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An Enterprise Cost-Effectiveness Approach to Decisionmaking

Improving Analytic Support to Senior Defense Leaders
About This Report

The objectives of this project are to explore the potential for new cost-per-effect measures, develop a framework for assessing those measures, and chart a roadmap for including them in future Air Force decisionmaking. This project will help the Secretary of the Air Force respond to congressional reporting requirements in the Fiscal Year (FY) 2021 National Defense Authorization Act.

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RAND Project AIR FORCE

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Summary

In July 2020, the Mitchell Institute for Aerospace Studies, based in Arlington, Virginia, released a policy paper entitled “Resolving America’s Defense Strategy-Resource Mismatch: The Case for Cost-Per-Effect Analysis.”¹ Shortly thereafter, Section 147 of the Fiscal Year (FY) 2021 National Defense Authorization Act called for a “study on measures to assess cost-per-effect for key mission areas” of the Air Force.² The 2020 policy paper appears to have directly informed the writing of Section 147.

Cost-per-effect analysis aims to improve decisionmaking through what we describe as an enterprise approach to cost-effectiveness. Such an approach would allow decisionmakers to compare alternatives not just within a single mission area or facet but also across an entire enterprise.

For more than a century, innovation in defense planning praxis has been driven by improvements in analytic techniques that have allowed national defense organizations to better understand the relationships between fiscal costs and military effects.³ Today, there are signs of a renaissance in defense analysis.⁴ The return of great-power competition to the forefront of strategic planning, coupled with the emergence of the cyber, space, and electromagnetic domains as loci of operational effectiveness, are providing new impetuses for innovation in defense analysis. Meanwhile, rapid improvements in practical computational scale, data analytics, artificial intelligence, and machine learning are creating the capacity for potential new forms of analysis.

Although advancements in defense planning are quite promising, it is important to remain cognizant of its analytic complexity, which has posed recurring challenges to improvement. Among the challenges are accounting for strategic interaction, resolving principal-agent problems, and defining effect because victory can be achieved through a range of mechanisms, including destruction, annihilation, dislocation, exhaustion, disruption, disintegration, preemption, isolation, circumvention, forestallment, compellence, impellence, and deterrence.

³ Charles Tilly argues convincingly that the need to plan and sustain armed forces was the principal driver in the emergence of the modern state; see, particularly, Charles Tilly, Coercion, Capital, and European States: A.D. 990–1992, Wiley, 1993.
⁴ See, for example, Kathleen H. Hicks, Deputy Secretary of Defense, “Creating Data Advantage,” memorandum, May 5, 2021; and Susanna Blume, “Senate Armed Services Committee Advance Policy Questions for Ms. Susanna Blume, Nominee to be Director, Cost Assessment and Program Evaluation,” responses, undated.
These advancements in defense planning will most likely be realized through deliberate and incremental improvements in current cost-effectiveness techniques. Cost-per-effect should therefore not be thought of as a discrete concept separate from cost-effectiveness; rather, it is an extension of cost-effectiveness. Cost-per-effect is cost-effectiveness with a broader joint, or combined, focus that supports higher-level decisionmaking. For this reason, we prefer the term enterprise cost-effectiveness to highlight that we are seeking to build on existing analytic best practices, rather than devising an entirely new approach. We also believe our preferred term shifts the discussion from the aspirational goals of cost-per-effect to the achievable advancements of enterprise cost-effectiveness.

Enterprise cost-effectiveness should be thought of as a hierarchy: Lower-end cost-effectiveness is defined narrowly but acceptably within a mission area, and upper-end cost-effectiveness is defined broadly at the national security enterprise level and incorporates a full joint concept. Analysis anywhere on the hierarchy serves an important role, but that role should be explicit. In most cases, other than deliberately narrow mission-area analysis, cost-effectiveness analysis should consider the full joint perspective. For instance, even an analysis of an Air Force operational area would need to incorporate the Air Force’s interaction with the joint force and the resulting joint force’s military effect.

The Department of the Air Force (DAF) can begin to implement cost-per-effect analysis by following our proposed analytic framework for measuring cost-per-effect. This framework consists of five interrelated measurements: effects, costs, campaigns, trade-offs, and optimization. It will be particularly important to develop analytic tools and dashboards to support the determination of trade-offs and optimizations. Accurate results alone may not be enough to influence decisionmakers without also providing a traceability that is readily understandable. Beyond correct answers, dashboards or other tools that provide clear and concise findings and transparent analyses will be invaluable.

At the same time, the DAF, with its joint partners, could follow our proposed programmatic framework of processes for implementing cost-per-effect. The processes would follow the Plan-Do-Check-Act approach, which would provide a formal mechanism to identify problem areas, based on national, operational, and support objectives. This approach would also formally document the goals, capabilities, organizations, concepts of operation, and metrics to be considered in the cost-per-effect analysis, thus spurring development of the requisite supporting joint analytic capabilities. The approach would likewise promote the establishment of both an infrastructure for joint analytic data governance and a hierarchy of confidence levels in the analytic outputs, making it possible to include cost-per-effect results in the annual Planning, Programming, Budgeting, and Execution cycle.
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Chapter 1. Introduction

In July 2020, the Mitchell Institute for Aerospace Studies, based in Arlington, Virginia, released a policy paper entitled “Resolving America’s Defense Strategy-Resource Mismatch: The Case for Cost-Per-Effect Analysis.”\(^5\) Shortly thereafter, Section 147 of the Fiscal Year (FY) 2021 National Defense Authorization Act called for a “study on measures to assess cost-per-effect for key mission areas” of the Air Force.\(^6\) The 2020 policy paper appears to have directly informed the writing of Section 147. Therefore, we examine this initial policy paper as part of our review of cost-per-effect analysis.

First, however, we provide our understanding of the goal of cost-per-effect analysis. Cost-per-effect analysis aims to improve decisionmaking through an enterprise approach to cost-effectiveness. A particular enterprise may be at the mission, service, joint, or combined joint level, depending on the needs of decisionmakers and the associated purpose of the analysis. Such an approach would allow decisionmakers to compare alternatives not just within a single mission area or facet but also across an entire enterprise.

More precisely, we envision that a cost-per-effect metric would allow defense planners to compare not just between capabilities (e.g., an upgraded 5th-generation fighter versus a new-design 6th-generation fighter) but also across capabilities (e.g., upgraded or new-generation fighters versus long-range precision fires). Thus, a cost-per-effect metric would help planners either maximize the level of national defense for a given cost or minimize cost for a given level of national defense. Comparing alternative capabilities by cost-per-effect would allow planners to focus explicitly on a capability’s contribution to national security rather than on narrower metrics, such as cost-per-shot or cost-per-flying-hour.

Effects refer to the consequences of kill chains that target adversaries. Quantifying comparative costs-per-effects would help to identify those military capabilities that contribute the most to national security at the least cost, regardless of service, domain, or mission area. Such an approach to cost-per-effect analysis—or what we prefer to call enterprise cost-effectiveness analysis—would provide increasingly valuable data to inform the joint decisionmaking process, specify explicitly what decisions the data should and should not inform, and connect individual acquisition decisions to broader national security outcomes.

As noted, we consider cost-per-effect analysis to be synonymous with enterprise cost-effectiveness analysis. We use the terms interchangeably in this report, but we prefer the latter

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term for a few reasons. In our view, cost-per-effect is not a discrete concept separate from cost-effectiveness; rather, it is an extension of cost-effectiveness. It is cost-effectiveness with a broader joint, or combined, focus that supports higher-level decisionmaking. The term *enterprise cost-effectiveness* highlights the fact that we are seeking to build on cost-effectiveness best practices rather than devise an entirely new approach. Throughout this report, we underscore that there are three simple ways to build on the best current practices of cost-effectiveness analysis to achieve the aims of cost-per-effect analysis (or enterprise cost-effectiveness analysis):

- Cost-effectiveness analysis should strive to take an increasingly enterprise view.
- Cost-effectiveness analysis should explicitly state the enterprise being considered.
- Regardless of the enterprise being considered, the cost-effectiveness analysis should make explicit connections to U.S. military and national security objectives.

In the next three sections of this chapter, we review the initial case for cost-per-effect analysis; propose an enterprise cost-effectiveness hierarchy; and using a key insight from the Mitchell Institute policy paper, devise a conceptual framework for visualizing cost-per-effect analysis (or enterprise cost-effectiveness analysis). The final section of this chapter outlines our three-part exploration of cost-per-effect analysis in the three chapters to follow.

### The Initial Case for Cost-Per-Effect Analysis

The July 2020 Mitchell Institute policy paper makes four key arguments regarding cost-per-effect analysis. The first argument focuses on *limited resources*:

> Resources are stretched thin, mission demand is on the rise, and key mission areas require recapitalization. The Air Force must prioritize solutions that yield maximum mission value and not rely on overly simplistic metrics, like cheapest per-unit acquisition cost or individual cost-per flying hour, as these may actually drive more expensive, less capable solutions.\(^7\)

This emphasis on achieving maximum *mission value* with the resources available, rather than fixating on simplistic metrics or ratios, is already codified in the Office of Management and Budget Circular A-4 and detailed in the *Analysis of Alternatives (AoA) Handbook*, published by Headquarters, Air Force.\(^8\) In fact, most good cost-effectiveness analysis, business case studies, or AoAs embrace this broader approach (although some published studies have certainly relied on simplistic cost-per-flying-hour metrics).

