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Toward Affordable Systems III

Portfolio Management for Army Engineering and Manufacturing Development Programs

Brian G. Chow, Richard Silberglitt, Caroline Reilly,
Scott Hiromoto, Christina Panis

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4570 Fifth Avenue, Suite 600, Pittsburgh, PA 15213-2665
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Summary

The U.S. Budget Control Act passed on August 2, 2011, marked a new era of austerity in the nation's budgetary environment. The changes appear to be indefinite and present the Army and the rest of the U.S. Department of Defense (DoD) with unprecedented fiscal challenges. No DoD domain will likely remain untouched, including acquisitions. Yet the U.S. Army's need for mission-capable weapon systems will remain constant. As a result, the Army will need to find ways to ensure that its scientists and engineers are designing both effective *and* affordable systems in this frugal environment.

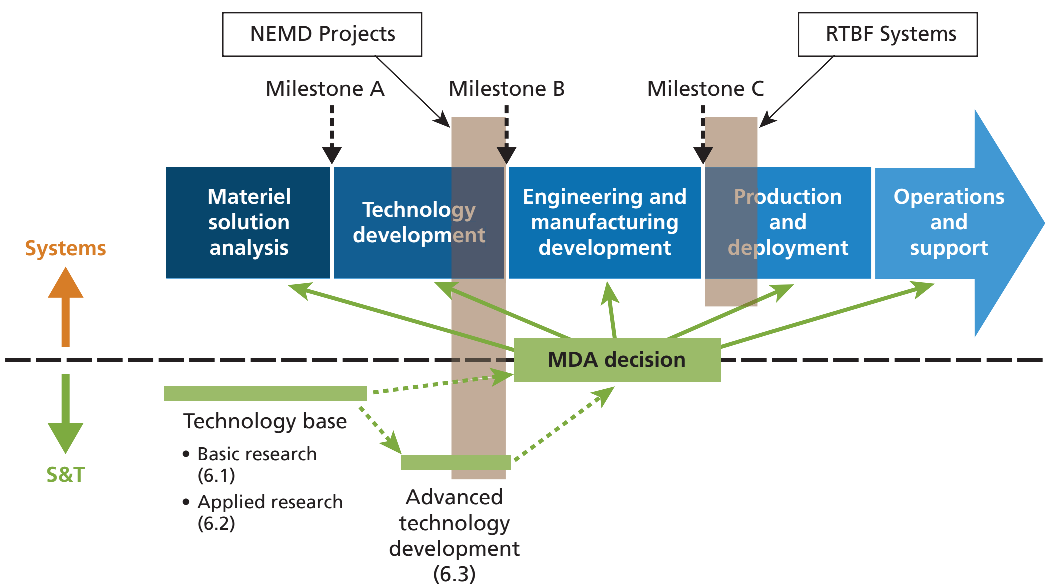
The 2011 legislation brought added urgency to what had already been a growing premium within DoD: reaping savings through improved efficiency and cost-effectiveness. In 2009, the establishment by Congress of a DoD cost czar to conduct independent cost assessments of new major weapon systems was a portent of this trend. Now, meeting these DoD-wide objectives has become critical. In 2006, Deputy Secretary of Defense Gordon England issued a memorandum requesting that DoD agencies experiment with capability portfolio management for planning and implementing capability development. In a 2008 directive, he formalized his call for experimentation via a mandate that all DoD agencies use capability portfolio management to optimize capability investments and minimize risk in meeting the DoD needs across the defense enterprise.

With these needs and guidance in mind, since 2006, the RAND Corporation has been developing a methodology for selecting and managing portfolios of Army research and development (R&D) projects. Sponsored by the U.S. Army Deputy Assistant Secretary for Cost and Economics, this multiyear work was designed to produce a process for the Army to identify optimal investments in cost-effective, affordable weapon systems. RAND's portfolio analysis and management (PortMan) method and model are the results. RAND has focused each phase of this work not only on developing and refining the methodology, but also on demonstrating PortMan using various portfolios of projects at different developmental stages, so that Army decisionmakers can see it in action at different stages and gain a tangible sense of its value.

