forecasts. Such scenarios can be forcing functions of change, can provide illustrative details to support a host of activities from training to exercising, and can definitely be used in analysis as the basis for choice and judgments about how much is enough. They do not just make up such scenarios out of thin air or slavishly follow some Intelligence Community projection. Further, if asked, they are eager for analysis that examines variations of assumptions and leads to robust conclusions. In my own mind, these modern-day defenders of what they call TBD are actually practitioners of CBP. However, by clinging to the terminology of TBD, by often putting too much emphasis on the planning-scenario cases, and by not more forcefully advocating—and even demanding—more exploratory work, they differ significantly in degree from proponents of CBP. It seems clear to me, if not to the reader, that CBP as defined here, is the “right” way to do analysis, and is rooted in deep principles. TBP, in contrast (even TBP+) will continue to take point

Table B.1
A Comparison of Planning Methods, Actual and Contrived

	Breadth of Analysis and Preparation		Generic Analysis (Parametric Scenario Space)	Sense of Capital-T Threat	Distinction Between Competitor and Threat	Threat Scenarios for Communication	Threat Scenarios for Analysis and Requirements	Analytic Basis for Threat Scenarios as Test Cases	Organizational Focus on FARness	Choice Under Budget (No Blank Checks)
	Major threat	Other threats								
Nutty TBP	•			•		•	•			
TBP	•	•		•		•	•			••
TBP +	•	•	•	•		•	•	•	•	••
CBP	••	••	••	Sometimes	••	•	•	••	••	••
Nutty CBP			••		••				••	

NOTES: TBP+: threat-based planning at the strategic level, especially in communication, but with broader and deeper work beneath the surface, in mission-level analysis and sometimes in strategic-level side rooms. By “nutty” I mean to suggest than no one sensible would—if pushed—define the methods in this way.

scenarios far too seriously, suppressing important uncertainties in the process and undervaluing flexibility, adaptiveness, and robustness. The organizational and psychological pressures for doing so are very strong.

Ultimately, labels are not especially important in themselves, especially when their meanings are so blurred. Thus, one solution if the controversy continues would include sharpening the definition of CBP and embracing it fully, noting that it contains the good features of TBD. Another possible solution could take the form of some new label purporting to combine the best features of both.

Communicating and Convincing Others

A remaining issue is the one flagged initially by Secretary Aspin and mentioned from time to time in many settings.⁴² What approach is better for “selling” the defense program? The question is uncomfortable because analysis should focus on objective assessments, not politics or salesmanship. Nonetheless, policy analysis must concern itself with communication and implementation.

Secretary Aspin may well have been correct with respect to what proved convincing to the House Armed Services Committee during his tenure, but he was not describing a law of nature. It is true that the U.S. public supports increases in the defense budget during periods of perceived threat and may demand decreases in periods of low perceived threat. It is not obvious, however, that the public is affected by the esoterica of planning methodologies. Influential members of Congress and their staffs might be, but it is worth noting that the U.S. Navy and U.S. Marine Corps have done well over the years with Congress even though their force structures have never been threat-based. More dramatically, the Intelligence Community’s programs have flourished over the last decade even though they are capabilities-based rather than built around particular scenarios.

Principles, Independent of Labels

It is important to move beyond labels and chronic misinterpretations. Some suggestions are listed here:

- The underlying core analysis and force planning should be capabilities-based because of massive uncertainty, but should also (rather obviously) consider specific threats that can be identified—whether to understand the potential challenges or assess how much capability is enough when the budget dictates the need for choice.
- Scenarios developed for force-sizing explanations must not be allowed to undercut preparing forces for flexibility, adaptiveness, and robustness. Nor should they be taken as forecasts.
- Clear distinctions should be maintained between test-case scenarios conceived for assessing balances of power and scenarios conceived for operational planning or more general contingency preparations. There may be overlaps, but the differences are and should be substantial.
- How the merits of a proposed defense program are communicated most effectively will depend on the era. Sometimes, it is most effective to dramatize particular threats;⁴³ other times, it is most effective to promote broad capabilities and illustrate their value for many possible purposes. In either case, however, both the underlying analysis and the programs themselves should be designed for flexibility, adaptiveness, and robustness.

Endnotes

¹ See a review written in 2001 (Troxell, 2001a, 2011b) or a recent editorial (Dudney, 2009).

² OSD (PA&E), 1981.

³ See discussion of such matters in Schmidt, 1997.

⁴ William Kaufmann described force-planning issues of the 1970s and 1980s in widely read books (Kaufmann, 1981, 1986).

⁵ Over the years, OSD's Office of Net Assessment has sponsored many studies departing from conventional wisdom. Such work often has well-identified threats (named countries or groups), but not stereotyped point-case scenarios. Is such work threat-based planning, capabilities-based planning, or something else?

⁶ OSD (PA&E), 1979.

⁷ The Wolfowitz report is declassified but difficult to find (OSD (PA&E), 1979). Documentation about this planning period is sparse. I wrote a short paper after leaving government, where I had led completion of the study under Wolfowitz and led follow-on analysis in 1979–1981 (Davis, 1982). One book discusses the Wolfowitz report, noting that it did not get a good reception from Secretary Harold Brown, who did not want to have Iraq cast as a major threat and who saw Iran as a bigger problem (Gordon and Trainor, 1995, pp. 8, 480). Nonetheless, Brown directed creation of the Rapid Deployment Joint Task Force and initiated programs to support it in 1980. See also a DoD report (Department of Defense, 1992, pp. 348–349) and a recent report on the process and intrigues outside the Pentagon itself as the new command evolved (Biddal, 2011).

⁸ As of 1988, some operations plans were still focused on defending Iran against invasion by the Soviet Union (Department of Defense, 1992). At the urging of Under Secretary of Defense Wolfowitz and the direction of Chairman Colin Powell, U.S. Central Command began reformulating the war plan to focus on a potential threat by Saddam Hussein to Kuwait and Saudi Arabia. Planning was only part way along when Saddam invaded Kuwait in 1990. See, e.g., Department of Defense, 1992, pp. 348–349, or Cohen et al., 1993. Why one force-building “programming scenario” from 1980 to 1981 had become the basis for a long-lasting operations plan, while another (oriented toward an Iraq threat to Kuwait) had been ignored is remarkable.

⁹ Jaffe, 1993.

¹⁰ Jaffe, 1993; Powell and Persico, 1995, pp. 451–452.

¹¹ Powell and Persico, 1995, 436ff.

¹² Jaffe, 1993, pp. 31–32.

¹³ This is widely cited as from a speech “National Security in the 1990s: Defining a New Basis for US Military Forces,” as given to the Atlantic Council of the United States, January 6, 1992.

¹⁴ Aspin had used the terminology of “Bottom-Up Review” before the election. He had in mind, loosely, rethinking everything with a clean sheet of paper. In reality, the Bottom-Up Review was a notable Top-Down Review that began by reviewing objectives, threats, and so on, and then drawing conclusions about force size. There was no tinkering with the nature of the Army, Air Force, Navy, or Marine Corps with the nature of military operations, or other matters that would be more

bottom-upish. Further, the changes mandated were only modest changes from the Base Force, changes consistent with the Presidential campaign. That consistency, presumably, was not accidental. The Bottom-Up Review is viewed by many as the “first” Quadrennial Defense Review.

¹⁵ Aspin, 1993, p. 14.

¹⁶ Kugler, 1995, pp. 212–213; Troxell, 2001a, p. 13.

¹⁷ Davis, 1994b.

¹⁸ Cohen, 1997a.

¹⁹ Cohen, 1997b.

²⁰ Flournoy and Tangredi, 2001.

²¹ Rumsfeld, 2001, p. v.

²² This was also true for the Cold War confrontation over NATO’s Central Region. The standard case was useful for force sizing and deterrence, but was otherwise inadequate because it ignored deception and surprise, differences in fighting quality among members of the Pact and NATO alliances, potential consequences of secret capabilities, and so on. Such additional degrees of freedom were discussed outside mainstream planning, partly in connection with arms-control analysis (Davis, 1988a, 1988b).

²³ Joint Defense Capabilities Study Team, 2004.

²⁴ Krieg, 2004. A number of salient papers were presented at a related Military Operations Research Society workshop in 2004 and a follow-up in 2006. The latter’s papers are available online. One of the 2004 papers discussed issues discussed in this monograph, including the number of cases for which analysis was needed and the inappropriateness of standard tools for doing so (Allen, 2004). The 2006 workshop included a useful Joint Staff white paper providing what the authors saw as a needed overview of capabilities-based planning broadly. A briefing described well the intentions of the Analytic Agenda activity (Bexfield, 2004). The collection is a good representation of Department thinking as of 2006.

²⁵ Gates, 2010, p. 43ff.

²⁶ Davis and Wilson, 2011a.

²⁷ Troxell, 2001a.

²⁸ Troxell, 2001b, p. 9.

²⁹ Troxell, 2001b, pp. 9–10.

³⁰ Davis and Finch, 1993; Davis, 1994a; Davis, Gompert, and Kugler, 1996.

³¹ See Goss, 2005, p. 11, and a paper by Joint Staff officers struggling with implementation of capabilities-based planning, including numerous process problems (Bankston and Key, 2006).

³² Bankston and Key, 2006.

³³ A Federal Emergency Management Agency definition is “Determining capabilities suitable for a wide range of threats and hazards while working within a framework that necessitates prioritization and choice. Capabilities-based planning addresses uncertainty by analyzing a wide range of scenarios to identify required capabilities.” See <http://training.fema.gov/EMIWeb/emischool/EL361Toolkit/glossary.htm>. Another paraphrasing is included in a thoughtful discussion (Caudle, 2005).

³⁴ Technical Cooperation Program, 2004.

³⁵ Fitzsimmons, 2007; Hicks and Ridge, 2007; Hales and Chouinard, 2011.

³⁶ Davis, 2002, p. 2.

³⁷ Brown and Winslow, 2012, p. 11.

³⁸ Davis, 2002, pp. 28–29.

³⁹ Department of Defense Directive 7045.20, September 25, 2008. A shorter definition is just “the ability to execute a specified course of action” (Joint Publication 1-02, November 8, 2010). A more recent DoD definition (from Joint Publication 1-02, amended in 2011) is “Capability: the ability to execute a specified course of action.”

⁴⁰ Fitzsimmons, 2007, p. 102.

⁴¹ Davis, 2002, pp. 5–8.

⁴² Dudney, 2009.

⁴³ From my own experience in 1979–1981 as the strategy, program, and command relationships associated with the Rapid Deployment Joint Task Force were communicated to senior officials and Congress, it was initially most effective to highlight the potential threat of Saddam Hussein threatening Kuwait because the notion of a Soviet threat to the Persian Gulf got little resonance. After the Soviets invaded Afghanistan in December 1979, this changed discontinuously: *Only* the Soviet threat was of interest and the Iraq threat was ignored. The underlying analysis and proposed defense initiatives, however, had not changed. They had both kinds of possibilities in mind. The dangers of fixating on a particular threat were demonstrated when, as late as 1989, the operational plans for U.S. Central Command were still Soviet-focused, largely ignoring the possibility of an Iraqi threat to Kuwait. A new plan attending to that possibility was still in development when Saddam invaded in 1990. See, e.g., Department of Defense, 1992, pp. 348–349, or Cohen et al., 1993.

