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THESIS

PUTTING THE LID ON THE DEVIL'S TOY BOX: HOW THE HOMELAND SECURITY ENTERPRISE CAN DECIDE WHICH EMERGING THREATS TO ADDRESS

by

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March 2018

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13. ABSTRACT

Evolving developments in nanotechnology, materials science, and artificial intelligence are paving the way for exponential growth in humanity's abilities to create—and destroy. Emerging Promethean technologies will deliver capabilities to average persons that, until recently, have been relegated only to governments, militaries, and large research laboratories. The responsibilities of the homeland security enterprise can be divided between two mission sets: the systemic mission (responding to known threats) and the future-shock mission (preparing for highly uncertain threats from emerging technologies). The latter mission encompasses forecasting which emerging Promethean technologies are most likely to be actualized and then used by bad actors, and which have the direst plausible consequences. Pandora's Spyglass, a decision-support tool for performing a "devil's toy box" analysis, fuses best practices from a wide variety of predictive analytical techniques. It produces an ordinal list of most-destructive scenarios involving emerging Promethean technologies likely to come to market within a five- to ten-year window—a "to-do" list for counter-future-shock research and development. It is a ranking tool, not meant to serve as a budget justification or formulation tool; however, the procedure's assumptions and variables can be validated so that it could legitimately serve that latter function.

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PUTTING THE LID ON THE DEVIL'S TOY BOX: HOW THE HOMELAND SECURITY ENTERPRISE CAN DECIDE WHICH EMERGING THREATS TO ADDRESS

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ABSTRACT

Evolving developments in nanotechnology, materials science, and artificial intelligence are paving the way for exponential growth in humanity's abilities to create—and destroy. Emerging Promethean technologies will deliver capabilities to average persons that, until recently, have been relegated only to governments, militaries, and large research laboratories. The responsibilities of the homeland security enterprise can be divided between two mission sets: the systemic mission (responding to known threats) and the future-shock mission (preparing for highly uncertain threats from emerging technologies). The latter mission encompasses forecasting which emerging Promethean technologies are most likely to be actualized and then used by bad actors, and which have the direst plausible consequences. Pandora's Spyglass, a decision-support tool for performing a "devil's toy box" analysis, fuses best practices from a wide variety of predictive analytical techniques. It produces an ordinal list of most-destructive scenarios involving emerging Promethean technologies likely to come to market within a five- to ten-year window—a "to-do" list for counter-future-shock research and development. It is a ranking tool, not meant to serve as a budget justification or formulation tool; however, the procedure's assumptions and variables can be validated so that it could legitimately serve that latter function.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE	Aggregative Contingent Estimation program
AEER	Air Entry and Exit Re-Engineering project
ASCO	Advanced Systems and Concepts Office
BAA	Broad Agency Announcement
BEAP	Border Enforcement Analytics Program
BKC	Bio-Defense Knowledge Center
BMD	Borders and Maritime Security Division
BTC	Bio-Threat Characterization
CBD	Chemical and Biological Defense Division
CIPHER	contradictions, inflections, practices, hacks, extremes, and rarities
CNCI	Comprehensive National Cybersecurity Initiative
CONOPS	Concept of Operations
CRS	Congressional Research Service
CSAC	Chemical Security Analysis Center
CSS	Coastal Surveillance System
DARPA	Defense Advanced Research Projects Agency
DHS	Department of Homeland Security
DIA	Defense Intelligence Agency
DTRA	Defense Threat Reduction Agency
EFMN	European Foresight Monitoring Network
EXD	Explosives Division
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FFRDC	Federally Funded Research and Development Center
FUSE	Foresight and Understanding from Scientific Exposition program
GDP	gross domestic product
GLANSER	Geospatial Location Accountability and Navigation System for Emergency Responders
GMO	genetically modified organism
GOTS	government off-the-shelf
HHM	Hierarchical Holographic Modeling
HIPS	Homeland Innovative Prototypical Solutions
HITS	High Impact Technology Solutions
HOST	Homeland Open Security Technologies
HSARPA	Homeland Security Advanced Research Projects Agency

HSRE	Human Systems Research and Engineering
IAO	Information Awareness Office
IARPA	Intelligence Advanced Research Projects Agency
IC	Intelligence Community
IED	improvised explosive device
INGT	improved nominal group technique
IPT	Integrated Product Team
IQT	In-Q-Tel
MITI/METI	Ministry of International Trade and Industry (Japan)
NBAF	National Bio and Agro-Defense Facility
NGT	nominal group technique
NPPD	National Protection and Programs Directorate
PAM	Policy Analysis Market
PCS	Process Control Systems
PLO	Palestine Liberation Organization
R&D	research and development
RFRM	Risk Filtering, Ranking, and Management
ROI	Return on Investment
RSD	Resilient Systems Division
SAIC	Science Applications International Corporation
SBIR	Small Business Innovative Research
SCIF	Sensitive Compartmented Information Facility
SME	subject matter expert
S&T	Science & Technology Directorate
STTR	Small Business Technology Transfer
SUMMIT	Standard Unified Modeling Mapping Integrated Toolkit
SWAMP	Software Assurance Marketplace
SWOT	Strengths, Weaknesses, Opportunities, and Threats
T&E	test and evaluation
TITAN	Targeted Innovative Technology Acceleration Network
TOG	Technology Oversight Group
TSA	Technology Sequence Analysis
TTP	Transition to Practice
VSL	value of a statistical life
WMD	weapon(s) of mass destruction

EXECUTIVE SUMMARY

The pace of technological development and change is accelerating. Current and near-term developments in nanotechnology, materials science, and machine learning and artificial intelligence promise to pave the way for exponential growth in humanity's abilities to create—and destroy. Emerging Promethean technologies promise to deliver to average persons of average financial means and average skills capabilities which, until the present time, have been relegated only to national governments, well-funded military establishments, and research laboratories employing hundreds of highly skilled scientists and technicians. The implications of these developments (foreshadowed by the rapid spread of consumer-grade 3D printing tech and CRISPR gene-editing tech) for the homeland security enterprise are ominous.

Rodrigo Nieto-Gómez separates the responsibilities of the homeland security enterprise into two mission sets: the systemic mission (preparing for and responding to known threats of either a natural or man-made origin) and the future-shock mission (preparing for highly uncertain or unknown threats from emerging technologies or combinations of current and/or emerging technologies).[1] He states that our existing homeland security apparatus handles its systemic mission capably and effectively; due in part to the nature of bureaucracy, a system evolved to apply standardized policies and procedures to deal with known, incremental threats.[2] He goes on, however, to point out that the very qualities of homeland security bureaucracies that make them effective in meeting their systemic mission make them *ineffective* in meeting their future-shock mission.[3]

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[1] Rodrigo Nieto-Gómez, "Power of 'the Few': A Key Strategic Challenge for the Permanently Disrupted High-Tech Homeland Security Environment," *Homeland Security Affairs* 7, Article 18 (December 2011): 5–8. https://www.hsaj.org/articles/50.

[2] Nieto-Gómez, "Power of 'the Few': A Key Strategic Challenge for the Permanently Disrupted High-Tech Homeland Security Environment,"

[3] Nieto-Gómez, "Power of 'the Few': A Key Strategic Challenge for the Permanently Disrupted High-Tech Homeland Security Environment," 13.

In its counter-future-shock role, the homeland security enterprise must forecast which, of an uncountable number of potential threats posed by innumerable combinations and re-combinations of existing and cutting-edge technologies, potentially wielded by a broad universe of malign actors, both known and unforeseen, are most likely to be actualized and have the highest potentially dire consequences for the Nation's security, stability, and well-being. Acting within an environment of limited budgets, time, and resources, and given the near-infinite number of potential future threats, how can the homeland security enterprise effectively identify and select those research and development projects best suited to carrying out the counter-future-shock role?

I suggest that the solution will be found through a "devil's toy box" analysis. This procedure begins with wide-scope environmental scanning—powered by computer learning—of emerging Promethean technologies. It continues with brainstorming by a varied team of experts of the direst consequences of each of those Promethean technologies (or combinations of emerging technologies with existing technologies), then, with application of red-teaming techniques and expert estimation of the likelihood of Promethean technologies coming to market, the subsequent likelihood of the actualized technologies being used for malign purposes, and the worst plausible consequences of those malign uses. The varied team of experts uses a risk calculation based upon consensus estimations arrived at through Delphi and nominal group technique processes to rank the many scenario stubs generated and narrow the list down to the worst of the worst, the "deadly dozen" scenarios. These "deadly dozen" are ranked in turn through an iterative application of more robust analytical estimating techniques. The result is an ordinal list of direst scenarios involving emerging Promethean technologies likely to come to market within a five- to ten-year window—a "to-do" list for the homeland security enterprise's counter-future-shock research and development (R&D) program.

A. RESEARCH QUESTION

How can the homeland security enterprise best select future-shock threats upon which to expend its limited research and development (R&D) resources?

B. METHOD AND DESIGN

I perform a Policy Options analysis, focusing on a review of existing knowledge. I chose my various types of predictive analyses to analyze, either as alternative techniques or sources of best practices for a fused procedure to support a "devil's toy box" analysis, based upon these procedures' prominence in the literature, as well as a discussion with my academic advisor. I selected the Homeland Security Advanced Research Projects Agency (HSARPA) as my default governmental agency for analysis because it is the lead agency identified by Congress for developing technological solutions to emerging threats to the Homeland.

I perform a review of the literature on the various types of predictive analyses, comparing the benefits and shortcomings of various techniques: the Delphi technique, the nominal group technique (NGT), and futures studies, which may collectively be referred to as techniques for elicitation of expert opinion; red-teaming techniques; and prediction/futures markets (the wisdom of the crowd). Additionally, I address the question of what types of experts should be included in the "devil's toy box" analytical team, examining the utility of including science fiction writers as members, due to their acculturation to and facility with using what I term "the science fiction mindset." I select appropriate best practices from a variety of predictive analytical techniques and use them to construct a fused procedure, which I term Pandora's Spyglass.

C. CONCLUSION

The "science fiction mindset," a mode of thinking that combines competitive scanning of the emerging technological landscape and extrapolation of technology's evolving capabilities with a commercially-driven focus on exciting, destructive conflict, is of especial utility to the homeland security enterprise in performing a "devil's toy box" analysis, and science fiction writers are a key part of a Pandora's Spyglass analytical team. Due to the science fiction mindset's parallels with the motivations driving terrorists who would seek to use Promethean technologies in innovative ways, having science fiction writers as key members of the analytical team is the next best thing to having reformed former terrorists as members.

Appropriate best practices for a "devil's toy box" analysis are adapted from the entire panoply of predictive analytics techniques developed since the end of World War II. Pandora's Spyglass, as envisioned, takes approximately six months, with a full-time, three- to four-week face-to-face portion sandwiched between two distance portions, during which participants would work part-time, an hour to 90 minutes per day. Pandora's Spyglass is intended to serve as a decision-support tool to facilitate the homeland security enterprise's identification and prioritization of emerging Promethean technology threats upon which to focus limited R&D resources. In its basic form, it is a ranking tool, not meant to serve as a budget justification or formulation tool; however, the procedure's assumptions and variables can be validated so that it could legitimately serve that latter function, if desired.