RAND's Latest Work on PortMan Focuses on R&D Projects in the Engineering and Manufacturing Development (EMD) Stage

The defense acquisitions process comprises many stages (see Figure S.1). The earliest of these run in parallel with science and technology (S&T) research. RAND's initial work on PortMan focused on optimizing portfolios in those earliest S&T stages: Companion monographs published in 2009 and 2011 offer demonstrations of PortMan on the Army's highest priority S&T projects, Army Technology Objectives. Yet PortMan can be used equally for portfolios of projects further along the acquisitions pipeline. Most recently, the RAND team turned to analyzing portfolios of projects in, and near, the EMD stage. As Figure S.1 shows, there are narrow windows just before and after EMD populated by near–engineering and manufacturing development (NEMD) projects (i.e., those that are almost ready to enter EMD) and ready-to-be-fielded (RTBF) systems (i.e., finished with EMD, but not yet in full production and deployment). For reasons related to performance and cost-effectiveness, when a planner is prepared to select investments, both NEMD projects and RTBF systems should be considered because they may be profitably substituted for EMD projects. Accordingly, including them in an analysis alongside EMD projects can help optimize EMD portfolios. We refer here

Figure S.1
Stages of the Defense Acquisition Process, with Related S&T Stages



SOURCE: Simplified graph from Bradford Brown, *Operation of the Defense Acquisition System, Statutory and Regulatory Changes*, Kettering, Ohio: Defense Acquisition University, December 8, 2008.
NOTE: MDA = Milestone Decision Authority.
RAND *MG1187-S.1*

to portfolios that include all three groups (N/EMD) as portfolios of EMD projects plus those near EMD's front end (NEMD) and EMD's back end (RTBF).

Together, RAND's two previous PortMan studies and the one we are documenting here provide a comprehensive method and model to analyze portfolios covering all R&D projects and systems up to full production and deployment.

PortMan Facilitates a New Mindset in Acquisitions Management

The particular challenges the Army faces in selecting projects that will meet future capability needs at an affordable overall cost are not new. Uncertainty has always compounded decisionmaking—uncertainty, for example, about whether all funded projects will succeed, what budgets will be available, and whether changes in the economic or strategic environment will force the Army to alter capability requirements. It is also difficult to think in terms of the "big picture" regarding the full lifecycle costs of fielding a system—from basic research all the way through operations and support—rather than the unique costs of one particular acquisitions stage.

Yet in portfolio analysis, it is important not only to consider the range of uncertainties and full lifecycle costs but also to bring these factors consistently into the evaluation process. Failing to do so can lead to dramatically different, often inferior, investment selections and outcomes—for example, if the result is a false impression of how well a given portfolio fills capability gaps.[2] Today's severe budget constraints also make it advisable to be able to distinguish between threshold ("must have") and objective "desirable" requirements in deciding the extent to fill each gap.

The newest version of PortMan provides a means for the Army's portfolio managers to perform these analyses and more. In the current demonstration with N/EMD portfolios, RAND has designed the process to allow for the possibility that there will be overruns in implementation costs and also that the implementation budget may be less than requested or desirable. With this feature, a manager can identify the best possible portfolio under such uncertainties. RAND has also introduced the concept of *threshold* (must-have) and *objective* (desirable) requirements, rather than a single fixed set of requirements. This feature permits the portfolio manager to measure the costs of aiming to fill all gaps against filling just the essential ones. Managers can also see the variety of anticipated costs when must-have requirements are set at different levels. This allows managers to see the trade-offs between level of requirements met and budget required.

At the same time, this latest version of PortMan retains the key features of previous versions, such as the ability to break out components of the total lifecycle budget

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2 Portfolios of S&T projects meet all capability gaps when the projects have a 100 percent success rate. But they have a very low probability of doing so when uncertainty about whether projects would succeed is taken into account.

and show what percentage of capability gaps can be filled with these component budgets set at various levels. In this way, Army leadership can optimally apportion the total lifecycle budget between costs for R&D and implementation, for example, rather than allocating R&D funds separately on a suboptimal use-it-or-lose-it basis.