Other Approaches to Risk Management

DoD's Risk-Management Language in Policy Documents

The main text treats reducing risk as just another kind of objective. Other approaches are possible. In particular, if one considers defense planning to be basically an exercise in risk management, then everything becomes a risk. That is, all of DoD's functions and objectives can be expressed in terms of reducing one or another kind of risk. That is the tack taken in the 2001, 2006, and 2010 Quadrennial Defense Reviews, which used a risk-management framework that evolved somewhat over time. The most recent version distinguishes four types of risk:¹

1. *Operational risk*: the ability of the current force to execute strategy successfully within acceptable human, materiel, financial, and strategic costs. Consideration of operational risk requires assessing the Department's ability to execute current, planned, and contingency operations in the near term
2. *Force management risk*: our ability to recruit, retain, train, educate, and equip the All-Volunteer Force, and to sustain its readiness and morale. This requires the Department to examine its ability to provide trained and ready personnel in the near term, midterm, and long term.
3. *Institutional risk*: the capacity of management and business practices to plan for, enable, and support the execution of DoD missions. It encompasses the ability to develop effective and efficient organizations and processes over the near term, midterm, and long term.

4. *Future challenges risk*: the Department's capacity to execute future missions successfully, and to hedge against shocks. Here most consideration is given to the Department's ability to field superior capabilities and sufficient capacity to deter/defeat emerging threats in the midterm and long term.

These categories are clearly appropriate focuses of attention. Note, however, that the definitions refer to "risk" with such words as "ability" and "capacity." The categories actually refer to objectives and the "risks" have to do with inability to meet those objectives. Thus, the framework is actually part of an objectives-based framework in disguise. When the Clinton administration referred to "Prepare Now" as part of its strategy, it was addressing "Future Challenges Risk" in different language. Preferences vary.

DoD's current risk framework is especially useful at the top level for distinguishing among organizationally and managerially different problems so as to help define the responsibilities charged to varied parts of the organization. It also distinguishes between the near and long term and between the more visible aspects of capability (e.g., forces and force capabilities) and underlying considerations such as the quality and training of personnel and the effectiveness and efficiency of organizational behavior.

Other Government Uses of "Risk"

DoD is a very large organization and the word "risk" has different meanings in its different parts. For example, a recent report by OSD means by risk the potential for a program to come in over cost or over schedule or to underperform.² In contrast, within a specific research and development program the risk of most concern might be that a technology cannot be made to work. In recruiting activities, the risk may be that economic developments will cause the supply of high-quality recruits to dry up before (if at all) Congress is willing to increase incentive pay.

Moving outside DoD for further examples, the Department of Homeland Security has used a risk-based approach to analysis in which various categories of risk are combined into an overall metric. Program alternatives can then be compared as to how much they “reduce risk,” i.e., how much they improve the risk metric. As discussed in the main text, there are major shortcomings to that approach, as noted also by a National Academy report (National Research Council, 2010). The risk metric is so aggregated as to have little meaning and comparing options by small changes in this dubious risk metric obscures important issues. As discussed in Chapter Three, it is important to maintain visibility across multiple top-level criteria. Department of Homeland Security leadership is aware of the shortcomings of the methodology and is attempting to deal with them in a variety of ways.

The conclusion from this should be, simply, that

- Referring without explanation to “risk” is not useful. It is necessary to attach modifiers specifying which kind of risk is being referred to.*
- In many contexts, it is important to have an explicit taxonomy of risks to ensure both good communication and appropriate attention to all of them.
- In many contexts, it is necessary to specify concretely how the particular risk being discussed is measured or calculated. Anything less than this specificity will likely result in misunderstanding.

What follows illustrates some of these points in more detail.

Normal Risk Versus Risk from Deep Uncertainties

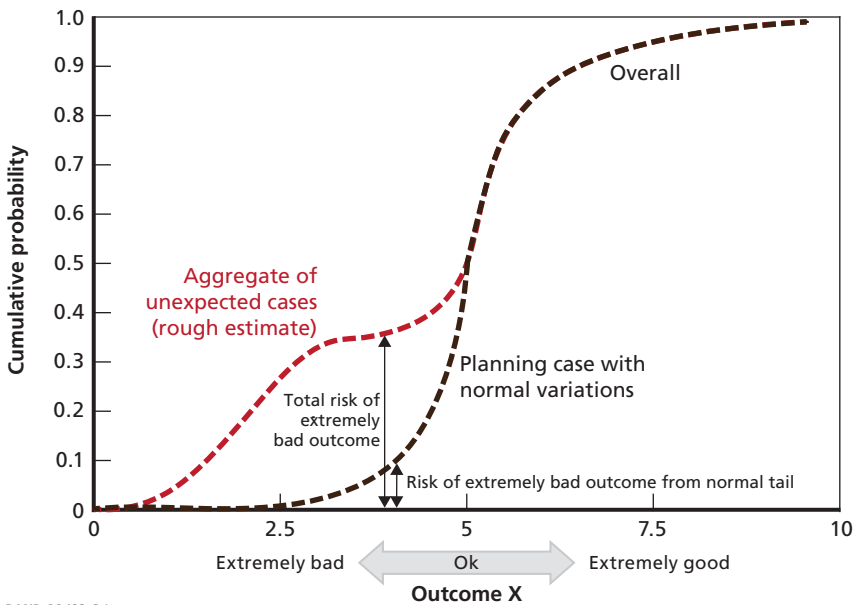
Strategic planning must distinguish clearly between what might be called “normal” variation of results, some of which is downside risk, and the risk that results will be *far* worse than expected because or

* This theme is also emphasized in recent work by Air Force A-9, which suggests a common standard for discussing risk.³

unplanned-for events, a misunderstanding of the problem, or something else.

Figure C.1 illustrates the issue schematically by plotting the cumulative probability that outcome will be worse than Outcome X, versus Outcome X itself. The expected result based on a planning case is 5, which is “ok.” The anticipated range is 4–6 because of various details and random factors, but anything in the range is acceptable. There is some possibility—even for this planning case—of worse results. This is the “tail effect” for the planning case. However, the much larger risk is that the basic planning case itself is fundamentally wrong. Although the unexpected cases have no well-specified probability distribution, the red dashed curve indicates a rough assessment that in aggregate such poorly understood or appreciated cases, part of deep uncertainty, add considerably to the risks. Some people refer to these as “black swan” risks.

Figure C.1
Distinguishing Normal Risks and Those from Deep Uncertainty



Interestingly, in strategic planning it is often possible to recognize the unexpected cases as hypothetical possibilities, but to see them individually as quite improbable.⁴ Unfortunately, if a number of such possibilities exist, then it may be fairly likely that at least one of them will occur. As an example, given six hypothetical bad cases, each with only a 10 percent probability, one has a roughly 50/50 chance that at least one of them will occur. This is why good engineers strive for exceedingly high reliability rates on system components with many components.

Because really bad cases are so often quite different in kind from marginally adverse versions of nominal cases, it is useful to preserve the term “risk” for referring to them rather than normal but adverse variations. If instead we use the word risk for what amount to the small tail effects of the normal case, we will have squandered an important word in the English language. Further, our statement about risk may be quite misleading. The suggestions for strategic planning, then, are:[†]

- Use “risk” to refer to the possibility of outcomes *significantly* worse than anticipated, which will often correspond to effects of deep uncertainty.
- Use “normal risk” when referring to more marginal worse-than-expected outcomes.

This might suggest a display such as in Table C.1 for comparing options. All of the options have the same “expected” consequence and the same normal range of consequences. Option 2, however, builds in the possibility of a somewhat better result without taking additional risks (maybe it includes a small investment in research and development with a very high upside potential). In contrast, Option 3 builds in the possibility of a great outcome (1), but at the expense of intro-

[†] In other domains of risk analysis, the phenomena may be well understood and characterizable by non-Gaussian probability distributions with “thick tails.” In such a case, it is appropriate to equate “risk” with the consequence of those thick tails.⁵ Invoking deep uncertainty and black swans is unnecessary. However, if the phenomenon itself is changing (as with climate change affecting the frequency and ferocity of storms), then historical statistics are unreliable and the concepts of deep uncertainty do apply.

Table C.1
Distinguishing Normal and Deeper Risks

Option	Expected Effectiveness and Normal Range	Best-Case Effectiveness (Upside Potential)	Worst-Case Effectiveness (Risk or Downside Risk)
1	5 (4–6)	6	4
2	5 (4–6)	7	4
3	5 (4–6)	10	0

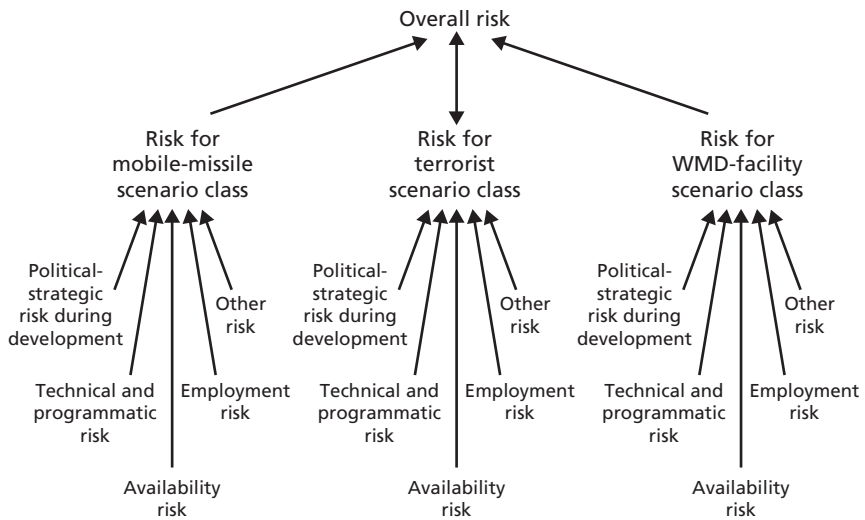
ducing substantial risk. An operational military example might be an option having all forces charge forward into battle as rapidly as possible, hoping to utterly rout and destroy the enemy, but at the price of having no reserves. The absence of reserves could be disastrous in the event of a surprise enemy maneuver. In the realm of force planning a real-world example might be the Future Combat System of the early 2000s. The program “bet the farm,” so to speak, on a combination of immature technology, undeveloped operational concepts, and a development program managed by a commercial contractor. It was a truly revolutionary concept with what seemed to some to have a very rosy upside potential, but admittedly significant risks that could hardly be called normal. The program failed. Although many elements of the program undoubtedly had value that will pay off in other ways, the outright losses amounted to many billions of dollars.