As one example of how some AoAs have already focused on military objectives rather than simplistic metrics, the RAND Corporation’s 2006 AoA for KC-135 recapitalization expressed the cost-per-effect concept in similar terms: “The most ‘cost-effective’ alternative means

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\(^7\) Deptula and Birkey, 2020, p. 1.

precisely the alternative whose effectiveness meets the military aerial refueling requirement at the lowest cost.” The study explicitly did not consider simpler metrics, such as cost-per-flight-hour or cost-per-aircraft, in recommending a course of action for the modernization of the aerial refueling tanker fleet. From this standpoint, the call for cost-per-effect analysis can be understood not as one to develop novel study approaches but rather to apply current best practices across all force development analysis.

The second argument from the policy paper focuses on using cost-per-effect analysis as a common baseline:

Cost-per-effect assessment should be adopted and applied across the Department of Defense as the preferred measure of merit in evaluating weapon system choices, especially as multiple services offer different solutions to achieve similar effects.10

In other words, cost-per-effect analysis is not just about good analysis; it is about consistently good analysis across studies, mission areas, and services to enable the accumulation of findings to inform strategic decisionmaking throughout the U.S. Department of Defense (DoD). The policy paper argues that the consistent application of cost-per-effect analysis will make it possible to inform decisions not only between similar systems but also across disparate systems to maximize U.S. national security for a given defense budget.

The policy paper also argues for taking a broad view of what is meant by efficiency and effectiveness. This third argument focuses on the enterprise-wide implications of doing so:

Cost-per-effect is an assessment measure that affords the ability to assess the “business cases” behind comparative technologies through the operational lens of enterprise mission effectiveness and fiscal efficiency, not just lowest up-front per-unit cost for a piece of equipment that may only address one facet of the kill chain.11

Naturally, it is easier to compare systems within a comparable mission set. For example, the KC-135 tanker AoA was able to define its effectiveness requirement as “the amount of fuel that aerial refuelers must supply, at specific times and locations, in a set of mission categories in future military scenarios.”12 The need for enterprise-level effectiveness would become more acute when comparing more-disparate systems (beyond aerial refuelers), such as comparing the relative costs and benefits of an aerial refueling tanker versus those of a 5th-generation fighter.

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10 Deptula and Birkey, 2020, p. 1.

11 Deptula and Birkey, 2020, p. 1.

12 Kennedy et al., 2006, p. 8.
Both of those aircraft platforms would play important, although very different, roles in achieving, among other things, air superiority. Whether the authors of the 2020 policy paper would consider a tanker and a fighter “comparative technologies” is unclear, but those are the types of trade-offs that the Air Force and, ultimately, the joint force must make.

One can imagine that as the acquisition alternatives become more and more disparate, the measure of enterprise cost-effectiveness would become more and more difficult to quantify. Comparing the cost-per-effect, or enterprise cost-effectiveness, of a ballistic missile submarine versus that of a next-generation RQ-170 Sentinel unmanned aerial vehicle might be possible only if the enterprise-level effectiveness of each alternative were interpreted to mean its direct contribution to U.S. national security—an almost incalculable metric.

For this reason, the authors of the 2020 policy paper seem to support taking the broadest possible view of cost-per-effect that would be tractable within a study. In other words, the effectiveness of individual systems should be measured, to the greatest extent possible, by their marginal improvements to U.S. national security writ large and not by the easiest “bean-counting” metrics available. Again, this view is consistent with current best practices for cost-effectiveness analysis but is certainly not exhibited in every DoD cost-effectiveness study.  

Finally, the fourth argument for cost-per-effect analysis put forth by the policy paper authors focuses on the potential benefits of its widespread adoption and implementation for key mission areas:

Congress should consider including language in the National Defense Authorization Bill requiring DOD to devise new measures to assess cost-per-effect for key mission areas, then implement such evaluations in the future force development process.

As with their second argument, this fourth argument is not about just doing cost-effectiveness analysis better but rather following a common approach that enables comparisons and trade-offs across systems, mission areas, and services. By instituting a common practice, not only would each analysis individually become better but also the comprehensive set of analyses could have greater positive impacts on the force development process, allowing for multidimensional trade-offs of operational impacts, particularly in key areas of mission planning.

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13 The U.S. Government Accountability Office (GAO) found that AoAs failed to consider a broad range of alternatives in some cases (see GAO, “Defense Acquisitions: Many Analyses of Alternatives Have Not Provided a Robust Assessment of Weapon System Options,” Highlights of GAO-09-665, September 2009), and AoAs have failed to connect effectiveness to mission needs in other cases (see GAO, Joint Intelligence Analysis Complex: DoD Partially Used Best Practices for Analyzing Alternatives and Should Do So Fully for Future Military Construction Decisions, GAO-16-853, September 2016).

14 Deptula and Birkey, 2020, p. 1.
An Enterprise Cost-Effectiveness Hierarchy

RAND’s seminal 1993 strategies-to-tasks framework offers a useful overview of how mission planners are necessarily forced to take broader and broader views of both cost and effectiveness when comparing acquisition systems. The central figure from the original strategies-to-tasks framework depicts this overview nicely. Replicated here as Figure 1.1, it shows that if we want to know the most cost-effective way to damage key hardened airbase facilities, we would define cost and effectiveness at the operational task level (near the bottom of the hierarchy). If, however, we seek to gain air superiority, we would recast our analysis at the campaign objectives level. If our aim is broader still, such as to deter or defeat large-scale aggression, we would need to do our analysis at the national military objectives level. Regardless of the aim, analysts must understand where the analysis needs to focus in the hierarchy of decisionmaking.
Figure 1.1. Strategies-to-Tasks Hierarchy of Decisionmaking (and Analysis)

Likewise, we can think of enterprise cost-effectiveness as a hierarchy: Lower-end cost-effectiveness is defined narrowly but acceptably within a mission area, and upper-end cost-effectiveness is defined broadly at the national security enterprise level and incorporates a full joint concept. Analysis anywhere on the hierarchy serves an important role, but that role should be explicit.

At the lower end of the hierarchy (e.g., at the level of operational tasks), the analysis and metrics should be carefully constructed to maximize ease of data collection and analysis while providing analytically representative results. The measure of effectiveness would be only as broad as necessary, and jointness would be included only to the extent required. Similarly, the measure of cost would be focused on differential costs, and any cost not directly attributable to the systems under consideration would often be disregarded. Nonetheless, the effectiveness measure should still be traceable to national security objectives through a strategies-to-task framework or another similar construct.

At the upper end of the hierarchy (e.g., at the level of national military objectives), the analysis and metrics should be as broad and encompassing as possible. At the upper limit, the measure of effectiveness would represent joint force effectiveness or the closest possible approximation of its direct contribution to national security objectives across the full range of military operations. Because of the breadth of capabilities involved, the cost estimation would similarly need to account for all facets of costs across the joint force.

Just as there could be deleterious effects of conducting an analysis too narrow for its purpose, there could be deleterious effects of conducting an analysis too broad for its purpose. Cost-per-effect analysis that falls short of its goals may, in fact, provide worse support to decisionmaking than that provided by current cost-effectiveness analysis. For this reason, it would be imprudent to mandate cost-per-effect analysis for all studies. A more worthwhile effort would be to expand on current cost-effectiveness analyses to incorporate a broader enterprise view and to provide a stronger basis for comparison across studies.

We recognize that the move from narrowly focused cost-effectiveness analysis to broader enterprise cost-effectiveness analysis will need to be incremental and evolutionary. We believe, however, that the term enterprise cost-effectiveness can shift attention away from either doing or not doing cost-per-effect analysis and toward the desired outcome of improving on the robust cost-effectiveness analysis capabilities already available within DoD.

A Framework for Visualizing Cost-per-Effect Analysis

The July 2020 Mitchell Institute policy paper offers a key insight for progressing from traditional cost-effectiveness analysis toward enterprise cost-effectiveness analysis. This insight distills several aspects of the defense analytic problem and its ongoing challenges, which we will discuss further in Chapter 2. Drawing from this insight, we developed a tentative conceptual framework for visualizing enterprise cost-effectiveness analysis.
The key insight from the 2020 policy paper is as follows: “Current measures favor lowest up-front per-unit cost (an ‘input’ measure) for a piece of equipment that may only address one facet of the kill chain . . . ”\(^\text{15}\) Up-front per-unit cost is a poor measure, which should be avoided to the greatest extent possible; nevertheless, the need for tractability often focuses cost-effectiveness analysis on a single or limited number of facets of the kill chain. This narrow focus can be particularly problematic if it is not made explicit, causing decisionmakers to misunderstand the findings of the analysis as being somehow related to a broader enterprise view, when in fact they are not.

One example of the danger of such analysis, even at the campaign objectives level, is the narrow focus placed on winning a war to the neglect of what happens after the war. As the 2020 policy paper argues, “the imperative to execute a mission, safely return to base, and [fight] again tomorrow is a common-sense objective as old as . . . warfare itself.”\(^\text{16}\)

However, the *Interim National Security Strategic Guidance* warns against taking such an approach, specifically in the Indo-Pacific.\(^\text{17}\) It is easy to imagine an analysis that focuses on fighting and winning a war in the Indo-Pacific and on deriving defense planning recommendations from that analysis. But even if the United States were to prevail in such a conflict, U.S. adversaries would not cease to compete in the region, and the U.S. forces deployed to fight that conflict would then need to be prepared for fighting future resulting conflicts.