Regarding the question of which organization is best suited to make use of Pandora's Spyglass—which federal agency is best equipped, in terms of mission set, organizational culture, and resources, to optimally implement a "devil's toy box" analysis and then use the findings generated to drive R&D efforts to counter-future-shock threats—I consider six different scenarios. Four of these scenarios involve HSARPA and the Department of Homeland Security Science and Technology (S&T) Directorate, and two of the scenarios involve DHS contracting out the "devil's toy box" analytical effort and management of subsequent R&D projects to either the Intelligence Advanced Research Projects Agency (IARPA) or the Defense Advanced Research Projects Agency (DARPA). Ranking these six scenarios, I judge the most preferable one to be DHS contracting out Pandora's Spyglass to DARPA, with the next most preferable scenario being a reformulated, "fresh sheet of paper" HSARPA, refocused on its original mission to support the counter-future-shock mission, no longer under the S&T Directorate umbrella (in this scenario, S&T would retain "old HSARPA" to perform R&D work to support the homeland security systemic mission).

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I. INTRODUCTION

A. RESEARCH QUESTION

How can the homeland security enterprise best select future-shock threats upon which to expend its limited research and development (R&D) resources?

B. A PARABLE

The devil has a toy box. It contains many toys the devil likes very much. The devil has his favorite play things, things he likes to play with again and again; however, he frequently becomes bored with his old, familiar toys and goes looking for new things to play with. His play, as befitting the devil, involves inciting fear, causing death and destruction, and sowing mayhem and distrust wherever and whenever he chooses. So, in addition to storing his old toys in the toy box, the devil also fills his toy box with smaller boxes, inside of which gestate new toys, some of them very strange, indeed.

The devil's victims do not like how the devil plays, nor do they like his toys. They spend much time and effort thinking up ways to defend themselves and their loved ones from the devil's vicious play. But the toy box poses a problem. Occasionally the defenders can see into the toy box, but not often. They can anticipate that the devil will most often choose to play with his favorite toys. They have thought up ways to protect themselves from those familiar toys, even though the devil still often wins his games through surprise and craftiness.

But for the defenders, the most frightening thought regards those strange, new toys gestating inside the smaller interior boxes. When the devil acquires brand-new toys, he will use those new toys in ways the victims are not expecting; because the devil is a crafty alchemist. He delights in taking ordinary things, seemingly harmless things, and combining them into dangerous, deadly toys no one has seen before. These new toys, whose limits are unknown, have the potential to be much more destructive than the devil's old, familiar toys, the ones to which the defenders have become accustomed.

In seeking to protect themselves and their loved ones, the defenders have a harder job than their antagonist. The devil can get lucky just once and claim victory, whereas his intended victims and their defenders must be lucky always. The latter must prepare defenses against the new toys which will inevitably emerge at some point from the devil's toy box. But preparing such defenses takes considerable time, as well as considerable resources. Should the defenders attempt to create shields against every possible new toy the devil might make or reconfigure with his alchemy, they would spend every penny in the treasury and never sleep, nor ever work on anything else. The defenders need to decide which new toys are most *likely* to emerge from the devil's toy box, and of those most *likely* new toys, which will be the most *dangerous*.

The defenders need a crystal ball to guide their efforts, to tell them what they will need to defend against five to ten years in the future, so they will have time to alert the weapons-smiths at the forgery to create the proper shields. But crystal balls are expensive, finicky, cumbersome to use, and unreliable. Worse, they often give wrong predictions and lead their users down blind alleys. This is bad because, for one thing, it will waste the weapons-smiths' time, effort, and iron to produce a shield of little or no value, and for another, having the weapons-smiths work on the wrong shield means they will be unavailable to work on the *right* shield. Crystal balls seem almost useless. But the alternatives to using a crystal ball are either trying to defend against *every* toy that might possibly emerge from the devil's toy box (*impossible*), or doing nothing, and, thus, accepting the possibly terrible consequences of allowing the devil to try out any new toy he fancies (*unwise*, and perhaps *immoral*).

As seemingly impractical as using a crystal ball appears to the defenders, the alternatives seem worse. Like it or not, they'll have to find one and use it as best they can. Their challenge? To find a crystal ball that is not so expensive that procuring it will empty the treasury, yet one that is not so arcane that only the most famed and powerful sorcerers can use it. They need one that will give repeatable results over time, not just work according to its own unpredictable whims. Perhaps most importantly, the defenders need a crystal ball that they can calibrate and improve with use. It will not always be accurate, the defenders realize—it will show, in its cloudy, obscured fashion, many futures which will

not come to pass. But the best that can be expected of this imperfect crystal ball is that it will provide enough foresight that its cost and inconvenience are outweighed by whatever destructive mischief the devil's new toys would have wrought in the absence of any forecasting at all.

C. PROBLEM STATEMENT

Rodrigo Nieto-Gómez separates the responsibilities of the homeland security enterprise into two mission sets: the systemic mission (preparing for and responding to known threats of either a natural or man-made origin) and the future-shock mission (preparing for highly uncertain or unknown threats from emerging technologies or combinations of current and/or emerging technologies).[1] I refer to this latter mission as the *counter*-future-shock mission, because the role of the homeland security enterprise is to prevent future-shock events from occurring. In the terms of our parable, the systemic mission represents the defense against the devil's old, familiar toys, whereas the counter-future-shock mission represents the attempt to prepare and deploy shields to protect against the devil's new, alchemized toys.

Existing Department of Homeland Security risk assessment doctrine appears to focus primarily on threats from natural hazards and man-caused threats encompassing known technological capabilities and modes of attack. A "devil's toy box" analysis would represent a supplement to this primarily systemic mission-focused risk assessment by facilitating a consideration of the potential threats that could emanate from technological capabilities not yet invented and from modes of attack not yet imagined by today's terrorists.

The Homeland Security Advanced Research Projects Agency (HSARPA), a unit of the DHS Science and Technology Directorate, has the Congressionally mandated mission of fostering revolutionary new technologies and methods to meet homeland security missions. Based on its founding charter, HSARPA would appear to be the most appropriate spearhead for the homeland security counter-future-shock mission; however, political and

[1] Nieto-Gómez, "Power of 'the Few,'" 5–8.

organizational pressures have funneled the majority of HSARPA's research and development (R&D) projects into near-term, moderate- or low-risk projects meant to support the current needs of DHS's operational agencies.[5]

In its counter-future-shock role, the homeland security enterprise must forecast which of an uncountable number of potential threats posed by innumerable combinations and re-combinations of existing and cutting-edge technologies, potentially wielded by a broad universe of malign actors both known and unforeseen, are most likely to be actualized and have the highest potentially dire consequences for the Nation's security, stability, and well-being. Acting within an environment of limited budgets, time, and resources, and given the near-infinite number of potential future threats, how can the homeland security enterprise effectively identify and select those R&D projects best suited to carrying out the counter-future-shock role? Additionally, of the possible Federal agencies that could serve as the technological spearhead of the homeland security counter-future-shock mission, is HSARPA the most appropriate candidate, given the agency's troubled history and organizational culture?[6] Or might another agency prove more effective in this role?

D. LITERATURE REVIEW

This literature review covers the following topics. The challenges that future-shock threats pose to the Nation's homeland security are reviewed first. The review then provides background regarding three sets of predictive analysis techniques: the Delphi technique, the nominal group technique (NGT), and futures studies, which may collectively be referred to as techniques for elicitation of expert opinion; red-teaming techniques; and prediction/futures markets (the wisdom of the crowd).

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[5] Dana A. Shea, *The DHS S&T Directorate: Selected Issues for Congress*, CRS Report No. R43064 (Washington, DC: Congressional Research Service, April 14, 2014), 17, https://fas.org/sgp/crs/homesec/R43064.pdf.

[6] Kristin L. Wyckoff, "Solving Homeland Security's Wicked Problems: A Design Thinking Approach" (master's thesis, Naval Postgraduate School, 2015), 38–39, https://calhoun.nps.edu/bitstream/handle/10945/47349/15Sep_Wyckoff_Kristin.pdf?sequence=3.

1. The Challenges of Future Shock Threats for the Homeland Security Enterprise

Numerous authors in the homeland security field have written about the accelerating pace of technological change and the challenges posed by the chaotic technology realm, combinatorial technologies, and "super-empowered angry guys" for the homeland security enterprise. The risks to our Nation's homeland security are increased by what Dr. Ronald Lehman has termed *strategic latency*, defined as "a package of diverse technologies that can be deployed quickly, often in new ways, with limited visibility that could have decisive military and geopolitical implications."[7] He goes on to state that any technology can be dual-use to the extent that it can be re-conceptualized to support improvements in existing weaponry or to more effectively apply force against a target.[8] The difficulty of defending against such developments in dual-use technology is heightened by what he terms the "emergent behavior" of complex technology, or the tendency for new technological capabilities to be used by adopters in ways unforeseen by the original developers of those technologies.[9]

Rodrigo Nieto-Gómez, in his analysis of the strategic challenges faced by what he terms "the permanently disrupted high-tech homeland security environment," highlights Bryan Arthur's concept of "combinatorial evolution" of technology, wherein technologies produce outputs that can be reconfigured and recombined in virtually endless combinations for new purposes, like how chemists can create new molecules from more basic elements. Nieto-Gómez postulates that this combinatorial evolution continually opens fresh vulnerabilities within our technologically dependent society. He further states that small,

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[7] Michael Nacht, "What is Strategic Latency? An Introduction," in *Strategic Latency and World Power: How Technology is Changing Our Concepts of Security*, ed. Zachary Davis, Ronald Lehman, and Michael Nacht (Livermore: Lawrence Livermore National Laboratory Center for Global Security Research, eBook edition, 2014), 4. https://cgsr.llnl.gov/content/assets/docs/Strategic_Latency.pdf.

[8] Ronald F. Lehman, "Unclear and Present Danger: The Strategic Implications of Latent, Dual-Use Science and Technology," in *Strategic Latency and World Power: How Technology is Changing Our Concepts of Security*, ed. Zachary Davis, Ronald Lehman, and Michael Nacht (Livermore: Lawrence Livermore National Laboratory Center for Global Security Research, eBook edition, 2014), 5. https://cgsr.llnl.gov/content/assets/docs/Strategic_Latency.pdf.

[9] Ibid., 18.

decentralized groups with the intent to disrupt that society—groups which he terms "the few"—are better situated to recognize and exploit those vulnerabilities than large, centralized, vertically-oriented organizations such as governments, law enforcement agencies, and homeland defense departments.[10] Nieto-Gómez's notion of "the permanently disrupted high-tech homeland security environment" is fully congruent with Lehman's concepts of strategic latency and emergent behavior, as those latter concepts describe an environment of surprise and unpredictability.

Nieto-Gómez helpfully defines the homeland security mission as having two components. The first is the systemic mission, which consists of prevention, mitigation, and response to known threats, both natural and man-made (the former including hurricanes, earthquakes, and floods, and the latter terror attacks on key infrastructure, transportation, or national symbols using conventional weaponry such as explosives, guns, knives, or vehicles). The second is the future-shock mission, which he characterizes as "neutraliz(ing) disruptive—almost random—threats posed by the rapid pace of technological evolution."[11] He states that our existing homeland security apparatus handles its systemic mission capably and effectively, due in part to the nature of bureaucracy, a system evolved to apply standardized policies and procedures to deal with known, incremental threats.[12] However, he goes on to point out that the very qualities of homeland security bureaucracies that make them effective in meeting their systemic mission make them *ineffective* in meeting their future-shock mission.[13]

Other observers have identified additional factors that work against the homeland security apparatus's achievement of its future-shock mission. Christopher Bellavita points out an important factor: in the U.S., much political and economic weight is given to the provision of services and equipment to the Nation's first responders community, whereas the role of prevention does not have a similarly weighty political and economic

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[10] Nieto-Gómez, "'Power of 'the Few,'" 5–8.