Distinguishing Among Sources of Risk

Both normal risks and those associated with deep uncertainty have different origins and different characters. To illustrate how taxonomies of risk can be useful, let us consider a particular study⁶ that looked at alternative ways to develop conventional prompt global strike. A subsequent National Academy study drew on this work but included additional options and reflected further debate and analysis (National Academy of Sciences, 2008). The options included, e.g., depending on forward-deployed aircraft, a new conventional warhead and delivery system for Trident missiles, a new intercontinental ballistic missile, and other pos-

sibilities. Each such option would have a certain estimated effectiveness, if developed and deployed successfully. Shortcomings in those measures of effectiveness were not considered “risks,” but, rather, just capability gaps. For example, some options would not provide enough firepower to damage a hard deeply buried facility for weapons of mass destruction. Others would not have the ability to find mobile missiles. Again, these were shortcomings, not “risks.” In contemplating what risks to consider, the RAND study developed the taxonomy in Figure C.2, ascribing risks of various types for each type of mission for which the option was being tested. The left-most branch in the figure was attacking mobile missiles such as mobile intercontinental ballistic missiles. We saw a risk that such a program would be terminated during development because of a political-strategic judgment by Congress or a next President that this was not an appropriate mission or not a mission of consequence. For some options, we also saw substantial technical and programmatic risks because the option required feasible but cutting-edge technology that had not yet been demonstrated (discussed

Figure C.2
An Illustrative Taxonomy of Risks for Options in a Particular Study



NOTE: WMD = weapons of mass destruction.

extensively in the National Academy study). The technology might simply fail (an unexpected possibility), or it might just take longer and cost more (normal risk). The possibility also existed that even if the option was successfully developed, the relevant systems might not be available when needed because of being maldeployed or otherwise engaged. If the capability were actually employed, there would be a risk of collateral damage or erroneous targeting. There were also other risks, such as the potential that employing this particular option would cause an unintended escalation (perhaps because it would overfly countries that would mistake its purpose or perhaps because the targeted country would choose to retaliate in a different and less limited way). The point here is not whether these were the “correct” risks, but rather that there were so many to consider even in an illustrative study. Again, discussion of risks should include adjectives distinguishing among them.

Significantly, the most important class of risk was not even shown in the taxonomy because it was treated in a different way. When evaluating the options against the several missions, we used two test-case scenarios for each. For the mission of attacking mobile missiles, we considered what amounted to a nonresponsive threat and a responsive threat—i.e., a threat as was currently being projected by intelligence and one that would, in addition, adopt countermeasures. Although we treated the responsive-threat case as merely a test scenario without labeling it as “risk,” the plausibility of a responsive threat is so high that a policymaker would certainly consider it a risky proposition to build an expensive system that might be totally ineffective.

To complete this example, note that someone working on cost-schedule risk might do a superb and precise job with empirical data and sophisticated statistical analysis. He or she might report the risk of being more than 10 percent over cost or more than two years behind schedule as less than 25 percent, a rather precise figure. In contrast, there is no way to “calculate” objectively the many other large risks, such as that effective countermeasures would be deployed or that use of the option would trigger escalation. Those risks have to be estimated subjectively and qualitatively—in some cases by policymakers themselves. The National Academy study had strong but subjective conclusions based on long experience with science, technology and weapon-

system developments. It identified some of the options as high risk if it was necessary to achieve deployment within a few years.

Common Problems in Risk Analysis

Since many approaches to risk analysis exist and many types of risk exist to be analyzed, it is worth mentioning some common sources of confusion and trouble.

- When an organization receives less than it requested in the budget, it may warn that the result is increasing risks. Such a claim might or might not be accurate.
 - Perhaps the decision was to forgo an objective. Inability of an option to achieve something that is no longer an objective is not usefully described as risk, even if the decision to forgo the objective is indeed risky (as when Great Britain pulled back from East of Suez).
 - Perhaps the decision drew on other organizations' experience and credible consultants to conclude that the organization's approach to its mission will soon be obsolete, that the organization should reform, and that—if it does—it will be effective with fewer resources. In this case, the actual worry is not the resource level but one of institutional risk: Will the organization be able to reform itself?
 - Perhaps the decision was to reject the organization's claim about "how much is enough?" based on judgments about intelligence on adversaries and related independent analysis. In that case, the risk would be that the intelligence or analysis was wrong rather than the resource levels per se.
- When a quantitative analysis using models defines risk as the gap between the goal and the predicted outcome of a test case, it is "using up" the term "risk" for something that may not be nearly as important as the possibility of having the wrong test case (see the first section of this appendix). It is better, in such case, to simply refer to the gap between goal and outcome.

- The most egregious problem is failure to treat “deep” uncertainties or treating them poorly, while simultaneously doing in-depth precise analysis of relatively trivial risks.
- Using probabilistic methods to estimate the likelihood of a bad outcome may appear elegant and scientific, but may be ignoring the most important uncertainties, assuming independence of correlated processes, or relying on “data” for which no reasonable basis exists.

Conclusions on Risk

My own conclusions on risk management are (1) it is preferable to organize around objectives (including risk reduction) than around risk; (2) the many types of risk should be explicitly identified in analysis rather than lumped together; (3) the term “risk” should be preserved for possibilities not addressed in the central line of analysis, as in “the risk that our planning scenarios are off-base” or “the risk that, despite promises, the system being acquired will never be able to accomplish the goals assumed in program “requirements”; (4) risk analysis based on optimizing risk reduction based on a single overall metric should be viewed with great skepticism; and (5) probabilistic methods should be used only for narrow purposes and advertised as such.

Endnotes

¹ Gates, 2010, p. 90.

² Kendall, 2013.

³ Boerman, 2013; Tompkins, Boerman, and Lesinski, 2013.

⁴ See the discussion and examples in Davis, 2003.

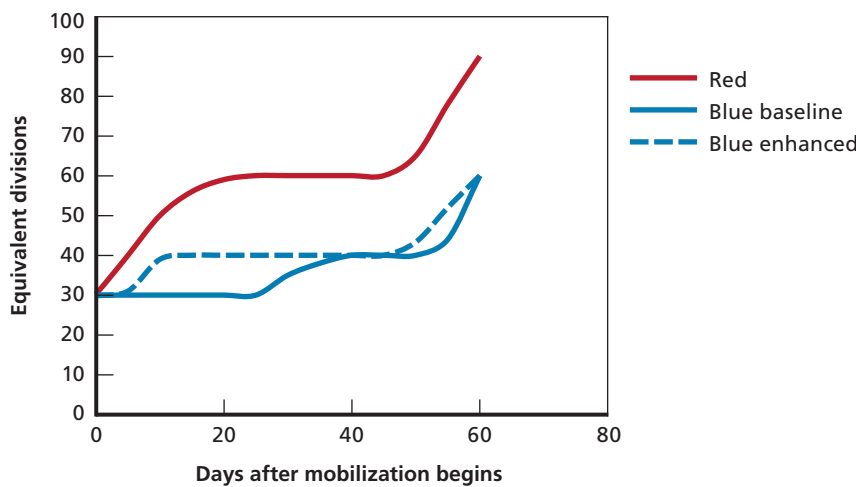
⁵ Haimes, 1998.

⁶ Davis, Shaver, and Beck, 2008.

Illustrative Threat-Based Analysis

Figure D.1 shows the kind of build-up chart used in the 1970s and 1980s for some requirement-setting and communication-related purposes. The story was that Red (the Warsaw Pact) could build its forces faster than could NATO shortly after mobilization for war began. For a period of time in the first month, Red could enjoy a force ratio of 2 or even 3:1—high enough to make a quick victory possible. However, if the United States could deploy a number of divisions quickly enough (dashed curve), the force ratio would never be worse than 1.5:1,

Figure D.1
An Illustrative Build-Up Chart from the Cold War



RAND RR482-D.1

which was deemed adequate for conventional deterrence because it was believed that would-be conventional aggressors seek quick and easy success.¹ NATO could mount a good initial defense and, thus, it was argued that Red could not be confident of victory.² The program to accomplish this involved prepositioning the divisional equipment in Europe and airlifting the personnel to man the equipment (the famous POMCUS program initiated in the 1970s).

This was an illustration of what purportedly was pure “threat-based planning.” The red curve was based on intelligence estimates; the blue curves were based on actual NATO capabilities and projected capabilities with the POMCUS program. The “problem” was simply maintaining an adequate force ratio. The program solved the problem. This type of analysis was regarded as clear and compelling.

The underlying reality of analysis was more complex. First, there was considerable debate over the years about how to characterize the strength of the forces.³ The “equivalent division” metric was imposed by the Office of the Secretary of Defense to simplify a much more complicated situation in which the various divisions were all somewhat different in manning, equipment, and readiness level. Second, there was controversy about how quickly Pact forces could actually build up and about how quickly NATO would see a threat and order its own mobilization. Third, there was controversy about what force ratio was sufficient—even for deterrence, but certainly for war-fighting. Fourth, there were disagreements about whether NATO’s air forces and command and control capabilities would tilt the balance and should somehow be included in the analysis. Finally, real war would have been much more complicated involving terrain, road networks, generalship, the role of airpower, etc. Such matters were gamed out to the extent feasible at the time, with results informing the more aggregate analysis. Thus, the depiction in Figure D.1 was very much simplified relative to what analysts had considered and debated about before going forward to Congress. Advocates of threat-based planning sometimes claim that such analysis is simple, clear, and compelling, but it is more accurate to say that the final story was relatively simple, clear, and compelling.

My own group in OSD (Program Analysis and Evaluation) used similar analysis in 1979–1981 to assess force needs for Southwest Asia,

whether against an invasion of Kuwait by Saddam Hussein or an invasion of the region through Iran by the Soviet Union. In that instance, both the deeper analysis and war-gaming was strongly affected by the mountain belts in Iran and by whether U.S. forces would be fighting along with, independently of, or with Iranian forces in defending against the Soviets. Thus, any discussion in terms of force ratios and buildup charts was as a much bigger simplification even than that for the Central Region. The potential for interdiction was intriguing.⁴ Our analysis was consciously more about replacing a worrisome vacuum with a deterrent strategy and modicum of capability than about preparing for likely war.⁵

Endnotes

¹ Mearsheimer, 1983.

² The 1.5:1 rule of thumb was dubious and DoD would have preferred using a ratio of 1.25:1. The reasoning behind it was described in a Congressional Budget Office paper (Hillier, 1980). For a later discussion of how force-ratio rules of thumb change with level (theater, corps, tactical) and with important assumptions, see Davis, 1995.

³ Until Enthoven's Office of Systems Analysis looked at the issue in the 1960s, assessments treated extremely low-readiness Soviet divisions as though they were real (Enthoven and Smith, 1971). In later years, "equivalent armored divisions" was a metric that adjusted for personnel and equipment modernity.

⁴ Levine, 1985.

⁵ The FY 1982 annual defense report illustrated the deterrence focus: "By showing the Soviets that we have the military capability and the national will to respond to aggression, we seek to deter such aggression in the first place. The determination and ability to move a credible American force rapidly and effectively changes the calculus for the Soviets; they must then consider the probability that any aggression by them will meet not only indigenous forces, but also those of the United States. Given such an ability on our part to meet them on the spot and our capability of shifting the geography of the conflict, the Soviets must consider the possibility that renewed aggression by them may lead to a much wider war, escalated both in intensity and geography."