In trying to incorporate (1) a broader enterprise view within cost-effectiveness analysis, (2) a joint and combined perspective on national strategic effectiveness, and (3) the practical need for future analytic tractability, we explored—as a theoretical exercise—a simple chess example. We acknowledge that using chess as an analogy for warfighting is extremely problematic. A square chessboard is infinitely more constrained than the theater of warfighting. Nonetheless, the “trivial” version of strategic complexity found in chess can offer a tractable model at least for visualizing the substantially greater complexity found in defense planning.

Consider investing in one additional knight (at a nominal cost of three units) instead of one additional pawn (at a nominal cost of one unit). Then imagine an analysis to measure the *effectiveness* of the knight, specifically by calculating the pieces the knight captures. If the knight captures pieces with a total value of greater than three units, the knight would be a cost-effective investment. If the knight captures pieces with a total value of exactly three units, the knight would be neutrally cost-effective. If the knight captures pieces with a total value of less than three units, the knight would not be cost-effective.

We ran thousands of simulated chess moves to calculate the value of the additional knight. In most cases, the knight captured either one enemy knight or one enemy bishop (which was also valued at three units) before being captured itself. That is to say, the knight delivered three units

\(^{15}\) Deptula and Birkey, 2020, p. 3.
\(^{16}\) Deptula and Birkey, 2020, p. 9.
of effect for three units of cost—a neutrally cost-effective investment. However, the neutral cost-effectiveness was only the up-front value. This up-front value failed to capture the value that the knight provided to the joint force. Although the knight sacrificed itself for a piece of equal value, by doing so, the additional knight was able to position all the other pieces on the board for a dominating win. In fact, on average, across thousands of simulated runs, the three-unit additional investment in that knight delivered over four units of additional effectiveness.

This simple example shows that if we do not take an enterprise view that looks far beyond the up-front costs, we may incorrectly assume that an additional investment in a knight is of inconsequential or net neutral value compared with that of a pawn. Conversely, if we do take an enterprise view, we may see that a knight provides an outsized value.

It is easy to imagine how an analogous Air Force investment in, for example, suppression of enemy air defenses (SEAD) might deliver broader effects to the joint force by first enabling air superiority; which could, in turn, improve intelligence, surveillance, and reconnaissance (ISR) collection; which could, in further turn, enable a ground force. If those enterprise-wide effects are not considered, the value, in this example, of SEAD might be obscured by its up-front cost.

A Three-Part Exploration of Cost-per-Effect Analysis

In the following chapters, we explore cost-per-effect analysis in three stages. In Chapter 2, we frame the current defense analytic problem as indicative of the enduring challenges that have plagued defense planning for decades. In Chapter 3, we propose analytic and programmatic frameworks for incorporating cost-per-effect measurements into defense planning and decisionmaking; these measurements would include effects, costs, campaigns, trade-offs, and optimization. In Chapter 4, we discuss a tabletop exercise (TTX) that we used to experiment with our proposed implementation of cost-per-effect analysis. Drawing from our findings in these three stages of exploration, we present, in Chapter 5, our conclusions and recommendations for incorporating cost-per-effect metrics into defense planning.

As an exploratory analysis, this work draws heavily on subject-matter expertise. We are keenly aware of the challenges of implementing significant improvements in the defense planning process. Therefore, we designed the research methodology to produce, for further consideration, a reasonable path for improving the defense planning process. The analysis does not purport to derive a single best possible path. We opted for this flexible exploratory research approach to enable us to move from simply contemplating the problem to producing useful and actionable next steps. We believe the tentative next steps described in this report can contribute to discussions about possibly implementing cost-per-effect analysis into defense planning and improving the defense planning process.
Chapter 2. The Defense Analytic Problem and Enduring Challenges

For more than a century, innovation in defense planning praxis has been driven by improvements in analytic techniques that have allowed national defense organizations to better understand the relationships between fiscal costs and military effects.\(^{18}\) During the early modern era, the key drivers of costs and effects were communications, steam transport, and national industrial and military mobilization.\(^{19}\) In the middle of the 20th century, defense analysis focused on the internal combustion engine and airpower.\(^{20}\) In the latter half of the 20th century, the advent of nuclear deterrence and Cold War tensions drove substantial progress in developing mechanisms and techniques, centered on modern systems analysis, to relate military effects with fiscal costs.\(^{21}\) In the post–Cold War era, the defense analytic challenge became diffuse and “capabilities-based,” losing much of its focus and momentum.\(^{22}\)

Today, however, there are signs of a renaissance in defense analysis.\(^{23}\) The return of great-power competition to the forefront of strategic planning, coupled with the emergence of the cyber, space, and electromagnetic domains as loci of operational effectiveness, are providing new impetuses to innovation in defense analysis. Meanwhile, rapid improvements in practical computational scale, data analytics, artificial intelligence, and machine learning are creating the capacity for potential new forms of analysis. The question remains whether this incipient renaissance will prove real and, if so, who and what will shape its character.

But defense analysis has also faced recurring challenges to continuous improvement. In the next four sections of this chapter, we discuss four aspects of the ongoing defense analytic

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18 Charles Tilly argues convincingly that the need to plan for and sustain armed forces was the principal driver in the emergence of the modern state (see, particularly, Charles Tilly, *Coercion, Capital, and European States: A.D. 990–1992*, Wiley, 1993).


23 See, for example, Kathleen H. Hicks, Deputy Secretary of Defense, “Creating Data Advantage,” memorandum, May 5, 2021; and Susanna Blume, “Senate Armed Services Committee Advance Policy Questions for Ms. Susanna Blume, Nominee to be Director, Cost Assessment and Program Evaluation,” responses, undated.
problem and its enduring challenges: (1) the analytic complexity of defense planning, (2) the analytic complexity of cost estimation, (3) the analytic complexity of effectiveness estimation, and (4) the limitations of modeling and analysis.

Analytic Complexity of Defense Planning

One of the key challenges in defense planning is accounting for strategic interaction and principal-agent problems. Strategic interaction refers to circumstances in which outcomes are contingent on the choices of other actors, and the payoff of each choice depends on both that choice and the choices of others.\(^{24}\) Likewise, principal-agent problems refer to the challenges faced by complex organizations and operations in aligning the actions of individual agents with the intentions of their principal leaders.\(^{25}\) The combination of an agile adversary with one’s own complex organizations and operations limits what defense planners can reliably know, making defense planning fraught with challenges.\(^{26}\)

The implications of this complexity are profound, and studies at all levels of analysis should carefully assess and articulate how they address, or do not address, key sources of uncertainty. For example, operational simulations may suggest the optimal quantities and placements of air defense assets, but the effectiveness of the plan depends on the adversary performing a scripted behavior. If the adversary adapts, the optimal “solution” may prove brittle and ineffective.

In cost-per-effect analyses, it is possible to cope with the analytic complexity of defense planning by adhering to three principles. First and foremost, the analyses should be understood holistically, which means that any findings should result from a combination and alignment of scoping conditions, key assumptions, input data, participant expertise, and formal models that are tightly interwoven. Comparisons of outputs alone may create unwarranted conclusions if the underlying analytic components are not aligned; for example, two studies that contribute to one cost-per-effect analysis may represent adversarial behavior differently or use different definitions for the same term. In such cases, analysts need to ensure that their databases, briefings, reports, and other analytic artifacts rely on inputs and outputs that are organized, linked, and aligned.


Second, cost-per-effect analyses must trade off between internal validity (how well the study is conducted) and external validity (how applicable the study is to the real world). Campaign models may offer high levels of internal validity but do so at the expense of oversimplifying the behaviors and decision-making of real-world military organizations for the sake of tractability. Conversely, wargames and TTXs may provide higher levels of external validity in representing real-world military organizations and operations but may, absent campaign models, be opaque about how engagements are resolved. Analysts should pursue both forms of validity by using a full set of tools—such as data analytics, case studies, lab and field experiments, and observational studies—to check for sensitivities and identify when changes would alter the conclusions. As the complexity of analysis increases, validity should be understood as a spectrum of conditions rather than a binary true-or-false condition. Given the analytic time and resource constraints, cost-per-effect analysis will similarly need to grapple with trade-offs between the pursuit of these two analytic validities.

Third, cost-per-effect analyses should strike a balance between exploring data and new concepts and improving the precision of findings that are already known. Doing so will require organizational discipline of two contrasting kinds.

On the one hand, as databases and analytics become increasingly available, the ability to discover relationships between military cost and operational effectiveness will present attractive opportunities that should not be neglected, but the patterns in newly “found data” and convenience samples may be biased. Therefore, the path from discovery to findings should be traveled carefully, avoiding assessments that rest on untested hypotheses regarding data relationships. Instead, newly discovered relationships of interest should themselves be subject to further analysis to determine if they persist when experiments (models, simulations, case studies, games, etc.) are designed to test for them specifically. Any commitments to explorations

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29 DoD, *DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)*, DoD Instruction 5000.61, October 15, 2018.