[11] Ibid., 10.

[12] Ibid., 11.

[13] Ibid., 13.

constituency. He identifies three additional factors which hamper homeland security institutions' provision of effective threat prevention services. These are fear of new behavior, fear of imagination, and fear of emergence.[14] Coming from a non-homeland security perspective, Helle Vibeke Carstensen and Christian Bason identify factors that make the task of innovation difficult for traditional governmental bureaucracies. These include organizational siloes of information within bureaucracies; heavy reliance on standardized processes and procedures; reliance on linear development processes; lack of effective performance evaluation; and the documented fact that public-sector agencies tend to be more focused on improving internal policies and procedures than they are on supplying innovative new services and improved outcomes to the public. Finally, the authors point out that governmental bureaucracies' optimization procedures are almost entirely focused upon verification efforts (are we doing things right?) rather than validation efforts (are we doing the right things?).[15] Nieto-Gómez, Bellavita, and Carstensen and Bason all agree that bureaucracies that were originally designed to carry out one set of mission tasks (what Nieto-Gómez calls the systemic mission, which focuses on standardization, repeatability, and reliability) are severely hampered by their governing structures and organizational cultures when they attempt to pursue a very different set of mission tasks (the counter-future-shock mission that focuses on innovation), tasks that national governments have newly assigned to them.

In the following sections of this literature review, I briefly describe various types of predictive analysis techniques developed since the end of World War II which may assist the homeland security enterprise in identifying and prioritizing emerging future-shock threats against which to develop countermeasures. I separate these techniques into three sets. The first is what I call the expert analysis or elicitation of expert opinion set of techniques; these include the Delphi process, nominal group technique (NGT), and futures

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[14] Christopher Bellavita, "What is Preventing Homeland Security?" *Homeland Security Affairs* 1 (June 2005), https://www.hsaj.org/articles/182.

[15] Helle Vibeke Carstensen and Christian Bason, "Powering Collaborative Policy Innovation: Can Innovation Labs Help?" *The Innovation Journal: The Public Sector Innovation Journal* 17, no. 1 (2012): 3–5, https://www.innovation.cc/scholarly-style/christian_bason_v17i1a4.pdf.

studies. The second set is critical thinking techniques collectively known as red-teaming. The third I refer to as "the wisdom of crowd" set of techniques, which includes prediction/futures markets and prediction polls.

2. Predictive Analysis Techniques 1: Elicitation of Expert Opinion (Delphi Technique / Nominal Group Technique (NGT) / Futures Studies)

The process of winnowing down those emerging technologies that are most likely to pose a significant threat to the Nation's homeland security and are most likely to be made use of by malign actors must begin with a more basic task: that of identifying which emerging technologies have "legs" and are likely to be developed into producible, marketable products that grant end-users significant or revolutionary new capabilities. Homeland security managers could choose to use one or more of several decision-support and predictive analysis techniques to assist with this process. The oldest of these are the expert analysis techniques—the Delphi technique, the nominal group technique, and futures studies.

Olaf Helmer provides a history, description, and critique of the *Delphi technique*, a post-World War II analytical process for eliciting useful, accurate answers to complicated questions from groups of experts.[16] More recently, Philip E. Tetlock and Dan Gardner, with their *Superforecasting: The Art and Science of Prediction*, have put some quantitative meat on the bones of the Delphi theory. Working for the Intelligence Advanced Research Projects Agency (IARPA), they conducted large-scale competitions between teams of futures analysts to determine what factors differentiate more accurate predictors of events six months to a year in the future from less accurate ones.[17]

The *nominal group technique (NGT)* is an alternative structured group interaction process, created by Andrew H. Van de Ven and Andre L. Delbecq in 1968. They sought to ameliorate some of the same problems associated with unstructured face-to-face group

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[16] Olaf Helmer, "Analysis of the Future: the Delphi Method" (Santa Monica, California: RAND Corporation, March 1967), http://www.rand.org/content/dam/rand/pubs/papers/2008/P3558.pdf.

[17] Philip E. Tetlock and Dan Gardner, *Superforecasting: The Art and Science of Prediction* (New York: Crown, 2015).

discussions with which the inventors of the Delphi technique had grappled, but without entirely removing the social benefits participants accrue from face-to-face interactions.[18] Slightly more than a decade later, William M. Fox identified several shortcomings of the nominal group technique as originally constituted and suggested a number of refinements, which he collectively termed the improved nominal group technique (INGT).[19]

Futures studies blossomed due to early optimism surrounding the use of the Delphi technique to forecast future events. The RAND Corporation, the think tank that sponsored the research that led to the development and first uses of the Delphi technique, published some of the earliest papers reviewing the emerging field of futurism or futures studies, the attempt to use predictive analytical techniques such as Delphi to extrapolate the development of technology, as well as social, political, and environmental trends, to some point in the future, perhaps a quarter-century or forty years out. Examples include *The Year 2000* (1967), a summation of then-current speculations about the beginning of the new millennium, and *The Future as an Object of Research* (1967), which focuses both on the then-nascent Futures Industry and the problems of predictive methodologies.[20] One of the progenitors of futures studies is Alvin Toffler, whose best-selling *Future Shock* initiated the field of cross-discipline futures studies in 1970.[21] Toffler followed up on this work with two sequels, and a flood of futures studies books, both scholarly and popular, accompanied them, including the Club of Rome's dour *The Limits to Growth* and its philosophical opposite, Herman Kahn's *The Next 200 Years*.[22]

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[18] Andre L. Delbecq, Andrew H. Van de Ven, and David H. Gustafson, *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes* (Glenview, IL: Scott, Foresman, and Company, 1975), 7–9.

[19] William M. Fox, "The Improved Nominal Group Technique (INGT)," *Journal of Management Development* 8, no. 1 (1989): 20–27, https://doi.org/10.1108/EUM0000000001331.

[20] Brownlee Haydon, *The Year 2000* (P-3571) (Santa Monica: the RAND Corporation, 1967); and N. Rescher, *The Future as an Object of Research* (P-3593) (Santa Monica: the RAND Corporation, 1967).

[21] Alvin Toffler, *Future Shock* (New York: Random House, 1970).

[22] Donella H. Meadows, Dennis Meadows, Jørgen Randers, and William W. Behrens III, *The Limits to Growth* (New York: Universe Books, 1972); Herman Kahn, *The Next 200 Years* (New York: Morrow, 1976).

Writers of science fiction have also come to play a role in advising governmental agencies regarding what types of future threats may be lurking over the horizon. Arlan Andrews, the founder of SIGMA, relates the history of this voluntary, non-profit association of science fiction writers with backgrounds in the hard sciences, engineering, or medicine. He explains why science fiction writers possess unique skills especially applicable to the homeland security counter-future-shock mission.[23]

3. Predictive Analysis Techniques 2: Red-Teaming

A different sort of predictive analysis technique, this one focused on the near-term decisions that might be made by one's opponents—*red-teaming*, the systematic effort to view one's side's weaknesses from an enemy's viewpoint, also factoring in the enemy's hoped-for outcomes, and thus predicts that enemy's most likely modes of attack—has roots going all the way back to the Prussian Army general staff of the Napoleonic Era. That organization, in the wake of severe defeats at Napoleon's hands, innovated the *Kriegspiele*, or war game, which could take the form of table top exercises, map exercises, general staff rides, or full-fledged unit exercises in the field.[24] Since the heyday of the Prussian Army general staff, the use of red-teaming has spread well beyond military applications. Dr. Mark Mateski asserts that red-teaming can be productively deployed by many types of organizations that must cope with adversaries or competitors, in that it serves as an analytical tool for avoiding rigidity and countering surprise.[25]

The U.S. Marine Corps defines red-teaming as "role-playing the adversary."[26] Major David F. Longbine of the U.S. Army describes the key roles of red-teaming as

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[23] Arlan Andrews, Sr., "SIGMA: Summing Up Speculation," *Analog Science Fiction & Fact* 132, 9 (September 2012): 384–393.

[24] Williamson Murray, *War, Strategy, and Military Effectiveness* (New York: Cambridge University Press, 2011), 142–143.

[25] Mark Mateski, "Red-Teaming: A Short Introduction (1.0)," *RedTeamJournal.com* (June 2009), 1–7. http://redteamjournal.com/papers/A%20Short%20Introduction%20to%20Red%20Teaming%20(1dot0).pdf.

[26] Major David F. Longbine, *Red-Teaming: Past and Present* (Fort Leavenworth, KS: School of Advanced Military Studies, United States Army Command and General Staff College, 2008), 6. http://indianstrategicknowledgeonline.com/web/2286.pdf.

challenging stale, outdated, or false thinking in an organization through filling the role of "devil's advocate" and strongly challenging what is accepted as "conventional wisdom," as well as providing a set of alternative analyses. Additionally, red-teaming provides decision makers with alternative perspectives by describing the operational environment as it might be seen through the eyes of allies and partners, adversaries, or other actors within the environment.[27] The U.S. Army has established a school at the University of Foreign Military and Cultural Studies (UFMCS), located at Fort Leavenworth in Kansas, to teach red-teaming techniques.[28] Both the UFMCS's *Red Team Handbook* and the U.K. Ministry of Defence's *Red-Teaming Guide* provide thorough descriptions of numerous techniques and exercises for red-teaming analyses.[29]

Dr. Mark Mateski, in his *Red-Teaming: A Short Introduction*, provides nine definitions of red-teaming from various military, government, and scholarly sources and compares them. He points out that their common elements are bringing to the fore an adversary's or competitor's point of view, and assisting decision makers to make the best possible choices or to optimize systems.[30] Mateski asserts that red-teaming is a type of alternatives analysis whose function is to assist leaders in making good decisions by aiding them in avoiding rigidity and countering surprise; red-teaming does this through drawing on the benefits of a variety of alternative analysis techniques, including "key assumptions checks; devil's advocacy; Team A/Team B; red-cell exercises; contingency 'what if' analysis; high-impact/low-probability analysis; [and] scenario development."[31] The

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[27] Ibid., 81–5.

[28] *Armed Forces Journal*, "A Better Way to Use Red Teams: How to Inject the Enemy's View into the Planning Process," *Armed Forces Journal* online, February 1, 2012, http://armedforcesjournal.com/a-better-way-to-use-red-teams/.

[29] University of Foreign Military and Cultural Studies, *Red Team Handbook* (version 6.0) (Leavenworth, KS: University of Foreign Military and Cultural Studies, April 2012), http://www.au.af.mil/au/awc/awcgate/army/ufmcs_red_team_handbook_apr2012.pdf; United Kingdom Ministry of Defence Development, Concepts and Doctrine Center, *Red-Teaming Guide* (2nd Edition) (Swindon, Wiltshire, UK: The Development, Concepts and Doctrine Center, Shrivenham, Ministry of Defence, January 2013), https://www.gov.uk/government/publications/a-guide-to-red-teaming.

