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**Driving in the Dark**  
*Ten Propositions About Prediction  
and National Security*

By Richard Danzig



Center for a  
New American  
Security

# Report Documentation Page

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OCTOBER 2011

# Driving in the Dark

## *Ten Propositions About Prediction and National Security*

By Richard Danzig

## *About the Author*

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DRIVING IN THE DARK:  
TEN PROPOSITIONS ABOUT PREDICTION  
AND NATIONAL SECURITY

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By Richard Danzig

## Ten Propositions About Prediction and National Security

### HUMANITY IS COMPELLED TO PREDICT AND WILL FAIL – THE FIRST FIVE PROPOSITIONS

1. The Propensity to Make Predictions – and to Act on the Basis of Predictions – Is Inherently Human.
2. Requirements for Prediction Will Consistently Exceed the Ability to Predict.
3. The Propensity for Prediction Is Especially Deeply Embedded in the U.S. Department of Defense.
4. The Unpredictability of Long-term National Security Challenges Will Always Confound the Irresistible Forces That Drive Prediction.
5. Planning Across a Range of Scenarios Is Good Practice but Will Not Prevent Predictive Failure.

### HOW TO PREPARE FOR PREDICTIVE FAILURE – THE LAST FIVE PROPOSITIONS

6. Accelerate Tempo – and Delay Some Decisions.
7. Increase the Agility of Production Processes.
8. Prioritize Equipment That Is Most Adaptable.
9. Build More for the Short Term.
10. Nurture Diversity; Create Competition.

## EXECUTIVE SUMMARY

By Richard Danzig

The U.S. military relies on prediction to forecast needs and influence the design of major equipment. A future or futures are envisioned, requirements are deduced and acquisition and design decisions are made and justified accordingly. However, both the experience of the Department of Defense (DOD) and social science literature demonstrate that long-term predictions are consistently mistaken. The acceleration, proliferation and diversification of technical and political changes make 21st-century security risks even more unpredictable than those of the past. Thus, whereas some efforts to predict the future are necessary and predictive techniques can be improved, acquisition programs should reflect the likelihood of predictive failure. The defense community should prepare to be unprepared.

The report presents 10 propositions regarding prediction. The first five are descriptive:

- The propensity to make predictions – and to act on the basis of predictions – is inherently human.
- Requirements for prediction will consistently exceed the ability to predict.
- The propensity for prediction is especially deeply embedded at the highest levels of DOD.
- The unpredictability of long-term national security challenges is an immovable object. It will repeatedly confound the irresistible forces that drive prediction.
- Planning across a range of scenarios is good practice but will not prevent predictive failure.

The second five propositions are prescriptive. They show how, even as they strive to improve their foresight, policymakers can better design processes, programs and equipment to account for the likelihood of predictive failure. Doing so will involve several actions:

- **Accelerating decision tempo and delaying some decisions.** In a world characterized by



unpredictability and increasingly frequent surprise, there are heavy penalties for ponderous decisionmaking and slow execution. The U.S. government is now designing and producing equipment on political and technological premises that are outdated by the time the equipment reaches the field. To counter this, military departments must dramatically narrow the time between the initiation of a concept and its realization. Programs must also be designed to defer some decisions into the later stages of development.

- **Increasing the agility of our production processes.** A 21st-century DOD must invest in capabilities to respond rapidly to unanticipated needs. Accordingly, ponderous defense manufacturing systems must be redesigned for agility, using adaptive manufacturing techniques that generate the ability to switch products and modify models quickly as new circumstances arise.
- **Prioritizing adaptability.** In the face of unpredictability, future military equipment should be adaptable and resilient rather than narrowly defined for niche requirements. To achieve this, the requirements process should be modified to place a premium on operational flexibility. New criteria of this kind will require new metrics of merit.
- **Building more for the short term.** Major acquisitions are now built for long-term use but would benefit from greater recognition of the unpredictability of technology development and combat environments. The defense community should seek to acquire more equipment for the short term, as is done in the consumer environment.
- **Nurturing diversity and creating competition.** Currently, the centralization of planning and acquisition, combined with an emphasis on efficiency and an avoidance of redundancy, stifle competition and technological diversity. The reality of unpredictability suggests another approach. Competition and diversity produce a valuable range of potential responses when unpredicted challenges and difficulties arise.

## I. INTRODUCTION

Prediction lies at the root of all strategic thinking. Indeed, it underlies most everyday decisions. People stop at red lights and proceed on green because they can predict consequences associated with these signals. However, whereas routine, short-term predictions are generally right, strategic judgments about future environments are often, one might say predictably, wrong. The common response to this shortcoming is to try to improve predictive capabilities.

I propose a different tack, namely that long-term strategies should be built not on “visions” of the future but instead on the premise that longer term predictions (that is, forecasts of situations years and decades out), however presently credible, will probably prove wrong. I attempt here to show that this premise is not sterile or disabling and instead point to five complementary strategies that will better prepare the defense community for what cannot be foreseen.

Two cases are illustrative. In recent decades, the Department of Defense designed armored vehicles for particular predicted circumstances (involving fighting the Soviet Union)<sup>3</sup> but then had to use them in unforeseen contexts (for example, in Iraq and Afghanistan). These unexpected contexts changed the demands on these vehicles. Relatively simple adjustments could meet some of these demands (for example, mismatched camouflage). For other demands, DOD was serendipitously well prepared.<sup>4</sup> Still other demands were difficult to meet and led to vulnerabilities. For example, the Abrams tank<sup>5</sup> suffered from high fuel consumption in an environment with inadequate infrastructure for delivering fuel. The tanks, and especially armored personnel carriers, were particularly vulnerable to “improvised explosive devices” (IEDs) embedded on roads.<sup>6</sup> The reality of unpredictability raises a central question: How do engineers design a tank or other armored vehicle if they

*“[T]he test of a first-rate intelligence is the ability to hold two opposed ideas in the mind at the same time, and still retain the ability to function.”*

F. Scott Fitzgerald, “The Crack-Up” (1936)<sup>1</sup>

*“My sole advantage in life is that I know some of my weaknesses.”*

Nassim Nicholas Taleb, *Foiled by Randomness* (2005)<sup>2</sup>

know that they do not know where, under what circumstances and how it will be used?

A second case derives from observing that systems to detect biological attack now depend on designating a short list of pathogens as “threat agents”<sup>7</sup> and developing methods to detect these pathogens in the air. However, revolutionary developments in biotechnology empower attackers to modify pathogens or to create entirely new ones.<sup>8</sup> This raises the question: How do researchers design a detection system if they know that they do not know what needs to be detected?

Although the following discussion is grounded in these cases and the institutional context of DOD, the arguments in this report are more broadly applicable. The implications should be apparent, for example, for the way DOD recruits and trains personnel,<sup>9</sup> locates bases, apportions its funds, plans cyber defenses, etc. (To take the last example as illustrative, software generations and planning horizons are commonly conceived in 18-month cycles, and experts regard evolution over 5 to 10 years as generally unpredictable. How should the government design its processes, structures, defenses and training in the face of such uncertainty?) Beyond this, I hope that the suggested

strategies will be useful to commercial entities and other governmental organizations that engage in capital investment and long-term planning.

### The Challenge of Prediction

DOD is required by law to produce, every four years, a 20-year forecast of the security environment and DOD's planned responses.<sup>10</sup> Enormous effort goes into this Quadrennial Defense Review (QDR). It is, however, merely the largest and most visible of a vast array of predictive efforts spawned every day in every government and business all over the globe.<sup>11</sup>

Paradoxically, the best of these efforts also decies, if incidentally, the ability to predict. The Joint Forces Command's "Joint Operating Environment," published at the time of the 2010 QDR, observes that "[t]he interplay of economic trends, vastly different cultures and historical experiences, and the idiosyncrasies of leaders, among a host of other factors, provide such complexity in their interactions as to make prediction impossible."<sup>12</sup> The document buttresses this point by summarizing strategic perspectives at different points throughout the 20th century. It starts, for example:

1900: If you are a strategic analyst for the world's leading power, you are British, looking warily at Britain's age-old enemy, France.

1910: You are now allied with France, and the enemy is now Germany.

1920: Britain and its allies have won World War I, but now the British find themselves engaged in a naval race with its [sic] former allies, the United States and Japan.

The Joint Forces Command also quotes Winston Churchill, saying that he "caught those complexities best in his masterful history of World War I":

One rises from the study of the causes of the Great War with a prevailing sense of the

defective control of individuals upon world fortunes. It has been well said, "there is always more error than design in human affairs." The limited minds of the ablest men, their disputed authority, the climate of opinion in which they dwell, their transient and partial contributions to the mighty problem, that problem itself so far beyond their compass, so vast in scale and detail, so changing in its aspects – all this must surely be considered...<sup>13</sup>

These two strands – the compulsion to predict and the recognition of the inadequacies of prediction – are not reconciled. Typically, predictive documents either ignore the problem or assert that their own methods and abilities are so improved as to warrant proceeding with prediction. The Joint Forces Command document is better than most: It at least emphasizes the problem. However, the authors then turn away from the issue, offering the bromide that forces must be "adaptable," and proceed to offer their views of the future.<sup>14</sup>

In this report, I accept that the inclination to predict is deeply embedded in U.S. institutions and in human nature. Like others, I favor efforts to improve capabilities for foresight, and I agree with the best thinkers in recognizing that foresight is not the same as prediction. Prediction implies an ability to discern a particular turn of events. Foresight identifies key variables and a range of alternatives that might better prepare for the future. Yet my concern here is not to abet this admirable effort but instead to recognize and cope with its limits.

In my view, long-term national security planning, such as that required for designing tanks or biological detection systems, will inevitably be conducted in conditions that planners describe as "deep" or "high" uncertainty, and in these conditions, foresight will repeatedly fail. However much the defense community continues to attempt to improve its predictive powers, it must nonetheless

grapple with the problem of how to design equipment for circumstances that are not foreseen. Predicting the future may be “an inescapable task for decisionmakers,” but it is not the only task and it is wrong to plan solely on predictive premises. Planners need to complement their efforts at foresight with thinking and actions that account for the high probability of predictive failure.

This kind of planning occurs rarely in national security forums.<sup>15</sup> The present processes result in pounds of prediction but barely ounces of investment in considering how best to position the nation to deal with these failures. This report attempts to right that balance.

### **Ten Propositions on Prediction**

I organize this discussion around 10 propositions. The first five describe why predictions are invaluable and why long-term predictions about complex matters such as national security are likely to fail. In the first proposition, I explain why humanity has such a hunger for prediction. In the second, I argue that people will repeatedly exceed their predictive capacities, no matter how much those capacities are strengthened or how often people remind themselves that humans are poor predictors. They will always drive beyond their headlights. In the third proposition, I argue that the hunger for prediction is particularly pronounced and inbred in bureaucratic and military organizations. Accordingly, it is hardly surprising that the world’s most successful military and largest bureaucracy, the U.S. Department of Defense, relies on prediction in its decisionmaking processes. Unfortunately, historical and institutional factors have intensified this dependency. In the fourth proposition, I identify the variables that I think most confound planners’ predictive capabilities and suggest that these will endure in the national security arena and result in ongoing poor predictions. In the fifth proposition, I note the value of moving from point prediction to the consideration of a range of scenarios. However,

I emphasize the limits of this approach and the enduring need for strategies that embrace and better account for unpredictability.

The second half of this report attempts to show how – while continuing to improve foresight – the defense community should also design processes, programs and equipment on the premise that predictions will often be incorrect. While trying better to illuminate the road, analysts should recognize that sudden twists and turns in areas of darkness demand special driving techniques. Propositions 6 through 10 propose strategies for improvement. The sixth proposition argues that present defense decision processes deliberate and design for environments that are changing faster than the pace of the deliberation. These decisionmaking systems need to be modified and accelerated; otherwise, evaluations intended as a means of risk reduction will actually increase risk. In addition, a complementary ultra-rapid procurement system should be developed to meet urgent requirements on the battlefield or elsewhere. At the same time, paradoxically, some decisions should be delayed to move them further along in the evolution of environments that cannot be foreseen. The seventh proposition points out that present defense investments for standby manufacturing capabilities focus on surge production of present systems. This proposition asserts that greater priority should be given to making manufacturing processes more agile and capable of meeting unanticipated requirements. The discussion outlines a path for achieving this result.

The eighth proposition asserts that, even if the previous recommendations are implemented, aspects of the world will change unpredictably and faster than procurement and production systems can adapt. Accordingly, the equipment itself should be adaptive whenever possible. I provide examples of ways to incentivize and achieve adaptability and show why the present system does the reverse. The ninth proposition is that the present propensity for

building new equipment for the long term should be tempered by greater investments in less-enduring equipment. This will provide greater flexibility to adapt as environments change unpredictably. The tenth proposition outlines the advantages of diversification and makes a case for inter-service competition and diversity in equipment among U.S. allies, even at the expense of presently much-valued “jointness” and concepts of efficiency that rest on error-prone predictive premises.

Policymakers are right to attempt to enhance their understanding of the future, but such efforts need to be complemented with a better recognition of likely failures of foresight. I recommend schizophrenia: People must simultaneously predict and plan for predictive failure. The best approach is not only to improve foresight but also to supplement it with the strategies recommended here (and others that hopefully will be developed). Put another way, people are now overly dependent on successful prediction. Correcting this imbalance requires a clear-eyed recognition of the problem, challenging changes in processes, new incentives and investment in strategies, and tactics that better prepare for predictive failure.

## II: HUMANITY IS COMPELLED TO PREDICT AND WILL FAIL – THE FIRST FIVE PROPOSITIONS

### 1. The Propensity to Make Predictions – and to Act on the Basis of Predictions – Is Inherently Human

“No one can predict the future” is a common saying, but people quite correctly believe and act otherwise in everyday life. In fact, daily life is built on a foundation of prediction. One expects (predicts) that housing, food and water will be safe and, over the longer term, that saved money will retain value. These predictions are typically validated by everyday experience. As a consequence, people develop expectations about prediction and a taste, even a hunger, for it. If security in everyday life derives from predictive power, it is natural to try to build national security in the same way.

This taste for prediction has deep roots.<sup>16</sup> Humans are less physically capable than other species but more adept at reasoning.<sup>17</sup> Reasoning is adaptive; it enhances the odds of survival for the species and of survival, power, health and wealth for individuals. Reasoning depends on predictive power. If what was benign yesterday becomes unpredictably dangerous today, it is hard to develop protective strategies, just as if two plus two equals four today and five tomorrow, it is hard to do math. Rational thought depends on prediction and, at the same time, gives birth to prediction. Humans are rational beings and, therefore, make predictions.

The taste for prediction has roots, moreover, in something deeper than rationality. Emotionally, people are uncomfortable with uncertainty<sup>18</sup> and pursue the illusion of control over events beyond their control. Systematic interviews of those who have colostomies, for example, show that people are less depressed if they are informed that their impaired condition will be permanent than if they

are told that it is uncertain whether they will be able to return to normal functioning.<sup>19</sup> Citing this and other work, Daniel Gilbert concludes that “[h]uman beings find uncertainty more painful than the things they’re uncertain about.”<sup>20</sup> An “illusion of control,” to employ a term now recognized in the literature of psychology, mitigates the pain of uncertainty.<sup>21</sup> People value random lottery tickets or poker cards distributed to themselves more than they do tickets or cards randomly assigned to others.<sup>22</sup> A discomfort with uncertainty and desire for control contribute to an unjustifiable over-reliance on prediction.