A Model That Could Have Been “Simple”

To illustrate the trickiness of characterizing a model as simple or complicated, consider Figure E.1, a depiction of the counterinsurgency problem in Afghanistan that appeared in the background of a *New York Times* article entitled “We Have Met the Enemy and He Is PowerPoint.”¹ It is reported that General Stanley McChrystal dryly remarked, “When we understand that slide, we’ll have won the war.” The article is worth reading, and many readers will appreciate the grumps about death by Power Point. However, what is perhaps interesting is that what was being shown was a visual depiction of a model that, in some respects, is fairly simple—even if the impression is precisely the opposite and even if, had there been an objective test of comprehension, the result for most audiences would have been a total lack of comprehension—beyond, perhaps, acknowledging that everything is related to everything in something as complicated as counterinsurgency.

Just as campaign models can be considered complex and opaque, or rather simplified and revealing, depending on one’s expertise and how the model is presented, so also the model underlying the graphic can be seen as a remarkable distillation of a great deal of knowledge that can be quite understandable—given some investment of time. The underlying model was developed in the System Dynamics modeling platform by the PA Consulting Group and the Joint Staff’s J-8.² It was based not on complex mathematics, but on the Petraeus-Mattis field manual.³ The effort to develop the model had been highly informative, as was the briefing, which was given numerous times to analysts and

operators. The operators reportedly found the diagram very useful, but had little or no interest in the running model—not just because it was below their level of resolution, but because they knew that it was the ability to see the overall system and how interactions occurred that was insightful.

Without elaboration, let me simply assert that the model’s opacity was largely an artifact of having been presented “flat” rather than in layers. Had the model been designed with multiresolution methods and presented accordingly, the top-level diagram would have been far simpler, and the primary points to be made could have been made in digestible chunks—rather like the zooming discussed in Figure 6.2 for portfolio analysis or in the multiresolution modeling of public support for terrorism mentioned in the text as one example of simple modeling (Davis and O’Mahony, 2013).

Endnotes

¹ Bumiller, 2010.

² The authors used the VENSIM and STELLA/iTHINK programming languages for diagramming and coding, respectively.

³ Petraeus and Amos, 2006.

An Example of Simplified Modeling: The Halt Problem

This appendix illustrates how it is sometimes possible to base a useful parametric model on a simple physical picture and freshman-level mathematics. It is perhaps most common to think of simple models as a place to begin, to sketch out ideas before doing “more serious” modeling. The following example, however, describes instead the instance in which one starts with a complicated computer model but finds it difficult to work with or explain, and of little help in identifying shortcomings of the analysis that should be addressed. In that case, reverting to simple modeling can bring clarification and insight.

Background

In the mid to late 1990s, a number of organizations used simulation modeling to examine whether precision fires could improve the ability of a defending force to halt an invading army. Much such analysis was complicated because it used large campaign models with considerable detail on ground forces, air forces, deployment processes, terrain, and so on. By running a case with and without the assumption of some precision-fires options, outcomes could be compared, but it was difficult to understand the essence of what was happening unless one were deeply expert with the model, and, even then, it was difficult to answer some questions because outcomes depended on so many variables.¹

A Simple Underlying Model

Upon stepping back from the campaign models, it became evident that outcomes were being driven by a simple process that could be isolated from the rest of the campaign model. The assumed process was that the armored vehicles of mechanized divisions moved down a road network and were being attacked by precision fires from fixed-wing or rotary-wing aircraft, or from postulated long-range precision artillery. The “shooters” were credited with the ability to kill a certain number of vehicles each sortie. A mechanized unit, such as a division, was assumed to become useless (and essentially stop) after suffering a sufficiently high level of attrition, such as 50 percent. The underlying picture, then, was just a race between the moving vehicles and the attrition of those vehicles.

In the tradition of simplified modeling, it was possible to assume that the invading army moved at a constant speed, and that interdiction could be represented roughly by an aggregate number of shooters with an average killing rate per sortie and an average sortie rate per day. The number of shooters on a given day could be represented as the number of shooters available at the outset plus those being added by deployment at an average deployment rate. A successful halt campaign would kill a critical number of armored fighting vehicles before the invading army had penetrated some unacceptable distance into the target country.² This glossed over many subtleties and complications, but allowed “seeing the whole” in a mathematical sense. Further, the simple problem was solvable in closed form, as shown below, using a trivial integral equation that one might understand from freshman calculus and the famous quadratic formula of eighth-grade algebra.

$$FN = \int_{T_S}^{T_h} KS\{A_0 + R_s\}ds = KSA_0(T_h - T_S) + \frac{1}{2}KSR(T_h - T_S)^2$$

$$\therefore T_h = T_S + \frac{-KSA_0 \pm \sqrt{(KSA_0)^2 + 2KSA_0FN}}{KSR}$$

$$D = VT_h$$

where

F is the fraction of the attacking force that must be killed to bring about a halt,

N is the number of armored vehicles in the attack,

K is the number of vehicles killed per sortie,

S is the number of sorties per day (for aircraft),

R is the rate at which shooters deploy into the theater,

A_0 is the initial number of shooters,

T_h is the time at which the halt occurs,

T_s is the time required to suppress air defenses so that interdiction can proceed,

D , the distance of penetration before halt occurs, is the average rate of movement times the halt time.

The first equation states that the required number of vehicles will have been killed after interdiction has proceeded from time T_s to time T_h .

Discovering Assumptions to Be Varied

To be sure, the simple model in the equation above was making “errors” aggregating even more than the campaign model itself—by referring to shooters rather than a number of different shooter types with somewhat different killing effectiveness, sortie rate (or shot rate), and deployment rate. The campaign model would distinguish among, say, F-15s, F-15s, F-18s, and long-range artillery with advanced munitions. However, these numerical “errors” (actually, just approximations) were trivial in comparison with uncertainties about the basic picture embodied in the initial campaign model as well as the simplified model. Even the full campaign model assumed, initially, that the invading army kept moving at constant speed despite attrition until “destroyed,” that “destruction” occurred when a certain fraction, F , of the vehicles were killed, that aircraft would be able to operate immediately rather than waiting until after air defenses were suppressed, that the kills per sortie

or shot metric was unaffected by the invader's maneuver strategy (e.g., vehicle spacing, the number of roads used), and that bases were available to accommodate deploying shooters. Each of these inputs was uncertain by at least a factor of two!

If these underlying assumptions were pointed out, the campaign model could readily be adjusted to permit variations. However, in some cases, it was the simple modeling that laid bare the assumptions. Further, it was often easier and faster for an analyst to adjust the simple model to accommodate different assumptions than to have a professional programmer make the lower-level coding changes in the campaign model. And, perhaps most important, when questioning the assumptions, it was easier to think in terms of the simple model when conceiving alternative strategies for both the invader and the interdictor. Literal back-of-the-envelope thinking (or white-board thinking) suggested that the interdictor might focus its efforts on the leading edge of the invading force, in which case attrition would not only destroy vehicles but slow the rate of the column's advance.³ On the other hand, the invader could increase the spacing between vehicles and use more roads, both of which would be expected to reduce the effectiveness of interdictors. At a higher level, suppression of air defense might take time (hours or a number of days) and airports might not have the capacity to accommodate new aircraft or might themselves be under attack, delaying the time at which the aircraft could be accommodated. Also, the number of shooters available initially and the deployment rates subsequently should depend sensitively on the nature of warning. Finally, it might be important to consider the potential value of a blocking force on the ground, even a relatively small one. All of these issues could be represented easily with a simple spreadsheet model or its equivalent in another high-level language.

One consequence of this period of work at RAND was that RAND's Project AIR FORCE spun off from the Joint Integrated Contingency Model campaign model a spreadsheet model called START that focused on the interdiction problem while representing air forces in adequate detail for RAND's analysis. In effect, this amounted to "discovering" a module of the campaign model, splitting it off, and reprogramming for convenience. START has been used frequently in

the intervening years. For other analyses, much more detail is needed, and a campaign model such as the Air Force's STORM model is often used.⁴

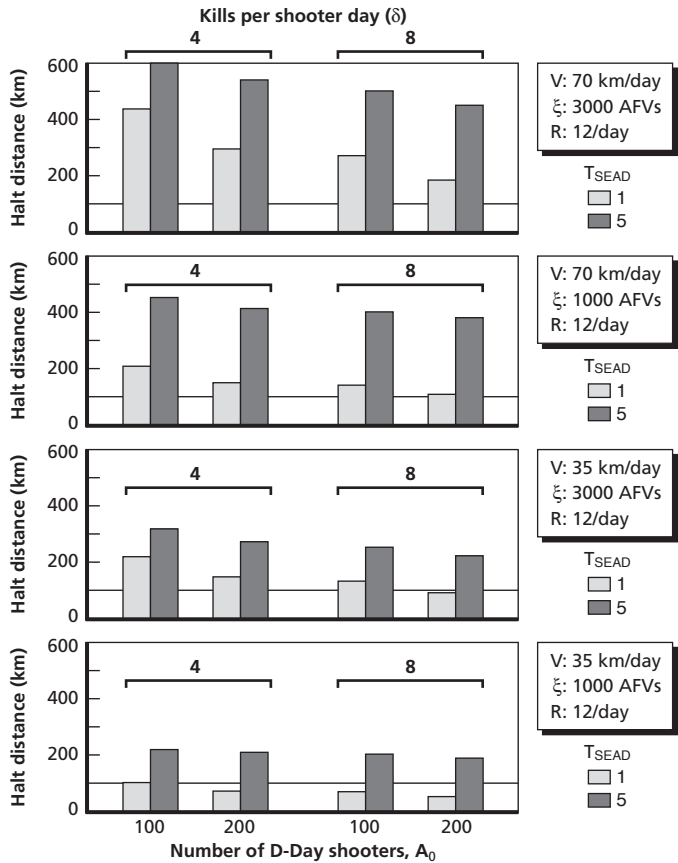
Parametric Analysis

The next great strength of the simplified modeling was exploratory analysis, i.e., analysis in which all of the important input assumptions are varied simultaneously so as to generate parametric plots such as shown in Figure F.1, an example showing how outcomes (halt distance) varies as a function of five variables. This is hardly ordinary sensitivity analysis, in which one assumes a baseline case and then does excursions around it, often varying only one assumption one at a time. It does not assume any particular base case, and it shows important interactions among the variables of a problem. For example, the lack of strategic warning, or even the lack of tactical warning, can be devastating because of effects on all aspects of the interdiction effort. Such work can be used for trade-space analysis and other purposes.

Takeaways

The intent of this discussion has been to illustrate how simple modeling can (1) clarify how the underlying phenomenon is being conceived within a more complex treatment, (2) be a convenient vehicle for the analyst to use when for relaxing or varying assumptions about phenomena and factor values, (3) be the basis for broad parametric analysis, and (4) be a way in which to sharpen requirements for how the more complex model should be enriched. These virtues of simple models have been exhibited in countless studies over the decades, but simple models are underused today because so much attention and education focuses on more complicated computer models.