[30] Mateski, *Red-Teaming: A Short Introduction*, 22–31.

[31] Ibid., 1–7.

Defense Threat Reduction Agency's "Evil Genius Study," the results of which were published in the April 2009 monograph, *Thwarting an Evil Genius*, is an example of analytical red-teaming that has special relevance to the counter-future-shock mission. This monograph poses a series of questions that could be used to help winnow down the universe of potential future threat vectors.[32]

Michael J. Skroch of Sandia National Laboratories discusses an avenue for the extension of red-teaming techniques beyond the limitations of human analysis: virtual red-teaming through modeling and simulation. He asserts that, when it comes to red-teaming, whereas human beings are effective in the realms of creativity and intuition, computers are good at crunching numbers, dealing with complexity, and exhausting a range of potential alternatives.[33] Of the three realms, red-teaming methods are called upon to analyze for strengths and vulnerabilities, the physical space, cyberspace, and the behavioral space; computer simulations have strong advantages in the first two realms, when compared to human analysts.[34] Following up on Skrotch's work, several computer programmers and mathematicians have worked to create actual systems to perform virtual red-teaming, including Yacov Y. Haimes and Barry M. Horowitz, with their Adaptive Two-Player Hierarchical Holographic Modeling Game for counterterrorism intelligence analysis, and Gerald G. Brown, Matthew Carlyle, Javier Salmerón, and R. Kevin Wood, who developed a "Defend-Attack-Mitigate risk-minimization model" and a tri-level "Defender-Attacker-

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[32] Dallas Boyd Trevor Caskey, Kevin A. Ryan, Joshua Pollack, George W. Ullrich, James Scouras, and Jonathan Fox., *Thwarting an Evil Genius: Final Report* (Washington, DC: Defense Threat Reduction Agency Advanced Systems and Concepts Office, April 13, 2009), https://fas.org/irp/agency/dod/dtra/thwart.pdf, 7.

[33] Michael J. Skroch, *Modeling and Simulation of Red-Teaming, Part 1: Why Red Team M&S?* (SAND 2009-7215 J, Rev 3) (Albuquerque, NM: Sandia Corporation, November 2, 2009), 2–4, http://umbra.sandia.gov/pdfs/resources/redteam.pdf.

[34] Ibid., 6.

Defender risk-minimization model," which they applied to the problem of defending various critical infrastructure systems against terror attacks.[35]

4. Predictive Analysis Techniques 3: The "Wisdom of Crowds" Techniques, Prediction/Futures Markets and Prediction Polls

James Surowiecki, with his book *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*, has popularized the well-studied phenomenon that groups of people, when their judgments are amalgamated, can often make more accurate predictions and estimations than the best experts among them, working alone.[36] Robin Hanson, a pioneer in the modern use of market techniques to forecast political, social, and technological developments and one of the primary creators of DARPA's short-lived Policy Analysis Market (PAM), has written extensively about the class of analytical tools to which PAM belonged, combinatorial information markets. He has also detailed the story of PAM's development, its promise, and its abrupt termination due to political fallout. DARPA hired Hanson and his team to design a predictive analysis system that would use financial information feedback tools associated with stock and commodities markets—buying and selling of shares, as well as holds and puts—to predict the likelihood of a wide range of sociopolitical events around the world occurring within a specified period. PAM, as designed, would rely upon the profit motive to incentivize participants in the informational market to uncover the best information possible. At any given time, the system's best available prediction of the likelihood of a sociopolitical event occurring would be the current price of that event's option in the market; however, when some details of the program were leaked to the media, immediate outrage ensued over experts "profiting" on

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[35] Yacov Y. Haimes and Barry M. Horowitz, "Adaptive Two-Player Hierarchical Holographic Modeling Game for Counterterrorism Intelligence Analysis," *Journal of Homeland Security and Emergency Management* 1, no. 3, art. 302 (June 2004), doi: https://doi.org/10.2202/1547-7355.1038; Gerald G. Brown, W. Matthew Carlyle, Javier Salmerón, and Kevin Wood, *Analyzing the Vulnerability of Critical Infrastructure to Attack and Planning Defenses* (Monterey, CA: Naval Postgraduate School, Operations Research Department, 2005), doi: 10.1287/educ.1053.0018.

[36] James Surowiecki, *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations* (New York: Doubleday, 2004), 4–5.

the occurrence of events such as political assassinations or terror attacks, and the media hullabaloo caused some national politicians to insist that funding for the program be revoked.[37]

In a series of articles, Hanson addresses the concerns that were raised in the political and media realms regarding PAM and suggests refinements to the project's design, should policy makers ever decide to reinstitute it. The pitfalls to avoid that he addresses include the moral implications of a terrorism predictions market; terrorists' potential manipulation of such a market to generate profits; the replacement of well-trained professional analysts with unproven amateurs; hiding prices; and decision selection bias. He suggests that future enhancements could include the combination of a prediction market with red-teaming techniques and the application of combinatorial methods of prediction.[38] Robert E. Looney further analyzes the arguments that were made against PAM.[39] Despite PAM's cancellation prior to implementation, more recent commentators in the intelligence and homeland security realms have proposed resurrecting the concept, saying it was euthanized far too quickly and still holds great promise.[40]

More recently, in 2011 the Intelligence Advanced Research Projects Agency (IARPA) sponsored a multi-year forecasting tournament called the Good Judgment Project, which provided the first opportunity for a large-scale comparison of the accuracy and efficacy of two crowd-sourcing predictive analysis techniques, prediction markets (the

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[37] Robin Hanson, "The Policy Analysis Market: A Thwarted Experiment in the Use of Prediction Markets for Public Policy," *Innovations: Technology, Governance & Globalization* 2 (Summer 2007): 73–88, doi: 10.1162/itgg.2007.2.3.73; Robin Hanson, Takashi Ishikida, and John Ledyard, *An Experimental Test of Combinatorial Information Markets* (Fairfax, Virginia: George Mason University Department of Economics, February 2005), http://mason.gmu.edu/~rhanson/testcomb.pdf.

[38] Robin Hanson, "Designing Real Terrorism Futures," *Public Choice* 128 (2006): 257–74, http://mason.gmu.edu/~rhanson/realterf.pdf.

[39] Robert E. Looney, "DARPA's Policy Analysis Market for Intelligence: Outside the Box or Off the Wall?" *International Journal of Intelligence and CounterIntelligence* 17 (2004): 405–19, http://www.au.af.mil/au/awc/awcgate/nps/pam/si_pam.pdf.

[40] Colonel Brett D. Weigle, "Prediction Markets: Another Tool in the Intelligence Kitbag" (master's thesis, U.S. Army War College, 2007); Brian A. Lozada, "The Emerging Technology of Predictive Analytics: Implications for Homeland Security," *Information Security Journal: A Global Perspective* 23 (2014): 118–22, doi: pdf/10.1080/19393555.2014.972598.

Hanson model) and prediction polls.[41] In prediction markets, traders use their best knowledge to seek profits by buying and selling shares of contracts about potential future events; the "wisdom of the crowd," the crowd's best estimation of the likelihood of the future events occurring, can be immediately distilled at any given point in time from the share price. Prediction polls do not rely upon probabilistic betting; rather, participants in the polls offer their forecasts, either individually or as members of teams, and are permitted to update their forecasts as often as they choose. Finally, they are given feedback on their degree of accuracy.[42]

Research derived from the Good Judgment Project forecasting tournament formed the basis for Philip E. Tetlock's and Dan Gardner's popular book, *Superforecasting: The Art and Science of Prediction*.[43] The widespread interest elicited by this book and the academic articles from which the book was born indicate that, despite the setback delivered to the use of prediction/futures markets in the public policy realm by the abrupt termination of DARPA's Policy Analysis Market, the "wisdom of the crowd" methods of forecasting most likely have a future in the intelligence, defense, and homeland security realms.

E. RESEARCH DESIGN

I perform a Policy Options analysis, focusing on a review of existing knowledge (per Eugene Bardach's typography).[44] I chose my various types of predictive analysis to analyze, either as alternative techniques or sources of best practices for a fused procedure to support a "devil's toy box" analysis, based upon these procedures' prominence in the literature, as well as discussions with my academic advisor, Rodrigo Nieto-Gómez. I selected the Homeland Security Advanced Research Projects Agency (HSARPA) as my

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[41] Pavel Atanasov, Phillip Rescober, Eric Stone, Samuel A. Swift, Emile Servan-Schreiber, Philip Tetlock, Lyle Ungar, and Barbara Mellers, "Distilling the Wisdom of Crowds: Prediction Markets vs. Prediction Polls," *Management Science* 63, no. 3 (April 2017):692–693, https://doi.org/10.1287/mnsc.2015.2374.

[42] Ibid., 691.

[43] Tetlock and Gardner, *Superforecasting*, 16–18.

[44] Eugene Bardach, *A Practical Guide for Policy Analysis* (New York: Seven Bridges Press, 2000).

default governmental agency for analysis because it is the lead agency identified by Congress for developing technological solutions to emerging threats to the homeland.

I perform a review of the literature on the various types of predictive analyses, comparing the benefits and shortcomings of various techniques:

- Delphi Technique / Nominal Group Technique / Futures Studies
- Red-teaming techniques
- Futures/Predictions Markets and Prediction Polls
- A blended technique

In conducting my research, I primarily relied upon searches of the amalgamated ProQuest databases regarding social sciences, management science, political science, military, science and technology, computer science, humanities, and health management. I also performed some searches using Google Scholar. My most frequently used search terms included: "Delphi technique," "nominal group technique," "futurism," "futures studies," "threat forecasting," "red-teaming," "wisdom of crowds," "futures market," "predictions market," "superforecasters," "critique of Delphi," "advantages of Delphi," "disadvantages of Delphi," "critique of nominal group technique," "advantages of nominal group technique," "disadvantages of nominal group technique," "advantages of predictions markets," "disadvantages of predictions markets," "Homeland Security Advanced Research Projects Agency," "HSARPA," "HSARPA and DARPA," and "HSARPA and IARPA." I selected additional research resources from the footnotes, end notes, and bibliographies of sources I acquired through electronic database searches. In researching HSARPA's processes for selecting and prioritizing R&D projects and that agency's breakdown of FY 2014 projects, I relied primarily upon documents retrieved from the DHS Science & Technology Directorate's intranet. I also reviewed sources recommended to me by one of my thesis advisors, Rodrigo Nieto-Gómez.

My success criteria upon which the various predictive analysis alternatives are ranked include effectiveness (highest attainable likelihood of accurately forecasting future threats), efficiency (time- and budget-effectiveness), and usability (a process not so

cumbersome that a modest-sized agency such as HSARPA would find it inappropriate to undertake). My intention is to provide a process recommendation to the managers of HSARPA (or another, more appropriate agency) for an effective, efficient, and usable predictive analysis tool for them to use to guide their identification, selection, and prioritization of R&D projects to support the homeland security counter-future-shock mission. As part of my analysis, I address the question of what types of experts should be included in the "devil's toy box" analytical team, examining the utility of including science fiction writers as members, due to their acculturation to and facility with using what I term "the science fiction mindset." I refer to my recommended process as Pandora's Spyglass.