## **2. Requirements for Prediction Will Consistently Exceed the Ability to Predict**

The literature on predictive failure is rich and compelling.<sup>23</sup> In the most systematic assessment, conducted over 15 years ending in 2003, Philip Tetlock asked 284 established experts<sup>24</sup> more than 27,000 questions about future political and economic outcomes (expected electoral results, likelihoods of coups, accession to treaties, proliferation, GDP growth, etc.) and scored their results.<sup>25</sup> Collateral exercises scored predictive achievement in the wake of the breakup of the Soviet Union, the transition to democracy in South Africa and other events. There are too many aspects of Tetlock’s richly textured discussion to permit a simple summary, but his own rendering of a central finding will suffice for this discussion: “When we pit experts against minimalist performance benchmarks – dilettantes, dart-throwing chimps, and assorted extrapolation algorithms – we find few signs that expertise translates into greater ability to make either ‘well calibrated’ or ‘discriminating’ forecasts.”<sup>26</sup>

As described below,<sup>27</sup> there are strong reasons for a high likelihood of failure of foresight when DOD attempts to anticipate the requirements for systems over future decades. Recent experience makes this point vividly. Over the past 20 years,<sup>28</sup> long-term predictions about the strategic

environment and associated security challenges have been wrong, like most multi-year predictions on complex subjects.<sup>29</sup> It is simple to list a half-dozen failures:<sup>30</sup> American defense planners in 1990 did not anticipate the breakup of the Soviet Union, the rapid rise of China, Japan’s abrupt transition from decades of exceptional economic growth to decades of no growth,<sup>31</sup> an attack like that on September 11, 2001 or the United States invasions of (and subsequent decade-long presences in) Afghanistan and Iraq.<sup>32</sup>

So, in this light, why does the defense community repeatedly over-invest in prediction?

A common conceptual error intensifies the hunger for prediction. History celebrates those who made good predictions. Because Winston Churchill’s fame rests on, among other things, his foresight about German militarism and the accuracy of his demands for preparation for World War II, it appears evident that confident prediction is the road to success. Yet it is an error to focus on numerators (instances of success) without asking about denominators (instances of failure).<sup>33</sup> Accordingly, there is a tendency to ignore Churchill’s failures in many other predictions (his disastrous expectations from military operations in Gallipoli, his underestimation of Gandhi, etc.). There is also a tendency to ignore the great number of other predictors who are not celebrated by history because they failed in analogous circumstances.

Moreover, prediction is subject to refinement and is often a competitive enterprise. As a result, predictive power is like wealth – gaining some of it rarely satisfies the needs of those who receive it. Predictive power intensifies the demand for more predictive power.

Tell a national security advisor that another country is likely to develop a nuclear weapon, and – after all his or her questions have been answered

about the basis of the prediction – he or she will want to know when, in what numbers, with what reliability, at what cost, with what ability to deploy them, to mount them on missiles, with what intent as to their use, etc. It is no wonder that U.S. intelligence agencies are consistently regarded as failing. Whatever their mixtures of strengths and weaknesses, they are always being pushed to go beyond the point of success.

Put another way, the surest prediction about a credible prediction is that it will induce a request for another prediction. This tendency is intensified when, as is commonly the case, prediction is competitive. If you can predict the price of a product but I can predict it faster or more precisely, I gain an economic advantage. If I can better predict the success of troop movements over difficult terrain, then I gain a military advantage. As a result, in competitive situations, my fears of your predictive power will drive me to demand more prediction regardless of my predictive power. Moreover, your recognition of my predictive power will lead you to take steps to impair my predictive ability.<sup>34</sup> Carl von Clausewitz saw this very clearly: “The very nature of interaction is bound to make [warfare] unpredictable.”<sup>35</sup>

These inherent psychological and practical realities will consistently lead to over-prediction. People are doomed repeatedly to drive beyond their headlights.

### 3. The Propensity for Prediction Is Especially Deeply Embedded in the U.S. Department of Defense

Five factors powerfully contribute to this propensity.

#### BUREAUCRATIC MANAGERS, AND ESPECIALLY GOVERNMENT OFFICIALS, SEEK PREDICTABILITY AS A MEANS OF MAINTAINING ORDER

Students of both business and government bureaucracies have observed that managers seek to

simplify problems in order to render them more predictable. In the words of Herbert Simon:

Administrative man recognizes that the world he perceives is a drastically simplified model of the buzzing, blooming confusion that constitutes the real world. He is content with the gross simplification because he believes that the real world is mostly empty – that most of the facts of the real world have no great relevance to any particular situation he is facing and that most significant chains of causes and consequences are short and simple.<sup>36</sup>

Henry Kissinger arrived at a similar observation after decades of interacting with U.S. national security bureaucracies. “The essence of bureaucracy,” he writes, “is its quest for safety; its success is calculability... The attempt to conduct policy bureaucratically leads to a quest for calculability which tends to become a prisoner of events.”<sup>37</sup> Andrew Krepinevich, a long-time observer of the Pentagon, comments that bureaucrats would prefer “no thinking about the future (which implies things might change and they might have to change along with it). To the extent they ‘tolerate’ such thinking, they attempt to insure that such thinking results in a world that looks very much like the one for which they have planned.”<sup>38</sup> Insofar as the future is forecast to differ from the present, it is highly desirable from a bureaucratic perspective for the forecast to at least be presented with certitude. James C. Scott discerns the reasons for this, arguing that for a government bureaucrat,

[t]he ... present is the platform for launching plans for a better future... The strategic choice of the future is freighted with consequences. To the degree that the future is known and achievable ... the less future benefits are discounted for uncertainty.<sup>39</sup>

Conceding uncertainty would weaken budgetary claims, power and status. Moreover, bureaucratic

actors who question alleged certainties soon learn that they are regarded skeptically. Whose team are they on? What bureaucratic interest is served by emphasizing uncertainty?

### **MILITARIES, IN PARTICULAR, SEEK PREDICTIVE POWER**

The military environment compounds managers' predisposition to prediction, and indeed, most security strategies are designed to reduce risk. Napoleon's maxim reflects present military attitudes: "To be defeated is pardonable; to be surprised – never!"<sup>40</sup> The American military, committed to harnessing technological superiority and overwhelming force, is particularly predisposed to a mind-set in which power and predictive accuracy are exaggerated. William Astor captures the point:

[W]hat disturbs me most is that the [U.S.] military swallowed the Clausewitzian/German notion of war as a dialectical or creative art, one in which well-trained and highly-motivated leaders can impose their will on events... a new vision of the battlefield emerged in which the U.S. military aimed, without the slightest sense of irony, for "total situational awareness" and "full spectrum dominance," goals that, if attained, promised commanders the almost god-like ability to master the "storm of steel," to calm the waves, to command the air. In the process, any sense of war as thoroughly unpredictable and enormously wasteful was lost.<sup>41</sup>

### **THE MODERN AMERICAN MILITARY TRACES ITS ROOTS TO PREDICTIVE FAILURE**

The present American military establishment was created in the wake of two wars – World War II and the Korean War – for which it was widely recognized that America was unprepared.<sup>42</sup> These led to a mantra of attempting to foresee and plan for risks so as never again to be comparably unprepared.

### **THE MCNAMARA REVOLUTION ENSHRINED PENTAGON PROCESSES DEPENDENT ON PREDICTION**

A half century ago, Robert McNamara and his "whiz kids" intensified the predictive tendency, but for different reasons than their predecessors. For McNamara and his colleagues, the challenge was to take an internally competitive, substantially disorganized and significantly dysfunctional DOD and make it more manageable and rational. A key step to this end was to adopt the then-modern concepts of strategic planning with which McNamara had been closely associated at Ford Motor Company.<sup>43</sup> A related initiative was to establish for DOD a single scenario – a Soviet invasion of Western Europe – against which most investments could be measured.<sup>44</sup> This mechanism of resource allocation became a mechanism of program planning in accord with the proposition that "what you measure is what you motivate."

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*The military environment compounds managers' predisposition to prediction.*

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This result was rationalized with the observation that the Soviet scenario was so stressful that all other contingencies would be lesser included cases; they could be readily handled with the equipment, training and doctrine designed for the most demanding Soviet scenario. Of course, this scenario was never as dominant in practice as it was in theory. Collateral investments were made, for example, in attack submarines. Subordinate combat commands worried about scenarios specific to their regions, such as fighting in Asia or the Persian Gulf. Occasional consideration was also given by the Office of the Secretary of Defense to some alternative opponents.<sup>45</sup> It was not that the system prohibited collateral thought



about unpredicted outcomes. Rather, it forced overwhelming attention to the predicted scenario and offered few incentives to consider unexpected contingencies.

Owen Brown and Paul Eremenko observe that the McNamara revolution introduced a bias toward design systems with long lives for allegedly predictable environments. Analyzing our space programs, they write:

Decisionmakers respond to increased marginal cost by ... increasing lifetime to minimize amortized annual costs. In a perfect world of no uncertainty (or certainty of the uncertainty) this is an appropriate decision. The scars of real world experience illustrate the true problems of this approach. These space systems, which (because of their complexity) take years to design and build, are designed to meet requirements based on today's threat forecasts. With constantly changing threat environments, requirements change during the design and build phase. The result is redesign, which costs time and money for a large, tightly coupled system. Once launched, there is little hope the capability of a space system can be adapted to a new threat.<sup>46</sup>

#### THE MONOLITHIC SOVIET OPPONENT WAS UNUSUALLY PREDICTABLE

The Cold War led to co-evolution: The mutually engaged American and Soviet military systems responded to each other's doctrines, processes and military products.<sup>47</sup> Because the massive Soviet system became largely ponderous and predictable,<sup>48</sup> the American system had unusual opportunities for forecasting.<sup>49</sup> Furthermore, the U.S. system was unusually disposed to produce large numbers of standardized systems. The Defense Science Board astutely commented on the result:

Focus was on long, predictable, evolutionary change against a Cold War peer opponent who suffered as much, if not more, than the United

States from a rigid and bureaucratic system.

There were certainly instances of adaptability during the Cold War period, but the surviving features of that period are now predominated by long compliance-based structures.<sup>50</sup>

These five strands combine to embed a propensity for prediction deeply within the DNA of the U.S. Department of Defense.

#### 4. The Unpredictability of Long-term National Security Challenges Will Always Confound the Irresistible Forces That Drive Prediction

After studying the corporate world, McKinsey and Co. partner Hugh Courtney distinguished four levels of uncertainty. Courtney usefully observed that organizations often simultaneously experience these different levels as they consider diverse decisions.<sup>51</sup> At the first, lowest level, some strategists can achieve "a clear single view of the future."<sup>52</sup> DOD, for example, routinely predicts dollars for man-power expenditures over the next few months with high precision. Accordingly, proposals for increases in pay and allowances can be evaluated with little doubt about their immediate consequences.

At a higher, second level, uncertainty can be distilled to a "limited set of outcomes, one of which will occur."<sup>53</sup> For example, by the time present appropriations expire, either a new military appropriations bill will be passed, a continuing resolution will extend more limited, but well-defined, financing or no legislative authorizations will occur. These three outcomes are, in Courtney's terminology, "mutually exclusive and comprehensive events."<sup>54</sup> Although decisionmakers cannot predict with certainty which of the alternative outcomes will prevail, it is certain that it will be one and only one of these options.

At the third level, "a range of possible future outcomes" can be identified, although the outcome that will eventually occur is hidden within that range. A Pentagon example might be that next

year's total budget cannot confidently be predicted but a range of levels within X billion dollars can reasonably be anticipated. In the fourth and highest state of uncertainty, there is "a limitless range of possible future outcomes."<sup>55</sup> Courtney suggestively writes that level-four situations occur when foresight is desired for extended periods and when these periods are likely to involve "major technological, economic or social discontinuities."<sup>56</sup> RAND Corporation analyses offer a related insight, distinguishing between unpredictability associated with statistically predictable variables (e.g., whether a coin will land heads or tails) and "deep uncertainty," in which one cannot assuredly weigh, or perhaps even identify, the variables.<sup>57</sup>

Pentagon programs to develop new weapons systems conform to Courtney's paradigm; they have aspects associated with all four levels of uncertainty. Some aspects of those programs inevitably depend on the ability to foresee environments in which the weapons will be used, decades after a program is initiated; these aspects will be at Courtney's fourth level of uncertainty. When considering these aspects, decisionmakers will confront "deep uncertainty." After examining the private sector, Courtney concludes that "[a]nyone who imagines they can put bounds on the range of potential outcomes in such [level-four] markets is engaged in wishful thinking."<sup>58</sup>

It is important to recognize that the difficulties inherent in level-four uncertainty do not result from limitations of the decisionmakers or their processes. To be sure, a rich literature identifies decisionmakers' tendencies to project biases, misuse heuristics,<sup>59</sup> make mistakes recognizing and weighing uncertainty,<sup>60</sup> employ inadequate and erroneous models, rely on deficient and distorted information, resist technological change because of its social implications<sup>61</sup> and so forth.<sup>62</sup> Tetlock's systematic study shows repeated failure even under level-two uncertainty conditions.<sup>63</sup> Nonetheless, at level four, errors in foresight are inevitable due to

the nature of the problem, not simply the nature of human decisionmaking.

The number and diversity of variables that influence the national security environment confound multi-decade forecasting. Accurate prediction would need to anticipate changes in, among other things, technologies, economies, institutions, domestic and international politics and, of course, the nature of warfare. Each of these alone would be imponderable. Getting them all right at once is wildly improbable. Worse still, the evolution of these variables is complex and nonlinear.<sup>64</sup>

Chaos theory uses a hypothesis about a butterfly to illustrate the interaction of variables in a complex system. Its proponents advance the proposition that the flapping of a butterfly's wings in Indonesia could initiate a chain of causation that would result in hurricanes in Florida. However, we do not have to resort to such subtle speculation to establish the proposition in the national security context.

Consider the role, not of a butterfly, but of a butterfly ballot. Specifically, consider the ballot used in Florida in America's 2000 presidential election. Whatever one's view about the propriety or outcome of that campaign, it is reasonable to conclude that the Palm Beach County ballot was poorly designed as a result of what came to be described as "the limited visual acuity" of the responsible county official.<sup>65</sup> It is generally accepted that this resulted in approximately 2,000 people inadvertently voting for Pat Buchanan rather than Al Gore.<sup>66</sup> That, in turn, cost Vice President Gore an electoral victory in Florida, which cost him the national election and led to the election of a President who chose to fight in Iraq. Although the alternative course of events cannot be described with certainty, it seems doubtful that Al Gore would have chosen to invade Iraq.<sup>67</sup> In sum, it is quite plausible that if not for the limited visual acuity of a county official in Florida, the war in Iraq would not have occurred. If this butterfly ballot

effect can determine whether a war was or was not fought, and that war itself had enormous repercussions, how then can one presume to predict other wars (and their consequences) at other times?

Extensive analysis of the American stock market teaches a similar humility.<sup>68</sup> No activity in human history has been so subject to sustained analysis and prediction by so many intelligent people with such substantial resources, such strong incentives for success and such a cornucopia of information. Moreover, the actors in the American stock market largely share the desire to make money -- a single, simple and well-defined goal. Their progress toward that goal is completely unambiguous and unusually measurable, the number of actors is very large, and substantial barriers keep individual participants from dominating (and therefore distorting) markets. Furthermore, in the American stock market, the information that is the basis of prediction is regulated to achieve unusually high levels (indeed, in other contexts, unobtainable levels) of transparency, frequency and regularity of reporting. By contrast, national security predictions must cope with disguise and disinformation; partial, irregular and unreliable information; errors bred by linguistic and cross-cultural translation; and widely varying motivations by idiosyncratic actors with the power to produce distorted decisions. Yet even with all the advantages that the stock market analyst has, it has been amply demonstrated that few professional fund managers sustainably beat the market average, and virtually none can be relied on to do so consistently.<sup>69</sup> If prediction in the stock market is so marked by failure, how can one expect success in national security prediction?