30 In organizational terms, this difference is often referred to as “exploration vs. exploitation,” in which resources are divided between striving for discoveries and innovation versus proliferating and increasing the effectiveness of best practices. See James G. March, “Exploration and Exploitation in Organizational Learning,” *Organization Science*, Vol. 2, No. 1, 1991.

31 This is commonly referred to as the streetlight effect (see David H. Freedman, “Why Scientific Studies Are So Often Wrong: The Streetlight Effect,” *Discover*, December 9, 2010).

32 The presentation of relationships discovered in data as having been subsequently tested is referred to as hypothesizing after results are known, or HARKing. See Norbert L. Kerr, “HARKing: Hypothesizing after the Results Are Known,” *Personality and Social Psychology Review*, Vol. 2, No. 3, August 1998; and Craig Pickering, “P-Hacking, HARKing, and Science’s Replication Crisis,” *SimpliFaster* blog, undated.
of data and new concepts should be matched with resources to test the findings before presenting them to decisionmakers.

On the other hand, commitments to deeply held analytic and operational beliefs must also be regularly challenged and tested by use of the evolving analytic tools and methods, based on changing real-world conditions. The more important an assumption, model, or result is to the analysis and decisionmaking, the more its rigor should be challenged using alternative input data, different modeling or analytic methods, and dissimilar evaluative metrics. An organization’s commitment to the continuous testing of its own critical analytic inputs and outputs can bolster its findings from being narrowly scoped point estimates to being broad, sturdy pillars on which decisionmakers can act with greater confidence. Analytic organizations should maintain resources not only for exploring new relationships but also for testing the robustness of established ones and for improving the precision of established findings.

Collectively, abiding by these three principles can support the development and performance of cost-per-effect analysis as it matures into a stronger capability at the service and joint levels.

**Analytic Complexity of Cost Estimation**

Cost estimates are intrinsically complex and uncertain, if only because cost estimators lack “knowledge about technology, economic conditions, and other future events.” Although cost estimation has a robust set of best practices and provides tremendous insight to decisionmakers, the realized costs still often diverge from even the best estimates: More often than not, the realized costs exceed the projected costs. As seen in Figure 2.1, the majority of cases have a cost growth factor that exceeds 1.25, meaning that for every $1 billion of projected costs, the actual costs grow to at least $1.25 billion. Factors beyond the DoD’s control can increase the complexity of cost estimates, “because they are tied to national and local economic conditions, labor relations, and overall inflation.” Critical breaches, in which the costs exceed 150 percent of the projections, are difficult to predict—had they been easily predictable, they likely would

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not have occurred.\textsuperscript{36} To add to the complexity, a cost estimate is not really a point value but rather a probability distribution as shown in Figure 2.1.

**Figure 2.1. Projected Versus Realized Costs**

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure21.png}
\caption{Projected Versus Realized Costs}
\end{figure}


NOTE: The x-axis represents the cost growth factor (CGF), which is the ratio of realized to projected costs, and the y-axis represents how often that level of deviation occurred.

Further adding to the complexity of cost estimation is that DoD accounting rules serve a wide range of purposes, which can create challenges when trying to compare the costs of disparate systems. One such challenge is whether and how to consider peacetime costs versus wartime costs. As examples, a guided missile destroyer can conduct freedom-of-navigation missions in peacetime and combat operations in wartime or a Minuteman III missile can provide deterrence in peacetime or destruction during combat. Many procurements serve multi-role purposes, and so the costs of these procurements apply to multiple missions, not just single kill chains.

Cost estimation is further complicated by issues of color of money.\textsuperscript{37} That is, numerous major categories of costs are subject to their own congressional appropriations bills that are based on their own cost-estimating assumptions and methodologies even if all costs ultimately apply to the U.S. government. As a result, for instance, military construction dollars are not comparable to operations and support (O&S) dollars, and personnel dollars are not comparable to research, development, test, and evaluation (RDT&E) dollars.


Over the long term, system lifespan contributes further to errors in cost estimation and comparison. Some systems outlive their estimated economic service lives, while others do not.

**Analytic Complexity of Effectiveness Estimation**

When we turn to estimating effectiveness, the analytic challenge shifts. Here, the fundamental challenge is to define the effect of interest—or put differently, to establish the objective of warfare. Military theorists have long relied on Carl von Clausewitz’s statement that “war is politics by other means”\(^{38}\) to argue that the objective of war is to achieve a preferred policy by defeating an adversary, generally by gaining an advantage over them.\(^{39}\) Defeat can, in turn, be achieved through a range of mechanisms, potentially including destruction, annihilation, dislocation, exhaustion, disruption, disintegration, preemption, isolation, circumvention, forestallment, compellence, impellence, and deterrence.\(^{40}\) All these mechanisms, except for the binary one of annihilation, depend on the myriad fluctuating impacts of facts on the ground, such as military, territorial, or financial losses and the changing decisions of political leaders who are able to shift policy to enable victory. In other words, the key effect of warfare is its effect on the decisions of individual leaders and their willingness to continue to fight.\(^{41}\)

But anticipating senior leader decisionmaking is analytically challenging. Classic studies of decisionmaking have repeatedly highlighted the interplay of personality, bureaucratic structure, and historical contingency.\(^{42}\) In exploring potential future conflicts, the uncertainty surrounding personalities and relationships greatly compounds the complexity. To manage (or set aside) the uncertainty of political outcomes, defense analysis has tended to fall back on understanding the physical—rather than moral or mental—effects of warfare, because the physical effects are easier to trace in terms of cause and effect, easier to measure in terms of outcomes, and easier to predict in terms of recovery.\(^{43}\) This focus has often been on the physical damage to a civilian


\(^{40}\) Paul, Wong, and Bartels, 2020, pp. 40–43.


\(^{43}\) Paul, Wong, and Bartels, 2020, p. 31.
population or economy, while operational analysis has generally focused on adversary attrition as the outcome of interest. Although the focus on physical attrition allows for traceable, physics-based modeling of the impacts of conflict, it generates two well-documented weaknesses. First, military capabilities that contribute to defeat through mechanisms other than attrition can appear to be less effective, potentially tilting estimates of cost-per-effect toward kinetic systems. Second, because not all defeat mechanisms relate directly to attrition, the causal impact of attrition on the willingness of senior leaders to fight can vary by context, such as government type, national identity, and economic circumstances. In other words, measuring attrition may not be the same thing as measuring the actual effect of interest—military defeat.

Limitations of Modeling and Analysis

The complexity of defense planning and the need to support time-sensitive decisionmaking can lead to questionable research practices, particularly in oversimplified modeling and simulation. Such oversimplifications can lead to unjustified conclusions.

To make matters worse, performative action can often be used to speciously justify models. For instance, if actions are taken to follow a model’s prescriptions, those actions can induce a self-fulfilling prophecy in the real world. Consider, for example, a model warning that an allied host nation is politically, economically, and militarily unstable. The decision to act as though the host nation is indeed unstable—by raising interest rates on the nation, demanding early payment of international loans granted to the nation, or withdrawing political and military support from the nation—may, in fact, cause the nation to become less stable and collapse, seeming to validate the model that contributed to the collapse. The result is that the model appears to have predictive power, but it does so only because it was believed by decisionmakers to have that power.

Likewise, in military operations, a model suggesting that particular tactics, techniques, and procedures (TTP) for performing a military mission are the correct TTP for that mission often results in the choice of operations that rely on those TTP. In a vicious cycle, these operations further justify and entrench the unwarranted belief that these TTP must be the correct ones to use.

44 This focus is particularly common in studies of countervalue strategies for the use of nuclear weapons. For a classic work of this kind, see Bernard Brodie, “Strategic Bombing: What it Can Do,” The Reporter, August 15, 1950. For a description of RAND-conducted Cold War wargaming with this focus, see Elizabeth M. Bartels, Building Better Games for National Security Policy Analysis: Towards a Social Scientific Understanding, dissertation, Pardee RAND Graduate School, RAND Corporation, RGSD-437, 2020, pp. 140–149.

45 Paul, Wong, and Bartels, 2020; and Connable et al., 2018.

46 McNerney et al., 2018.

47 Social scientists note such relationships occur regularly in economic markets where models can be seen as “engines” that drive market forces and behaviors rather than as “cameras” that capture the true state of the world (see Donald MacKenzie, An Engine, Not a Camera: How Financial Models Shape Markets, MIT Press, 2008).
Failing to recognize that analytic models are merely partial representations of reality can lead to further misunderstandings of the results. This failure most often occurs when key variables are omitted or when high-level assessments mask low-level processes. For instance, modeling methods that assume rationality and unity of command and organization may provide grossly and gravely misleading results if real humans and organizations do not behave as game theory often predicts they should.
In this chapter, we propose two frameworks: one for measuring enterprise cost-effectiveness and the other for implementing it. The first is an analytic framework for developing the tools, software, analytics, and data to measure enterprise cost-effectiveness. The second is a programmatic framework for developing the processes to incorporate the new metrics into decisionmaking.

Analytic Framework for Measuring Enterprise Cost-Effectiveness

Figure 3.1 shows an overview of our proposed analytic framework. It consists of five interrelated measurements: effects, costs, campaigns, trade-offs, and optimization. In essence, the costs divided by effects equal the cost-effectiveness, and the cost-effectiveness multiplied across the broader set of campaign contexts equals the overall cost-per-effect, which can then be analyzed for purposes of trade-offs and optimization. We specify the mathematical equations—or the metrics—for these five measurements in the next five sections (for those readers who might be interested).