I analyze the question of whether HSARPA is the most appropriate agency to serve as the R&D spearhead for the homeland security counter-future-shock mission. I perform a Policy Options analysis, focusing on a review of policy history, per Eugene Bardach's typography.[45] This analysis is based upon a review of Congressional and governmental reports concerning HSARPA and the Department of Homeland Security Science & Technology Directorate (DHS S&T), plus some internal DHS working and planning documents, as well as historical analyses of DARPA (the Defense Advanced Research Projects Agency) and IARPA (the Intelligence Advanced Research Projects Agency). In addressing the question as to whether HSARPA, as historically and currently constituted, is the most appropriate Federal agency to spearhead the homeland security counter-future-shock mission, my analysis is more exploratory and tentative than the analysis underlying the creation of my blended predictive analysis technique. An in-depth comparison of resources, histories, and organizational cultures of HSARPA, DARPA, and IARPA is beyond the scope of this thesis. My intention is to provide for an audience of Federal homeland security leadership suggestive, exploratory analysis regarding whether HSARPA is the most appropriate agency to serve as technological spearhead for the homeland security counter-future-shock mission, or whether that responsibility might better be given to a different federal organization, such as DARPA or IARPA.

[45] Bardach, *Practical Guide for Policy Analysis*.

F. THESIS ORGANIZATION

Chapters II through VIII consider how our defenders may best calibrate their crystal ball in their attempt to protect their people and vital institutions against whichever new toys the devil may pull from his toy box. Chapter II introduces two tools that a homeland security agency could use to begin winnowing down the massive universe of potential future-shock threats: IARPA's FUSE (Foresight and Understanding from Scientific Exposition) Program and the guidelines from the *Thwarting an Evil Genius* study. Chapters III through V provide background on the expert analysis or elicitation of expert opinion techniques—the Delphi technique (Chapter III), the nominal group technique (Chapter IV), and futures studies (Chapter V). Chapter VI explores red-teaming techniques.

Chapter VII takes up the question of what types of experts should be included in an "devil's toy box" analytical team. I build a case for the inclusion and centrality of science fiction writers, due to their acculturation to and facility in using the "science fiction mindset," a mode of thinking that combines competitive scanning of the emerging technological landscape and extrapolation of technology's evolving capabilities with a commercially-driven focus on exciting, destructive conflict. I offer the hypothesis that this science fiction mindset is of special utility to the homeland security enterprise in deciding on which emerging Promethean technologies to focus research and development resources, because the mindset parallels the thinking of those terrorists who would seek to innovate in their destructive activities with new Promethean tools. I hypothesize that having science fiction writers as key members of the analytical team is the next best thing to having reformed former terrorists as members. (Appendix B illustrates correlations between the socioeconomic and educational backgrounds of science fiction fandom, from which much of science fiction writers emerge, and of terror group leaders and followers, correlations that support the inclusion of possessors of the science fiction mindset as key members of a "devil's toy box" analytical team. Appendix B also offers a case study of Aum Shinrikyo, an apocalyptic cult that engaged in prototypical "devil's toy box" attacks in Japan, also illustrating the centrality of science fiction concepts and tropes to the cult's eschatology and goals.)

Chapter VIII examines techniques that do not rely upon expert opinion but instead rely upon "the wisdom of the crowd," including prediction/futures markets and prediction polls. Chapters III–VI and Chapter VIII compare the strengths and disadvantages of each of these "crystal ball" techniques in serving the counter-future-shock mission, building up a list of best practices which I make use of in Chapter IX.

Chapter IX is the keystone chapter of this thesis, the chapter in which I develop my recommended procedure for carrying out a "devil's toy box" analysis, a procedure I call Pandora's Spyglass. I begin the chapter by stating up-front all the assumptions on which I rely in designing Pandora's Spyglass the way I have. I then make use of the best practices I have culled from those predictive analytics procedures I reviewed in preceding chapters, after justifying which best practices are applicable in the case of a "devil's toy box" analysis. Pandora's Spyglass is an iterative process that begins with wide-scope environmental scanning to determine the universe of emerging technologies with Promethean potential that could come to market within a five- to ten-year timeframe, then deploys a team of experts to develop abbreviated scenarios (scenario stubs) from the identified universe of possible technological developments. The expert analytical team then winnows down the large list of scenario stubs to a manageable list of a "deadly dozen" scenarios, judged to be the worst of the worst in terms of maximum potential dire consequences, as well as likelihood of Promethean technologies both coming to market and being used for malign purposes. After the science fiction writer members of the team flesh out these "deadly dozen" scenario stubs into detailed narratives, the "deadly dozen" are then subjected to a more rigorous analysis so that the team can rank them in descending order of risk (risk, in this case, equaling the consensus estimated dollar value of the scenario's consequences times the consensus estimated probability of the scenario becoming actualized).

Pandora's Spyglass, as envisioned, takes approximately six months, with a full-time, three- to four-week face-to-face portion sandwiched between two distance portions, during which participants would work part-time, an hour to 90 minutes per day. Pandora's Spyglass is intended to serve as a decision-support tool to facilitate the homeland security enterprise's identification and prioritization of emerging Promethean technology threats

upon which to focus limited R&D resources. It is not meant, as set forth in this chapter, to serve as a budget justification or formulation tool, although I offer suggestions regarding how the procedure's assumptions and variables could be validated so that a Pandora's Spyglass analysis could legitimately serve that function. I also address potential criticisms which might be leveled against the Pandora's Spyglass procedure.

Appendix A addresses the question of which agency is best suited to make use of Pandora's Spyglass. Which federal agency is best equipped, in terms of mission set, organizational culture, and resources, to best implement a "devil's toy box" analysis such as Pandora's Spyglass, and then use the findings generated to drive R&D efforts intended to deploy defensive measures against the future-shock threats identified in the "deadly dozen" scenarios? This Appendix provides an in-depth examination of HSARPA's suitability for the counter-future-shock mission, based upon that agency's history, organizational culture, methods for identifying, selecting, and prioritizing projects, record of Congressional oversight and criticism, and an analysis of the agency's FY2014 portfolio of R&D projects. I conclude Appendix A with a consideration of six different scenarios for potential utilization of Pandora's Spyglass, four of these scenarios involving HSARPA and the DHS Science and Technology Directorate, and two of the scenarios involving DHS contracting out the "devil's toy box" analytical effort and management of subsequent R&D projects to either IARPA or DARPA. I rank these six scenarios in ascending order of what I judge to be suitability to support the homeland security enterprise's counter-future-shock mission, offering the qualification that such decisions will be based upon political, budgetary, and organizational factors, perhaps more so than generalized suitability.

II. BEGINNING THE WINNOWING PROCESS

A. HOW TO KNOW THE DEVIL'S MIND?

In terms of our parable, the defenders would appear, at first glance, to have many advantages over the devil. They are more numerous. They have access to more resources, both money and material. They have the backing of virtually their entire society in their work; however, the devil possesses one enormous advantage—that of holding the initiative. *The devil knows what is in his own mind.* The defenders would give virtually anything to possess even partial knowledge of the devil's intentions. They expend vast sums from the treasury and send thousands of agents into the field, employing thousands more that monitor listening devices, all to catch the devil revealing his intentions or to gain that information from his partners or supporters.

Sometimes the defenders get lucky. Sometimes they learn enough of the devil's intentions early enough that they can go on offense and upset the devil's plans before those plans come to deadly fruition. But the defenders know that no matter how many resources they may sink into their surveillance and intelligence-gathering efforts, there will be times when the devil and his toys will evade their best efforts. For those dreaded occasions, defensive measures must already be in place to protect as many innocent lives as possible. Yet the devil is an alchemist, a tinkerer, an inventor. To create his toys, he has all the physical matter that man's ingenuity has extracted from the earth for his raw materials. Plus, he can reuse and repurpose the fruits of other persons' benign genius for his own malign ends, twisting those gifts of genius into dark variations undreamed of by their original creators. To put the rancid icing on the poisoned cake, the devil can then use the products of his alchemy, his shocking, surprising, deadly toys, at a time and place of his choosing.

How can the defenders decide against which of a nearly infinite variety of potential deadly toys to prepare defenses? Their money, time, and manpower are not inexhaustible; and the devil counts upon that. The defenders must rely upon their imperfect crystal ball to winnow down the possible universe of devil's toys to those the devil is most likely to create

and those he will take the most delight in using. The most effective users of the crystal ball will be those defenders who learn best to think the way the devil thinks.

The key to learning to think like the devil thinks?… Imagination.

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Perhaps the most famous and memorable quote from *The Final Report of the National Commission on Terrorist Attacks Upon the United States* was its conclusion that, of all the mistakes and missed opportunities made by the intelligence and law enforcement sectors in the years and months leading up to the 9/11 attacks, "the most important failure was one of imagination."[46] The planners and executors of the 9/11 attacks showed no failure of imagination. Their judo-like use of Western civilization's technologies—a mix of large, commercial airliners, skyscraper office buildings, and implements as seemingly innocuous as box cutters—has been described as a "hacking" of our high-tech society by terrorist actors whose aggressions are "a deviant result of the innovation process that also fuels progress inside our technologically dependent civilization."[47]

Dr. Lehman's concepts of strategic latency and emergent behavior, introduced earlier, may be useful in analyzing the future-shock nature of the 9/11attacks.[48] Prior to the attacks on the World Trade Center and the Pentagon, the offensive capability of a box cutter would have been considered limited and most assuredly tactical; a handheld implement with a short blade measuring less than two inches, only enabling an attacker to strike perhaps six inches beyond the reach of his arm, it would have been thought inferior to such other bladed instruments as a Bowie knife or a broadsword, and certainly inferior to projectile weapons such as throwing knives or crossbows. Yet the humble box cutter possessed strategic latency which none of these supposedly more formidable weapons encompassed. None of those other instruments were permitted to be carried on board a

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[46] The 9/11 Commission Report: *Final Report of the National Commission on Terrorist Attacks Upon the United States, Authorized Edition* (New York: W. W. Norton & Company, 2004), Kindle edition, 9.

[47] Rodrigo Nieto-Gómez, "Preventing the Next 9/10: The Homeland Security Challenges of Technological Evolution and Convergence in the Next Ten Years," *Homeland Security Affairs* 7, no. 8 (September 2011).

[48] Nacht, "Introduction," *Strategic Latency and World Power*, 4; Lehman, "Unclear and Present Danger," *Strategic Latency and World Power*, 5.

passenger aircraft by travelers at the time of the 9/11attacks. Box cutters, on the other hand, *were* allowed. Limited in their deadliness, nonetheless box cutters were considered by airplane attendants and passengers deadly *enough* in the hands of determined terrorists that the humble tools compelled the attendants' and passengers' obedience. What had been thought the most limited of tactical weapons—less dangerous, perhaps, than the sharp end of a broken bottle—brought about the immediate deaths of nearly three thousand persons, and, within a ten-year window, the deaths of tens of thousands more. Box cutters, when guided by the minds and hands of the 9/11terrorists, directly ignited one war, the American war against the Taliban and al Qaeda in Afghanistan, and indirectly ignited a second, the American invasion of Iraq and the consequent counter-insurgency campaign. The strategic aftershocks of that threatened use of a dozen box cutters are still rumbling around the world and will likely continue to rumble and thunder for years to come.