Temporal prediction is harder than substantive prediction. Even when a foreseen event is impending, it is difficult to discern when a decisive turn will take place. Investors are very familiar with this problem. A description of the recent bubble in American housing prices details both how a handful of investors were successful in predicting a collapse

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*Temporal prediction is harder than substantive prediction. Even when a foreseen event is impending, it is difficult to discern when a decisive turn will take place.*

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and the difficulties that they suffered from not being able to predict the timing of the market shift.<sup>70</sup> In a more methodical study, Niall Ferguson shrewdly used changes in the bond market on the eve of World War I as an indicator of foresight about the impending cataclysm. After establishing that bond prices did not fall significantly in the weeks after the assassination of Archduke Ferdinand, Ferguson concludes that “even to the financially sophisticated, as far as can be judged by the financial press, the First World War came as a surprise.”<sup>71</sup> It was not that the possibility of war was unforeseen – to the contrary, it was discussed for decades: “[L]ike an earthquake on a densely populated fault line, its victims had long known that it was a possibility, and how dire its consequences would be; but its timing remained impossible to predict, and therefore beyond the realm of normal risk assessment.”<sup>72</sup>

### **5. Planning Across a Range of Scenarios Is Good Practice but Will Not Avoid Predictive Failure**

Current Pentagon planners recognize that a monolithic scenario can no longer be justified (if it ever was) and that a range of scenarios may capture many of the benefits of predictive planning while ameliorating the faults.<sup>73</sup> The Quadrennial Defense Review, DOD’s primary planning document, states:

Because America’s adversaries have been adopting a wide range of strategies and capabilities ... it is no longer appropriate to speak of “major

regional conflicts” as the sole or even the primary template for sizing, shaping, and evaluating U.S. forces. Rather, U.S. forces must be prepared to conduct a wide variety of missions under a range of different circumstances.... The QDR thus employed several scenario combinations to represent the range of likely and/or significant challenges anticipated in the future and tested its force capacity against them ...<sup>74</sup>

The types of contingencies that U.S. forces will actually be called upon to conduct in the future will certainly extend beyond the range of these examples. Reality is always less clear-cut and less predictable than our planning paradigms. For this reason, DOD’s force planning stresses the importance of fielding forces that are versatile and that, in aggregate, can undertake missions across the full range of plausible challenges.<sup>75</sup>

This approach reflects thinking that is more sophisticated than previous DOD efforts at prediction. In the early 1980s, Peter Schwartz and others at Shell Oil emphasized that multiple scenarios could be more illuminating than point predictions.<sup>76</sup> Well-crafted scenarios could not only illuminate a diversity of potential futures, but their creation and discussion could serve as a starting point and template for discussion, clarifying premises and illuminating the present world. Moreover, scenarios could help participants recognize markers indicating that they were moving along a particular path.

The government of Singapore has tapped into Schwartz’s work and the insights of some other American and British thinkers<sup>77</sup> to develop a sophisticated scenario planning effort, a “Risk Assessment and Horizon Scanning System” and a Centre for Strategic Futures.<sup>78</sup> Leon Fuerth<sup>79</sup> and others<sup>80</sup> have argued for broader application of this approach – for more disciplined efforts at “foresight”<sup>81</sup> – in the operations of the American government.

In the most technically ambitious efforts, RAND Corporation analysts have linked scenario development with computer-assisted reasoning.<sup>82</sup> The RAND group evaluated scenario techniques as “tremendous boons to forward-looking strategic thinking,”<sup>83</sup> but “the choice of any small number of scenarios to span a highly complex future is ultimately arbitrary.”<sup>84</sup> Furthermore, “the logic used to sort the scenarios may seriously bias any conclusions drawn from them.”<sup>85</sup> To counter this, their “Long Term Policy Analysis” uses a software scenario generator to create an “ensemble” of hundreds, thousands or millions of scenarios. The ensemble should be composed of

... as diverse a range of plausible alternatives as possible. No widely accepted standards of rigor for assessing the quality of such scenario generators currently exist. However, it is clear that such standards should be very different from those used for predictive models. The ideal scenario generator would produce only plausible scenarios, but in constructing the software, analysts should err on the side of including potentially implausible futures.<sup>86</sup>

I will return to the consideration of robust and adaptive decisionmaking in the discussion of Proposition 8, below, which emphasizes the reward of these approaches as a means of evaluating adaptivity across a range of scenarios. For the moment, however, it suffices to note that the propagation of scenarios, however sophisticated, broad ranging or insightful, does not obviate the need for strategies for coping with uncertainty. Scenarios provide some good ways of evaluating strategies. They do not provide the strategies. The final propositions in this report suggest five methods by which performance can be improved in the face of intractable “deep uncertainty.”

### III: HOW TO PREPARE FOR PREDICTIVE FAILURE – THE LAST FIVE PROPOSITIONS

Despite the challenges of prediction discussed above, practical strategies can improve U.S. security in the face of strategic unpredictability. DOD leaders do need to make assumptions about how the world works, but they also can do a better job of coping with the likelihood that many of their assumptions will prove wrong.

Although planners in other domains confront comparable problems and defense analysts can benefit from their thinking, the defense world is uniquely challenging and requires special approaches. For example, a number of investors and economists have embraced the premise that prediction is a fool's game and have suggested strategies for proceeding given financial uncertainty. Many of these strategies have lost credibility because they led their proponents (and investors) to disaster. Yet even if only the soundest and most modest of these strategies – for example, theories of investment in indexes, hedging, diversification and avoidance of very volatile areas – were embraced, they would not be straightforwardly applicable to defense expenditures. Defense planners cannot rely on the expectation that their political masters will abstain from engaging in volatile areas. They cannot construct databases about armed conflict that will be as standardized and richly populated as those relied upon by quantitative stock market modelers. Most fundamentally, investments in organizing, training and equipping our armed forces are not as short term, discreet, rapid, liquid, tolerant of loss or subject to hedging as investments in financial instruments.

Each year, DOD buys a very limited number of tanks, fighter aircraft, destroyers and comparable equipment for delivery some years in the future.<sup>87</sup> Typically, it anticipates using them for at least 20 years. These investments produce

more or less only one Army, one Air Force, one Marine Corps and one Navy, although these organizations are interconnected. DOD cannot skip some of these components (leaving our troops, for example, without aircraft and ships to transport and protect them). Nor can they act like capital markets, investing in a hundred different versions of the Navy, Air Force, Army or Marine Corps, tolerating failure in some while expecting that, on average, they will protect us. As a result, even if one admires the flawed and fragile tools for coping with unpredictability in financial securities, they cannot simply be extrapolated to deal with the unpredictability of challenges to national security.

How then should the defense community proceed? The first of my five recommended complementary strategies calls for dramatically accelerating acquisition decisionmaking. Shortening these processes can diminish the dependence on long-term prediction. Such rapidity reduces risk but should be complemented by a “second standby procurement process” that can respond to unanticipated circumstances by making decisions at a speed proportionate to the need. This strategy also highlights the desirability of deferring some decisions to be made as the future unfolds.

The next strategy outlines opportunities for modifying manufacturing processes to better marry agility in manufacturing to speed in procurement. More adaptive manufacturing processes will permit less reliance on prediction. Defense planners can then respond to unanticipated circumstances by rapidly making new equipment designed for those circumstances.

The third strategy proposes a prioritization of the equipment that is most adaptable. This requires systems for evaluating and valuing resilience across missions and physical environments and also over time. This strategy encourages systems that operate as platforms on which specific

applications can be positioned, platforms that can be adapted in the field and platforms that are “leanly designed to function.”

The fourth strategy recommends the design of more equipment for the short term. Instead of planning for decades of use, with elaborate maintenance and occasional upgrades, some equipment would be designed for obsolescence in order to liberate resources for redesign.

The final strategy argues for diversity and competition as sources of resilience in the face of unpredictable challenges. This runs counter to the mantra of efficiency often pursued in present DOD processes. Instead, it urges a culture of competition in which, rather than attempting to definitively foresee what works best, decisionmakers empower conflicting solutions and embrace survival of the fittest as the future environment becomes clearer. Real efficiency is a factor of the eventual successful use of systems, not an abstract model that involves minimizing cost and duplication.

Taken together, these five “propositions about prediction” are, in fact, propositions about how to wean the defense community away from relying so heavily on prediction. Put simply, one can make better decisions by adopting a premise of long-term predictive failure. This prescription contrasts with most present decisionmaking, which is premised on predictive success. It is, moreover, very different from most present efforts that strive for improvement by pursuing more predictive power.

## **6. Accelerate Decision Tempo – and Delay Some Decisions**

There is a paradox in this two-headed recommendation. However, just as automobiles require first and fourth gears – and even reverse – for maneuvering a vehicle in varying traffic and over varying terrains, decision vehicles require diverse tools in order to operate across a range of conditions. In a

world of uncertainty, significant defense acquisition is crippled by procrustean procedures – all major programs are treated similarly.<sup>88</sup> A sound recognition of unpredictability should lead to much faster decisions in some circumstances and slower, staged decisionmaking in other contexts.

### **ACCELERATE TEMPO**

In a world of unpredictability, there are heavy penalties for ponderous decisionmaking and slow execution. This is primarily a result of the fact that although prolonged procedures may improve the likelihood of hitting a fixed or predictably moving target, they doom decisionmakers to fall behind an unpredictably moving target. Accordingly, private-sector managers make and execute decisions in days, weeks or months. Only in a minority of cases do they develop products with schedules extending beyond two or three years because more extended development cycles are understood to be too vulnerable to unpredictable evolution (sometimes revolution) in the market. The aim is to reduce uncertainty by narrowing the time between the initiation of a concept and its realization.

DOD processes operate in quite a different way. Decision cycles in three overlapping domains (the Joint Capabilities and Development Integration System; the Planning, Programming and Budgeting System (PPBS); and the Defense Acquisition System)<sup>89</sup> are measured in years. The time from conception to mass production is measured in decades.

This over-extended system attracts criticism due to issues of cost and delay in delivering desired equipment.<sup>90</sup> However, the criticism suggested by my first five propositions points in a different direction: Delay increases the likelihood that an acquisition will fail because it increases dependence on prediction. A Defense Science Board study on the need for more adaptability in defense forces recognizes this point, saying flatly: “The lengthy preparation cycles and associated

enterprise culture and processes that evolved over the past decades are a liability within the Department of Defense.<sup>91</sup>

By narrowing the gap between system decisions and system delivery, increased speed reduces the length of time that must be predicted.<sup>92</sup> The prevalent premise of predictability enshrines the false concept that more time will allow more precise planning for the future. Faster decisionmaking and execution should be priorities throughout the defense acquisition system in order to reduce exposure to the unpredictable changes that will arise between the time of conception and the time of execution.

Although improvements in pace are necessary, they are insufficient. A recognition of unpredictability also points to a need for a second procurement process to cope with unpredicted emergencies. The need for such a system is well illustrated by the recent, much discussed, delays in obtaining Mine Resistant Ambush Protected (MRAP) armored vehicles:

From the summer of 2005 until the spring of 2008, the IED threat was responsible for 50 to 80 percent of US fatalities [in Iraq].... The IED threat evolved over time, but all the major forms of IEDs were apparent early on – by 2004 or 2005 at the latest.<sup>93</sup>

However, the Pentagon would not act upon the request for MRAPS until late 2007. It took more than 2 years.<sup>94</sup>

A study published by the National Defense University concludes that the delays in MRAP procurement are best explained by resistance to MRAP purchases.<sup>95</sup> There were operational objections (for example, the higher clearance of MRAPs made them less vulnerable to blasts but also more at risk of tipping over). Even more fundamentally, “MRAPS were unappealing because they are useful for a limited defensive purpose in select irregular

warfare campaigns like Iraq and Afghanistan that military Service leaders hoped would be short-lived.”<sup>96</sup>

For the purposes of this report, the issue is not the legitimacy of these objections but the time it took to resolve them. A system built in the Cold War could keep pace with a largely predictable Soviet opponent via a decision cycle measured in years. That environment is gone. An environment where surprise is more prevalent requires more rapid decisions.<sup>97</sup> An unnamed “participant” who defended the MRAP delay remarked:

If anybody could have guessed in 2003 that we would be looking at the kind of [high-powered, buried] IEDs that we’re seeing now in 2007, then we would have been looking at something much longer term as a solution .... But who had the crystal ball back then?<sup>98</sup>

Indeed, no one had, or could have had, “the crystal ball.” Thus, in a world without crystal balls, we need a new kind of wizardry: faster decisions.

Presently, we accelerate only as a reaction when we encounter the unexpected, such as IEDs that compel the rapid production of MRAPs. That acceleration is effective, in a delayed and ad hoc manner. Yet if the thesis of this report is correct, then planners should design decision systems on the premise that the unpredicted will occur. Such a design would complement more deliberate, consensus-oriented, heavily analytic decision processes with a second, rapid but regularized, system that could be invoked when the Secretary of Defense judged it to be warranted as a result of urgent, unanticipated requirements.<sup>99</sup>

In a 2008 paper, Andrew Krepinevich argues that “high priority must be placed on compressing the time it takes for investments to create military capability that will enable the U.S. military to prevail in key ... competitions.”<sup>100</sup> In a footnote, he ties this to a distinction drawn in business:

With the advent of the information technologies revolution and repeated discontinuities in the corporate sector, “time pacing” has become an increasingly important attribute. As Kathleen Eisenhardt and Shona Brown point out: “For most managers, event pacing constitutes the familiar and natural order of things. Companies change in response to events such as moves by the competition, shifts in technology, poor financial performance, or new customer demands... In contrast, time pacing refers to creating new products or services, launching new businesses, or entering new markets according to the calendar.”<sup>101</sup>

In these terms, DOD should supplement its dominant time-based acquisition systems with event-based acquisition capabilities.

#### **DELAY SOME DECISIONS**

As a complement to reducing total cycle times, a new strategy should defer decisions regarding particular program characteristics (e.g., software systems) as far back in the cycle as possible. This enables choices to be made with the maximum information as to the currency and maturity of those systems and with the maximum insight as to expected use. Put another way, this strategy mitigates unpredictability by pushing choices closer to the future.

Private sector executives understand the virtue of this approach. Disney’s Michael Eisner reportedly would find the latest point in time that he could make a decision.<sup>102</sup> Yet DOD processes enforce the opposite approach; the requirements, PPBS and acquisition systems each demand great specification about activities and environments that cannot be predicted. Uncertainties and unresolved issues are regarded as points of weakness, impeding go/no-go decisions, budgetary accuracy, systems integration and competitive fairness. These considerations are not inappropriate. However, they feed and are fed by incorrect

premises about predictability. As a result, major defense systems are subject to excessively frequent, disruptive and costly changes; they are pursued with a rigidity that ensures they are outmoded when delivered; and they are poorly adapted to the circumstances and requirements of their actual use.