Figure F.1
Results of Exploratory Analysis with Five Variables



NOTE: The charts show how far the invader moves before being stopped, the halt distance (vertical axis), as a function of the number of shooters available on D-Day (horizontal axis), the kills per shooter per day (left and right sides of the each chart), the time required for suppression of air defenses before the shooters can operate (the white versus black bars), the number of vehicles to be killed before stopping the invading force (ξ , which is different for the first and second chart, reading downward, and for the third and fourth chart), and the average speed of the invading columns (V , which is half as much for the bottom two charts as for the top two charts). If a halt distance less than 100 km were sought, then it is obvious from a quick perusal that T_{SEAD} , the time to suppress air defenses, must be small, and that either the average movement rate must be small or the number of D-Day shooters and the kills per shooter day must be large. AFV refers to armored fighting vehicles.

Endnotes

¹ My own experience is mostly with RAND's Joint Integrated Contingency Model (Jones and Fox, 1999), largely built by colleague Carl Jones, with mechanisms permitting exploratory analysis (Fox, 2003).

² See Davis and Carrillo, 1997, for early exploratory analysis. An influential study the next year for the Air Force used a simple simulation model (Ochmanek et al., 1998). Much richer analysis was published later and included extensive exploratory analysis across major strategic-level uncertainties bearing on the access issue (McEver, Davis, and Bigelow, 2000; Davis, McEver, and Wilson, 2002).

³ The leading-edge interdiction strategy was suggested by my late and legendary colleague Glenn Kent (Lieutenant General, Ret., USAF). A comparison of results with and without the benefits of this strategy, which might or might not have been feasible depending on air defenses and counters, is included in a 2002 study (Davis, McEver, and Wilson, 2002).

⁴ STORM is a campaign-level analysis simulation developed by Group W with offices in Fairfax, Virginia, and Triangle, Virginia.

Bibliography

60 Minutes (2009), “Interrogator Shares Saddam’s Confessions,” February 11.

Akst, George, “Analysis Support for Unrestricted Warfare,” in Ronald R. Luman, ed., *Proceedings on Combating the Unrestricted Warfare Threat: Terrorism, Resources, Economics, and Cyberspace*, Laurel, Md.: Johns Hopkins University Applied Physics Laboratory.

Alberts, David S. (2007), “The Future of C2: Agility, Focus and Coverage: The Future of Command and Control,” *International C2 Journal*, Vol. 1, No. 1.

——— (2011), *The Agility Advantage: A Survival Guide for Complex Enterprises and Endeavors*, Washington, D.C.: DoD Command and Control Research Program.

Allen, Thomas (2004), “Analysis To Support Capabilities-Based Planning,” presented in MORS Capabilities-Based Planning Workshop, October 19–21, Arlington, Va.: Military Operations Research Society.

Arnas, Neyla, ed. (2009), *Fighting Chance*, Herndon, Va.: Potomac Books and National Defense University Press.

Arquilla, John (2008), *Worst Enemy: The Reluctant Transformation of the American Military*, Ivan R. Dee, Publisher.

Aspin, Les (1993), *Report of the Bottom Up Review*, Washington, D.C.: Department of Defense.

Bankes, Steven C., and James Gillogly (1994), *Validation of Exploratory Modeling*, Santa Monica, Calif.: RAND Corporation.

Bankston, LTC Boyd (USA), and LTC Todd Key (USA) (2006), “White Paper on Capabilities-Based Planning (draft),” *Proceedings of MORS: Capabilities Based Planning II*, April 4–6.

Bennett, Bruce W., Carl Jones, Arthur M. Bullock, and Paul K. Davis (1988), *Main Theater Warfare Modeling in the RAND Strategy Assessment System (3.0)*, Santa Monica Calif.: RAND Corporation. As of January 8, 2014: <http://www.rand.org/pubs/notes/N2743.html>

Bensahel, Nora, Olga Olikar, and Heather Peterson (2009), *Improving Capacity for Stabilization and Reconstruction Operations*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
<http://www.rand.org/pubs/monographs/MG852.html>

Bexfield, James N. (2001), "Deep Attack Weapons Mix Study (DAWMS) Case Study," Vol. D-2706.

Bexfield, James (2004), "U.S. Department of Defense: The Analytic Agenda," *Proceedings of MORS Capabilities-Based Planning Workshop*, Arlington, Virginia: Military Operations Research Society.

Biddal, Hernik (2011), *Reforming Military Command Arrangements: The Case of the Rapid Deployment Joint Task Force*, Letort Paper, Carlisle Barracks, Pa.: U.S. Army War College.

Bigelow, James H., and Paul K. Davis (2003), *Implications for Model Validation of Multiresolution, Multiperspective Modeling (MRMPM) and Exploratory Analysis*, Santa Monica, Calif.: RAND Corporation. As of August 12, 2013:
http://www.rand.org/pubs/monograph_reports/MR1750.html

Blechman, Barry M. (Chairman), and Committee (2012), *A New US Defense Strategy for a New Era: Military Superiority, Agility, and Efficiency: A Summary of the Findings of the Defense Advisory Committee*, Washington, D.C.: Peter G. Peterson Foundation.

Body, Howard, and Colin Marston (2011), "The Peace Support Operations Model: Origin, Development, Philosophy and Use," *Journal of Defense Modeling and Simulation*, Vol. 8, No. 4, pp. 69–77.

Boerman, Douglas (2013), "A Risk Framework for the Air Force," *Proceedings of Special MORS Meeting: The Role of Analytics in Addressing the New Budget Environment*, May.

Box, George E. P. (1979), "Robustness in the Strategy of Scientific Model Building," in Robert L. Launer, and Graham N. Wilkinson, eds., *Robustness in Statistics: Proceedings of a Workshop*, Academic Press, pp. 201–236.

——— (2000), *Statistics for Discovery*, Report No. 179, Madison, Wisc.: Center for Quality and Productivity, University of Wisconsin.

Bracken, Paul, Ian Bremer, and David Gordon, eds. (2008), *Managing Strategic Surprise*, New York: Oxford University Press.

Brands, Hal, and David Palkki (2012), "Conspiring Bastards: Saddam Hussein's Strategic View of the United States," *Diplomatic History*, Vol. 36, No. 3, pp. 625–659.

Bremer, L. Paul (2006), *My Year in Iraq: The Struggle to Build a Future of Hope*, New York: Threshold Editions.

Brown, Gerald G., and Richard E. Rosenthal (2008), "Optimization Tradecraft: Hard-Won Insights from Real-World Decision Support," *Interfaces*, Vol. 38, No. 5, pp. 356–366.

Brown, Harold, and Joyce Winslow (2012), *Star Spangled Security*, Washington, D.C.: Brookings Institution.

Builder, Carl H. (1983), *Toward a Calculus of Scenarios*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
<http://www.rand.org/pubs/notes/N1855.html>

Bumiller, Elisabeth (2010), "We Have Met the Enemy and He Is PowerPoint," *New York Times*, April 27, p. A1.

Carr-Smith, Colonel James (2013), "Experiences in the Adaptation of Security & Defence Services: The British Army 2020," *Proceedings of Transformation and the Future of the Public Forces [of Colombia]*.

Caudle, Sharon L. (2005), "Homeland Security Capabilities-Based Planning: Lessons from the Defense Community," *Homeland Security Affairs*, Vol. 1, No. 2.

Cebrowski, Arthur K., and John Garstka (1998), "Network-Centric Warfare: Its Origins and Future," *Naval Institute Proceedings*, pp. 28–35.

Center for Strategic and Budgetary Assessments (2013), "Comparison to DoD's SCMR Results," unpublished briefing, Washington, D.C.

Chinoy, Mike (2008), *Meltdown: The Inside Story of the North Korean Nuclear Crisis*, St. Martin's Press.

Chow, Brian G. (2013), *Portfolio Optimization by Means of Multiple Tandem Certainty-Uncertainty Searches: A Technical Description*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
http://www.rand.org/pubs/research_reports/RR270.html

Cohen, Eliot A., et al. (1993), *Gulf War Air Power Survey (GWAP)*, Department of the Air Force.

Cohen, William (1997a), *Report of the Quadrennial Defense Review*, Washington, D.C.: Department of Defense.

——— (1997b), "Remarks to the Center for Strategic and International Studies." As of January 8, 2014:
<http://www.defense.gov/releases/release.aspx?releaseid=1265>

Darilek, Richard E., Walter L. Perry, Jerome Bracken, John Gordon IV, and Brian Nichiporuk (2001), *Measures of Effectiveness for the Information-Age Army*, Santa Monica, Calif.: RAND Corporation. As of April 8, 2013:
http://www.rand.org/pubs/monograph_reports/MR1155.html

- Davis, Paul K. (1982), *Observations on the Rapid Deployment Joint Task Force: Origins, Direction, and Mission*, Santa Monica, Calif.: RAND Corporation. As of January 7, 2014:
<http://www.rand.org/pubs/papers/P6751.html>
- (1988a), *The Role of Uncertainty in Assessing the NATO Pact Central Region Balance*, Santa Monica, Calif.: RAND Corporation. As of August 10, 2013:
<http://www.rand.org/pubs/notes/N2839.html>
- (1988b), *Toward a Conceptual Framework for Operational Arms Control in Europe's Central Region*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
<http://www.rand.org/pubs/reports/R3704.html>
- (1994a), "Institutionalizing Planning for Adaptiveness," in Paul K. Davis, ed., *New Challenges for Defense Planning: Rethinking How Much Is Enough*, Santa Monica, Calif.: RAND Corporation, pp. 73–100. As of August 11, 2013:
http://www.rand.org/pubs/monograph_reports/MR400.html
- ed. (1994b), *New Challenges for Defense Planning: Rethinking How Much Is Enough*, Santa Monica, Calif.: RAND Corporation. As of August 11, 2013:
http://www.rand.org/pubs/monograph_reports/MR400.html
- (1995), *Aggregation, Disaggregation, and the 3:1 Rule in Ground Combat*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
http://www.rand.org/pubs/monograph_reports/MR638.html
- (2002), *Analytic Architecture for Capabilities-Based Planning, Mission-System Analysis, and Transformation*, Santa Monica, Calif.: RAND Corporation. As of August 1, 2013:
http://www.rand.org/pubs/monograph_reports/MR1513.html
- (2003), "Uncertainty Sensitive Planning," in Stuart E. Johnson, Martin C. Libicki, and Gregory F. Treverton, eds., *New Challenges, New Tools for Defense Decisionmaking*, Santa Monica, Calif.: RAND Corporation, pp. 131–155. As of January 8, 2014:
http://www.rand.org/pubs/monograph_reports/MR1576.html
- (2009), "Specifying the Content of Humble Social Science Models," *Proceedings of the 2009 Summer Computer Simulation*, in O. Balci, M. Sierhuis, X. Hu, and L. Yilmaz, eds., reprinted by the RAND Corporation as RP-1408.
- ed. (2011), *Dilemmas of Intervention: Social Science for Stabilization and Reconstruction*, Santa Monica, Calif.: RAND Corporation. As of April 8, 2013:
<http://www.rand.org/pubs/monographs/MG1119.html>
- (2012), *Lessons from RAND's Work on Planning Under Uncertainty for National Security*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
http://www.rand.org/pubs/technical_reports/TR1249.html