The transportation system of large, commercial aircraft demonstrated both strategic latency and emergent behavior on September 11, 2001. Commercial aircraft, in the timespan of little more than half a century, evolved from piston engine-driven single-passenger craft, weighing barely a couple hundred pounds and with a range of just a few miles, to jet engine-driven behemoths weighing hundreds of tons, carrying several hundred passengers across entire oceans. In the process of this evolution, the strategic latency of passenger aircraft gathered force, as their speed, mass, and fuel load increased tremendously. As was so dreadfully demonstrated on September 11, 2001, the destructive power of a large passenger jetliner, when utilized as a missile, rivals that of the biggest non-nuclear bombs in the U.S. arsenal. Apart from this strategic latency, the transportation system of commercial passenger airliners also demonstrated unfortunate emergent behavior on the day of the 9/11attacks. Decades of terror-related hijackings of commercial passenger aircraft, from the 1970s through the turn of the millennium, had taught governments, law enforcement agencies, the managers of commercial airlines, and commercial passenger plane pilots that the safest response to terrorists' demands on in-flight aircraft, the response most likely to result in the survival and well-being of passengers and crew, was to accede to the terrorists' demands regarding control of the aircraft and its heading. Protocols instructed pilots to land the aircraft at the location demanded by the

terrorists and then allow local law enforcement agencies to resolve the standoff. The prevailing, guiding assumptions were that hijackers would issue negotiable demands and that the longer the standoff persisted, the more likely it was that passengers would emerge safely.[49] Thus, decades of experience with aircraft hijackings resulted in the emergent behavior of commercial passenger airlines willingly, although unwittingly, providing guided missiles of enormous destructive power to terrorists who were willing to sacrifice their own lives. The 9/11plotters were obviously aware of this emergent behavior, and they took full advantage of this evolved protocol to achieve strategic surprise by behaving in a way that previous airplane hijackers had not.

Dr. Lehman sets forth a series of hypotheses which offer a framework within which to consider issues raised by the concept of strategic latency. He states them as follows:

> (1) Weapons and technologies related to them are advancing and spreading widely, (2) lead times for exploitation by more actors are shrinking significantly, (3) intelligence information and awareness are fuzzy, (4) vulnerabilities exist that increase the risk of leveraged threats, (5) players with deadly motivations exploit latency, (6) challenges to timely response are significant, (7) norms and goals are unclear, (8) enforcement options may be unattractive or ineffective, (9) tipping points are approaching, and (10) consequences are strategic in that they alter international security relationships in important ways.[50]

All these hypotheses may be viewed as a restatement of key aspects of our parable of the devil's toy box—the devil is becoming more skilled at his alchemy; his increased proficiency results in the production of new, deadly toys at a faster pace; and the defenders' crystal ball is "fuzzy," its reception of the devil's in-progress or upcoming feats of nefarious alchemy as indistinct and intermittent as that of an old-fashioned analog television set when deprived of its antenna.

Zachary S. Davis asserts that the risks posed by strategic latency are both increased and made harder to detect and predict by the fact that research, development, and implementation of many key cutting-edge technologies are no longer under the control of

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[49] 9/11 Commission Report, 84-85.

[50] Lehman, "Unclear and Present Danger," *Strategic Latency and World Power*, 6.

governments. He states that "(p)otentially world-changing technologies in biology, lasers, nanotechnology, space, and computers are essentially ungoverned;" to this list of strategically latent, dual-use technologies he adds breakthrough developments in advanced materials science, robotics, and medicine.[51] He characterizes the challenge posed to national security by strategic latency as being twofold: "black swan" strikes, which may either encompass innovative uses of older technologies or unforeseen, bolt-from-the-blue uses of cutting-edge technologies; and threats that emerge so gradually and innocuously—hidden in plain sight—that they may remain undetected by the homeland security apparatus.[52]

The term "Promethean technology(ies)," as best as I can discern, was first introduced by economist Nicolas Georgescu-Roegen in 1979 in the context of an article, "Energy and Matter in Mankind's Technological Circuit," that discussed entropy and sustainable technologies. Georgescu-Roegen listed two Promethean technologies, or technologies that had granted mankind the ability to alter the environment; these were fire and the heat engine.[53] Technologist Ted G. Lewis uses the terms "Promethean fire" and "Promethean challenge" to help explain the development of technology and the internet, describing disruptive technologies such the railroads and the internet as "Promethean" in the sense that they are powerful, yet dangerous, offering enormous new creative capabilities to their users and yet also laden with latent dangers.[54] However, regarding my use of the term "Promethean technologies" throughout this thesis, I grant to it a meaning more focused upon homeland security concerns than either Georgescu-Roegen's or

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[51] Zachary S. Davis, "Ghosts in the Machine: Defense Against Strategic Latency," in *Strategic Latency and World Power: How Technology is Changing Our Concepts of Security*, ed. Zachary Davis, Ronald Lehman, and Michael Nacht (Livermore: Lawrence Livermore National Laboratory Center for Global Security Research, eBook edition, 2014), 22.

[52] Ibid., 23.

[53] Cutler J. Cleveland, "Biophysical Constraints to Economic Growth," in *Encyclopedia of Life Support Systems*, ed. D. Al Gobaisi (Oxford, UK: EOLSS Publishers Co., 2003), 7, https://www.peakoil.net/files/biophysical%20constraints%20to%20economic%20growth%20by%20Cleveland.pdf.

[54] Ted G. Lewis, "Cybersecurity: The Promethean Challenge" (classroom lecture, The Internet, Society, and Cyberconflict, Center for Homeland Defense and Security, Monterey, CA, October 16, 2017).

Lewis's definitions: any technology which grants to its possessors, persons with average resources, skills, abilities, and intelligence, capabilities that formerly had only been available to governments, military establishments, or large resource laboratories (or perhaps not even available to those institutions). Promethean technologies are those technologies that combine elements of strategic latency and emergent behavior and thus threaten to create situations of strategic surprise when directed against a population, critical national infrastructure, significant national symbols, or the homeland security enterprise. Just as Prometheus's mythical gift of fire to man gave mankind powers which had formerly been available only to the gods, so do modern Promethean technologies grant to ordinary individuals and small groups capabilities formerly attainable only by large, well-funded institutions.

The homeland security enterprise's defensive role against potential malign uses of established and emerging technologies is made even more complex by the fact that strategically latent technologies do not exist in a vacuum; they can be combined to work with one another in ways unforeseen by their developers. In terms of our parable, I speak now of the devil's skill in the art of alchemy. Nieto-Gómez postulates that the phenomenon of combinatorial evolution of technology, as outlined by Bryan Arthur, continually opens up fresh vulnerabilities within our technologically dependent society, in an ongoing, unpredictable dynamic.[55] He further asserts that, since not all malign innovations can be predicted, two of the central dictates offered by the 9/11 Commission in their final report—that intelligence agencies and the homeland security community must strive to always "connect the dots" and that exercise of imagination must be bureaucratized, or made routine within the intelligence and homeland security bureaucracies—are unachievable or, at best, ineffectual.[56]

Should one possible interpretation of Nieto-Gómez's assertions be accurate—that he believes the innumerable varieties of the devil's alchemical efforts, complexities bestowed by technological systems' inherent strategic latency, emergent behavior, and

[55] Nieto-Gómez, "'Power of 'the Few,'" 5-8.

[56] "Preventing the Next 9/10," 4.

potential combinatorial evolution, render any crystal ball used by defenders ineffectual, or that the defenders' bureaucratic culture so cripples them that they are unable to make good use of any crystal ball—I must disagree. This interpretation of Nieto-Gómez's thinking may be off the mark. I hope it is, for if this interpretation of his thinking reflects strategic realities, the only possible response from the homeland security is a reactive one—waiting for innovative strikes using Promethean technologies to hit, and then formulating defenses based on what has been painfully learned. The aim of this thesis, however, is to suggest that the homeland security enterprise can take a more proactive stance against the threats of emerging Promethean technologies, if it chooses to.

My intention is certainly not to show that any forecasting method or combination of methodologies is infallible, or anywhere near infallible. My objective is to suggest a feasible method of "better than nothing" prognostication that combines the best features of already tested methods, one that, I hope, can counteract some of those methods' shortcomings. My goal is to take what has already been done in the field of prognostication and make it incrementally better and more usable for its prospective customers, the homeland security leaders most concerned with countering potential future-shock threats. I hypothesize that a crystal ball sorts is attainable, imperfect though it may be, and that the defenders' bureaucratic culture (optimized for the homeland security enterprise's systemic mission and thus made non-optimal for the counter-future-shock mission) can be altered and its deleterious aspects overcome, given enough will on the part of leadership and staff.

Insight into the devil's thinking will not come all at once, in a burst of helpful illumination. Insight, the reward of effective use of a crystal ball, will in this case be the result of a deliberate process. To be most useful to the homeland security enterprise, this process needs to be repeatable. It must not be haphazard, or the fortunate outcome of one or a few especially gifted analysts making lucky stabs in the dark. Too much is at stake, both the lives of innocents and precious resources that will be expended by the shield makers in efforts to protect those lives, to rely purely on good fortune and lucky hunches. The process of insight, as best as possible, must be routinized.

Where to begin? What is Step One of using a crystal ball? Does it have an "on" switch?

B. FUSE AND THE PROBLEM OF PROMETHEAN TECHNOLOGIES

The first step in gaining insight into the devil's intentions, in winnowing down those emerging technologies that are most likely to pose a significant threat to the Nation's homeland security *and* are most likely to be used by malign actors, is this: identifying which emerging Promethean technologies have "legs" and are likely to be developed into producible, usable products that grant end-users significant or revolutionary new capabilities. Fortunately for the homeland security enterprise, information technology can act as a force multiplier, using algorithms to automatically sift through vast troves of worldwide data and dig up those emerging technology "nuggets of gold" hidden within gargantuan deposits of false leads. In 2011, the Intelligence Advanced Research Projects Activity (IARPA), a branch of the Office of the Director of National Intelligence, launched the Foresight and Understanding from Scientific Exposition (FUSE) Program; its goal was to develop automated procedures for gathering, winnowing, and analyzing patterns of technological emergence by continuously monitoring publicly available scientific, patent, and technical literature from around the world.[57] Program manager Dewey Murdick, in a presentation delivered at the 2011 Graph Exploitation Symposium, defined the FUSE Program's goal as tracking technical emergence, "the process whereby innovative ideas, capabilities, applications, and even entirely new fields of study arise, are tested, mature, and if conditions are favorable, make a significant impact," by "scan(ning) the horizon" on the lookout for "the early signs of technical emergence" so as to enable the U.S. to "take advantage of the resulting capabilities and applications" and "gain a significant competitive edge."[58] Raytheon BBN Technologies was selected as the developer for FUSE and was awarded $5.2M for the first phase and $1.7M for the second phase of development.[59]

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[57] "IARPA Launches New Program to Enable the Rapid Discovery of Emerging Technical Capabilities," Office of the Director of National Intelligence website, September 27, 2011, https://www.dni.gov/index.php/newsroom/press-releases-2011/327-iarpa-launches-new-program-to-enable-the-rapid-discovery-of-emerging-capabilities.

[58] Dewey Murdick, "Foresight and Understanding from Scientific Exposition (FUSE)—Incisive Analysis Office" (PowerPoint presentation at the 2011 Graph Exploitation Symposium, August 9-10, 2011), 2.