#### **7. Increase the Agility of Production Processes**

Production agility is the capability of design and manufacturing systems to respond, in terms of both quantities and characteristics, to unanticipated needs. Although this imperative received some attention during the Cold War, the focus was overwhelmingly on quantity, with little attention to the need for flexibility to modify what was produced. Cold War standby acquisition mechanisms were designed for “mobilization,”<sup>103</sup> which involves conscripting existing assets or facilitating surges of equipment already being produced. The architects of systems like CRAF (the civilian reserve air fleet that reallocates civilian aircraft to military uses) and Defense Production Act<sup>104</sup> priority rights were clear about what they needed. They wanted to ensure that existing industrial capabilities were preserved, and they wanted production augmentation capabilities analogous to the manpower augmentation capabilities they had through conscription, the Reserves and the National Guard.<sup>105</sup>

The implication of the first five propositions is that 21st-century planners face a further challenge: to meet unanticipated needs. Can a production system be designed for adaptiveness in type, as well as in quantity? Commercial production systems clearly show that the answer is yes. Automobile plants, specialty steel mills and semiconductor foundries all have been conceived and constructed to switch products rapidly as demands, designs and technologies change. Defense production shows little of this adaptability.



Helpfully, some programs have adopted open systems architecture, modular systems and spiral development. They move toward these goals by decoupling parts of the system, so it is possible to change subsets of the system without changing the whole.<sup>106</sup> The Defense Science Board singles out the Navy's system for repeated upgrading of submarine acoustic equipment as path-breaking in this regard,<sup>107</sup> but other examples are available (the Board also commends the Air Force's F-16 modular upgrade program and the Army's AMRAAM missile system).<sup>108</sup>

The Defense Advanced Research Projects Agency (DARPA) is developing programs that go further by re-conceptualizing not only products but also manufacturing processes. As one prong of the effort, the DARPA Defense Science Office focused on the problem of vaccine preparation against unpredictable requirements. Even vaccine variants for recurring diseases like flu require such long lead times for seasonal adaptations that the resulting vaccines are typically mismatched to the need. Worse, wholly new vaccines take decades to develop, whereas new diseases like SARS or H5N1 can reach pandemic levels within a year of being recognized. The resulting program has demonstrated that within 16 weeks, it can produce a million units of a capable vaccine against a previously unknown virus. The key is to invest in "scaffolds" that can produce immunizing proteins when infected with virus "vectors" tailored to counter the identified pathogen.<sup>109</sup> Recent efforts focused on countering the H1N1 flu virus,<sup>110</sup> but because the scaffolds can be used for a broad range of protein production and achieve high production within 30 days, they do not require pathogen prediction in order to be effective.<sup>111</sup>

Employing different tactics, but a similar strategy, the J. Craig Venter Institute and its spin-off, Synthetic Genomics Vaccines, are using synthetic biology to create genomes<sup>112</sup> and then embed them

in recipient bacteria to produce vaccines. As with DARPA's project, the first priority is a flu vaccine, but according to an article describing the process, "Venter says the speedier DNA synthesis technique could also make it possible to keep up with even more rapidly evolving pathogens that change too fast for conventional vaccine development to keep up. This includes HIV, malaria, and rhinovirus – one of the causes of the common cold."<sup>113</sup>

Working in a different domain, DARPA's Tactical Technology Office<sup>114</sup> has initiated a cluster of programs under the heading "Adaptive Vehicle Make." One component program, known as Instant Foundry Adaptive through Bits (iFAB), "looks to lay the groundwork for the development of a foundry-style manufacturing capability ... capable of rapid reconfiguration to accommodate a wide range of design variability and specifically targeted at the fabrication of military ground vehicles."<sup>115</sup>

A core insight of the Adaptive Vehicle Make program is that the manufacturing of complex defense systems is slowed by a lack of standardization among components and by dependence on trial and error (test and retest) as a means of integrating these components. At the simplest level, the ideal is the Lego set, with its universal snap-in interface.<sup>116</sup> However, Lego pieces need to be matched in only three spatial dimensions. Components of complex systems require compatibility in many domains – for example, they must avoid electromagnetic interference, be compatible in their software and avoid generating excessive heat when operating together. As this multidimensional complexity increases, integration becomes more challenging,<sup>117</sup> and the costs and delays from using trial and error to ascertain system problems accelerate.<sup>118</sup> DARPA attempts to counter this by building the Army's armored vehicles primarily from components with standardized interface attributes. It aims to reach a point at which designers and foundries can develop and manufacture components by mixing and matching parts according to agreed design rules,<sup>119</sup> thereby improving efficiency and reliability.<sup>120</sup>

For the purposes of this report, however, such work is important because, if achieved, it will accelerate manufacturing adaptiveness.<sup>121</sup>

### **8. Prioritize Equipment That Is Most Adaptable**

To the extent that future environments and tasks are predictable, one can make a strong case for precisely defined equipment that fits a particular niche. To the extent that unpredictability reigns, however, adaptability is at a premium. The F-22 is an example of a military airplane with low adaptability; it is precisely designed for a narrowly defined mission and will have trouble taking on other roles. At the other end of the spectrum, the B-52 bomber is an airplane with high inherent resilience; essentially a flying box, it is used as a platform for weapons, communications and missions that were not, indeed could not have been, envisioned by its designers.

Five changes would facilitate greater adaptability of equipment.

First, a premium should be placed on operational flexibility in requirements processes.<sup>122</sup> It is easy to identify challenging scenarios, like air-to-air combat, in which military equipment profits from a high degree of specialization. However, other characteristics of the military environment should push toward more resilience – toward more weapon systems like B-52s and fewer like F-22s. Military equipment takes longer to develop and stays in service longer than private equipment, such as automobiles. It will also be used under a much greater variety of circumstances, many of which will be unpredictable.

For all these reasons, one would expect military systems to be more inherently resilient than civilian systems. In fact, they are less so. The U.S. military keeps generating systems, like the M-1 tank, that are marvelous for defined circumstances (e.g., fighting other tanks on the planes of central Germany) and poor in their utility for other circumstances (e.g., so heavy

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*To the extent that future environments and tasks are predictable, one can make a strong case for precisely defined equipment that fits a particular niche. To the extent that unpredictability reigns, however, adaptability is at a premium.*

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that they cannot travel across most bridges in the developing world).<sup>123</sup>

A major reason for this is that our evaluation mechanisms put a premium on performance in specified scenarios and no value on inherent resilience.<sup>124</sup> The evaluative systems now used in the Pentagon are heavily quantitative. Performance payoffs are measured against agreed scenarios. Yet how does one assign quantitative weight to flexibility? Paul Davis usefully outlined an approach based on viewing defense assets as a portfolio whose capabilities can be optimized against adaptive needs in a range of scenarios.<sup>125</sup> Owen Brown and Eremenko suggest that one should value flexibility analogously to stock options: Flexibility provides additional options for future action.<sup>126</sup> They also recommend the use of large numbers of scenarios, in a manner analogous to that recommended by RAND (which they do not reference),<sup>127</sup> to calculate net present values with and without flexibility. These are good initial concepts. The U.S. military needs both a better bureaucratic process and a more developed science of decisionmaking<sup>128</sup> to properly place value on flexibility and agility.<sup>129</sup>

Second, DOD should maximize the platform approach suggested by the B-52 example. Using a software analogy, the basic weapon platform is like the operating system, and the addition and delivery of additional focused capabilities is like the installation and use of applications. Designing systems that provide only generic sets of capabilities (platforms), yet can readily be customized and adapted for particular uses (applications), will often yield more long-term value and efficiency than developing a system with a rich but narrowly focused set of capabilities that is more “efficient” according to bureaucratic, nonoperational and predictively biased standards.<sup>130</sup>

Third, resilience over time is as important as resilience over a range of capabilities and conditions. Evaluations should not only examine the equipment as designed but also account for the likelihood that this design will be modified in unpredictable ways over the course of its service life. To borrow a metaphor from a related field, our systems should, where possible, be designed to operate like immune systems rather than fortresses.<sup>131</sup> The defense community should move away from designing rigid lines of defense to cope with static threats and instead seek capabilities for adaptation to threats that cannot be predicted with precision.

In general, it is likely that this design orientation will increase our reliance on software rather than hardware because software can more readily be adapted or swapped out.<sup>132</sup> Moreover, the greatest rewards are likely to arise from software systems that achieve immediately adaptive responses without human intervention. An example of what should be sought can be found in the announcement for DARPA’s Behavioral Learning for Adaptive Electronic Warfare (BLADE) system:

The goal of BLADE ... is to ... counter adaptive wireless communication threats in tactical environments and in tactically relevant time scales.

Wireless communication threats include an adversary’s use of wireless radios and networks for Command, Control, and Communication (C3), as well as for other malicious uses, such as Radio Control Improvised Explosive Devices (RC-IED’s) [sic].

Currently, the development of new Electronic Attack (EA) techniques requires technicians in a laboratory to characterize a new communication threat and then synthesize and evaluate potential countermeasures. Meanwhile, U.S. and allied forces remain vulnerable to the new threat until the new countermeasure is fielded. In addition to taking a significant amount of time to develop, EA techniques today are rigidly designed to address a specific threat with known characteristics. As wireless communication devices become more adaptive and responsive to their environment by using technology such as Dynamic Spectrum Allocation (DSA), the effectiveness of fixed countermeasures may become severely degraded.

To protect U.S. forces and enable the rapid defeat of new communication threats, a paradigm shift in Electronic Attack is needed from a manual lab-based EA development approach to an adaptive in-the-field systems approach. The BLADE program will achieve this objective by developing novel algorithms and techniques that will enable our EW systems to automatically learn to jam new RF threats in the field.<sup>133</sup>

Fourth, the military should encourage, plan for and facilitate field modification. Army units responded to IEDs in Iraq by soldering additional armor onto vehicles.<sup>134</sup> This adaptation follows a rich tradition. In World War II, for example, when soldiers in Normandy found that the less-armored underbellies of their tanks were exposed as they rode over hedges, they jury-rigged cutting devices to take the tanks through, rather than over, the obstacles.<sup>135</sup> Present policies ignore, and in some

ways impede, these field adaptations. An enlightened policy would facilitate them – for example, by deploying armored vehicles with armor module attach points and supplemental componentized armament.<sup>136</sup> Fighting forces would thereby be empowered to reconfigure their equipment in the field to meet challenges that cannot be predicted.

Fifth, the military could achieve more general utility by designing equipment leanly. This approach would involve clarifying a desired core function and designing as closely as possible to that function. This path is well illustrated by the bio-detection conundrum described at the outset of this report. Calls for a national strategy to defend against bioterrorism have emphasized that detection and surveillance are required to indicate that a pathogen has been disseminated.<sup>137</sup> Only then can we initiate distribution of drugs that must be received (typically within 48 hours) to save the lives of those who are exposed.<sup>138</sup> Present aerosol detection systems determine whether predetermined pathogens (e.g., smallpox) are present. These systems depend, however, on precise assays matched to a predicted threat list.

The evolution of modern biology has produced techniques of genetic sequencing and synthesis that will permit the modification (and therefore disguise) of existing pathogens and the creation of new ones.<sup>139</sup> If achieved, this will render our present aerosol sampling strategies antiquated and ineffective. Yet instead of coming to grips with this, Department of Homeland Security (DHS) and DOD plans for development of detectors have been simply expanding the number of pathogens that must be assessed. In a world of unpredictability, they continue to assume a world of continued predictability.

A strategy for coping with this unpredictability is to make the detection mechanism synchronous with the target. Adversaries do not aim to contaminate the environment; they aim to make people

sick.<sup>140</sup> A detection system that identifies whether people are becoming sick is therefore closely linked to the target. An adversary can take any of a number of unpredictable paths to reach the target, but to be effective, he or she must ultimately attack the target. Focusing on the target thus circumvents the uncertainties about how the adversary may proceed.

Over the next decade, this lean focus is technically feasible. DARPA has, for example, demonstrated that it can use blood samples to discern virus infections almost immediately after they occur – days before symptoms become apparent.<sup>141</sup> If this system were employed routinely to evaluate police and fire personnel as they come off shifts, we would build a known baseline against which routine changes could be characterized and aberrational changes immediately recognized. Individual deviations would be of little concern, but if widespread aberrational infections were observed, these could be correlated with GPS (Global Positioning Systems) records derived from squad cars and fire trucks to analyze where infected personnel had been and, thereby, which areas had been contaminated.

This proposition has immediate significance for DHS and the DOD Joint Chemical-Biological Detection Office as a recommendation for the allocation of their research and development funds. More generally, however, it is indicative of a set of requirements and opportunities that arise when one recognizes that systems dependent on predictability must be replaced by new approaches that are resilient in the face of unpredictability.<sup>142</sup>

## 9. Build More for the Short Term

In *How Buildings Learn*, Stewart Brand grapples with the conundrum that buildings are usually built for a particular purpose but over time are put to uses that were not (and frequently could not have been) envisioned when they were designed.<sup>143</sup> In a query that is parallel to the one in this report, Brand asks how an architect would

design a building to maximize flexibility. Among his insights is the observation that adaptive buildings often fall into two different categories, which he labels “high road” and “low road.” High road buildings are built to endure, elegantly designed and typically rather rigid. Only slowly and expensively can they be adapted to new uses. “Try putting modern plumbing and heating into a stone [17th century mansion] – it is like performing lung surgery on a tetchy giant. The high road is high-visibility, often high-style, nearly always high cost.”<sup>144</sup> Low road buildings, by contrast, are rapidly constructed for temporary purposes. They are inexpensive, and their cheap materials are easy to reconfigure. Because no one puts a premium on preserving low road buildings, they easily lend themselves to field adaptation.<sup>145</sup>

DOD’s acquisition process has been so focused on “high road” sophistication that it has lost the ability to take Brand’s “low road.” Proposition 6 argued that an accelerated tempo is important not only because slow responses fail to protect troops in immediate danger but also because delay pushes products further into the future, where their relevance and performance is less predictable than it would be in the near term. This ninth proposition argues that concomitant with acceleration of tempo, a healthy recognition of unpredictability increases the attractions of shorter-life products.

The private sector is replete with short-life products, ranging from cell phones and computers with expected uses of a few years to automobiles that typically will be on the road for a decade. Eighty percent of DOD procurement consists of consumables and short-lived products, but in its acquisition of platforms, DOD traditionally commits emphatically to long-lived systems. Ships are built for 30 years (carriers longer), aircraft and ground vehicles for more than 20 years. In fact, the average ship now in the U.S. Navy has been in service for more than 20 years, and the average airplane almost 20 years. This entails heavy dollar

costs (including maintenance and refurbishment), and it also reduces our security. We are locked into outdated equipment.

The rise of unmanned systems opens opportunities for a different procurement emphasis – one that accepts expectations of service periods more like those of computers than carriers. Recognition of unpredictability in technology development and combat environments would place a premium on this attribute and begin to refashion the defense world to look more like the consumer environment. This approach would be more viable if coupled with the three just-recommended strategies of speed, flexibility and adaptability. The four propositions together could create a self-reinforcing virtuous cycle that substantially alters defense procurement, making it more resilient and less dependent on the unreliable pillar of prediction.

### 10. Nurture Diversity; Create Competition

The genius of the capitalist system is that it has no pretensions about prediction: It does not preselect winners and losers but instead facilitates competition based on different premises. The resulting diversification of options hedges against predictive failure: Jones invests in a future premised on A, Smith invests on a theory of not A, Thomas invests without reference to A. At least one will be wrong, but at least one will be right. As resources are shifted from losers to winners, the system comes closer to optimal allocations than if systemic predictions were used for resource allocation. Market-based systems seem to be “inefficient” in that many resources are used and “wasted” by the losing firms, but the reality is that markets are the “least bad” way of allocating resources because prediction-based systems are built on false premises.