Being able to think in terms of overall costs, setting priorities between must-have and desirable capabilities, and bringing uncertainty into the mix can all contribute to a new mindset that would help the Army fulfill the DoD's desire for savings from improved efficiency and effectiveness in a future that realistically will be rife with unknowns.

Demonstrating PortMan on N/EMD Portfolios Highlights How It Can Assist Army Acquisition Managers

Using a linear programming model together with a simulation, PortMan aids in carrying out two fundamental acquisitions planning tasks:

- **Setting optimal budgets:** In our demonstration, we ask "What is the optimal remaining R&D budget, and the optimal total remaining lifecycle (TRLC) budget for ongoing N/EMD projects?"
- **Selecting an optimal N/EMD portfolio for any set of budgets:** Here we ask "Which N/EMD projects should be terminated, and which continued for any given R&D and lifecycle budgets—including a budget cut?"

To generate the answers to these questions, PortMan also must be able to calculate how well a given portfolio will be able to fill gaps in the Army's current capabilities. One can think of this in terms of a third task: mapping supply (i.e., a particular portfolio) to demand (i.e., given requirements).

Mapping Supply and Demand

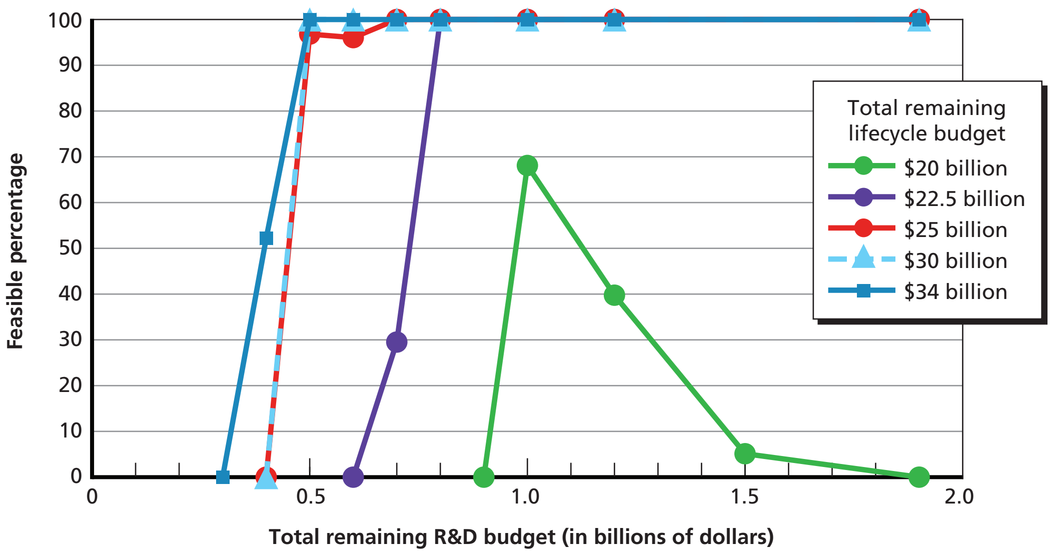
PortMan can evaluate the overall performance of a portfolio of N/EMD projects (the supply) and broadly expose potential problem areas—that is, which requirements (or areas of demand) are at risk of not being met by that particular portfolio. Similarly, PortMan can identify where certain requirements will be met by too many projects, leading to unnecessary redundancies and certain requirements actually being over-met. One can also refer to the results of such an evaluation as the portfolio's "expected value." Because the success of N/EMD projects—that is, whether ultimately they will lead to a fielded system—is uncertain, one must deal with probabilities in assessing their performance. The PortMan concept of *feasible percentage* is a way of managing this inherent uncertainty. *Feasible percentage* indicates the degree of likelihood that a particular portfolio of N/EMD projects within a given budget will meet a set of predefined requirements, including a calculation for the possibility that some projects in the portfolio will ultimately lead to systems with a much higher unit cost than originally expected.