- Davis, Paul K., and James A. Winnefeld (1983), *The RAND Strategy Assessment Center: An Overview and Interim Conclusions About Utility and Development Options*, Santa Monica, Calif.: RAND Corporation. As of January 20, 2014: <http://www.rand.org/pubs/reports/R2945.html>
- Davis, Paul K., and Lou Finch (1993), *Defense Planning for the Post–Cold War Era: Giving Meaning to Flexibility, Adaptiveness, and Robustness of Capability*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013: http://www.rand.org/pubs/monograph_reports/MR322.html
- Davis, Paul K., and Manuel Carrillo (1997), *Exploratory Analysis of “The Halt Problem”: A Briefing on Methods and Initial Insights*, Santa Monica, Calif.: RAND Corporation. As of August 12, 2013: http://www.rand.org/pubs/documented_briefings/DB232.html
- Davis, Paul K., and James H. Bigelow (2002), *Motivated Metamodels: Synthesis of Cause-Effect Reasoning and Statistical Metamodeling*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014: http://www.rand.org/pubs/monograph_reports/MR1570.html
- Davis, Paul K., and Amy Henninger (2007), *Analysis, Analysis Practices, and Implications for Modeling and Simulation*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013: http://www.rand.org/pubs/occasional_papers/OP176.html
- Davis, Paul K., and Kim Cragin, eds. (2009), *Social Science for Counterterrorism: Putting the Pieces Together*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014: <http://www.rand.org/pubs/monographs/MG849.html>
- Davis, Paul K., and Paul Dreyer (2009), *RAND’s Portfolio Analysis Tool (PAT): Theory, Methods, and Reference Manual*, Santa Monica, Calif.: RAND Corporation. As of April 8, 2013: http://www.rand.org/pubs/technical_reports/TR756.html
- Davis, Paul K., and Peter A. Wilson (2011a), *Looming Discontinuities in U.S. Military Strategy and Defense Planning: Colliding RMAs Necessitate a New Strategy*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013: http://www.rand.org/pubs/occasional_papers/OP326.html
- (2011b), “The Looming Crisis in U.S. Defense Planning,” *Joint Force Quarterly*, Vol. 63, No. 4, pp. 13–20.
- Davis, Paul K., and Angela O’Mahony (2013), *A Computational Model of Public Support for Insurgency and Terrorism: A Prototype for More-General Social-Science Modeling*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013: http://www.rand.org/pubs/technical_reports/TR1220.html

Davis, Paul K., Donald Blumenthal, and Donald Gaver (1996) "Appendix I: Combat Modeling Issues," in National Research Council, ed., *Modeling and Simulation: Volume 9 of Technology for the United States Navy and Marine Corps: 2000–2035*, Washington, D.C.: National Academies Press, pp. 226–264.

Davis, Paul K., David C. Gompert, and Richard L. Kugler (1996), *Adaptiveness in National Defense: The Basis of a New Framework*, Santa Monica, Calif.: RAND Corporation. As of August 4, 2013:
http://www.rand.org/pubs/issue_papers/IP155.html

Davis, Paul K., Richard L. Kugler, and Richard Hillestad (1997), *Strategic Issues and Options for the Quadrennial Defense Review*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
http://www.rand.org/pubs/documented_briefings/DB201.html

Davis, Paul K., James H. Bigelow, and Jimmie McEver (2001), *Exploratory Analysis and a Case History of Multiresolution, Multiperspective Modeling*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
<http://www.rand.org/pubs/reprints/RP925.html>

Davis, Paul K., Jimmie McEver, and Barry Wilson (2002), *Measuring Interdiction Capabilities in the Presence of Anti-Access Strategies: Exploratory Analysis to Inform Adaptive Strategies for the Persian Gulf*, Santa Monica, Calif.: RAND Corporation. As of August 4, 2013:
http://www.rand.org/pubs/monograph_reports/MR1471.html

Davis, Paul K., Jonathan Kulick, and Michael Egner (2005), *Implications of Modern Decision Science for Military Decision-Support Systems*, Santa Monica, Calif.: RAND Corporation. As of August 12, 2013:
<http://www.rand.org/pubs/monographs/MG360.html>

Davis, Paul K., Steven C. Bankes, and Michael Egner (2007), *Enhancing Strategic Planning with Massive Scenario Generation: Theory and Experiments*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
http://www.rand.org/pubs/technical_reports/TR392.html

Davis, Paul K., Russell D. Shaver, and Justin Beck (2008), *Portfolio-Analysis Methods for Assessing Capability Options*, Santa Monica, Calif.: RAND Corporation. As of August 11, 2013:
<http://www.rand.org/pubs/monographs/MG662.html>

Davis, Paul K., David C. Gompert, Richard J. Hillestad, and Stuart E. Johnson (1998), *Transforming the Force: Suggestions for DoD Strategy*, Santa Monica, Calif.: RAND Corporation. As of January 8, 2014:
http://www.rand.org/pubs/issue_papers/IP179.html

Davis, Paul K., Stuart E. Johnson, Duncan Long, and David C. Gompert, (2008a), *Developing Resource-Informed Strategic Assessments and Recommendations*, Santa Monica, Calif.: RAND Corporation. As of April 8, 2013:
<http://www.rand.org/pubs/monographs/MG703.html>

- Davis, Paul K., Russell D. Shaver, Gaga Gvineria, and Justin Beck (2008b), *Finding Candidate Options for Investment Analysis: From Building Blocks to Composite Options and Preliminary Screening*, Santa Monica, Calif.: RAND Corporation. As of April 19, 2013:
http://www.rand.org/pubs/technical_reports/TR501.html
- Davis, Paul K., Richard Hillestad, Duncan Long, Paul Dreyer, and Brandon Dues (2010), *Reflecting Warfighter Needs in Air Force Programs: Prototype Analysis*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
http://www.rand.org/pubs/technical_reports/TR754.html
- Davis, Paul K., Eric Larson, Zachary Haldeman, Mustafa Oguz, and Yashodhara Rana (2012), *Understanding and Influencing Public Support for Insurgency and Terrorism*, Santa Monica, Calif.: RAND Corporation. As of April 8, 2013:
<http://www.rand.org/pubs/monographs/MG1122.html>
- Davis, Paul K., Walter L. Perry, Ryan Andrew Brown, Douglas Yeung, Parisa Roshan, and Phoenix Voorhies (2013), *Using Behavioral Indicators to Help Detect Potential Violent Acts*, Santa Monica, Calif.: RAND Corporation. As of August 13, 2013:
http://www.rand.org/pubs/research_reports/RR215.html
- De Spiegeleire, Stephan (2011), "Ten Trends in Capability Planning for Defence and Security," *RUSI Journal*, Vol. 156, No. 5, pp. 20–28.
- Defense Science Board (1996), *Tactics and Technologies for 21st Century Military Superiority (in Three Volumes)*, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.
- (1998), *Joint Operations Superiority in the 21st Century: Integrating Capabilities Underwriting Joint Vision 2010 and Beyond*, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition and Technology.
- Department of Defense (1992), *Final Report to Congress on Conduct of the Persian Gulf War*, Washington, D.C.: Office of the Under Secretary of Defense for Policy.
- Department of Defense Directive 7045.20, "Capability Portfolio Management," September 25, 2008.
- Dewar, James (2003), *Assumption Based Planning*, London: Cambridge.
- Downes-Martin, Stephen (2013), "Adjudication: The Diabolus in Machina of War Gaming," *Naval War College Review*, Vol. 66, No. 3, Summer 2013, pp. 67–80.
- Dudney, Robert S. (2009), "Threats or Capabilities?" *Air Force Magazine Online*, Vol. 11, October.
- Dunn, Richard J., Price T. Bingham, and Charles A. ("Bert") Fowler (2004), *Ground Moving Indicator Radar and the Transformation of U.S. Warfighting*, Washington, D.C.: Northrop Grumman Analysis Center.

Dupuy, Trevor Nevitt (1987), *Understanding War: History and Theory of Combat*, New York: Paragon House.

Enthoven, Alain, and K. Wayne Smith (1971), *How Much Is Enough? Shaping the Defense Program, 1961–1969*, Santa Monica, Calif.: RAND Corporation.

Feith, Douglas J. (2008), *War and Decision: Inside the Pentagon at the Dawn of the War on Terrorism*, New York: Harper.

Fenstermacher, Laurie, et al. (2010), *Protecting the Homeland from International and Domestic Terrorism Threats: Current Multi-Disciplinary Perspectives on Root Causes, the Role of Ideology, and Programs for Counter-Radicalization and Disengagement*, Washington, D.C.: Department of Defense Strategic Multilayer Assessment Program.

Fitzsimmons, Michael (2007), “Whither Capabilities-Based Planning,” *Joint Force Quarterly*, Vol. 44, No. 1.

Flournoy, Michèle A. (2009), *Department of Defense Instruction Number 3000.5: Stability Operations*, Washington, D.C.: Department of Defense.

Flournoy, Michèle A., and Sam J. Tangredi (2001), “Defense Strategy Alternatives: Choosing Where to Place Emphasis and Where to Accept Risk,” in Michèle A. Flournoy, ed., *QDR 2001: Strategy-Driven Choices for America’s Security*, Fort McNair, Washington, D.C.: Institute for National Strategic Studies, National Defense University, pp. 137–166.

Flournoy, Michèle A., and Shawn Brimley (2008), “The Defense Inheritance: Challenges and Choices for the Next Pentagon Team,” *Washington Quarterly*, Vol. 31, No. 4, pp. 59–76.

Foster, John S., Earl Gielde, Robert J. Hermann, Henry M. Kluepfel, Richard L. Lawson, Gordon K. Soper, Lowell L. Wood, and Joan B. Woodard (2008), *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures*.

Fox, Daniel (2003), “Using Exploratory Modeling,” in Stuart Johnson, Martin Libicki, and Gregory F. Trevorton, eds., *New Challenges, New Tools for Defense Decisionmaking*, Santa Monica, Calif.: RAND Corporation, pp. 258–298. As of January 9, 2014:

http://www.rand.org/pubs/monograph_reports/MR1576.html

Gates, Robert (2010), “Report of the Quadrennial Defense Review.”

Glenn, Russell W. (2012), *All Glory Is Fleeting: Insights from the Second Lebanon War*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:

<http://www.rand.org/pubs/monographs/MG708-1.html>

Gompert, David C. (2013), *Sea Power and American Interests in the Western Pacific*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:

http://www.rand.org/pubs/research_reports/RR151.html

Gompert, David C., and Phillip C. Saunders (2011), *The Paradox of Power: Sino-American Strategic Restraint in an Age of Vulnerability*, Center for the Study of Chinese Military Affairs, Institute for National Strategic Studies, National Defense University, Washington, D.C.: National Defense University Press. As of February 3, 2014:

<http://www.ndu.edu/press/lib/pdf/books/paradox-of-power/paradox-of-power.pdf>

Gordon, Michael R., and General Bernard E. Trainor (USMC, Ret.) (1995), *The General's War: The Inside Story of the Conflict in the Gulf*, Boston, Mass.: Little, Brown & Company.