As indicated in the introduction to this report, it would initially appear that the U.S. national security establishment could not operate on this premise. One might think that the nation cannot afford either the economic or political costs

of having multiple armies, navies, air forces or marine corps. In fact, however, we do have a measure of competition by having an Army, Navy, Air Force and Marine Corps. In recent years, the nation has also put more emphasis on Special Operations Forces that are, in important respects, independent of these services. Also, communities within each of the services compete with one another for resources, promotions and status. This results in redundancies, rivalries and inefficiencies that are often decried. As a counterforce, a push for “jointness” has aimed to minimize inter-service competition.

Jointness is richly rewarding, and indeed often imperative, in many operational settings. However, the perspective about prediction offered here suggests that long-term planners should recognize limits to their enthusiasm for central staffs and central control. Studying successes and failures in military institutions, Elting Morison concluded his work a half-century ago by stressing the importance of “the experimental mood.”<sup>146</sup> Yet he recognized that centralization of power countered this essential ingredient for innovation.<sup>147</sup> That same centralization fuels an over-investment in canonical predictions.

Insofar as the aircraft chosen by the various branches of the military reflect different concepts of warfare, they compete with one another and hedge against uncertain futures. Differing missile defense programs created a greater diversity of opportunities and a lesser exposure to unpredictable technical and political risks. Returning to the MRAP example, it is apparent how the services’ diverse priorities create some long-term resiliency. When the Army eventually pursued an MRAP for Iraq, it was a 40,000-pound vehicle because heavy armor was the greatest priority. By contrast, the Marine Corps wanted MRAPs closer to the weight of Humvees (16,000 pounds) because that is what their helicopter fleet was able to transport. Afghan commanders particularly value mobility

and all-terrain attributes not relevant to Iraq. They might optimally choose something in between the two above designs (a 25,000-pound MRAP?). However, the diversity introduced by the Marine Corps increased the flexibility and, therefore, resilience of the program.

Similarly, although the diversity of investments and system designs among U.S. allies can be frustrating, it can be rewarding if compatibility can be achieved. When, for example, the United States underinvested in naval mine sweeping but then very much wanted such capabilities for contingencies in the Straits of Hormuz, Italian investments shielded the United States from its inability to foresee its needs.

The military should be willing to pay for diverse approaches in procurement.<sup>148</sup> It should value competition not just for reducing prices but also for encouraging different approaches to similar problems. Respect for unpredictability argues against keeping many eggs in one basket. Moreover, if the U.S. military increases emphasis on software elements within its systems and facilitates in-field reprogrammability (the eighth proposition, above), interoperability can be more readily achieved in the future across services and across allies.

Effective capitalist competition is premised on something subdued in the defense context: Starting more programs than can be sustained, comparing them side by side, killing the ones that are least cost-effective and allowing only survival of the fittest. This approach is anathema for central planners. By definition, it instills conflict. It requires starting more ventures than can be completed and, therefore, ensures the failure of some ventures (which will be described as waste). Perhaps worst, such competition in the defense world would compel senior decisionmakers to judge and label failure. However, genuine competition – a radical innovation in the world of defense procurement – offers the best probability of survival in an

unpredictable world. There are real inefficiencies to be found and rooted out when redundant systems are operated or proposed. Yet if this report is persuasive, great care should also be taken to reveal whether perceptions of redundancy are based on overly confident predictions. Where that occurs, it should be recognized that what may be inefficient in a predicted world may be life-saving if the unpredicted occurs. When point solutions cannot be confidently predicted, then a range of options must be nurtured, recurrently assessed and either sustained or killed in the unpredictable environments that emerge.

#### IV. CONCLUSION

DOD's systems for selecting and designing major weapons systems rely too heavily on successful prediction. Based on both the Department's track record and social science research, we should expect frequent error in decisions premised on long-term predictions about the future. This high rate of error is unavoidable. Indeed, it is inherent in predictions about complex, tightly intertwined technological, political and adversarial activities and environments in a volatile world.

Accordingly, we should balance efforts to improve our predictive capabilities with a strong recognition of the likelihood of important predictive failures. We should identify, improve and implement strategies to design processes, programs and equipment to prepare us for those failures. This report shows how five approaches can help: narrowing dramatically the time between conceptualizing programs and bringing them to fruition; investing in the agility of production processes so they can meet unanticipated needs; designing and selecting equipment with a premium on operational flexibility; building more for the short term so that equipment will be more frequently replaced, opening opportunities to capitalize on emerging technologies; and valuing diversity and competition in order to foster a wider range of potential solutions to currently unknowable problems.

Policymakers will always drive in the dark. However, they must stop pretending that they can see the road. A much better course is to adopt techniques to compensate for unpredictable conditions and, in so doing, better prepare us for perils that we will not have foreseen.

## ENDNOTES

1. F. Scott Fitzgerald, "The Crack-Up," *Esquire*, February 1936. The quotation continues with a comment also relevant to this paper: "This philosophy fitted on to my early adult life, when I saw the improbable, the implausible, often the 'impossible,' come true."

2. Nassim Nicholas Taleb, *Foiled by Randomness: The Hidden Role of Chance in Life and in the Markets* (New York: Random House, 2005), 69.

3. In a short monograph decrying repeated predictive failures in Army planning, LTC Eric A. Hollister observes:

The Arab-Israeli War of October 1973, seen as a portent of a U.S.-Soviet conflict, resulted in massive, rapid losses of highly lethal conventional forces and equipment. Lessons from that war led to a substantial revision, in 1976, of army field manual (fm) 100-5, Operations – doctrine that became known as "Active Defense." The manual stated that the "first battle of the next war may be the last," making it imperative that the army be trained and equipped to "win the first battle of the next war." Active defense led to the 1982 revision known as "AirLand Battle," which drove the army's modernization program for years to come, producing what came to be known as the "Big Five": the M1 Abrams tank, the M2 Bradley infantry fighting vehicle, the AH-64 Apache attack helicopter, the UH-60 Black Hawk utility helicopter and the Patriot high- to medium-altitude air defense system.

LTC Eric A. Hollister, "A Shot in the Dark: The Futility of Long-Range Modernization Planning," *Land Warfare Paper 79* (The Institute of Land Warfare, 2010), 2.

4. For example, firing opportunities could be exploited over much more open terrain than was expected in Germany. The "interstitial range" for tank engagements in Europe was estimated to be 800 meters, but it was beneficial in Iraq that the Abrams tank's 120mm cannon can engage accurately as far as 3 kilometers.

5. "The first M1 Abrams battle tanks were delivered to the US Army in 1980. 3,273 M1 tanks were produced for the US Army. 4,796 M1A1 tanks were built for the US Army, 221 for the US Marines and 880 co-produced with Egypt." [www.army-technology.com/projects/abrams/](http://www.army-technology.com/projects/abrams/).

6. "Like *AV2010, OF2015* [published in 2002] makes no mention of insurgencies, post-conflict operations or contractors on the battlefield. Incredibly, it does not address counter-IED (improvised explosive device) operations or how IED strikes would be mitigated. Three months after its publication, the U.S. Central Command (CENTCOM) commander, General John P. Abizaid, stated that IEDs in Iraq were the number one threat to the force." Hollister, "A Shot in the Dark," 4.

7. See "Bioterrorism Agents/Diseases," [www.emergency.cdc.gov/agent/agentlist-category.asp#a](http://www.emergency.cdc.gov/agent/agentlist-category.asp#a). A comprehensive identification of toxins and agents that could pose a severe risk to public health and safety is now required by the Public Health Security and Bioterrorism Preparedness and Response Act of 2002. For the present list, see [www.selectagents.gov/Select%20Agents%20and%20Toxins%20List.html](http://www.selectagents.gov/Select%20Agents%20and%20Toxins%20List.html).

8. Anthony Cordesman, "Biological Warfare and the Buffy Paradigm" (Center for Strategic and International Studies, September 2001).

9. While this paper was in draft, the Defense Science Board published a study urging more adaptability in DOD processes and products. Defense Science Board, *Report of the Defense Science Board 2010 Summer Study on Enhancing the Adaptability of U.S. Military Forces, Part A. Main Report* (January 2011). An appendix prepared by Michael Rumsey of the U.S. Army Research Institute for the Behavioral and Social Sciences suggests a "program for research" for developing adaptable personnel. Defense Science Board, *Report of the Defense Science Board 2010 Summer Study on Enhancing the Adaptability of U.S. Military Forces, Part B. Appendices* (January 2011), 75.

10. 10 U.S.C. § 118.

11. Notable within the DOD, in addition to the Quadrennial Defense Review, the Joint Forces Command's *Joint Operating Environment* and the Jasons' reports discussed below, are the on-going effort to identify "Trends and Shocks" and Defense Science Board, *Report of the Defense Science Board 2008 Summer Study on Capability Surprise: Volume 1: Main Report* (September 2009). The discussion that follows references predictive initiatives by the Netherlands Armed Forces and the Government of Singapore as representative foreign efforts.

12. Joint Forces Command, *Joint Operating Environment* (2010), 9. More whimsically, but no less accurately, this document might have also recalled a statement often attributed to Churchill in which he said that it was essential for an aspiring statesman to have "the ability to foretell what is going to happen tomorrow, next week, and next year. And to have the ability afterwards to explain why it didn't happen." Quoted in Bill Adler, ed., *The Churchill Wit* (New York: Coward- McCann, 1965).

13. Joint Forces Command, *Joint Operating Environment*, (2010), 10. A group of eminent scientists known as the Jasons responded similarly when they were asked by senior Pentagon officials to evaluate the potential for predicting "rare events," that is, "extreme, deliberate act[s] of violence, destruction or socioeconomic disruption, such as an attack of 9/11 scale or greater." The group observed: "One problem is that rare events are rare. There will necessarily be little or no previous data from which to extrapolate future expectations in any quantitatively reliable sense or to evaluate any model. In the extreme, how can the probability of an event that has never been seen or may never even have been imagined be predicted? The second problem is that the mechanisms at work are largely human behaviors not just physical forces. . . . There is no credible approach that has been documented to date to accurately anticipate the existence and characterization of WMD-T threats." "Rare Events" (The MITRE Corporation, October 2009), 6.

14. A representative foreign effort at long-term planning by the Netherlands Armed Forces does the same thing. However, it provides a series of examples of unforeseen events, e.g., "Who would have thought in 2000 that Dutch military personnel would be deployed in Afghanistan?" The Netherlands Armed Forces, *Future Policy Survey: Summary and Conclusions*, (2010), 59. The report proceeds to forecast the world from now to 2030, explaining that a "time horizon of twenty years is necessary because the capital spending on



development and procurement of military capabilities is often spread out over many years." *Ibid.*, 56. The summary report for policymakers states that "[n]ever before in the Netherlands has there been an interdisciplinary, interagency, or international exercise in the area of defense comparable with the Future Policy Survey. Many experts . . . have participated . . . The primary aim of the Future Policy Survey is to provide an authoritative and objective basis for political choices with regard to the Netherlands defense effort." *Ibid.*, 7. A British defense planning process came closer to recognizing the limitations of prediction and the need for adaptability after a ministerial paper initiated the process with the observation that there was "no single, overwhelming threat against which we should shape our Armed Forces. But the development of a number of major trends will produce a wider range of potential threats to stability than we have previously faced, many of them transnational in nature. It will be harder to predict which threats will emerge as the most significant, leading to a future international context characterized by uncertainty." United Kingdom Ministry of Defense, *Adaptability and Partnership: Issues for the Strategic Defence Review* (February 3, 2010), 15. This document paved the way for a later strategic statement: *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review* (Presented to Parliament by the Prime Minister, October 2010).

15. A notable exception is the Defense Science Board summer study prepared while this report was in draft. Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces*. I have noted instances where some of that report's conclusions parallel those I offer here. See also Ministry of Defense, *Adaptability and Partnership*.

16. Steven W. Popper, "The Third Ape's Problem: A Parable of Reasoning Under Deep Uncertainty," P-8080 (Santa Monica, CA: RAND Corporation, 2004) and Robert J. Lempert and Steven W. Popper, "High-Performance Government in an Uncertain World," in *High Performance Government: Structure, Leadership and Incentives*, eds. Robert Klitgaard and Paul C. Light (Santa Monica, CA: RAND Corporation, 2005).

17. According to Daniel Gilbert and Timothy Wilson, "All animals can predict the hedonic consequences of events they've experienced before. But humans can predict the hedonic consequences of events they've never experienced by simulating those events in their minds. Scientists are beginning to understand how the brain simulates future events, how it uses those simulations to predict an event's hedonic consequences, and why these predictions so often go awry: All animals are on a voyage through time, navigating toward futures that promote their survival and away from futures that threaten it. Pleasure and pain are the stars by which they steer. When animals experience pleasure they hold a steady course, and when they experience pain they tack. With a bit of practice, most animals learn to associate pleasures and pains with their antecedents – the smell of an approaching predator or the call of a beckoning mate – which enables them to steer toward pleasure and away from pain before they actually experience either. When a mouse hides before a cat enters the room it is responding to an event that has not yet happened, and its ability to do so is one of evolution's most remarkable achievements. Humans have this ability too. But they also have another ability that extends their powers of foresight far beyond those of any other animal. Just as retrospection refers to our ability to re-experience the past, prospection refers to our ability to 'pre-experience' the future by simulating it in our minds. We know that chocolate pudding would taste better with cinnamon than dill, that it would be painful to go an hour without blinking or a day without sitting, that

winning the lottery would be more enjoyable than becoming paraplegic – and we know these things not because they've happened to us in the past, but because we can close our eyes, imagine these events, and pre-experience their hedonic consequences in the here and now. Unfortunately, the conclusions that we draw in this way aren't always right." Daniel Gilbert and Timothy Wilson, "Prospection: Experiencing the Future," *Science* (September 7, 2007), 1351-2.

18. It is commonplace to observe that people are typically uncomfortable with change. (As one author nicely titled her book, *Only Wet Babies Like Change* [Mary-Frances Winters, *Only Wet Babies Like Change: Workplace Wisdom for Baby Boomers* (Rochester, NY: Winters Group, 2002).] More reflection and study may suggest, however, that this is largely a subset of discomfort with uncertainty and desire for control. The evidence cited in the balance of this paragraph points in this direction.

19. Dylan Smith et al., "Happily Hopeless: Adaptation to a Permanent, But Not to a Temporary, Disability," *Health Psychology* 28 no. 6 (November 2009), 787-791. Smith and his colleagues note that their study involved only 107 patients and that there are a number of alternative explanations "for why the prospect of hope could impede adaptation. One obvious mechanism relates to differences in motivation between the two groups. Because acknowledging loss can be momentarily painful, people may not be willing to 'take the hit', and therefore may fail to engage in the conscious and/or unconscious processes that produce adaptation until and unless they have no alternative. People may also not want to expend the mental effort required to adapt if there is some possibility that such measures might later prove to have been premature and/or unnecessary. A belief that one's adversity is temporary may also impede adaptation by complicating reality and impeding sense-making – e.g., the ability to find a silver lining in a calamity. . . . Finally, knowledge of a potentially better future could remind people of ways in which their current circumstances are less than ideal, serving as an upward point of comparison that causes one's present circumstances to be viewed in a negative light." See also Peter Ubel (a co-author of the Smith study), "Emotional Adaptation and the End of Economics," PowerPoint Presentation, University of Michigan, no date.

20. Daniel Gilbert, "What You Don't Know Makes You Nervous," *New York Times*, May 21 2009.

21. Suzanne Thompson, "Illusions of Control," in Rüdiger Pohl, ed., *Cognitive Illusions: A Handbook on Fallacies and Biases in Thinking, Judgment and Memory* (New York: Psychology Press, 2004). See also Peter M. Gollwitzer and Ronald F. Kinney, "Effects of Deliberative and Implemental Mind-Sets on Illusion of Control," *Journal of Personality and Social Psychology*, 56 no. 4 (April 1989), 531.