Setting Optimal Budgets

In our current demonstration, PortMan applies the ability to calculate how well the supply matches the demand to estimating the expected values of various portfolios when budgets are set at different levels. In this way, PortMan can enable portfolio managers to see which budgets will generate a cost-effective portfolio that meets an acceptable level of requirements. It can also help them identify cut-off points below which it would become imprudent to let a budget fall because the chance of meeting requirements would drop to an uncomfortably low level.

Known-Budget Case. Figure S.2 provides an illustration of expected values. Here the N/EMD demonstration draws on PortMan's ability to break out components of the total lifecycle budget. For the purposes of the demonstration, we excluded the costs that had already been spent on projects at the time of the analysis—i.e., the sunk costs—and looked specifically at the costs still to be incurred: the total *remaining* lifecycle budget. This total cost includes (1) the remaining R&D cost (the amount required to finish developing a system) and (2) the implementation cost (the cost of acquiring, fielding, operating, and maintaining a system over its lifetime).[3] The Port-

Figure S.2
Likelihood of Meeting Threshold Requirements Within a TRLC Budget for N/EMD Systems



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3 Here this lifetime is assumed to be 20 years.

Man analysis discloses all three budgets, so that managers can see the trade-offs in setting each of them at different levels.

The demonstration takes five different TRLC budgets and shows (on the y-axis) what percentage of a set of threshold requirements each of those budgets can meet.[4] At the same time, it shows the effects of varying the remaining R&D budget *within* a given TRLC budget. This sort of output can be particularly helpful to portfolio managers in that it reveals a "sweet spot" at which the TRLC and R&D budgets are both at the most cost-effective levels. A closer look at Figure S.2 shows how this plays out—and reveals the degree of influence of the R&D budget amount. As long as the R&D budget remains above a certain amount (here $0.8 billion), there is no difference between setting the TRLC budget at $34 billion, $30 billion, $25 billion, or $22.5 billion: All four alternatives make it fully feasible for the Army to meet all threshold requirements.[5] But even subtle variations in the R&D budget can make a huge difference. For example, when the total lifecycle budget is $22.5 billion, lowering the R&D budget by just $0.1 billion—from $0.8 to $0.7 billion—has dramatic effects, with the probability of meeting requirements plummeting from almost 100 percent to just 30 percent.

In contrast, a total lifecycle budget of $25 billion is more robust to reductions in the total remaining research and development (TRRD) budget. At $0.7 billion for R&D rather than $0.8 billion, the probability of satisfying must-have requirements remains very close to 100 percent. In fact, the R&D budget can fall as low as $0.5 billion with minimal consequences, as the probability of meeting requirements stays above 95 percent. Accordingly, the sweet spot for ongoing N/EMD projects is a TRLC budget of $25 billion and a TRRD budget of $0.7 billion. The sweet spot is the most cost-effective budget with which most of the ongoing projects will be funded. It also suggests that certain projects should be terminated, because the money saved from not funding them can be more cost-effectively spent on new projects.

Because the sweet spot should not be set too close to a point at which the probability of meeting requirements drops off starkly, going lower than $0.7 for R&D is inadvisable. This provides a hedge for unexpected budget contingencies: If, for some reason, it turns out that the R&D budget needs to drop within a window of up to $0.2 billion, the Army's ability to meet requirements will still remain quite strong. Once