Goss, Ghomas (2005), "Building a Contingency Menu: Using Capabilities-Based Planning for Homeland Defense and Homeland Security," *Homeland Security Affairs*, Vol. 10, No. 1.

Government Accountability Office (2013), *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-13-294SP, Washington, D.C.

Grant, Robert M (2002), *Instructors' Manual to Accompany Contemporary Strategy Analysis: Concepts, Techniques, Applications*, Malden, Mass.: Blackwell.

——— (2010), *Contemporary Strategy Analysis*, New York: John Wiley & Sons, Inc.

Gray, Colin (2010) "Coping with Uncertainty: Dilemmas of Defense Planning," in Stephen J. Cimbala, ed., *The George W. Bush Defense Program: Policy, Strategy, & War*, Washington, D.C.: Potomac Books Inc., pp. 1–10.

Greenberger, Martin, Matthew A. Crenson, and Brian L. Crissey (1976), *Models in the Policy Process: Public Decision Making in the Computer Era*, New York: Russell Sage Foundation.

Grier, Peter (2010), "STRAT-X," *Air Force Magazine*, Vol. 1, January, pp. 52–55.

Hagel, Chuck (2013), *Statement on Strategic Choices and Management Review*, Washington, D.C.: Department of Defense, July 31.

Haimes, Yacov (1998), *Risk Modeling, Assessment, and Management*, New York: John Wiley & Sons, Inc.

Hales, Doug, and Paul Chouinard (2011), "Implementing Capability Based Planning in the Public Safety and Security Sector: Lessons from the Defence Experience."

Hammond, John S., Ralph L. Keeney, and Howard Raiffa (2002), *Smart Choices: A Practical Guide to Making Better Decisions*, New York: Broadway.

Helms, Josh (2012), "Using Stochastic Demand Profiles to Generate Army Force Structure," unpublished briefing, Fort Belvoir, Va.: Center for Army Analyses.

Hicks, Kathleen H., and Eric Ridge (2007), *Planning for Stability Operations: The Use of Capabilities-Based Approaches*, Washington, D.C.: Center for Strategic & International Studies.

Hillier, Pat (1980), "U.S. Ground Forces: Design and Cost Alternatives for NATO and on-NATO Contingencies."

Hoehl, Louise, and Tom Scales (2011), "Informing the Strategic Defence and Security Review: The Strategic Balance of Investment Study," United Kingdom: Defence Science and Technology Laboratory.

Hoffman, David E. (2009), "1989: The Lost Year," *Foreign Policy*.

Hughes, Wayne P. (2000), *Fleet Tactics and Coastal Content*, Annapolis, Md.: Naval Institute Press.

Jackson, Brian A., Tom LaTourette, Edward W. Chan, Russell Lundberg, Andrew R. Morral, and David R. Frelinger (2012), *Efficient Aviation Security: Strengthening the Analytic Foundation for Making Air Transportation Security Decisions*, Santa Monica, Calif.: RAND Corporation. As of April 8, 2013:
<http://www.rand.org/pubs/monographs/MG1220.html>

Jaffe, Lorna S. (1993), *The Development of the Base Force 1989–1992*, Washington, D.C.: Joint History Office, Office of the Chairman of the Joint Chiefs of Staff.

Jervis, Robert (1976), *Perception and Misperception in International Politics*, Princeton, N.J.: Princeton University Press.

Johnson, Stuart, Martin Libicki, and Gregory Treverton (2003), *New Challenges, New Tools for Defense Decisionmaking*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
http://www.rand.org/pubs/monograph_reports/MR1576.html

Johnson, Stuart E., Irv Blickstein, David C. Gompert, Charles Nemfakos, Harry J. Thie, Michael J. McNerney, Duncan Long, Brian McInnis, and Amy Potter (2012), *A Strategy-Based Framework for Accommodating Reductions in the Defense Budget*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
http://www.rand.org/pubs/occasional_papers/OP379.html

Joint Chiefs of Staff (2011), *Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS)* (updated January 31, 2011), Washington, D.C.: Department of Defense.

——— (2012), "Manual for the Operation of the Joint Capabilities Integration and Development System," Washington, D.C.: Department of Defense.

Joint Defense Capabilities Study Team (2004), *Joint Defense Capabilities Study: Improving DoD Strategic Planning, Resourcing and Execution to Satisfy Joint Capabilities (the "Aldridge Report")*, Washington, D.C.: Department of Defense.

Joint Staff (1996), *Joint Vision 2010*, Washington, D.C.: Department of Defense.

Jones, Carl, and Daniel Fox (1999), "JICM 3.5: Documentation and Tutorials," Santa Monica, Calif.: RAND Corporation, unpublished.

Kahn, Herman (1962), *Thinking About the Unthinkable*, New York: Horizon Press.

——— (1966), *On Thermonuclear War*, Princeton, N.J.: Princeton University Press.

Kahn, Herman, and Irwin Mann (1957), *Techniques of Systems Analysis*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
http://www.rand.org/pubs/research_memoranda/RM1829-1.html

Kahn, Herman, and Thomas C. Schelling (2009), *On Escalation: Metaphors and Scenarios*, Hudson Institute.

Kaufmann, William W. (1981), *Defense in the 1980s (studies in Defense Policy)*, Washington, D.C.: Brookings Institution.

——— (1986), *A Reasonable Defense (studies in Defense Policy)*, Washington, D.C.: Brookings Institution Press.

Keeney, Ralph L. (1992), *Value-Focused Thinking: A Path to Creative Decisionmaking*, Cambridge, Mass.: Harvard University Press.

Keeney, R., and H. Raiffa (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, New York: John Wiley & Sons, Inc.

Kendall, Frank (2013), *Performance of the Defense Acquisition System: 2013 Annual Report*, Washington, D.C.; Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.

Kennedy, Michael, et al. (2006), *Analysis of Alternatives (AoA) for KC-135 Recapitalization: Executive Summary*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
<http://www.rand.org/pubs/monographs/MG495.html>

Kent, Glenn A. (1963), *On the Interaction of Opposing Forces Under Possible Arms Agreements*, Occasional Papers in International Affairs, No. 5, Cambridge, Mass.: Harvard University, Center for International Affairs.

——— (2002), "Looking Back: Four Decades of Analysis," *Operations Research*, Vol. 50, No. 1, pp. 122–124.

Kent, Glenn A., and William E. Simons (1994), "Objective-Based Planning," in Paul K. Davis, ed., *New Challenges for Defense Planning: Rethinking How Much Is Enough*, Santa Monica, Calif.: RAND Corporation, pp. 59–72. As of January 9, 2014:
http://www.rand.org/pubs/monograph_reports/MR400.html

Kent, Glenn A., David A. Ochmanek, Michael Spirtas, and Bruce Pirnie (2008), *Thinking About America's Defense: An Analytical Memoir*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
http://www.rand.org/pubs/occasional_papers/OP223/

Krepinevich, Andrew F. (2009), "The Pentagon's Wasting Assets: The Eroding Foundations of American Power," *Foreign Affairs*, July/August, pp. 18–33.

Krieg, Kenneth J. (2004), "Capabilities-Based Planning: The View from PA&E," *Proceedings of MORS Workshop of Capabilities-Based Planning*, Arlington, Va.: Military Operations Research Society.

Kugler, Richard (1995), *Toward a Dangerous World: U.S. National Security Strategy for the Coming Turbulence*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
http://www.rand.org/pubs/monograph_reports/MR485.html

——— (2006), *Policy Analysis in National Security Affairs: New Methods for a New Era*, Washington, D.C.: National Defense University.

Lehrer Hour (2003), *Interview with Secretary of Defense Donald Rumsfeld*, Washington, D.C.: National Public Broadcasting, February 20.

Lempert, Robert J., David G. Groves, Steven W. Popper, and Steven C. Bankes (2006), "A General Analytic Method for Generating Robust Strategies and Narrative Scenarios," *Management Science*, Vol. 4, April, pp. 514–528.

Lempert, Robert J., Michael E. Schlesinger, and Steven C. Bankes (1996), "When We Don't Know the Costs or the Benefits: Adaptive Strategies for Abating Climate Change," *Climatic Change*, Vol. 33, pp. 235–274.

Leonard, Mike, Jim Thomason, and Jim Bexfield (2013), "QDR: The Role of Analytics in Addressing the New Budget Environment," *Phalanx*, June, p. 21.

Levine, Robert A. (1985), *Flying in the Face of Uncertainty: Alternative Plans and Postures for Interdiction in Southwest Asia*, Santa Monica, Calif.: RAND Corporation.

Lewis, Kevin (1994), "The Discipline Gap and Other Reasons for Humility and Realism in Defense Planning," in Paul K. Davis, ed., *New Challenges in Defense Planning: Rethinking How Much Is Enough*, Santa Monica, Calif.: RAND Corporation, pp. 10–134. As of January 9, 2014:
http://www.rand.org/pubs/monograph_reports/MR400.html

Lucas, Thomas W., and Turker Turkes (2003), "Fitting Lanchester Equations to the Battles of Kursk and Ardennes," *Naval Research Logistics*, Vol. 51, No. 1, pp. 95–116.

Luman, Ronald R. (ed.) (2008), *Proceedings on Combating the Unrestricted Warfare Threat*, Laurel, Md.: Johns Hopkins University Applied Physics Laboratory.

Markowitz, Harry M. (1952), "Portfolio Selection," *Journal of Finance*, Vol. 7, pp. 77–91.

Markowitz, Harry M., William F. Sharpe, and Merton H. Miller (1991), *The Founders of Modern Finance: Their Prize-Winning Concepts and 1990 Nobel Lectures*, Charlottesville, Va.: The Research Foundation of ICFA (CFA Institute).

McChrystal, Stanley (2011), "It Takes a Network: The New Front Line of Modern Warfare," *Foreign Policy*.

——— (2013), *My Share of the Task: A Memoir*, New York: Portfolio/Penguin.

McEver, Jimmie, Paul K. Davis, and James H. Bigelow (2000), *EXHALT: Interdiction Model for Exploring Halt Capabilities in a Large Scenario Space*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
http://www.rand.org/pubs/monograph_reports/MR1137.html

McNamara, Laura A. (2010), “Why Models Don’t Forecast,” presentation in workshop, August 16, 2010, of Board on Human-Systems Integration, National Academy of Sciences. As of January 9, 2014:
http://sites.nationalacademies.org/dbasse/bohsi/dbasse_071321

McNamara, Lauren A., Timonthy G. Trucano, and Charles Gieseler (2011), “Challenges in Computational Social Modeling and Simulation for National Security Decision-Making,” Albuquerque, N.M.: Sandia National Laboratory.