22. Suzanne Thompson, "Illusions of Control: How We Overestimate Our Personal Influence," *Current Directions in Psychological Science* 187 (1999); Scott Plous, *The Psychology of Judgment and Decision Making* (New York: McGraw-Hill, 1993).

23. One of the earliest observations is from Tacitus: "The wider the scope of my reflections on the present and the past, the more I am impressed by their mockery of human plans in every transaction." P. Cornelius Tacitus, *Annals of Tacitus, Book III* trans. Alfred John Church and William Jackson Brodrick (New York: Macmillan, 1895), 86.

24. For observations on their expertise, see Philip Tetlock, *Expert Political Judgment: How Good Is It? How Can We Know?* (Princeton, NJ: Princeton University Press, 2005), 44. For a more polemical layman's treatment of the same subject, see David Freedman, *Wrong: Why Experts Keep Failing Us and How to Know When Not to Trust Them* (New York: Little, Brown and Company, 2010).

25. See Tetlock's methodological appendix. *Tetlock, Expert Political Judgment*, 242-246. DOD's Office of Defense Research and Engineering has recently requested proposals for systematic evaluation of the methodologies and success rates of technology forecasting techniques. See "Retrospective Analysis of Technology Forecasting," [www.fbo.gov/index?s=opportunity&mode=form&id=4506b5a2051571687e0aae52450bffc0&tab=core&\\_cview=1](http://www.fbo.gov/index?s=opportunity&mode=form&id=4506b5a2051571687e0aae52450bffc0&tab=core&_cview=1).

26. Tetlock, *Expert Political Judgment*, 20. See also Henry Mintzberg, who summarizes the then-current literature and comments caustically on "the performance of forecasting." Henry Mintzberg, *The Rise and Fall of Strategic Planning* (New York: Free Press, 1994), 228. Some RAND analysts recently returned to a famous 1964 RAND effort to develop "Delphi," a predictive technique built around achieving consensus among experts. The more recent RAND report observed that the 1964 effort was "driven by a desire to 'lessen the chances of surprise and provide a sounder basis for long range decision-making.' However, anyone relying on their answers would have been surprised indeed. Of the eight specific projects for 2000 reported in this study, seven failed to transpire as conceived by the panel . . . the important thing is to recognize why the predictive task is important to carry out. . . . Many of the topics of most interest . . . are simply unpredictable, no matter how much is known about them." Robert J. Lempert, Steven W. Popper and Steven C. Bankes, *Shaping the Next One Hundred Years* (Santa Monica, CA: RAND Corporation, 2003), 17. The work of Lempert, Popper and Bankes is discussed under Propositions 4 and 5. I note that they were generous in grading the eighth prediction a success, anticipating that by 2000, we would have achieved "general immunization against bacterial and viral diseases" – an idea disproved by SARS, AIDS, Avian Flu, the common cold, antibiotic resistant TB, among others.

27. The discussion is in Proposition 4.

28. Even the most often cited example of predictive-based planning, developed in the relatively stable environment of the Cold War, was of questionable power. LTC Eric A. Hollister observes:

. . . the o[perational] e[nvironment] is far too complex to be predictable, as past efforts have clearly shown. There are simply too many variables – e.g., politics, economics, natural disasters and nonstate actors – to make any kind of far-reaching plans with any degree of certainty. President Dwight D. Eisenhower's "Project Solarium" and subsequent "New Look" are often held up, and with considerable justification, as shining examples of a far-reaching strategy that subsequently directed force structures and future planning. But the plans' large reduction in army forces and focus on strategic nuclear deterrence did nothing to prepare the army for what would be an extended conflict in Vietnam. Hollister, "A Shot in the Dark," 1.

29. Those who would like a systematic assessment of predictive capability will find it in Tetlock, *Expert Political Judgment*.

30. The following list is merely illustrative of predictive failures. Paul Davis provides his own list from the last half-century, including a number of other items (for example, the fall of the Shah of Iran) in Paul K. Davis, "Defense Planning and Risk Management in the Presence of Deep Uncertainty," in Paul Bracken et al., eds., *Managing Strategic Surprise: Lessons from Risk Management and Risk Assessment* (New York: Cambridge University Press, 2005), 170.

31. As one measure of this change, the Nikkei index exceeded 39,000 in December 1989. Today, it is around 10,000.

32. These errors, in turn, caused even the most sophisticated observers to erroneously predict defense budgets, manpower demands and programs. For example, supported by the U.S. Department of Defense, Williamson Murray and Allan Millett produced a richly insightful study of how, in the wake of World War I, the British, French, German, Japanese and U.S. militaries anticipated – and failed to anticipate – future military conflicts. Williamson Murray and Allan R. Millett, eds., *Military Innovation in the Interwar Period* (New York: Cambridge University Press, 1996). Notwithstanding their insights into predictive failure, in the introduction to their study (published 15 years ago), they flatly declare: "[T]he period we are now entering appears to be one in which there is no clear threat to the United States, nor is one likely to appear for the foreseeable future. In such an environment it is inevitable, particularly in democratic nations, that one will see continuing and substantial declines in defense spending. . . . [T]he decline will most likely not be cyclical but instead represent a steady erosion of support." *Ibid.*, 2.

33. Taleb, *Fooled by Randomness*. See also his better known sequel, *The Black Swan*. Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House, 2007).

34. In *Fooled by Randomness*, Taleb talks about "the problem of stationarity." He writes, "Think of an urn that is hollow at the bottom. As I am sampling from it, and without my being aware of it, some mischievous child is adding balls of one color or another. . . . I may infer that the red balls represent 50 percent of the urn while the mischievous child hearing me, would swiftly replace all the red balls with black ones. This makes much of our knowledge derived from statistics quite shaky." Taleb, *Fooled by Randomness*, 113.

35. Carl von Clausewitz, ed. trans. Michael Howard and Peter Paret, *On War* (Princeton, NJ: Princeton University Press, 1984), 139.

36. Herbert Simon, *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations* (New York: Free Press, 1957), xv.

37. *Ibid.* Reflecting on his experience, Henry Kissinger makes a similar point: "For the spirit of policy and that of bureaucracy are diametrically opposed. The essence of policy is its contingency; its success depends on the correctness of an estimate which is in part conjectural. The essence of bureaucracy is its quest for safety; its success is calculability. Profound policy thrives on perpetual creation, on a constant redefinition of goals. Good administration thrives on routine, the definition of relationships which can survive mediocrity. Policy involves an adjustment of risks; administration an avoidance of deviation. Policy justifies itself by the relationship of its measures and its sense of proportion; administration by the rationality of each action in terms of a given goal. The attempt to conduct policy bureaucratically leads to a quest for calculability which tends to become a prisoner of events. The effort to administer politically leads to total irresponsibility, because bureaucracies

are designed to execute, not to conceive.” Henry Kissinger, *A World Restored: Metternich, Castlereagh and the Problems of Peace, 1812-1822* (Boston: Houghton Mifflin, 1957), 356.

38. Andrew Krepinevich, in a memorandum to the author commenting on this manuscript, August 30, 2011.

39. James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven: Yale University Press, 1998), 95.

40. Napoleon Bonaparte, *Maxims of War* (1862). Eliot Cohen and John Gooch provide a sophisticated modern view. The authors identify three dominant types of failure: failure to anticipate, failure to learn from the past and failure to adapt. Eliot Cohen and John Gooch, *Military Misfortunes: The Anatomy of Failure in War* (New York: Free Press, 1990). This paper suggests that what one learns from the past is that one must be prepared to adapt without relying on present powers of anticipation. Put differently, a temporal change is warranted in Cohen and Gooch’s framework. One should recognize that much adaptation must occur when it is needed in the future. One cannot rely on learning the specifics of that adaptation in advance (that is, it cannot be predicted), but one can use the present to introduce measures that will facilitate adaptation in the future.

41. William Astore, “American Blitzkrieg,” TomDispatch.com (February 18, 2010), [archive.truthout.org/american-blitzkrieg56996](http://archive.truthout.org/american-blitzkrieg56996). Regarding U.S. Army planning, see also James Dewar, *Assumption-based Planning: A Tool for Reducing Avoidable Surprises* (New York: Cambridge University Press, 2003). Ted Turner contends that large business enterprises exhibit the same insatiable thirst for control: “You need to control everything. You need to be like Rockefeller with Standard Oil. . . . You want to control everything.” Quoted in Ken Auletta, *Googled: The End of the World as We Know It* (New York: Penguin, 2009), 255.

42. T.R. Fehrenbach offers classic commentary on this point, still read and taken to heart in the U.S. military, particularly the Marine Corps. Indicative of its view are the following quotes: “. . . the West did not prepare for trouble. It did not make ready, because its peoples, in their heart of hearts, did not want to be prepared.” T.R. Fehrenbach, *This Kind of War: A Study in Unpreparedness* (Macmillan, 1963), 12. Additionally, “[a]t the end of World War II . . . [t]he only war that military planners could envision was a big one between the United States and the Soviet Union. They assumed that in the future, as historically, America would never fight for limited goals.” *Ibid.*, 48. And, “[t]he United States could not be bought, or even intimidated, but it had a long history of looking the other way if not immediately threatened.” *Ibid.*, 53.

43. Though strategic planning was “[l]argely a budget exercise in the America of the 1950s, it began to spread quickly, having become firmly installed in most large corporations by the mid-1960s.” Mintzberg, *The Rise and Fall of Strategic Planning*, 6.

44. Davis, “Defense Planning and Risk Management in the Presence of Deep Uncertainty,” 167.

45. *Ibid.*, 166.

46. Owen Brown and Paul Eremenko, “Acquiring Space Systems in an Uncertain Future: The Introduction of Value-Centric Acquisition,” *High Frontier*,

6 no. 1 (November 2009), 39. Other aspects of their critique are discussed in the context of Propositions 6–10, particularly with regard to Eremenko’s present work at DARPA described under Proposition 7.

47. Martin Walker provides an insightful retrospective account of the interaction, beginning with his observation that “the Cold War had one great merit: it became an institution, marked by a kind of warped stability. . . .” Martin Walker, *The Cold War: And the Making of the Modern World* (Fourth Estate, 1993), 1. Looking back on this period, the Defense Science Board aptly observed, “Focus was on long, predictable, evolutionary change against a Cold War peer opponent who suffered as much, if not more, than the United States from a rigid and bureaucratic system. There were certainly instances of adaptability during the Cold War period, but the surviving features of that period are now predominated by long compliance-based structures.” Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces*, 19.

48. Predictability increased over time. The early Soviet nuclear tests, Sputnik, and, later, the invasion of Afghanistan were not well predicted.

49. LTG David W. Barno, USA (Ret.) described the military during this period as follows: “Predictability and an unusual degree of certainty – in enemy, location, equipment, tactics – became an expected norm for military planning. Uncertainty was reduced to nuances of when, where, and how to apply the “knowns” of doctrine, tactics, and equipment that the Warsaw Pact employed.” David W. Barno, “Military Adaptation in Complex Operations,” *Prism*, 1 no. 1 (December 2009), 29. Parallel developments in the economic world may have added to security planners’ sense of stability and predictability. Mintzberg suggests that the 1960s were generally propitious for prediction. “If the world holds still, or at least continues to change exactly as it did in the past, then forecasting can work fine. . . . This may help to explain why the 1960s were such good times for forecasters and planners. . . .” Mintzberg, *The Rise and Fall of Strategic Planning*, 236. A number of economists, most famously Ben Bernanke, noted that over the last two decades of the 20th century, national growth rates became steadier and more predictable from quarter to quarter. Speaking in 2004, Bernanke popularized a description of this: “The Great Moderation, the substantial decline in macroeconomic volatility over the past twenty years, is a striking economic development. Whether the dominant cause of the Great Moderation is structural change, improved monetary policy, or simply good luck is an important question about which no consensus has yet formed.” Ben S. Bernanke, “The Great Moderation,” Remarks at the Meetings of the Eastern Economic Association, Washington (February 20, 2004), 7, [www.bis.org/review/r040301f.pdf](http://www.bis.org/review/r040301f.pdf). Of course, this expectation of steady predictability should now itself be taken as a vivid example of the failure of prediction.

50. Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces*, 15. A more extended discussion of a similar observation may be found in Andrew Krepinevich, “Defense Investment Strategies in an Uncertain World: Strategy for the Long Haul” (Center for Strategic and Budgetary Assessments, 2008), 7-8.

51. Hugh Courtney, *20/20 Foresight: Crafting Strategy in an Uncertain World* (Boston: Harvard Business Press, 2001).

52. *Ibid.*, 21.