48 It is generally more convenient to first calculate the effects and then the costs to achieve those effects. This convenience, however, produces the oddity that Step 1 appears below Step 2 (as shown in Figure 3.1).
Effects

Effects refer to the consequences of kill chains that target adversaries. Kill-chain analysis could be done with a variety of tools, which would need to be carefully selected for the mission under consideration. For example, a software tool, such as the Defense Advanced Research Project Agency Adapting Cross-Domain Kill-Webs (DARPA ACK) program or the Synthetic Theater Operations Research Model (STORM), could conceptually calculate the effect, $E_{t,w}$, across targets, $t$, and the optimum allocation of assets given a particular force structure in a campaign, $w$. A context vector, $\omega_w$, would need to encompass all other relevant parameters regarding a campaign, $w$, including adversary behavior and decisionmaking.\textsuperscript{49} Converting existing operational plans (OPLANs), concept plans (CONPLANs), campaign plans (CAMPLANs), and defense planning scenarios (DPSs) into a workable context vector, $\omega_w$, would require further research, because these plans would need to be interpreted precisely enough to capture the meaningful context yet expansively enough to allow room for alternative and novel capabilities.

\textsuperscript{49} For more information on DARPA ACK, see Greg Kuperman, “Adapting Cross-Domain Kill-Webs (ACK),” DARPA, undated; for more on STORM, see GroupW, “USAF Synthetic Theater Operations Research Model (STORM),” webpage, undated.
Given a joint force structure of air, $A$, maritime $M$, ground, $G$, space, $S$, and cyber, $C$, assets, $(A_1, \ldots, M_1, \ldots, G_1, \ldots, S_1, \ldots, C_1, \ldots)$ and the ability to convert existing plans into a sufficiently defined context vector $w$, a campaign-level tool could calculate the effect, $E_{t,w}$, on each target, $t$, in the campaign, $w$, with the context vector describing the warfight, $\omega_w$, which would contain many parameters, including the disposition of forces, the nature of the conflict, and the political constraints as follows:

$$E_{t,w} = f(\omega_w, A_1, \ldots, M_1, \ldots, G_1, \ldots, S_1, \ldots, C_1, \ldots).$$

We can then average across all possible targets, $T$, including both kinetic and non-kinetic targets, to calculate the net effect, $E_w$, in the context of a campaign, $w$, as follows:

$$E_w = \sum_{t=1}^{T} E_{t,w}.$$  

**Costs**

To lay the foundation for costing a force structure, DoD has baseline tools for both analytic cost estimation and program objective memorandum decision support. It would not be necessary to calculate absolute cost but only the changes in cost with changing force structure. These changes would be driven largely by support assets (e.g., refueling tankers for fighters); thus, these cost elements need to be accurate, and it is important to validate these aspects of any analysis.

Again, for a given force structure of air, $A$, maritime $M$, ground, $G$, space, $S$, and cyber, $C$, assets, $(A_1, \ldots, M_1, \ldots, G_1, \ldots, S_1, \ldots, C_1, \ldots)$, it is possible to calculate the cost, $C_{t,w}$, associated with the joint force structure corresponding to each target, $t$, in the campaign, $w$, given all the parameters in the context of a given warfight, $\omega_w$, as follows:

$$C_{t,w} = g(\omega_w, A_1, \ldots, M_1, \ldots, G_1, \ldots, S_1, \ldots, C_1, \ldots).$$

We can then add the cost across all possible targets, $T$, to calculate the net cost, $C_w$, in the context of a campaign, $w$,

$$C_w = \sum_{t=1}^{T} C_{t,w}.$$  

This metric can be simplified by assuming that, in any given campaign, all joint assets would be applied against a target, even if that target is null (i.e., the asset does not deploy). In this case, the cost, $C_w$, in the context of a campaign, $w$, could simply be the entire defense budget.

**Campaigns**

Most campaign models are designed to assess the effects of a given campaign, $E_w$. However, modeled optimizations for a single campaign could lead to decisions that would be overly optimized for a single future and thus fragile to changes in the security environment. To ensure robustness, it would be important to test the modeled results against as many scenarios as
possible, including OPLANs, CONPLANs, CAMPLANs, and DPSs with appropriate weightings.

To represent the combined effect of supporting U.S. national security objectives across a full range of military operations, we could average our effect, $\bar{E}$, across all potential warfights, $W$, including antecedent campaigns as follows:

$$\bar{E} = \frac{1}{W} \sum_{w=1}^{W} E_w.$$

In contrast, we have already found a simplifying relationship to capture the entire defense budget:

$$\bar{C} = \frac{1}{W} \sum_{w=1}^{W} C_w.$$

This metric of cost for the entire defense budget would then allow us to calculate the ultimate ratio of the total combined cost-per-effect, $H$, as a function, $\eta$, of any given joint force structure as follows:

$$H = \frac{\bar{E}}{\bar{C}} = \eta(A_1, \ldots, M_1, \ldots, G_1, \ldots, S_1, \ldots, C_1, \ldots).$$

Averaging the effect results from the campaign models and the cost results from the cost tools could suggest the direct relationship between cost and effect—i.e., the enterprise cost-effectiveness, $H$, of any given investment. But even with accurate results, they alone would not be enough to influence decisionmakers without also providing clear traceability that would be readily understandable. Beyond calculating correct answers, providing dashboards or other tools that would offer clear and concise findings and traceable analyses to decisionmakers would be invaluable.

**Trade-Offs**

By comparing the cost-per-effect of two discrete investment options, it would be possible to determine which would offer the lower cost-per-effect. For example, this methodology could indicate whether an investment in one aircraft system would have a higher or lower cost-per-effect than the same investment in another aircraft system.

Consider an additional investment, $\alpha$, in aircraft $A_1$. In this case, the cost-per-effect could be written as

$$H = \eta(A_1 + \alpha, \ldots, M_1, \ldots, G_1, \ldots, S_1, \ldots, C_1, \ldots).$$

For small additional investments, the Taylor series expansion would be

$$H \approx H_0 + \frac{\partial \eta}{\partial A_1}(A_1, \ldots) \times \alpha.$$
Then, the chain rule tells us that the change in cost-per-effect, \( \Delta H = H - H_0 \), would be

\[
\Delta H \approx \frac{E \frac{\partial \bar{C}}{\partial A_1} - \bar{C} \frac{\partial \bar{E}}{\partial A_1}}{E^2} \times \alpha.
\]

We could similarly look at cost-neutral changes in force structure, such as an additional investment, \( \alpha \), in \( A_1 \), paired with an equivalent divestment, \( \beta \), in \( A_2 \), to calculate the change in cost-per-effect of this trade-off as follows:

\[
\Delta H \approx \frac{E \frac{\partial \bar{C}}{\partial A_1} - \bar{C} \frac{\partial \bar{E}}{\partial A_1}}{E^2} \times \alpha - \frac{E \frac{\partial \bar{C}}{\partial A_2} - \bar{C} \frac{\partial \bar{E}}{\partial A_2}}{E^2} \times \beta.
\]

**Optimization**

Whereas trade-offs could allow us to determine whether an additional investment in one aircraft system had a higher or lower cost-per-effect than did the same investment in another aircraft system, optimization could consider all (or many) possible investments across all (or many) possible weapon systems to determine which comprehensive set of investments could have the lowest cost-per-effect. By exploring a wide variety of potential investments, it could be possible to optimize the force structure for a given set of constraints. The complexity of the exploratory space is such that specific machine-learning techniques, or other computation tools, would be needed for an efficient search. Existing machine-learning tools could be used to begin to explore the combinatorial space.

Some investment decisions could improve outcomes but still lead to suboptimum results. Using machine-learning techniques, it could be possible to get closer to the “global optimum.” Consider a differential change in investment across all capabilities \( \delta = (\delta_1, \delta_2, \cdots) \), such that

\[
H = \eta(A_1 + \delta_1, A_2 + \delta_2, \cdots).
\]

For small changes in force structure, the Taylor series expansion would be

\[
H \approx H_0 + J(A_1, \cdots)\delta,
\]

where \( J \) would be the Jacobian of \( \eta \). For larger changes in force structure, the accuracy could be increased by including higher-order terms. In this case,

\[
H \approx H_0 + J(A_1, \cdots)\delta + H(A_1, \cdots)\delta^2/2,
\]

where \( H \) would be the Hessian of \( \eta \). Machine-learning techniques could then find the global optimum \( \delta \), subject to budget constraints.
Programmatic Framework for Implementing Enterprise Cost-Effectiveness

Figure 3.2 shows an overview of our proposed processes for implementing enterprise cost-effectiveness. This cycle of processes would rely on the Plan-Do-Check-Act scientific method. Although this framework would be aligned around the DoD’s annual Planning, Programming, Budgeting, and Execution (PPBE) process, the cost-per-effect construct could be applied throughout the requirements and acquisition processes as well. We describe each step below in further detail.

**Figure 3.2. Proposed Processes for Implementing Enterprise Cost-Effectiveness**

**Plan.** Identify key problem areas for a cost-per-effect analysis. Convene stakeholders and performers to develop the necessary analytics.

**Do.** Create a concepts package specifying goals and systems of interest. Develop necessary analytics and associated decision dashboards.