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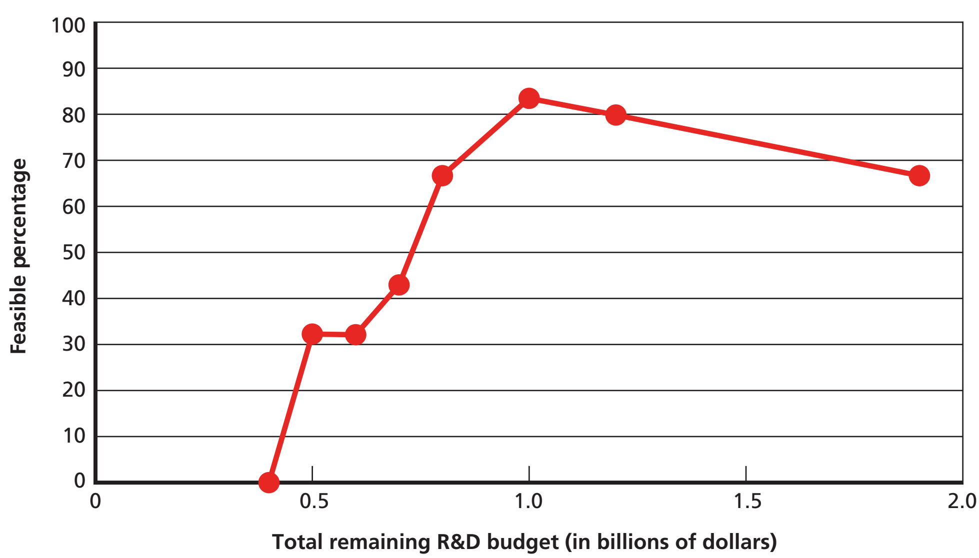
4 A graph that showed the results for objective requirements—that is, the complete set of gaps the Army would ideally like to fill—would likely look very different. For our demonstration, we used capability gaps defined by the Army Training and Doctrine Command's/Capabilities Integration Center as the basis for threshold and objective requirements.

5 This is most likely because there is enough redundancy between certain projects in these portfolios to overfill capability gaps at all of these budget levels. In addition, recall that the remaining lifecycle budget consists of both the remaining R&D budget and the implementation budget. We assume here in the demonstration that money saved from the total remaining R&D budget will be reapportioned to the total implementation budget, rather than approached from the wasteful use-it-or-lose-it perspective.

PortMan has identified the optimal remaining R&D budget of $0.7 billion, the Army will know that it should plan on needing a total of $24.3 billion to cover the implementation costs of this N/EMD portfolio.[6] In other words, a sweet spot is the budget with which most of the ongoing projects will be funded, suggesting that the money saved from not funding projects that are recommended to be terminated can be more cost-effectively spent on new projects.

Uncertain-Budget Case. In a second illustration, Figure S.3 shows the results for a situation in which portfolio managers do not know how much a given budget will be. Here we designate the TRLC budget as the uncertain one. We create a case in the demonstration where this overall budget is equally likely to be $20, $22.5, or $25 billion, but planners cannot know which it will actually turn out to be. We assume that the source of this uncertainty in the overall lifecycle budget is due to uncertainty in how much will be available for the total implementation budget. The results that PortMan generates show portfolio managers why they should not underestimate what will be needed to cover implementation costs, as this is a decisive factor in meeting requirements successfully. Managers should, without question, consider implementation costs when they select which N/EMD projects to keep and which to terminate.

Figure S.3
Likelihood of Meeting Threshold Requirements with an Uncertain TRLC Budget ($20 Billion to $22.5 Billion to $25 Billion Range)



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[6] This is because the balance of the total remaining *lifecycle* budget of $25 billion—after apportioning the needed total remaining *R&D* budget of $0.7 billion—is the total *implementation* budget of $24.3 billion.

Under these uncertain conditions, PortMan takes a number of different TRRD budgets and for each and calculates the maximum possible probability that that budget will be able to produce an N/EMD portfolio that will satisfy threshold requirements. Within this demonstration group, PortMan indicates that the best option is the TRRD budget of $1 billion: It gives the Army an 83 percent chance of satisfying must-have requirements. Figure S.3 makes it easy to see that $1 billion constitutes a low-end cut-off point for R&D when the TRLC budget is in this uncertainty range. With any smaller amount, the probability of meeting requirements falls drastically—down by 20 percent even for a relatively small cut of about $0.2 billion. Unlike in the certain budget case, it is not possible to build in a cushion here—staying away from the cliff—because PortMan indicates that a larger R&D budget adds no value in terms of meeting requirements.[7] In fact, Figure S.3 shows that the maximum possible probability of meeting requirements is actually *lower* when the R&D budget exceeds $1 billion.[8]