Mearsheimer, John J. (1983), *Conventional Deterrence*, Ithaca, N.Y.: Cornell University Press.

Military Operations Research Society (1989), *Human Behavior and Performance as Essential Ingredients of Realistic Modeling of Combat, MORIMOC II, Vols. 1–2*, Arlington, Va.: Military Operations Research Society. As of January 17, 2014:
<http://www.dtic.mil/dtic/tr/fulltext/u2/a227841.pdf>

Mintzberg, Henry (1994), *Rise and Fall of Strategic Planning*, New York: Free Press.

Mintzberg, Henry, Joseph Lampel, and Bruce Ahlstrand (2005), *Strategy Safari: A Guided Tour Through the Wilds of Strategic Management*, New York: Free Press.

Mullen, Mike G. (2011), “The National Military Strategy of the United States of America,” Department of Defense.

Murdock, Clark A. (1974), *Defense Policy Formation: A Comparative Analysis of the McNamara Era*, New York: State University of New York Press.

National Academy of Sciences (2008), *U.S. Conventional Prompt Global Strike Capability: Issues for 2008 and Beyond*, Washington, D.C.: National Academies Press.

National Defense Panel (1997), *Transforming Defense: National Security in the 21st Century*, Washington, D.C.: Department of Defense.

National Research Council (1997), *Technology for the United States Navy and Marine Corps: 2000–2035*, Washington, D.C.: National Academies Press.

——— (2000), *Network Centric Naval Forces*, Washington, D.C.: Naval Studies Board, National Academies Press.

——— (2005), *Naval Analytical Capabilities: Improving Capabilities-Based Planning*, Washington, D.C.: Naval Studies Board, National Academies Press.

——— (2006), *Defense Modeling, Simulation, and Analysis: Meeting the Challenge*, Washington, D.C.: National Academies Press.

——— (2010), *Review of the Department of Homeland Security's Approach to Risk Analysis*, Washington, D.C.: National Academies Press.

NATO RTO SAS-065 (2010), *NATO NEC C2 Maturity Model*, Washington, D.C.: Command and Control Research Program (CCRP).

Obama, Barack (2010), *National Security Strategy of the United States*, Washington, D.C.: The White House.

——— (2012), "Sustaining U.S. Global Leadership: Priorities for 21st Century Defense (Strategic Guidance for the Department of Defense)," Washington, D.C.: The White House.

Ochmanek, David A., Edward Harshberger, David E. Thaler, and Glenn A. Kent (1998), *To Find, and Not to Yield: How Advances in Information and Firepower Can Transform Theater Warfare*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:

http://www.rand.org/pubs/monograph_reports/MR958.html

O'Hanlon, Michael E. (2013), *Healing the Wounded Giant: Maintaining Military Preeminence While Cutting the Defense Budget*, Washington, D.C.: Brookings Institution Press.

OSD (PA&E) (1979), *Capabilities for Limited Contingencies in the Persian Gulf (the "Wolfowitz Report")*, Washington, D.C.: Department of Defense.

——— (1981), *Congressionally Mandated Mobility Study: Volume 1 and 2: Summary 1981*, BiblioGov.

Petraeus, David, and James Amos (2006), *U.S. Army/Marine Counterinsurgency Field Manual*, Old Saybrook, Conn.: Konecky & Konecky.

Porter, Gene, Jerome Bracken, and Royce Kneece (2007), *Portfolio Analysis in the Context of Capabilities-Based Planning: A Presentation to the 75th MORS Symposium, Annapolis, Md., June 13, 2007*, Alexandria, Va.: Institute for Defense Analyses.

Powell, Colin L., and Joseph E. Persico (1995), *My American Journey: An Autobiography*, New York: Random House.

Quanbeck, Alton H., Archie L. Wood, and Louisa Thoron (1976), *Modernizing the Strategic Bomber Force: Why and How*, Washington, D.C.: Brookings Institution.

Quinlivan, James T. (1995), "Force Requirements in Stability Operations," *Parameters*, Winter, pp. 59–69.

——— (2003), "Burden of Victory: The Painful Arithmetic of Stability Operations," in *RAND Review*, Vol. 27, No. 2, Summer; Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:

http://www.rand.org/pubs/corporate_pubs/CP22-2003-08.html

- Ricks, Thomas E. (2004), "Army Historian Cites Lack of Postwar Plan," *Washington Post*, December 25, p. A01.
- Rogers, Alex (2012), "The MRAP: Brilliant Buy, or Billions Wasted?," *Time*, October 2.
- Ross, Dennis (2005), *The Missing Peace: The Inside Story of the Fight for Middle East Peace*, New York: Farrar, Straus & Giroux Inc.
- Rowland, David (2006), *Stress in Battle, Quantifying Human Performance in Battle*, London: Stationery Office.
- Rumsfeld, Donald (2001), *Report of the Quadrennial Defense Review*, Washington, D.C.: Department of Defense.
- (2006), *Quadrennial Defense Review Report*, Washington, D.C.: Department of Defense.
- Rumsfeld, Donald (Chairman) and Commission (1998), *Executive Summary*, Washington, D.C.: Commission to Assess the Ballistic Missile Threat to the United States.
- Schelling, Thomas C. (1960), *The Strategy of Conflict*, Cambridge, Mass.: Harvard University Press.
- (1966), *Arms and Influence*, Cambridge, Mass.: Harvard University Press.
- (1987), "The Role of War Games and Exercises," in Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket, eds., *Managing Nuclear Operations*, Washington, D.C.: Brookings Institution, pp. 426–444.
- Schlesinger, James (1974), *Selected Papers on National Security, 1964–1968*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013: <http://www.rand.org/pubs/papers/P5284.html>
- Schmidt, Rachel (1997), "Evaluating Lift Requirements and Capabilities (Chapter Five)," in Rachel Schmidt, ed., *Moving U.S. Forces*, Washington, D.C.: Congressional Budget Office.
- Sessler, Andrew M. (Chair), John M. Cornwall, Bob Dietz, Steve Fetter, Sherman Frankel, Richard L. Garwing, Kurt Gottfried, Lisbeth Gronlund, George N. Lewis, Theodore A. Postol, and David C. Wright (2000), "Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System," Union of Concerned Scientists and MIT Security Studies Program.
- Sharpe, William F. (2006), *Macro-Investment Analysis*, Stanford University. As of January 31, 2014: <http://www.stanford.edu/~wfsarpe/mia/mia.htm>
- Simon, Herbert A. (1982), *Models of Bounded Rationality, Vol. 1*, Cambridge, Mass.: MIT Press.

Solly, Rob (2013), "Presentation at MORS Meeting on QDR," Arlington, Va.: Military Operations Research Society.

Stevens, Sayre (2013), "The SAM Upgrade Blues," CIA Historical Review Program. As of August 8, 2013:
https://www.cia.gov/library/center-for-the-study-of-intelligence/kent-csi/vol18no2/html/v18i2a03p_0001.htm

Sweetser, Al (2010), "MORS Analytic Agenda Conference, Final Outbrief," Arlington, Virginia: Military Operations Research Society.

Taleb, Nassim Nichol (2007), *The Black Swan: The Impact of the Highly Improbable*, New York: Random House.

Taylor, Ben (2013), "Comparing Allied Approaches to Strategic Planning Analysis," in *Proceedings of Special MORS Meeting: The Role of Analytics in Addressing the New Budget Environment*.

Taylor, James G. (1983), *Force-on-Force Attrition Modeling (2 Volumes)*, Alexandria, Va.: Military Application Section of the Operations Research Society of America.

Technical Cooperation Program (2004), *Guide to Capability-Based Planning*, TR-JSA-TP3-2-2004, Technical Cooperation Program, Washington, D.C.: Department of Defense

Thomson, James A. (1988), *An Unfavorable Situation: NATO and the Conventional Balance*, Santa Monica, Calif.: RAND Corporation. As of January 20, 2014:
<http://www.rand.org/pubs/notes/N2842.html>

Thomson, James A., and Nanette C. Gantz (1987), *Conventional Arms Control Revisited: Objectives in the New Phase*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
<http://www.rand.org/pubs/notes/N2697.html>

Tompkins, Clifford, Douglas Boerman, Maj (USAF), and Walter Lesinski (2013), "Risk Assessment Framework (RAF)," *Phalanx*, Vol. 45, No. 2, pp. 29–33.

Toomay, John, and Paul J. Hannen (2004), *Radar Principles for the Non-Specialist (third edition)*, Raleigh, N.C.: SciTech.

Troxell, John F. (2001a), "Force Planning and U.S. Defense Policy," in Joseph R. Cerami and James F. Holcomb, eds., *The U.S. Army War College Guide to Strategy*, Carlisle Barracks, Pa.: Strategic Studies Institute, U.S. Army War College, pp. 157–178.

——— (2001b), "Sizing the Force for the 21st Century," in Steven Metz, ed., *Revising the Two MTW Force Shaping Paradigm*, U.S. Army War College, Carlisle, Pa.: Strategic Studies Institute, pp. 7–40.

van de Riet, Odette (2003), *Policy Analysis in Multi-Actor Policy Settings: Navigating Between Negotiated Nonsense and Superfluous Knowledge*, Delft, Netherlands: Eburon Publishers.

Watts, Barry (2013), *The Evolution of Precision Strike*, Washington, D.C.: Center for Strategic and Budgetary Assessments.

Wild, Willam G., Robert Howe, and Paul K. Davis (1989), *Simulated Central Region Conflicts at Nominal Parity and Low Force Levels*, Santa Monica, Calif.: RAND Corporation. As of January 9, 2014:
<http://www.rand.org/pubs/notes/N3006.html>

Wilkening, Dean (1999), "A Simple Model for Calculating Ballistic Missile Defense Effectiveness," *Science & Global Security*, Vol. 8, No. 2, pp. 183–215.

Wilkening, Dean A., Ken Watman, Michael Kennedy, and Richard E. Darilek (1989), *Strategic Defenses and Crisis Stability*, Santa Monica, Calif.: RAND Corporation. As of August 8, 2013:
<http://www.rand.org/pubs/notes/N2511.html>

Woods, Kevin M., and Mark E. Stout (2010), "Saddam's Perceptions and Misperceptions: The Case of 'Desert Storm,'" *Journal of Strategic Studies*, Vol. 33, No. 1, pp. 5–41.

Defense analysis can do a better job supporting policymakers dealing with multiple objectives and deep uncertainties. This will involve seeing through the fog with simple analysis and undergirding results with depth as necessary. It will emphasize balancing across objectives and hedging against both uncertainty and disagreement among policymakers. Modern methods for doing so are available but they require displacing some familiar processes and demanding more from analysis. Once decisions are made, analysis should help policymakers explain, convince, and shape implementation guidance with sharpened requirements, forcing functions, and metrics for monitoring, feedback, and adaptation.



NATIONAL DEFENSE RESEARCH INSTITUTE

www.rand.org

\$39.95

ISBN-10 0-8330-8507-7
ISBN-13 978-0-8330-8507-8