**Act.** Produce materials and data summarizing results and recommendations of the cost-per-effect for defense planning decisions.

**Check.** Validate and verify model, data, and assumptions. Review the strategic relevance of results and applicability to relevant decisions.

**Plan-Do-Check-Act Scientific Method**

SOURCE: Adapted from Lean Enterprise Institute, undated.

**Process 1: Plan**

At the start of each PPBE cycle, DoD and joint planners identify key problem areas, based on national, operational, and support objectives. The problem areas are classified as either critical, important, or less important. Questions, constraints, and assumptions are also formulated for each problem area.

One organizational approach to process 1 would be to establish and convene, at this juncture, an Enterprise Cost-Effectiveness Executive Steering Committee (ECEESC), chaired by a Deputy Secretary of Defense. This committee would endorse enterprise cost-effectiveness priorities, delegate tasks to Enterprise Cost-Effectiveness Working Groups (ECEWGs) to implement those priorities at the service and joint levels, and integrate the cost-per-effect findings from the

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50 Lean Enterprise Institute, “Plan, Do, Check, Act (PDCA),” webpage, undated.
service and joint levels into their respective PPBE processes. The ECEESC would also establish and convene a Joint Enterprise Cost-Effectiveness Council (JECEC) consisting of three-star general officers, flag officers, and senior executive service members to identify the requirements for tools to calculate cost-per-effect across the joint force.

This juncture would also be the time to design the analytic approach; identify the requirements for an appropriate kill-chain effects campaign model; model the assets required for producing those effects; and identify the software requirements for synchronizing manpower, weapon system sustainment, order of battle (OOB), gaming, and force structure dependency. It would also be important to model attrition with tools that fully capture adversary OOB, decisionmaking, and adaptation. Of prime importance would be the selection of relevant OPLANs, CONPLANs, CAMPLANs, and DPSs as proxies for all potential future conflicts.

**Process 2: Do**

During the PPBE cycle, ECEWGs would write a concept package for enterprise cost-effectiveness, outlining its goals, capabilities, organizations, concepts of operation (CONOPs), and metrics. The package should be developed through a strategies-to-task approach in alignment with national guidance, including from the Joint Staff and combatant commanders. The package would describe the key operational problems, prospective decisions, and constraints. Endorsed by the ECEESC and JECEC, the package would detail the end-to-end joint operational concepts for accomplishing specific operational tasks across relevant missions and would frame the forthcoming data analysis. The ECEWGs would use the package to develop and refine the cost-per-effect analytic and data capabilities, the output of which would be the tools and analytic plans required to calculate the cost-per-effect of relevant systems.

The ECEWGs should select data methods appropriate for the specific issues raised in the concept package, provide advice and recommendations to acquisition authorities regarding infrastructure and personnel, and normalize and test inputs and outputs across methods. Planners should integrate multiple analytic methods into coherent campaigns—spanning case studies, gaming, modeling, and exercises—and rationalize the inputs across the analytic lines.

**Process 3: Check**

The goals at this stage would be to ensure that the analytic inputs, outputs, and methods are well defined; ensure that the modeling, games, and exercises are cumulative and relevant to the uncertainties and options of decisionmakers; test the reliability of critical assumptions; and establish a hierarchy of confidence levels in the analytic outputs, allowing for the results to be differentiated by method and by metric.

The ECEESC should define clearly what results are “good enough” and should prioritize the essential areas for greater accuracy (or depth), while the JECEC should provide guidance with respect to documenting the analytic inputs, outputs, and methods. The documentation should be readable by both humans and machines. The JECEC should present and appropriately caveat the
work, given its limitations and constraints. The results should be transparently understandable to ECEESC and other stakeholders and should clearly communicate uncertainties.

The ECEWGs should ensure that the analytic products and processes meet near-term decisionmaking and long-term institutional needs. Three potential sub-ECEWGs could support this effort. One sub-ECEWG, committed to verification and validation, could meet regularly with planners to do deep dives into the reliability and sensitivity of results. Another sub-ECEWG, committed to strategic relevance and communications, could ensure that the implications and limitations are communicated to multiple stakeholders. Finally, a third sub-ECEWG, committed to analytic infrastructure, could oversee the computational resources and overall data governance.

Process 4: Act

Cost-per-effect findings could be shared at the beginning of subsequent PPBE cycles to promote continuous improvement in defense planning and decisionmaking through cost-per-effect analysis. The ECEWG and defense planners should routinely incorporate the analytic results into the cost-per-effect dashboard, which could prompt the design of an improved dashboard or other visualization tools to present the data and insights that decisionmakers need.

The JECEC should present the ECEESC with results of the cost-per-effect analyses for each of the identified key problems. The ECEESC would then coordinate with service and Joint Staff stakeholders on integrating the analytic results into the next planning phase of the PPBE cycle. The JECEC could also serve as an interface between all parties—the ECEESC, the ECEWGs, and the defense planners—to resolve any outstanding issues or concerns, particularly of an analytic nature.

The ECEWGs and joint and DoD planners should be available to answer technical questions and run excursions to support decisionmakers. The ECEWGs and planners should also seek feedback on how the cost-per-effect results are being used, how they are being challenged, how their presentations should be improved, and how foundational challenges could be incorporated into future iterations of the cost-per-effect toolkit.
Chapter 4. Enterprise Cost-Effectiveness Tabletop Exercise

To prototype and improve on the Plan-Do-Check-Act method discussed in Chapter 3, we conducted a high-level TTX to mirror the proposed analytic and programmatic frameworks for a single mission area. We have found these types of events to be helpful for understanding the potential strengths and weaknesses of a proposed policy prior to its implementation, particularly in cases involving entrenched bureaucratic equities. Our goal was to conduct a first-order walkthrough of the proposed processes with participants who have extensive experience with both the analytic substance of the problem and the bureaucratic incentives of key stakeholders.

For our prototype, we chose the air superiority mission area, contextualized in a common Pacific planning scenario. We selected this core mission because of the central role that air and space superiority plays in defense planning and because of the RAND research team’s subject-matter expertise. Although the TTX was not conducted in enough detail to produce its own rigorous cost-per-effect analysis, we found the TTX to be valuable in identifying the kinds of inputs, processes, and outputs that would be needed for such an analysis to be smoothly produced.

For the air and space superiority TTX, we assembled a small group of former DoD officials with diverse backgrounds, including a former Office of the Secretary of Defense Deputy Assistant Secretary of Defense for Policy, representing joint concept development and warfighter communities; a former service program manager, representing service force provider and acquisition communities; and a former Cost Assessment and Program Evaluation special assistant, representing the joint validation community. The TTX also enlisted an air analyst with over 30 years of wargaming and campaign-modeling experience to conduct an initial survey of the analytic scope and requirements. These officials discussed their likely decisionmaking processes across the four steps of the proposed Plan-Do-Check-Act method.

Prior to the TTX, we asked the air analyst to conduct a very high-level review of the current state of air mission analysis. He scoped the mission area, identified the structure and key functions to include, and surveyed the existing analytic tools. In doing so, he drew on experience with wargaming relevant to the scenario of interest and with campaign analysis relevant to the air superiority mission. Drawing on his experience, he recommended STORM as the most suitable analytic tool, because it combined mission-level modeling with widespread credibility across the joint community. Therefore, we used STORM as the exemplar campaign-level model for existing analyses of air superiority. Our goal was to identify the elements of enterprise cost-

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51 For a similar approach in a different area of defense decisionmaking, see Elizabeth M. Bartels, Jeffrey A. Drezner, and Joel B. Predd, Building a Broader Evidence Base for Defense Acquisition Policymaking, RAND Corporation, RR-A202-1, 2020.
effectiveness that could be missed by current modeling tools as a starting point for deeper exploration.

The need for an enterprise view became clear as we detailed the key campaign elements required for any cost-per-effect analysis of air superiority. Those elements appear in Table 4.1.

**Table 4.1. Key Campaign Elements Required for Analyzing Air Superiority**

<table>
<thead>
<tr>
<th>Increase Number of U.S. Sorties</th>
<th>Increase Effectiveness of U.S. Sorties</th>
<th>Reduce Adversary Sortie Rate/Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fighter inventory</td>
<td>Weapons</td>
<td>Attacks on adversary air bases (e.g., cruise/ballistic missiles, B-21 bombers, loitering weapons)</td>
</tr>
<tr>
<td>Aircraft readiness</td>
<td>ISR and communications</td>
<td>Attacks on adversary tanker orbits</td>
</tr>
<tr>
<td>Sortie rates</td>
<td>Tactics and campaign strategy</td>
<td>Cyberattacks</td>
</tr>
<tr>
<td>Training</td>
<td>Survivability</td>
<td>Reductions of adversary situational awareness (AEW aircraft, OTHR, space surveillance/communications)</td>
</tr>
<tr>
<td>Airbase defense</td>
<td>UAS swarms and teaming</td>
<td></td>
</tr>
<tr>
<td>Airbase resiliency</td>
<td>5th- and 4th-generation fighter teaming</td>
<td></td>
</tr>
<tr>
<td>Airbase dispersal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra support, transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrier ASBM defense</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanker inventory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defense of tanker orbits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyber defense</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: AEW = airborne early warning; ASBM = air-to-surface ballistic missile; OTHR = over-the-horizon radar; UAS = unmanned aircraft system.