Our demonstration shows just how much of a difference the presence of uncertainty can make in portfolio planning. Here an uncertain TRLC budget leads to a considerable discrepancy in projected outcomes: The optimal $1 billion R&D budget under heightened uncertainty is *43 percent larger* than the sweet-spot R&D budget of $0.7 billion that PortMan identifies as optimal when the TRLC budget is certain. In brief, PortMan suggests that should portfolio managers face the level of uncertainty specified in our demonstration, they should allocate 43 percent more money for R&D costs. Coping with some uncertainty is nearly unavoidable in planning. Budget cuts, for example—expected or unexpected, for any part of the acquisitions process—are always a possibility. But PortMan can help portfolio managers to handle such uncertainty effectively.

Selecting an Optimal Portfolio

Within these optimal budgets, PortMan can then recommend which projects to keep in a portfolio and which to drop in order to keep the chances of meeting requirements as high as possible. Countless different portfolios of N/EMD projects are, of course, possible for each combination of remaining lifecycle, R&D, and implementation budgets; various portfolios may perform better or worse. PortMan again draws on its ability to match supply with demand, but now builds in budget as an additional factor: It uses an algorithm that automatically searches for the best combinations of N/EMD projects meeting any given set of budget constraints. The projects that

7 For a given total lifecycle budget, a larger R&D budget will result in less money for implementation.

8 In Figure S.3, we have assumed that the resources saved by not increasing the R&D budget are diverted instead to the implementation budget.

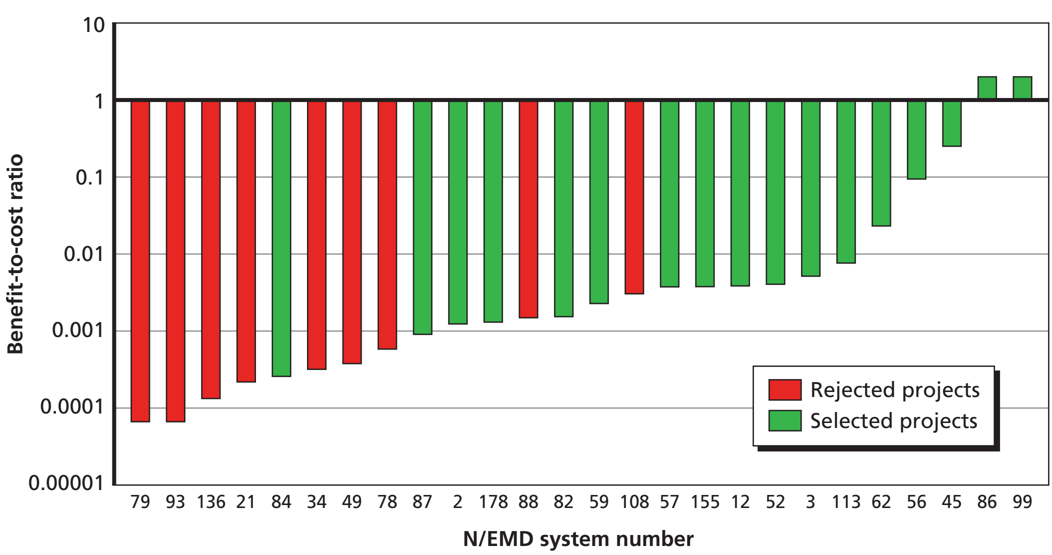
PortMan selects for continuation are those that will produce systems that will provide the highest chance of meeting all capability requirements under a given budget.

Recommended N/EMD Portfolio with a Known Budget

To demonstrate, we take the sweet spot of certain budgets from our analysis: $25 billion for lifecycle costs and $0.7 billion for R&D costs. We also again use the threshold requirements. Within these budget constraints, the model points to 17 of the existing 26 N/EMD projects to keep (i.e., those in green) and recommends that the other 9 projects be terminated (i.e., those in red) (see Figure S.4).