53. *Ibid.*

54. Courtney offers the acronym MECE.
55. *Ibid.*, 21.
56. *Ibid.*, 32.
57. Furthermore, “[d]eep uncertainty exists when analysts do not know, or the parties to a decision cannot agree on, (1) the appropriate models to describe the interactions among a system’s variables; (2) the probability distributions to represent uncertainty about key variables and parameters in the models; and/or (3) how to value the desirability of alternative outcomes.” Lempert et al., *Shaping the Next One Hundred Years*, 3-4.
58. *Ibid.*, 33.
59. See particularly the work of Amos Tversky and Daniel Kahneman, especially Amos Tversky and Daniel Kahneman, “Judgment Under Uncertainty: Heuristics and Biases,” *Science*, 185 no. 4157 (September 27, 1974), 1124-1131.
60. Gregory F. Treverton, *Reshaping National Intelligence for an Age of Information* (Cambridge University Press, 2001).
61. Elting E. Morison’s classic, *Men, Machines and Modern Times*, paints the picture vividly in military contexts. Morison states that the “opposition . . . of the soldier and the sailor to such change springs from the normal human instinct to protect oneself, and more especially one’s way of life. Military organizations are societies built around and upon the prevailing weapons systems. Instinctively and quite correctly the military man feels that a change in weapons portends a change in the arrangement of his society. Elting E. Morison, *Men, Machines and Modern Times* (Cambridge, MA: The MIT Press, 1966), 35-36.
62. Note the discussion of sources of uncertainty in Paul Davis, “Planning for Adaptiveness,” in *New Challenges in Defense Planning: Rethinking How Much is Enough*, ed. Paul Davis (RAND Corporation, 1994).
63. See the discussion in Proposition 2.
64. This point is well developed by Joshua Cooper Ramo in *The Age of the Unthinkable*, particularly in his discussion of Per Bak’s sand pile metaphor: “Bak hypothesized that after an initial period, in which the sand piled itself into a little cone, the stack would organize itself into instability, a state in which adding just a single grain of sand could trigger a large avalanche – or nothing at all.” Joshua Cooper Ramo, *The Age of the Unthinkable: Why the New Global Order Constantly Surprises Us and What to do About It* (New York: Little, Brown and Company, 2009), 48-49. Ramo describes his own book as “one that takes complexity and unpredictability as its first consideration and produces, as a result, a different and useful way of seeing our world.” *Ibid.*, 11. Or, as he puts it later, “important things cannot be predicted with accuracy.” *Ibid.*, 131.
65. As a result, “[s]hortly after election day, eleven groups of [Palm Beach County] voters filed independent lawsuits seeking relief, claiming they and others had made mistakes in their votes for president because of the confusing format of the ballot. Many of them stated that they had intended to vote for Democratic candidate Al Gore but by mistake chose Reform candidate Pat Buchanan. The number of votes involved was more than enough to have tipped the presidential vote in Florida from Republican candidate George W. Bush to Gore, thus giving him Florida’s 25 electoral votes and the presidency.” Jonathan N. Wand et al., “The Butterfly Did It: The Aberrant Vote for Buchanan in Palm Beach County, Florida,” *American Political Science Review*, 95 no. 4 (December 2001), 793.
66. This hardly predictable deficiency was apparently reinforced by some physical deficiencies in the ballots. As reported by ABC News, “Officials in several Florida counties have spent days arguing over bits of paper divots called chads that may have kept the poll machines from properly counting votes.” Allen G. Breed, “Inventor Pained by Fla. Voting Problems,” ABC News, November 16, 2000.
67. While emphasizing the limits of prediction, one cannot “predict” with certainty what Al Gore would have done had he become President. It is reasonably certain, however, that the small variable of a butterfly ballot produced large effects.
68. Taleb’s *Fooled by Randomness* and *The Black Swan* have attracted considerable attention to this point, but most comprehensively see Justin Fox, *The Myth of the Rational Market: A History of Risk, Reward, and Delusion on Wall Street* (New York: Harper Business, 2009).
69. More broadly, see Eric Beinhocker’s argument in *The Origin of Wealth* that economic theory assumes separated rational decisionmakers whereas, in fact, they are interconnected and these correlations expand complexity and undermine the conclusions from disaggregated analysis. Eric Beinhocker, *The Origin of Wealth: Evolution, Complexity and the Radical Remaking of Economics* (Boston: Harvard Business School Press, 2006).
70. Michael Lewis, *The Big Short: Inside the Doomsday Machine* (New York: W. W. Norton & Company, 2010). See also Lewis’s previous book, Michael Lewis, *Panic: The Story of Modern Financial Insanity* (New York: W. W. Norton & Company, 2008).
71. Niall Ferguson, “Political Risk and the International Bond Market Between the 1848 Revolution and the Outbreak of the First World War,” *Economic History Review*, 59 no. 1 (February 2006), 70.
72. *Ibid.*
73. Andrew Krepinevich made good use of scenario planning in a short piece published in 1996. His aim was to show the “merits of scenario-based planning as a way for the U.S. military to escape the trap of preparing for the last war, instead of for a rapidly changing conflict environment. [The Center for Strategic and Budgetary Assessments] presents two scenarios which demonstrate that future contingencies may, indeed, be quite different from the one which Pentagon planners are employing as they structure tomorrow’s military.” Andrew Krepinevich, “Restructuring Defense for A New Era: The Value Of Scenario-Based Planning” (Center for Strategic and Budgetary Assessments, April 1996). Krepinevich also comments on the first efforts to move from the single Soviet scenario to two regional contingencies. He points out that “[w]hile the BUR [the Bottom Up Review conducted in 1993 at the direction of the Secretary of Defense] purportedly employs two scenarios, one each for the Korean Peninsula and the Persian Gulf, in both cases the aggressor possesses the same force structure, U.S. forces respond on the same ‘short notice,’ with the same force package, and the same four-phased approach to combat operations. Thus there seems to be little or no real difference in the

two scenarios. Other planning scenarios are included in the Defense Planning Guidance (DPG). However, the recommendations of the BUR still guide U.S. defense planning and force structure requirements.' Ibid. The two CSBA scenarios are an effort to block the straits of Hormuz by Iran (hypothesized to have eight nuclear weapons) in 2004 and conflict in the Taiwan Straits. The latter arose as Taiwan moved toward independence in the context of "an air of desperation in Beijing in the summer of 2008. [China is] mired in a recession that threatens to erode a fragile political stability ..." Ibid. For a more expansive and recent presentation of Krepinevich's thinking about scenarios, see his book, Andrew Krepinevich, *7 Deadly Scenarios: A Military Futurist Explores War in the 21st Century* (New York: Bantam, 2009).

74. Department of Defense, *Quadrennial Defense Review Report* (February 2010), 42. The report states that "[c]ombinations of scenarios assessed in the QDR included the following:

-A major stabilization operation, deterring and defeating a highly capable regional aggressor, and extending support to civil authorities in response to a catastrophic event in the United States. This scenario combination particularly stressed the force's ability to defeat a sophisticated adversary and support domestic response.

-Deterring and defeating two regional aggressors while maintaining a heightened alert posture for U.S. forces in and around the United States. This scenario combination particularly stressed the force's combined arms capacity.

-A major stabilization operation, a long-duration deterrence operation in a separate theater, a medium-sized counterinsurgency mission, and extended support to civil authorities in the United States. This scenario combination particularly stressed elements of the force most heavily tasked for counterinsurgency, stability, and counterterrorism operations.

QDR force analysis also tested the force's ability to sustain robust levels of engagement overseas through forward stationing and routine rotational deployments. Successfully achieving any of the core missions of the U.S. Armed Forces requires strong security relationships with a host of allies and partners—relationships best enabled and maintained through both a long-term presence abroad and sustained, focused interactions between U.S. and partner forces.

In all of the scenario sets it tested, the Department assumed ongoing U.S. military engagement in presence and deterrence missions."

75. Ibid., 43.

76. The canonical work is Peter Schwartz, *The Art of the Long View: Planning for the Future in an Uncertain World* (New York: Currency Doubleday, 1996). See also, Peter Cornelius, Alexander van der Putte and Mattia Romani, "Three Decades of Scenario Planning in Shell" *California Management Review*, 48 no. 1 (Fall 2005), 92-109. For a critique, see Mintzberg, *The Rise and Fall of Strategic Planning*, 248.

77. In a retrospective account, Peter Ho, then chief of the Singapore Civil Service, also credited John Petersen, John Poindexter, David Snowden and Jeff Jonas. Peter Ho, "The Singapore Strategic Planning Story: Experimentation, Discovery and Networks," (Singapore, August 4, 2010). Petersen's Arlington

Institute conceived and developed the Risk Assessment and Horizon Scanning System. John Petersen, correspondence with the author, Sept. 16, 2010. The Netherland's Armed Forces, *Future Policy Survey* provides another example of a foreign government's ambitious use of scenario-based planning. See also Helene Lavoix, "Actionable Foresight: The Cases of Finland and Singapore" (Prepared for Actionable Foresight Conference, Washington, January 12, 2011).

78. The effort runs well beyond scenario planning, including, for example, the networking of "Strategic Futures Officers" from multiple ministries, but I am concerned here only with the scenario planning aspect of the effort. Similar efforts have spread in Europe and Australia, often under the rubric of Capability Based Planning. See, for example, the work of The Technical Cooperation Program at [www.acq.osd.mil/ttcp/](http://www.acq.osd.mil/ttcp/) and Stephan De Spiegeleire, "10 Trends in Capability Planning for Defense and Security" (2010), [www.slideshare.net/sdspieg/10-trends-in-capability-planning-for-defence-and-security](http://www.slideshare.net/sdspieg/10-trends-in-capability-planning-for-defence-and-security).

79. The intellectual premises of this effort and the personal history of evolution of his commitment to efforts at "foresight" are well articulated by Leon Fuerth in an article in *Foresight*. Fuerth proceeds from the premise that "practitioners of diverse origins actually do share at least one conviction, in the midst of many probable differences. This would be a shared belief that humanity has the wisdom needed for anticipatory governance: that we can shape the future based on foresight combined with practical action." Leon Fuerth, "Foresight and Anticipatory Governance," *Foresight* 11 no. 4 (2009), 14. He observes that "[m]any would say that a belief in foresight and anticipatory governance vastly overstates our capacity for understanding and shaping the forces that govern our destinies. But the alternative is to continue to practice governance that is blind to the longer term implications of its decisions, slow to detect the onset of major defects in policy, and inattentive to its best options until they have been allowed to slide by." Ibid. Nonetheless, he argues that there is no good alternative and that disciplined, interdisciplinary efforts at foresight can be rewarding.

80. Among other American efforts, Fuerth cites the Project on Forward Engagement, the Foresight and Governance Project (2009) at the Woodrow Wilson Center and the congressionally funded Project on National Security Reform. Fuerth, "Foresight and Anticipatory Governance," 25. Fuerth is also a principal organizer of several workshops at the National Defense University on this subject. A memorandum summarizing the first workshop is available through Leon Fuerth. Leon Fuerth, "Actionable Foresight Project: Strengthening the Linkage between Longer-term Analysis and National Security Decision Making, Workshop I: Can Foresight Be Actionable Today?" (National Defense University, June 16-17, 2010).

81. "Foresight is the capacity to anticipate alternative futures, based on sensitivity to weak signals, and an ability to visualize their consequences, in the form of multiple possible outcomes." Fuerth, "Foresight and Anticipatory Governance," 14.

82. Lempert et al., *Shaping the Next One Hundred Years*, 49.

83. Ibid., 36.

84. Ibid., 35.

85. Ibid.

86. Ibid., 50.

87. The approximately \$1.5 trillion presently spent on 87 major DOD programs is enumerated in “Selected Acquisition Report (SAR) Summary Tables as of December 31, 2009,” [www.acq.osd.mil/ara/2009%20DEC%20SAR.pdf](http://www.acq.osd.mil/ara/2009%20DEC%20SAR.pdf).

88. The seniority of decisionmakers varies by acquisition category (ACAT), but the processes are essentially the same. Some of the attributes of the process are defined by law. See, for example, 10 U.S.C. § 144.

89. The interaction of these systems is well described in Moshe Schwartz, “Defense Acquisitions: How DOD Acquires Weapon Systems and Recent Efforts to Reform the Process” (Congressional Research Service, April 23, 2010), 3.

90. Pressing for shorter program timelines, the Under Secretary of Defense for Acquisition, Technology and Logistics wrote: “The leisurely 10-15 year schedule of even the simplest and least ambitious Department programs not only delays the delivery of needed capability to the warfighter, but directly affects program cost.” Ashton Carter, “Memorandum for Acquisition Professionals,” September 14, 2010. Also see Secretary Carter’s Memorandum for Secretaries of the Military Departments, “Implementation Directive for Better Buying Power – Obtaining Greater Efficiency and Productivity in Defense Spending,” (November 3, 2010), 3. It contains the directive to “[s]et shorter program timelines and manage to them.” To the same effect, see the Defense Acquisition Performance Assessment Report (sometimes referred to as the DAPA Report or the Kadish Report, after the panel’s chairman) Assessment Panel of the Defense Acquisition Performance Assessment Project, *Defense Acquisition Performance Assessment* (January 2006), 48, [www.acq.osd.mil/dapaproject/documents/DAPA-Report-web/DAPA-Report-web-feb21.pdf](http://www.acq.osd.mil/dapaproject/documents/DAPA-Report-web/DAPA-Report-web-feb21.pdf). Also see the comments of the House of Representatives Committee on Armed Services, which say: “Simply put, the Department of Defense (DOD) acquisition process is broken. The ability of the Department to conduct the large scale acquisitions required to ensure our future national security is a concern of the committee. The rising costs and lengthening schedules of major defense acquisition programs lead to more expensive platforms fielded in fewer numbers.” The Committee on Armed Services, House of Representatives on *H.R. 5122*, Report 109–452 (May 5, 2006), 350.

91. Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces*, 7. See also the United Kingdom Ministry of Defense’s *Adaptability and Partnership* report, which observes that in the British context, “[t]he long lead-times associated with developing military equipment or fully trained high quality military personnel limit our ability to adapt our force structures and capabilities quickly.” Ministry of Defense, *Adaptability and Partnership*.

92. The DAPA report did note an aspect of the prediction problem: “When lengthy development nears completion, changes in threat definition and test scenarios cause systems to fail Initial Operational Test and Evaluation. The rework required to accommodate the changes prior to first article delivery drives cost and schedule growth. The vulnerability of programs to these changes increases as schedule lengthens.” Assessment Panel of the Defense Acquisition Performance Assessment Project, *Defense Acquisition Performance Assessment* (January 2006), 49, [www.acq.osd.mil/dapaproject/documents/DAPA-Report-web/DAPA-Report-web-feb21.pdf](http://www.acq.osd.mil/dapaproject/documents/DAPA-Report-web/DAPA-Report-web-feb21.pdf).

93. Christopher J. Lamb, Matthew J. Schmidt and Berit G. Fitzsimmons, “MRAPS, Irregular Warfare and Pentagon Reform,” *Joint Force Quarterly*, 55 (2009), 1.

94. Ibid., 12.

95. Ibid.

96. Ibid., 25-26.

97. Written against the backdrop of the MRAP controversies, the 2010 Quadrennial Defense Review recognizes this, at least in the context of wartime decision-making: “The Department must not only prepare for those threats we can anticipate, but also build the agile, adaptive and innovative structures capable of quickly identifying emerging gaps and adjusting program and budgetary priorities to rapidly field capabilities that will mitigate those gaps. . . . To prepare the Department for the complex threats that will surely emerge in the future, we need to make our ‘deliberate’ processes more agile and capable of responding to urgent needs. During periods of conflict, in the traditional risk areas of cost, schedule, and performance, ‘schedule’ often becomes the least acceptable risk.” *Quadrennial Defense Review Report* (2010), 80.

98. Lamb et al., “MRAPS, Irregular Warfare and Pentagon Reform,” 24.

99. Attempts have been made to graft small offices for rapid procurement, or rapid development and procurement, onto the existing bureaucracy. The bureaucratic innovations—for example, the Technical Support Working Group; the Joint IED Task Force; its successor, the Joint IED Defeat Organization (JIEDDO); the OSD Rapid Fielding Directorate; and the Army Rapid Fielding Force Office—all had high aspirations for speed, flexibility and adaptiveness. See, for example, [www.acq.osd.mil/rfd/](http://www.acq.osd.mil/rfd/). The evolution of these offices, however, is not inspiring. Viewed as low-cost appendages to the dominant system, they tend to be marginalized and irrelevant or to aspire to grow and become more bureaucratic. I am indebted to Michael Hopmeier of Unconventional Concepts for his observations on this point. Hopmeier points out that there is no bureaucratic history of these organizations and that one is required if we are to understand this pattern.

100. Krepinevich, “Defense Investment Strategies in an Uncertain World,” 25-26. Krepinevich also advances the “key observation that if the time required to translate resources to capabilities can be compressed, it is possible to apply resources more efficiently.” Ibid., 39.

101. Ibid., 26. Krepinevich cites Kathleen Eisenhardt and Shona Brown, “Time Pacing: Competing in Markets that Won’t Stand Still,” *Harvard Business Review* (March/April 1998), reprinted in *Harvard Business Review, On Managing Uncertainty* (Boston, MA: Harvard Business School Press, 1999), 178.

102. See Mintzberg regarding the virtues of “emergent strategies,” that is, strategies developed in light of emerging experience. Mintzberg, *The Rise and Fall of Strategic Planning*, 25 and 227.

103. Jacques Gansler writes that “America’s planning for industrial mobilization has always been inadequate . . . . In the early months (or even years) of conflicts, the United States has always been able to mobilize troops far faster and more effectively than it has been able to arm them.” Jacques

S. Gansler, *The Defense Industry* (Cambridge, MA: MIT Press, 1980), 109. To the same effect, see James Huston “[f]ollowing its practice in all wars, the United States on the eve of World War II mobilized troops before weapons and equipment could possibly be available for them.” James A. Huston, *The Sinews of War: Army Logistics 1775-1953* (Washington: United States Army, 1966), 455.

104. The Defense Production Act, 50 U.S.C. App 2061, was originally passed as emergency legislation to meet Korean War requirements. It has been repeatedly amended and reenacted over the past 60 years.