We then brought the air analyst’s initial work to the full group, and we asked them to talk through the steps of the Plan-Do-Check-Act method to identify the potential strengths and weaknesses of our proposed approach. This discussion highlighted three key areas that would need to be addressed for the analytic process to be implemented smoothly.

First, TTX participants recommended that a new process should connect the cost-per-effect analysis with enterprise-wide resourcing and procurement. Participants said that the existing PPBE process is poorly suited to the envisioned level of analysis because PPBE is designed to manage mainly individual programs rather than portfolios of investments. At the same time, participants warned that the existing PPBE process would likely still be necessary to inform a variety of other types of decisions, requiring that additional resources be put toward analysis compared with the status quo level of resources. One participant went so far as to describe the proposed analytic framework as needing a “JCIDS [Joint Capabilities Integration and Development System] level of investment” to cover the personnel and other resources needed to make the system work. Key drivers behind the anticipated scale of the required investment...
included the need to consider a wide variety of scenarios with uncertain prioritization levels and the need to define the values of alternative systems across all mission areas to support joint prioritization. If such values were not defined, it would be trivially easy for proponents of alternative systems to flag the analytic gaps—in defense of their own alternatives. For example, proponents of a multi-mission system like the F-35 could argue that unless the versatility of their system were considered by valuing it across all relevant missions, the results of any mission-specific analysis would underrate the system’s value. Likewise, stakeholders with a vested interest in a particular outcome could opt to make analytic scoping decisions that would be designed to produce results that would support their preferred outcome. Consequently, it is critical that stakeholders use a common approach in process 3 (check) to ensure that apples-to-apples comparisons are being made.

Second, the TTX indicated that current modeling tools tend to be stronger at mission-level than campaign-level representations. Strong kinetic mission-level modeling and extensive cost modeling are available, but their limited abilities to represent human factors constrain most existing models. Significantly, defense analysts currently face an acute difficulty in modeling war strategies that account for training and learning, which are highly pertinent for campaigns. In addition, the existing models often offer very little consideration of strategic, and particularly political, dynamics, which are key to understanding the ultimate effects of campaigns. As a result, the greatest challenge when adopting a broader enterprise view to cost-effectiveness analysis may be that it will be difficult “agreeing on a measurable [campaign] effect—no joint room will be able to agree on the basis for the analysis,” according to TTX participants. Rather, the joint room will ultimately “need to just make some assumptions and then just execute.”

That statement leads to the third key takeaway from the TTX: Cost-per-effect analysis is a process rather than an end point. In the words of one participant, “Cost-per-effect will fail at some level—can’t trade off industrial base, with having an army, with freedom of information.” In other words, the scope and diversity of the defense problem set is so vast and the values of its effects so dependent on the judgments of individual decisionmakers that defense analysts will likely fall short of the analytic goal for some considerable time to come. At the same time, participants stressed that cost-per-effect analysis does not need to reach its full maturation to offer valuable improvements to decisionmakers today. Participants suggested that defense analysts adopt a crawl-walk-run approach of “providing better analytic support to senior leaders” to avoid the imponderably vast array of potential trade-offs that could be influenced by partially subjective judgments of national security priorities across the full range of military operations. Regardless of the quality of analysis, “fundamental choices about what is important to the nation have to be made by decisionmakers”; participants also stated that they did not want a “machine that makes those decisions.” There remains a preference for “more people thinking about the problem.”
Chapter 5. Findings, Recommendations, and Next Steps

In this chapter, we summarize the findings, recommendations, and proposed next steps for cost-per-effect analysis (or enterprise cost-effectiveness analysis), as discussed in the previous chapters. We wrap up this exploratory analysis by bringing together subject-matter expertise and our findings from the literature analysis and the TTX to synthesize several key insights. In the context of Air Force planning, the analytic recommendations and proposed next steps would be driven primarily by the Department of the Air Force (DAF), whereas the programmatic recommendations would apply primarily to DoD because of their joint implications.

Findings

- Key elements of a cost-per-effect measure that can meaningfully inform decisionmaking are being developed. This progress is being driven by rapid improvements in practical computational scale, data analytics, artificial intelligence, and machine learning, creating the capacity for potential new forms of analysis.
- The analytic complexity of defense planning has posed recurring challenges to such progress. Some of the challenges are accounting for strategic interaction (of adversaries); resolving principal-agent problems (of large organizations); and defining effect, because victory can be achieved through a range of mechanisms, including destruction, annihilation, dislocation, exhaustion, disruption, disintegration, preemption, isolation, circumvention, forestallment, compellence, impellence, and deterrence.
- To move from cost-effectiveness to cost-per-effect (or enterprise cost-effectiveness), it will be necessary to create an accurate joint warfighting model that can capture the interdependent effects of different weapon systems. Cost-per-effect analysis will require a joint perspective to be able to assess the effects at the campaign and strategic levels.
- Cost-per-effect processes, methodologies, and findings must be intelligible and traceable. Accurate results alone may not be enough to influence decisionmakers without also providing a traceability that is readily understandable. Beyond correct answers, dashboards or other tools that provide clear and concise findings and traceable analyses to decisionmakers will be invaluable.
- The goal of cost-per-effect analysis, as envisioned in the 2020 Mitchell Institute policy paper, is aspirational yet achievable, because cost-per-effect analysis is—and will continue to be for a considerable time to come—a process rather than an end point.

Recommendations

- The DAF should develop an analytic framework for measuring cost-per-effect. This framework would consist of five interrelated measurements: effects, costs, campaigns, trade-offs, and optimization.
- DoD should develop a programmatic framework of processes for implementing cost-per-effect. The processes would need to be joint in nature. They could include an ECEESC
(led by a DoD Deputy Secretary of Defense) and various ECEWGs across the services and joint forces. The processes would follow the Plan-Do-Check-Act approach:

- **Plan.** Identify DoD/joint problem areas for analysis, based on national, operational, and support objectives.
- **Do.** Draft a concept package for achieving enterprise cost-effectiveness in each problem area. Within each package, outline the goals, capabilities, organizations, CONOPs, and metrics. Develop the supporting analytic capabilities.
- **Check.** Establish an infrastructure for collecting, storing, and governing the analytic data. Establish a hierarchy of confidence levels for the analytic outputs.
- **Act.** Include the cost-per-effect results in the PPBE cycle. Planners should adopt a continuous cycle of cost-per-effect improvement.

- The DAF should develop trade-off and optimization tools, including associated dashboards, based on cost-per-effect analysis.
- The DAF should consider adopting the term *enterprise cost-effectiveness* because it emphasizes expanding current cost-effectiveness best practices to an enterprise or joint level rather than devising an entirely new approach.

**Next Steps**

To initiate the crawl-walk-run approach discussed at the TTX, we propose a set of next steps for the DAF to conduct an enterprise cost-effectiveness analysis of the air superiority core mission enterprise. We also offer a baseline assessment of the proposed analytic tools and data sources available for assessing costs and effects. We are certain the specifics of both the next steps and the baseline assessment will need to evolve as the exploratory process continues.

Regarding next steps, we suggest that the DAF refine the cost-per-effect methodology by selecting one of the eight National Defense Strategy key mission challenges and considering the role of air superiority in addressing that challenge. This process of refinement should follow five steps that would align with the five metrics in our proposed analytic framework (shown in Figure 3.1):

1. **Effects.** Use STORM to model the air superiority campaign effects, with subject-matter expert analysis focused on the campaign elements that are not readily modeled.
2. **Costs.** Use the Defense Acquisition Management Information Retrieval (DAMIR) database to provide cost estimates for RDT&E and procurement, and use the Air Force Total Ownership Cost (AFTOC) database to provide cost estimates for O&S. In both cases, use appropriate cost-estimating relationships for new design systems.
3. **Campaigns.** Integrate scenarios from across the defense analytic agenda, as represented in joint data support (JDS), to inform exploration of the trade space.
4. **Trade-offs.** Develop analytic tools and dashboards to support decisionmaking for individual trade-offs.
5. **Optimization.** Develop further analytic tools and dashboards to support defense planning across many potential force structures.
Figure 5.1 depicts this approach by updating Figure 3.1 with air superiority–specific inputs from the TTX. The solid green gears with white checks in Figure 5.1 indicate that tools and data for that step already exist and are generally of acceptable quality. The hollow red gears indicate where significant future development is needed. As the figure shows, future efforts should focus on steps 4 and 5: developing the tools, dashboards, and infrastructure to make trade-offs among a small set of capabilities; and comparing across all possible force structures to optimize enterprise cost-effectiveness. Future iterations could build on these techniques to develop more complex optimization tools.

Figure 5.1. Initial Assessment of Existing Tools and Data

Regarding the baseline assessment, Figure 5.2 rates the current suitability and accuracy of the proposed tools and data sources for measuring costs and effects across the relevant parameters. This baseline offers analysts a starting point for selecting models and data sources. The baseline also highlights areas for further development. Solid green stars indicate that, in the assessment of subject-matter experts at the TTX, these models and data sources are well defined and can provide reliable results “as is.” Partially filled yellow stars indicate that our subject-matter experts believe it is possible to use these existing data and models but care should be taken. In these cases, analyst judgment and skill will be necessary to ensure that the relevant questions are being correctly answered. Finally, hollow red stars indicate areas in which the current data and
models are lacking. In these cases, either new tools will need to be developed or analysts will need to decide if the lack of existing tools would not be detrimental enough to produce inaccurate findings.