The PortMan selection contains some choices that appear on first glance counterintuitive. For example, PortMan flags N/EMD project 84 for continuation, even though its ratio of benefits to R&D cost is similar to many other projects that are rejected. This means that project 84 is contributing to the ability to meet requirements in some important way that other projects are not—and its higher R&D costs are consequently an acceptable trade-off. In contrast, N/EMD project 108 has a benefit-to-cost ratio well within the range of many other projects that are selected. But PortMan nevertheless recommends that it be discontinued. This could be because the system(s) to which it will lead will be redundant with systems generated by other projects, causing certain requirements to be overmet. Or it simply may not contribute to the Army's

Figure S.4
PortMan's Selection of N/EMD Projects with a Known Budget



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ability to satisfy must-have requirements in a significant enough way to warrant continuing it. PortMan flags projects with less value-added in a readily evident way, so that planners can choose the most effective portfolio for the cost.

Our demonstration shows that this kind of analysis—and the portfolio recommendations it produces—is not something that can be replicated by using simple approaches to project selection, such as rank-ordering N/EMD projects according to a basic ratio of total expected benefits to remaining R&D cost. Using the sort of traditional benefit-to-cost-ratio approach rather than the PortMan model would lead to a very different selection. It would first pick the N/EMD project with the highest benefit-to-R&D cost ratio (i.e., the project on the far right in Figure S.4). It would then flag the project with the next highest ratio, and so on, until the TRRD budget was fully committed. But this selection would be suboptimal, resulting in a lower likelihood that the Army would meet all threshold requirements than that possible with the projects in PortMan's recommended portfolio. The extent of sub-optimality depends on the combination of TRRD budget and the TRLC budget. Chapter Four shows three cases where the traditional approach's "optimal" portfolios yield either a 28 percent likelihood to meet all threshold requirements or no likelihood at all, while PortMan's portfolios yield 100 percent, 68 percent, and 40 percent, respectively. These are the results because PortMan's linear programming model and simulation are able to weigh simultaneously the complex interplay of requirements, system capabilities, costs, and uncertainty in a way that no simple criterion or set of criteria can reproduce.

The common use of benefit/cost ratio is not the only problem. We also study the problem of ignoring uncertainties, which PortMan considers. A "certainty model" can use linear programming to address the aforementioned benefit/cost problem. However, for each of its inputs, it would typically use only a single, expected number to approximate a future that is full of uncertainties. Chapter Four shows two of the three cases where a certainty model would produce inferior "optimal" portfolios that mildly lower the likelihood to meet all threshold requirements to 56 percent (from PortMan's 68 percent) and severely to 0 percent (from PortMan's 40 percent). Worse yet, it is not possible to use the certainty model only in the mildly sub-optimal cases because, without PortMan, one cannot tell in advance which cases would yield only mild sub-optimality.

In sum, PortMan finds a portfolio that has a better chance to meet all threshold requirements than those found by models of benefit-cost type and certainty type for any given budget.

PortMan Offers Army Acquisition Managers a Useful Tool to Balance Effectiveness with Affordability

Today, ensuring that R&D portfolios achieve an optimal balance of effectiveness and affordability in all stages of the defense acquisitions process is essential. RAND's Port-

Man method and model provide novel capabilities that can help the Army fulfill this mission. PortMan offers means to consistently take into account inevitable uncertainties about budgets, the costs of systems, and the performance of projects. Acquisitions managers gain more-realistic assessments of a portfolio's ability to meet requirements and are better equipped to deal wisely with suboptimal budgets or sudden budget cuts. In particular, they can evaluate a very wide range of plausible future budgets and see "cut-off" amounts below which the likelihood of meeting requirements falls rapidly. In addition, PortMan's ability to distinguish between must-have and desirable requirements enables planners to more easily envision a bottom line and make tough but informed choices should budget constraints tighten. By being able to flag projects in a portfolio whose cost outweighs their value, PortMan can potentially help secure sizable long-term cost savings. And by suggesting how to optimally allocate a total lifecycle budget between R&D and implementation, PortMan can help create the new, more cost-effective mindset—toward the use of R&D funds in particular—called for by the current austere budget environment.