105. The Cold War architecture has present utility. The Secretary of Defense, for example, invoked DX authority for the MRAP procurements discussed in the context of the next proposition. Lamb et al., “MRAPS, Irregular Warfare and Pentagon Reform” (National Defense University, 2009), 16. However, the system is now handicapped even in its limited surge objectives because of private sector incentives for leanness and the increasing separation between defense and private manufacturing systems and suppliers.

106. Defense Science Board, *Report of the Defense Science Board 2010 Summer Study on Enhancing the Adaptability of U.S. Military Forces, Part B. Appendices* (January 2011), particularly “Appendix C: Open Architecture Systems.”

107. Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces, 7* and Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces, Part B. Appendices, 21*.

108. Regarding the AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM), see Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces, Part B. Appendices, 23*. Regarding the F-16, see *Ibid.*, 31. Ashton Carter pushes for this approach as a means of encouraging competition and, therefore, cost reduction. “Implementation Directive for Better Buying Power – Obtaining Greater Efficiency and Productivity in Defense Spending,” (November 3, 2010), 4.

109. According to a recent article, “[t]he plant-based vaccine production method works by isolating a specific antigen protein – one that triggers a human immune response – from the targeted virus. A gene from the protein is transferred to bacteria, which are then used to ‘infect’ plant cells. The plants then start producing the exact protein that will be used for vaccinations. From first transfer to final extraction, the method takes around five weeks.” Katie Drummond, “DARPA-funded Researchers: Tobacco versus Viral Terror,” *Wired* (February 24, 2010), [www.wired.com/dangerroom/2010/02/darpa-funded-researchers-tobacco-vs-viral-terror/](http://www.wired.com/dangerroom/2010/02/darpa-funded-researchers-tobacco-vs-viral-terror/).

110. The production scaffolds selected for the present version of the program are tobacco leaves. “For the largest program, called AMP for Accelerated Manufacture of Pharmaceuticals, companies in four states are building facilities where they can quickly produce vaccine-grade proteins grown in the cells of tobacco plants. Once they produce the proteins, the goal is for each company to scale up its process to produce 100 million doses of H1N1 flu vaccine per month. Existing vaccine manufacturers worldwide produce a fraction of that – about 300 million doses of vaccine in six months . . .” Cheryl Pellerin, “DARPA Effort Speeds Biothreat Response” *American Forces Press Service*, November 2, 2010, [www.defense.gov/news/newsarticle.aspx?id=61520](http://www.defense.gov/news/newsarticle.aspx?id=61520).

111. The significance of this point is well illustrated by flu preparations, many of which were focused as late as 2009 on H5N1, but when that prediction did not materialize, pivoted to countering H1N1.

112. Daniel Gibson, “One-Step Enzymatic Assembly of DNA Molecules Up to Several Hundred Kilobases in Size,” *Nature Methods* (April 16, 2009), <http://www.nature.com/protocolexchange/protocols/554>.

113. Katherine Bourzac, “Making a Genome Quickly from Scratch,” *Technology Review*, October 12, 2010, <http://www.technologyreview.com/biomedicine/26495/>.

114. DARPA’s Tactical Technology Office is working with Army Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Missouri.

115. More information on the project can be found at [www.darpa.mil/AVM.aspx](http://www.darpa.mil/AVM.aspx). The program is scheduled to run for the next four years.

116. DARPA has already taken other steps down that path. Its Defense Science Office reports that it “has provided a suite of armor solutions that can be tailored to meet mission and vehicle-specific weight and performance requirements in response to specific and emerging threats. New insights and infrastructure for armor manufacturing has changed hybrid, composite armor production from a labor-intensive, small-quantity process to a quality-controlled, high-throughput operation. The program applied automated high-precision production fabrication technologies to adaptively and rapidly produce panels to specification and at a cost comparable to that of traditional armor.” “DARPA Composite Armor Development,” *Composite Material Blog*, March 22, 2010, [www.compositesblog.com/2010/03/darpa-composite-armor-development.html](http://www.compositesblog.com/2010/03/darpa-composite-armor-development.html).

117. Army combat vehicles must also operate under very stressful conditions. It is notable that some of the most effective integration efforts have occurred in the semiconductor industry, whose “integrated” circuits are packaged to insulate them from the larger environment.

118. Put another way, chaos theory suggests that greater system complexity induces less predictable emergent behavior.

119. Paul Eremenko, “Adaptive Vehicle Make,” PowerPoint briefing by the DARPA Tactical Technology Office (August 18, 2010). This would meet a standard articulated by the Defense Science Board: “A true test of openness with a system is whether or not a third party provider can develop an application to work with the system without any assistance from the system provider.” Defense Science Board, *Enhancing the Adaptability of U.S. Military Forces, Part B. Appendices, 63, 67*.

120. The program manager stresses that because “the seams” between components are presently not effectively standardized, present modes of verification and validation cause exposure to unpredicted “emergent behaviors” when they interact: “Resulting architectures are fragile point designs.” Eremenko, “Adaptive Vehicle Make.”

121. The program manager clearly has this in mind as well. Indeed, his earlier work on space vehicles emphasized this priority. See Brown and Eremenko, “Acquiring Space Systems in an Uncertain Future.”

122. For analogous examples of policy choices in domestic matters, see Donald A. Schön and Martin Rein, *Frame Reflection: Toward the Resolution of Intractable Policy Controversies* (New York: Basic Books, 1994), especially Chapter 7, "Design Rationality Reconsidered."

123. A total force could achieve inherent resilience even if composed solely of equipment designed with high specificity and low inherent resilience. However, a force that aimed for resilience by relying on the complementarity of highly specific systems would depend on the availability of these systems. It would be resilient only if there were great numbers of specific items (tanks, planes, ships, etc.), the manpower to operate them and an ability to deliver equipment and operators at the times and places required. These characteristics were often present in the later part of World War II and contributed to de-emphasizing inherent resilience as a planning priority. Furthermore, World War II equipment was designed for use in contexts that were rather predictable. These conditions are not present now. In a much less predictable environment, with less lead-time for responses to crises throughout the world, we are buying many fewer platforms (for example, only 10 ships a year and only a half dozen different classes of ships over any given period, or only a few different types of combat aircraft). In this context, we need to program inherent resilience not only into the total force but also into the platforms themselves.

124. "At present, there are no tools provided in the decision making process to make appropriate trades in flexibility, cost, risk, and performance. . . . Attributes such as flexibility and robustness, for which no commonly accepted definitions much less quantitative metrics are available (within the current acquisition framework) are still universally excluded." Brown and Eremenko, "Acquiring Space Systems in an Uncertain Future," 38, 41.

125. Davis, "Defense Planning and Risk Management in the Presence of Deep Uncertainty."

126. Brown and Eremenko, "Acquiring Space Systems in an Uncertain Future," 40.

127. However, see the discussion of Proposition 5. See also the discussion of "alternative histories" and Monte Carlo analysis in Taleb, *Foiled by Randomness*, 46-51.

128. "Disturbingly, science has only recently been able to handle randomness (the growth in available information has been exceeded only by the expansion of noise.) Probability theory is a young arrival in mathematics: probability applied to practice is almost nonexistent as a discipline." Ibid., xii. Abhi Deshmukh of Purdue University has been leading a team doing promising work on this topic in a "Study of Flexibility" for the Systems Engineering Research Corporation.

129. For example, some field test trials and simulations could be against a broader range of scenarios, including scenarios not specified in advance. DARPA's Adaptive Vehicle Make Program may make a contribution in this regard. One of its aims is to "develop a quantitative metric of adaptability associated with a given system architecture that can support trade-offs between adaptability, complexity, performance, cost, schedule, risk, and other system attributes." See "Tactical Technology Office: Adaptive Vehicle Make (AVM)," <http://www.darpa.mil/AVM.aspx>.

130. I am indebted to Mark Ryland for crystallizing the concept and providing some of the language in this paragraph.

131. Aaron Wildavsky offers this metaphor while recommending incremental adaptation to safety risks as they come to be recognized in test operation rather than in advance. Aaron Wildavsky, *Searching for Safety* (New Brunswick, NJ: Transaction Publishers, 1988).

132. For example, software-defined radio systems permit rapid adaptation to new coding and modulation standards. The technology is outlined in Markus Dillinger, Kambiz Madani and Nancy Alonistioti, *Software Defined Radio: Architectures, Systems and Functions* (West Sussex, England: Wiley, 2003).

133. Defense Advanced Research Projects Agency, "DARPA-BAA-10-79: Behavioral Learning for Adaptive Electronic Warfare (BLADE)" (July 9, 2010), [https://www.fbo.gov/index?s=opportunity&mode=form&id=0b115a25c758b4890f4c603016dbe6de&tab=core&\\_cview=0](https://www.fbo.gov/index?s=opportunity&mode=form&id=0b115a25c758b4890f4c603016dbe6de&tab=core&_cview=0).

134. "As the IED problem grew and better armored vehicles could not immediately be fielded, innovative U.S. troops began adding improvised armor to their light Humvees. Scrap metal, plywood and sandbags were used to increase protection." Lamb et al., "MRAPS, Irregular Warfare and Pentagon Reform," 4. Similarly, the Army describes the jury-rigging of a camera by field personnel to look for weapons hidden in wells in Afghanistan. A 2004 Army briefing explains that the device was developed from "spare parts" on March 3, 2003 and used effectively to discover weapons, [www.army.mil/aps/06/maindocument/infopapers/18.html](http://www.army.mil/aps/06/maindocument/infopapers/18.html).

135. Martin Blumenson writes:

In order to speed up the movement of armor, Ordnance units and tankers throughout the army had devoted a great deal of thought and experimentation to find a device that would get tanks through the hedges quickly without tilting the tanks upward, thereby exposing their underbellies and pointing their guns helplessly toward the sky. The gadgets invented in July 1944 were innumerable.

As early as 5 July the 79th Division had developed a 'hedgecutter,' which Ordnance personnel began attaching to the front of tanks. Five days later the XIX Corps was demonstrating a 'salad fork' arrangement, heavy frontal prongs originally intended to bore holes in hedgerow walls to facilitate placing engineer demolition charges but accidentally found able to lift a portion of the hedgerow like a fork and allow the tank to crash through the remaining part of the wall. Men in the V Corps invented a 'brush cutter' and a 'green-dozer' as anti-hedgerow devices.

The climax of the inventive efforts was achieved by a sergeant in the 102d Cavalry Reconnaissance Squadron, Curtis G. Culin, Jr., who welded steel scrap from a destroyed enemy roadblock to a tank to perfect a hedgecutter with several tusklike prongs, teeth that pinned down the tank belly while the tank knocked a hole in the hedgerow wall by force. General Bradley and members of his staff who inspected this hedgecutter on 14 July were so impressed that Ordnance units on the Continent were ordered to produce the device in mass, using scrap metal salvaged from German underwater obstacles on the invasion beaches. General Bradley also sent Col. John B. Medaris, the army Ordnance officer, to England by plane to get depots there to produce the tusks and equip tanks with them and to arrange for



transporting to France by air additional arc-welding equipment and special welding crews. . . .

The device was important in giving tankers a morale lift, for the hedgerows had become a greater psychological hazard than their defensive worth merited.

Named Rhinoceros attachments, later called Rhinos, the teeth were so effective in breaching the hedgerows that tank destroyer and self-propelled gun units also requested them, but the First Army Ordnance Section carefully supervised the program to make certain that as many tanks as possible were equipped first." Martin Blumenson, *US Army in World War II, European Theater of Operations, Breakout and Pursuit* (Washington: U.S. Army Center of Military History, 1961), 205-207.

136. Our response through attempts at rapid manufacture of MRAPs from 2007 onward is discussed above.

137. Other detection systems could provide similar examples. Defenses against electronic warfare have historically depended on compiling signature libraries in advance of attack and then programming electronic countermeasures to confound the anticipated signals. Analogously, cyberdefenses require intrusion detection systems that rely on identifying attack signatures. Like the biological detection mechanisms discussed in the text, these systems are on the cusp of being defeated by technology that renders attack signatures less predictable. In each of these areas, defenses must move beyond building a threat library. The past is an inadequate predictor of the future; defenses must prepare for uncertainty. Thus, the need exists for initiatives like the BLADE program described above.

138. Several of these demands for strategy are recently summarized by the Government Accountability Office. GAO, United States Government Accountability Office, *Biosurveillance: Efforts to Develop a National Biosurveillance Capability Need a National Strategy and a Designated Leader*, GAO-10-645 (June 2010), 32-33. The National Security Council and the U.S. Department of Health and Human Services reiterated and referenced the GAO's call for such a strategy in 2001 and issued similar declarations. National Security Council, *National Strategy for Countering Biological Threats*, (November 2009) and U.S. Department of Health and Human Services, *National Health Security Strategy of the United States of America* (December 2009).

139. Robert H. Carlson, for example, writes that "[t]he primary reason that we fret about bioterror and bioerror is that in human hands biological components aren't yet LEGOS. But they will be, someday relatively soon." Robert H. Carlson, *Biology is Technology: The Promise, Peril and New Business of Engineering Life* (Cambridge, MA: Harvard University Press, 2010), 8. Additionally, "the parts for typical DNA synthesizer – mostly plumbing and off-the-shelf electronics – can now be purchased for less than \$5,000. . . . [P]ossession of a DNA synthesizer does not a new organism make. Current chemical synthesis produces only short runs of DNA. Ingenuity and care are required to assemble full-length genes. . . . Commercialization methods to assemble the many millions of contiguous bases required to specify bacteria have been labor intensive and therefore expensive. Yet this barrier is certain to fall as automation and on-chip synthesis becomes more capable. . . . Even if great care is taken to limit the commercial synthesis of DNA from pathogens or toxins, it is unlikely the chemical tricks and instrumentation that companies develop in the course of building their businesses will remain confined within their walls." Ibid., 78-80.

140. For purposes of this discussion, I am ignoring attacks on animals and crops.

141. The Predictive Health Diagnosis (PHD) program is run by DARPA's Defense Science Office.

142. Thus, for example, cyberdefenses commonly now seek to identify particular virus signatures and then to block software that has these signatures. The implicit proposition is that viruses downloaded in the future will replicate past examples. Yet as viruses proliferate and attack modalities become accordingly less predictable, leaner defenses will be required: that is, defenses that identify unique and recurring anomalies common to cyberviruses and quarantine or disable software exhibiting these characteristics. Some biotechnology companies are attempting to execute this strategy for viruses attacking humans. See, for example, the website of Functional Genetics, [www.functional-genetics.com](http://www.functional-genetics.com).

143. Stewart Brand, *How Buildings Learn: What Happens After They Are Built* (New York: Viking Press 1994).

144. Ibid., 38.

145. Brand's example is a temporary building "hastily constructed" at MIT that has been used for many purposes over a half century. Ibid., 24.

146. Morison, *Men, Machines and Modern Times*, 223.

147. Ibid.

148. An approach that accepted predictive failure would also embrace greater diversity in military training and personnel systems. Not surprisingly, our uniform services preach uniformity. The most extreme example, the Marine Corps, processes all its members through the same initial curriculum (every Marine learns to shoot a rifle) and through some highly controlled streams thereafter. No service places a high premium on educational or career experience outside its own schools. The result is that when Arabic language or knowledge of biology is unpredictably required, if the system missed this focus – as the system did miss these foci – the entire service, or all services, have great difficulty coping with the exigencies of the moment. A more diverse educational system, more tolerant of individual choices, would better prepare the military departments for an uncertain world.

How would such a system function? As an example, it would be reasonable for a service like the Marine Corps to establish a year out for officers viewed as potential future generals. Such a program would provide a year's support for officers to join other governmental or private organizations, to enroll in academic programs not directly applicable to their military duties and to travel on their own.





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