[59] "Raytheon BBN Technologies awarded additional funding to enable early awareness of emerging technology: Program to automate big data search, indexing and analysis," *PR Newswire*, May 28, 2013.

A promising step, certainly. Yet for the shield-makers of the homeland security enterprise, with their limited budgets, staffs, and resources, the process of winnowing down the ranks of those emerging technologies that could become the terror tools of the future would only begin with the use of a tool such as FUSE. As has already been noted, analyst Zachary Davis has identified potentially world-changing developments in the fields of biology, lasers, nanotechnology, space, computers, advanced materials science, robotics, and medicine, with many of these developments proceeding essentially ungoverned by governmental authorities or ruling standards bodies.[60] To Davis's list I can add other technologies rising on the horizon—autonomous automobiles, the Internet of Things, modular fission reactors, fusion power plants, commercial space travel, asteroid mining, do-it-yourself genetic engineering, micro-drones, and bio-machine hybrids (cyborgs). The users of my proposed analytical crystal ball must also consider the almost innumerable ways these various technologies and their products (industrial, military, and consumer) could be combined in unforeseen and malign fashions, fusions not anticipated by their creators.

Therefore, a tool such as FUSE may be extremely helpful as an initial discovery and sifting device, but use of FUSE, or its equivalent, falls far short of functioning as a crystal ball on its own. Even sifting down two hundred elements the devil might opt to use in his alchemy to merely twenty still leaves the necessity, for the defenders, of making choices. To illustrate this point, let us consider just two emerging technologies that may likely tempt the devil—computer-enabled, "home brew" genetic sequencing kits such as CRISPR, and 3D printers. These two innovations have a basic quality in common: they are Promethean in nature. Just as Prometheus stole fire from Zeus and gave it to mankind, vastly increasing the power of formerly puny humanity, these new tools grant the ability to accomplish technological feats formerly only achievable by large, complex institutions, such as research universities, medical foundations, government labs, or manufacturing firms, to ordinary individuals possessing little more than an enterprising spirit, a home computer, and a few hundred dollars. Prometheus gave fire to *all* mankind, not just to a

[60] Davis, "Ghosts in the Machine: Defense Against Strategic Latency," in Strategic Latency and World Power: How Technology is Changing Our Concepts of Security, 22–23.

vetted few. Some chose to use fire to cook their meals and to warm their hearths. Others chose to use it for the smelting of metal into superior weapons, or for setting enemies' towns ablaze. These Promethean tools are the sorts of force-multiplying implements that can act to make the "super-empowered angry guys" mentioned earlier so super-empowered.

I will first ponder CRISPR. Daniel M. Gerstein, an analyst at the RAND Corporation and formerly the DHS Science and Technology acting under secretary and deputy undersecretary, has written that

> CRISPR differs from other proliferation threats. The novelty and importance of CRISPR is not that it can enable the genetic editing of a pathogen—tools for this have been available for decades. What CRISPR does is make the technology widely available, allowing even largely untrained people to manipulate the very essence of life. CRISPR-based kits go for less than $500 in some cases, with pathogen-specific kits—West Nile virus, human coronavirus 229E, human adenovirus 35, to name a few—offered up like so many choices at a grocery store. Companies selling these kits are certainly not keeping registries of buyers or attempting to control the technology beyond the intellectual property that has been invested. The kits come with operator manuals that have only minimal warnings about containing hazardous materials and being for laboratory use only.[61]

Gerstein's article poses the question of whether the invention and distribution of CRISPR has made the Biological Weapons Convention, an international treaty that outlawed the development and use of biological weapons, obsolete. The treaty, written and ratified in the early 1970s, emerged from the then-current paradigm of national governments being the only institutions with the technical ability to develop and produce biological weapons. Accordingly, the treaty's provisions revolve around controls on exports, non-proliferation regimes, and inspections of government labs and facilities. CRISPR, by making capabilities formerly available only to government, military, or academic labs easily accessible to the public for the price of a mid-range television set, has made such provisions, if not obsolete, then certainly grossly inadequate to the present situation. As Gerstein notes, "(t)raditional verification based on quotas for proscribed

[61] Daniel M. Gerstein, "Can the Bioweapons Convention Survive Crispr?," *Bulletin of the Atomic Scientists*, July 25, 2016, http://thebulletin.org/can-bioweapons-convention-survive-crispr9679.

items, restrictions on use, and intrusive inspections is simply not an option for this new technology; counting pathogens or conducting exhaustive inspections of biological facilities is an infeasible and impractical way to monitor CRISPR usage and would not increase confidence in compliance." His suggestions for solutions are vague; he states that scientists will need to be the primary defenders against the new dangers posed by CRISPR and associated technologies and that they and their national governments will need to invent new surveillance technologies to detect non-natural pathogens. He envisions an altered, somewhat diminished role for the Biological Weapons Convention, seeing it as a tool to pressure national governments into providing better training for scientists and lab technicians and investing in new surveillance technologies.[62]

Providing additional insights on the potential dangers posed by gene editing systems such as CRISPR, Eben Kirksey notes that synthetic lifeforms, or GMOs (genetically modified organisms), routinely escape from government and commercial labs. He shares the story of bioartist Adam Zaretsky, who, while working as a visiting professor at San Francisco State University, accidentally released genetically modified fruit flies from his lab, stirring controversy when he reported the incident. Later, to bring attention to the issue of GMOs mistakenly released into the environment, he created his own GMOs using CRISPR and purposefully released them into the wild. Kirksey points out that the evolving biohacking movement, encompassing both bioartists and pranksters, has attracted the attention of the FBI, resulting in a raid on the Buffalo, New York home of a founder of the Critical Art Ensemble; agents clad in bio-hazard gear uncovered only harmless bacteria. The homeland security enterprise should not count on this always being the case, however. Also, given the private, surreptitious nature of the use of a home-based technology such as CRISPR, should the FBI and other law enforcement agencies make a concerted effort to crack down on potentially harmful uses of this tech and its equivalents, they will have their hands full. Kirksey further writes that an Indiegogo campaign launched by an activist seeking to "democratize science" raised $45K to provide $130 CRISPR kits for all takers; the kits included donor bacterial DNA as well as full instructions for how to modify it. The

[62] Ibid.

genie has escaped his bottle; in fact, he has pulverized his bottle and scattered its shards to the four winds. Kirksey may be charmed by the glowing green bunny rabbit made luminescent by jellyfish genes inserted into its DNA. But after describing such an adorable creation, something the pet industry would love to market, he then focuses on the E. coli bacteria, commonly available from biological supply companies, which had been worked over by the bioartists of the Critical Art Ensemble. Had their intention not been to create new forms of bio-art, but rather to indiscriminately sicken and kill, the gene splicers could have inserted DNA from the more virulent strains of E. coli, which can cause severe diarrhea, bleeding, fever, and sometimes death, into insects that commonly come into contact with people, then set them loose.[63]

I'll now turn to another Promethean tool, 3D printers. 3D printers, as the name implies, compile 3D shapes and objects from patterns downloaded to the printer from online schematics; devices currently available for home use utilize plastic as their building material. Robert J. Bunker provides an overview of the rapid application of this new technology to firearms. The first printed firearm, a single-shot plastic pistol known as the Liberator, was created in 2013. Since then, the craft of 3D-printed firearms has progressed rapidly, and the next anticipated breakthrough in 3D printing will be the substitution of aluminum for plastic as a building material, which will allow for the printing of high-powered, semi-automatic rifles, such as AK47s. The federal government forced the creator of the Liberator 3D-printed gun schematics to remove those schematics from the Internet. But just as pirated music, movies, and software have proliferated across the Internet despite international bans, we can expect the same difficult-to-obstruct proliferation to occur regarding online schematics for toys from the devil's toy box, not limited to guns. Although as of 2015, the date of the article's writing, no known use of 3D-printed firearms had been made by terror organizations, criminal cartels have shown an interest in the technology, and Bunker postulates that it is likely terrorists have not made use of 3D printing to date simply because it is so much more convenient for them at present to acquire conventional firearms on the black market, or from government arsenals in poorly governed countries.

[63] Eben Kirksey, "Who is Afraid of CRISPR Art?," Somatosphere.net, March 19, 2016, http://somatosphere.net/2016/03/who-is-afraid-of-crispr-art.html.

Bunker feels terrorists may become far more interested in 3D printing, however, once the confluence between firearms and remote computerized controls facilitates remote-controlled sniping weapons. A Texas commercial firm briefly marketed the Live-Shot system in 2005, which allowed disabled hunters to fire pre-placed deer rifles from controls on the Internet. Political revulsion against the idea of video-game-type hunting of deer resulted in the product being banned, but there is no reason to expect such Internet-firearms synergistic developments will not continue and improve. In 2013 and 2014, the Free Syrian Army made battlefield use of remotely controlled sniper rifles to avoid counter-sniper fire. Bunker foresees future terror applications of the 3D-printed firearm-Internet synergy in the areas of remote sniping, virtual targeting presence (being able to remotely keep a weapon aimed at a target under remote surveillance), and virtual combined arms (remotely carrying out sophisticated, layered attacks involving both firearms and explosives).[64] Regarding terrorism on a potentially exponentially larger scale, the U.S. Defense Threat Reduction Agency (DTRA) is sponsoring research through the Project on Advanced Systems and Concepts for Countering WMD, a component of the Naval Postgraduate School's Center on Contemporary Studies, to determine the likelihood of currently available (as of 2016–17) 3D printing technologies to subvert nuclear export ban regimes. The danger they foresee is that these technologies may provide rogue regimes and terror organizations with easy access to 3D-printed centrifuges and other technological implements required for the nuclear fuel cycle.[65]

With these two Promethean technologies in mind, I'll perform a simple analytical experiment. Let's postulate we are the managers of a homeland defense research and development agency focused on countering future-shock threats. We have $20M to spend on R&D for the upcoming fiscal year, and we must spend the entirety of that $20M on a

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[64] Robert J. Bunker, "Home Made, Printed, and Remote Controlled Firearms—Terrorism and Insurgency Implications," TRENDS Research & Advisory, Terrorism Futures Series, June 21, 2015, http://trendsinstitution.org/homemade-printed-and-remote-controlled-firearms-terrorism-and-insurgency-implications/.

[65] Center on Contemporary Conflict, "Use of 3D Printing to Bypass Nuclear Export Controls" (Monterey, CA: Naval Postgraduate School, Center on Contemporary Conflict, CCC-PASCC Research in Progress Ripsheets, October 2016), http://hdl.handle.net/10945/50621.

single project; our two alternatives, the two future-shock threats we are considering developing counters for, are genetic sequencing kits and 3D printers. How should we decide between the two options? Where would we begin? What questions should we initially ask?