Figure 5.2. Baseline Assessment of Existing Tools and Data for Measuring Costs and Effects

<table>
<thead>
<tr>
<th>Cost: Acquisition Structure (DAMIR)</th>
<th>Effect: Air Superiority (STORM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>★ Development</td>
<td>★ Aircraft ready rates</td>
</tr>
<tr>
<td>★ MILCON</td>
<td>★ Training</td>
</tr>
<tr>
<td>★ Procurement</td>
<td>★ Airbase resiliency</td>
</tr>
<tr>
<td>★ Classified programs</td>
<td>★ Carrier ASBM defense</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost: O&amp;S Structure (AFTOC)</th>
<th>Increasing Number of Blue Sorties</th>
</tr>
</thead>
<tbody>
<tr>
<td>★ Unit-Level Manpower</td>
<td>★ Fighter inventory/deployment</td>
</tr>
<tr>
<td>★ Operations</td>
<td>★ Surge/sustainable sortie rate</td>
</tr>
<tr>
<td>★ Unit-level maintenance</td>
<td>★ Airbase defense</td>
</tr>
<tr>
<td>★ Other unit-level manpower</td>
<td>★ Airbase dispersal</td>
</tr>
<tr>
<td>★ Energy (fuel, electricity, etc.)</td>
<td>★ Tanker inventory/deployment</td>
</tr>
<tr>
<td>★ Support services</td>
<td>★ Cyber defense</td>
</tr>
<tr>
<td>★ Training munitions</td>
<td></td>
</tr>
<tr>
<td>★ Temporary duty travel</td>
<td></td>
</tr>
<tr>
<td>★ Second destination transportation</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Increasing Effectiveness of Blue Sorties</th>
</tr>
</thead>
<tbody>
<tr>
<td>★ Consumables</td>
<td>★ Weapons</td>
</tr>
<tr>
<td>★ Intermediate maintenance</td>
<td>★ ISR/comms - on/offboard</td>
</tr>
<tr>
<td>★ Depot level repairables</td>
<td>★ Tactics and campaign strategy</td>
</tr>
<tr>
<td>★ Depot maintenance</td>
<td>★ Survivability</td>
</tr>
<tr>
<td></td>
<td>★ 5th.-4th. gen teaming</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Sustaining Support</th>
<th>Reducing Number of Red Sorties</th>
</tr>
</thead>
<tbody>
<tr>
<td>★ System-specific training</td>
<td>★ Attack Red air bases</td>
</tr>
<tr>
<td>★ Sustaining/systems engineering</td>
<td>★ Attack Red tanker orbits</td>
</tr>
<tr>
<td>★ Support equipment repair</td>
<td>★ Cyber attack</td>
</tr>
<tr>
<td>★ Program management</td>
<td>★ Attack Red SA</td>
</tr>
<tr>
<td>★ Data and technical publications</td>
<td>★ Attack Red SA</td>
</tr>
<tr>
<td>★ Simulator operations</td>
<td>★ Attack Red SA</td>
</tr>
<tr>
<td>★ Other sustaining support</td>
<td>★ Attack Red SA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continuing System Improvements</th>
<th>Increasing Green Survival/Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>★ Hardware modifications</td>
<td>★ More/improved SAMs</td>
</tr>
<tr>
<td>★ Software maintenance</td>
<td>★ SAM survivability</td>
</tr>
<tr>
<td></td>
<td>★ Airbase survivability</td>
</tr>
<tr>
<td></td>
<td>★ Interoperate with Blue</td>
</tr>
</tbody>
</table>

NOTE: In common wargaming parlance, Blue refers to U.S. forces, Red to adversary forces, and green to partner-nation forces. ATO = air tasking order; C2 = command and control; comms = communications; SA = situational awareness; SAM = surface-to-air missile.

Figure 5.2 also suggests numerous categories of effects (e.g., increased number of Blue sorties and reduced number of Red sorties), all of which could contribute to a broader effect. To simplify joint enterprise-level comparisons, it would be useful to distill these categories of effects into a single measure. We propose using STORM to model the campaign until one side is (analytically) annihilated, and the military effect could be measured as the difference in surviving force values. This measure would be positive when Blue ends the campaign with a larger surviving force and negative when Red ends with a larger surviving force. Although this approach would not directly trace to all the possible defeat mechanisms discussed earlier, it would provide a reasonable measure of the overall force strength and of the contribution of some defeat mechanisms.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AFTOC</td>
<td>Air Force Total Ownership Cost</td>
</tr>
<tr>
<td>AoA</td>
<td>analysis of alternatives</td>
</tr>
<tr>
<td>CAMPLAN</td>
<td>campaign plan</td>
</tr>
<tr>
<td>CONOP</td>
<td>concept of operation</td>
</tr>
<tr>
<td>CONPLAN</td>
<td>concept plan</td>
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<tr>
<td>DAF</td>
<td>Department of the Air Force</td>
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<tr>
<td>DAMIR</td>
<td>Defense Acquisition Management Information Retrieval</td>
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<tr>
<td>DARPA ACK</td>
<td>Defense Advanced Research Project Agency Adapting Cross-Domain Kill-Webs</td>
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<tr>
<td>DoD</td>
<td>U.S. Department of Defense</td>
</tr>
<tr>
<td>DPS</td>
<td>defense planning scenario</td>
</tr>
<tr>
<td>ECEESC</td>
<td>Enterprise Cost-Effectiveness Executive Steering Committee</td>
</tr>
<tr>
<td>ECEWG</td>
<td>Enterprise Cost-Effectiveness Working Group</td>
</tr>
<tr>
<td>FY</td>
<td>fiscal year</td>
</tr>
<tr>
<td>ISR</td>
<td>intelligence, surveillance, and reconnaissance</td>
</tr>
<tr>
<td>JDS</td>
<td>joint data support</td>
</tr>
<tr>
<td>JECEC</td>
<td>Joint Enterprise Cost-Effectiveness Council</td>
</tr>
<tr>
<td>O&amp;S</td>
<td>operations and support</td>
</tr>
<tr>
<td>OPLAN</td>
<td>operational plan</td>
</tr>
<tr>
<td>PPBE</td>
<td>Planning, Programming, Budgeting, and Execution</td>
</tr>
<tr>
<td>RDT&amp;E</td>
<td>research, development, test, and evaluation</td>
</tr>
<tr>
<td>STORM</td>
<td>Synthetic Theater Operations Research Model</td>
</tr>
<tr>
<td>TTP</td>
<td>tactics, techniques, and procedures</td>
</tr>
<tr>
<td>TTX</td>
<td>tabletop exercise</td>
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</tbody>
</table>
References


Blume, Susanna, “Senate Armed Services Committee Advance Policy Questions for Ms. Susanna Blume, Nominee to be Director, Cost Assessment and Program Evaluation,” responses, undated.


DoD—See U.S. Department of Defense.


Lean Enterprise Institute, “Plan, Do, Check, Act (PDCA),” webpage, undated. As of October 1, 2021:
https://www.lean.org/lexicon-terms/pdca/

https://www.rand.org/pubs/monograph_reports/MR1626.html


https://www.rand.org/pubs/research_reports/RR2477.html


Paul, Christopher, Yuna Huh Wong, and Elizabeth M. Bartels, Opportunities for Including the Information Environment in U.S. Marine Corps Wargames, RAND Corporation, RR-2997-USMC, 2020. As of October 1, 2021:
https://www.rand.org/pubs/research_reports/RR2997.html

Pickering, Craig, “P-Hacking, HARKing, and Science’s Replication Crisis,” SimpliFaster blog, undated. As of December 21, 2021:
https://simplifaster.com/articles/p-hacking-harking-scientific-replication/


https://www.rand.org/pubs/monograph_reports/MR300.html


U.S. Department of Defense, DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A), DoD Instruction 5000.61, October 15, 2018.


Cost-per-effect analysis aims to improve decisionmaking through an enterprise-wide approach to cost-effectiveness. Such an approach would allow decisionmakers to compare alternatives not just within a single mission area or facet but also across an entire enterprise.

Promising advancements in defense planning will most likely be realized through deliberate and incremental improvements in current cost-effectiveness techniques. Cost-per-effect is cost-effectiveness with a broader, or joint, focus that supports higher-level decisionmaking.

The authors show how the Department of the Air Force (DAF) can begin to implement cost-per-effect analysis by following the analytic framework for measuring cost-per-effect proposed in this report. This framework consists of five interrelated measurements: effects, costs, campaigns, trade-offs, and optimization. The authors also show how the DAF, with its joint partners, could follow the programmatic framework of processes, proposed in this report, for implementing enterprise cost-effectiveness analysis. These processes adopt the Plan-Do-Check-Act approach to incorporate continuous improvement.

Drawing from subject-matter expertise and findings from the literature analysis and a tabletop exercise, the authors highlight several key insights about the ongoing defense analytic problem and its enduring challenges, including the analytic complexity of defense planning, the analytic complexity of cost estimation, the analytic complexity of effectiveness estimation, and the limitations of modeling and analysis. They conclude by offering next steps to contribute to discussions about possibly implementing cost-per-effect analysis into defense planning and improving the defense planning process.