Fortunately for us, the Defense Threat Reduction Agency has also focused on this analytical challenge. The DTRA's Advanced Systems and Concepts Office (DTRA ASCO) worked with the Science Applications International Corporation (SAIC) from 2006 to 2009 on what came to be known as the "Evil Genius study," the results of which were published in the April 2009 monograph, *Thwarting an Evil Genius*.[66] The genesis of this study may be said to be found in the following observation:

> [T]here are obvious limits to the imagination that prevent us from predicting which among the endless number of nightmare scenarios an intelligent terrorist will choose. … [T]he impulse to defend against every conceivable attack … can be self-defeating—we would simply spend ourselves to economic collapse. Nonetheless, a small number of attack scenarios, by their ease of execution and the magnitude of their effects, require extraordinary countermeasures.[67]

In selecting their "Evil Genius" scenarios, the authors stipulated that the scenarios must combine tremendous negative impact with relative ease of execution. Additionally, such attack modes must be plausible (in this context, I will define "plausible" as a project that, in the view of a reasonable person, is achievable given the resources—time, material, understanding, manpower, and funding—which can reasonably be expected to be available), innovative (the authors assigned additional points for innovation for those attacks that could likely catalyze cascading, second- and third-order consequences, by pushing defenders into self-harmful overreactions), and inexpensive.[68] The authors contrasted their ten "Evil Genius" scenarios with the fifteen National Planning Scenarios

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[66] Dallas Boyd et al., *Thwarting an Evil Genius: Final Report* (Washington, DC: Defense Threat Reduction Agency Advanced Systems and Concepts Office, April 13, 2009), https://fas.org/irp/agency/dod/dtra/thwart.pdf, 7.

[67] Ibid., 9.

[68] Ibid., 12-13.

identified by the Homeland Security Council in 2004. Twelve of the fifteen NPSs involved man-caused disasters, with the other three being natural events. They suggested a comparison of the two lists would be instructive for homeland security planners and would indicate shortcomings in existing homeland security doctrine.[69] For purposes of the study, the authors grouped their notional attackers into three categories (while allowing that there could be many others): *jihadists*, who value casualties and negative psychological impacts above all other outcomes; *nihilists*, who may be fulfilling a desire to strike back at society or financially enrich themselves, but who lack the jihadist's desire for mass casualties; and *thrill seekers*, who primarily seek notoriety but who will also place a high value on avoiding capture.[70]

The "Evil Genius" risk tool divides the *consequence* of attacks into two subcategories, *prompt effects* (which include casualties and physical damage) and *human response effects* (second- and third-order effects, including psychological changes in the general population, the responses of government to the attack, and economic impacts).[71] The authors place great emphasis on the importance of the latter. They stress the necessities to build a public culture of resilience and for government to avoid counterproductive, self-defeating responses, pointing out that the bulk of a terror attack's negative consequence often falls within the realm of human response effects.[72]

Getting back to my thought experiment, in this instance I have presumed that FUSE, or a comparable system, has identified two looming Promethean threats the homeland security enterprise should consider countering. Yet the enterprise only has resources to counter one of those threats. The "Evil Genius" study provides the intellectual foundation for a set of opening questions that homeland security managers could use in making their decision. These questions, as I have compiled them, include:

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[69] Ibid., 14-15.

[70] Ibid., 24.

[71] Ibid., 20.

[72] Ibid., 28-30.

What are the *prompt effects* which could result from a malign use of the identified technology/threat vector? What *magnitude of consequences* could result?

What are the *human response effects* that could result? What could be the *magnitude of consequences*?

How *accessible* to potential malign actors are the products of the identified emerging technology? How much *technical skill or training* would be required to use them? How much *manpower*? How much *planning*?

How *expensive* are the products of the identified emerging technology? How *affordable* are they for individual malign actors? For international terror groups?

Let us apply these questions to our two Promethean technologies and see how those technologies stack up as potential toys in the devil's toy box: see Table 1.

Table 1. Comparison of Gene Splicing Kits and 3D Printing Tech on "Evil Genius" Questions

"Evil Genius" Question	**Gene Splicing Kits (CRISPR)**	**3D Printing Technologies**
Prompt effects?	Spread of infectious diseases; could cause illnesses or deaths; if infectious agent is unknown to medical science, currently available antibiotics and cures might prove ineffective, leading to an uncontrollable outbreak, potentially an epidemic	Firearms made from plastics or other non-metals could be easier to sneak aboard passenger aircraft or other public transportation conveyances; targeted assassinations would require less manpower, potentially less skill if computer guidance is added to the remote weapon; could potentially allow rogue regimes and large transnational terror organizations to complete their nuclear fuel cycles and create atomic weapons

"Evil Genius" Question	Gene Splicing Kits (CRISPR)	3D Printing Technologies
Magnitude of consequences?	Potentially very great; could cause massive resource drain in medical and public health sectors; if epidemic results, could harm the economy	Most likely consequences (use of plastic firearms or remote-controlled firearms) are low to moderate on a societal scale; less likely consequences (fabrication of parts which allow the completion of a nuclear fuel cycle) are potentially extremely high
Human response effects?	Knowledge of and rumors of a new, unknown pathogen and a spreading outbreak could cause widespread panic, leading to large numbers of people avoiding public places, not going to work, pulling their children out of school, not going to stores	Human response effects in the case of the more likely consequences (use of plastic firearms or remote controlled firearms) would be low, because to the public, these home-brewed weapons would not represent a paradigm shift or even much of a noticeable change from the weaponry already used by criminals and terrorists; should, however, the tech be used to complete the nuclear fuel cycle, the human response effects could be very significant, as panic spreads over terrorists' possible deployment of a deliverable nuclear weapon
Magnitude of consequences?	Potentially very great; widespread panic would adversely impact the economy, and large numbers of employees staying home from work could adversely impact other vital infrastructure sectors	In the case of mild human response effects, the magnitude of consequences would be low; in the case of very significant human response effects (panic over potential nuclear strikes), the public response could push the government and military into counter-productive overreactions
Accessibility to malign actors?	Highly accessible over the Internet	Highly accessible over the Internet

"Evil Genius" Question	Gene Splicing Kits (CRISPR)	3D Printing Technologies
How much technical skill & training required?	At present, at least an undergraduate-level background in biology is required to formulate and gene splice an entirely new pathogen; creating lesser, known pathogens using genetic material from sources such as *e. coli* requires less educational background	High levels of technical skill are required on the part of those individuals who upload schematics of various weapons or components to be printed, but virtually no technical skill is required for the end user who benefits from the former's intellectual efforts; this calculus changes, of course, in the case of a vastly more sophisticated project, such as the creation of a nuclear fuel cycle and the assembly of a working nuclear weapon
How much manpower needed?	Minimal; equipment can be operated by a single individual	To fabricate relatively simple, man-carried weapons such as firearms, a lone individual can use a 3D printer
Affordable for transnational terror groups?	Yes	Yes
Affordable for lone malign actors?	Yes	Low-level 3D printers are currently affordable to many individuals; higher-level 3D printers which utilize aluminum or other metals as a feed stock are presently only affordable for businesses or wealthy individuals

From a first glance at our chart, were I an analyst working for our hypothetical homeland security R&D operation, I would recommend programing the $20M towards research projects to counter, defend against, and mitigate the impact of gene-splicing kits such as CRISPR. My reasoning? The more likely usages of 3D printer technologies by malign actors would not represent a paradigm shift or major change from the weaponry already used by terror and criminal groups and bad actors. Rather, easier accessibility to a variety of firearms of varying capability and the addition of remote-control features to firearms represent incremental improvements to the devil's toys. Human response effects

will likely be very low, if they are present at all; only law enforcement agents will take an interest in where and how malign actors acquired or fabricated their firearms. To members of the public, a gun is a gun is a gun. By way of contrast, gene-splicing kits such as CRISPR, especially when combined with the sort of "Genetic Manipulation for Dummies" guide provided by the "democratizing science" activist with his Indiegogo campaign, can provide a paradigm-shifting new capability to individual malign actors or terror cells by giving them access to biological weapons formerly only creatable by large, government- or military-sponsored labs. Even failed attempts by malign actors to create a viable biological weapon, if the attempt is publicized widely enough, could create very damaging human response effects with high-magnitude consequences; fear of the unknown is a potent inciter of panics. Apart from the activities of malign actors, homeland security and public health sentinels need to be alert to the possibility of accidental release of malign biological entities created with gene-splicing kits. Hobbyists may not intend to cause harm, but, through carelessness or error, may produce harms no less significant than those caused by persons acting with malign intent. This possibility does not exist (or exists to a greatly decreased extent) for hobbyists' use of 3D printers; printed firearms do not fly or crawl out of hobbyists' homes on their own.

If the use of 3D printer technology to create atomic weapons were to be judged a higher likelihood than I have in Table 1, my resource allocation decision between the two Promethean technologies would become far more difficult; however, as an analyst, I judge the likelihood of malign actors using 3D printing technology to complete the nuclear fuel cycle to be significantly lower than that of malign actors using gene-splicing kits to create harmful biological agents. My reasoning is that biological expertise is more widely distributed than nuclear weaponry expertise; "Genetic Manipulation for Dummies" guides are more ubiquitous and produced by a larger group of potential authors than (presently nominal) "Precision-Machined Parts to Complete the Nuclear Fuel Cycle for Dummies" guides (i.e.: schematics to download to high-end 3D printers), which could be authored by a far more limited number of specialized industrial and engineering sources. Such sources have no economic incentive to put their proprietary schematics on the internet and enable their own competition (unless they are doing so for ideological or mercenary reasons, such

as those of Dr. Khan, father of the Pakistani nuclear program, or of Russian nuclear engineers who lost their employment and incomes after the dissolution of the Soviet Union). Also, due to their relatively small population, such authors would be far easier for homeland security and Intelligence Community (IC) agents to track down, compared to the authors of gene-splicing how-to guides.

So, in this hypothetical instance of a binary resource allocation choice between two Promethean technologies, use of the "Evil Genius" questions as an analytical and decision-making guide seems, on its face, to be adequate; however, a reader would not be out of line to ask: "But what if, rather than just two Promethean technologies, FUSE (or a system akin to it) had identified *twenty* emerging technologies of concern? How useful would the 'Evil Genius' questions, on their own, be for making resource allocation decisions in *that* situation?"

In response, an analyst might be tempted to create a risk evaluation chart assigning a different column to each of the "Evil Genius" questions and a different row to each of the emerging Promethean technologies, assign color values (Green=Low; Yellow=Moderate; Red=High) or numeric values (1=Low; 5=Moderate; 10=High) to the various likelihoods of negative impacts and severities of consequences, perhaps put in some weighting values to assign more significance to certain factors, run the numbers (or colors), and call it a day. One could choose to allocate R&D funding to projects regarding the three top-risk-scored technologies out of the twenty. Why go any further? The decision-making process outlined above has the advantages of being simple, cheap, quick, replicable, easily documentable, and can be performed by any analyst with a modicum of intelligence and familiarity with the subject matter area. What's not to like?

Well, let's look at some of the assumptions I made as an analyst in the binary resource allocation exercise above. Full disclosure: my professional background is in acquisition and program management, IT procurement, supplemental nutrition program management, personnel management, and writing science fiction and horror novels. When it comes to science and technology, I am strictly a layman; the knowledge I possess in those areas has come from research I have done for various novels and for my master's degree studies in homeland security. With this in mind, let's reconsider the following assumptions

that guided my decision to select gene-splicing kits, rather than 3D printing, as the Promethean technology more urgently requiring $20M in R&D funding for defense and mitigation programs.

- Regarding gene-splicing kits, I assumed that readily available, online technical guidance would make it comparatively simple and easy for an evil-intentioned layman or a careless hobbyist to produce harmful genetically modified organisms that would be viable in the wild and could cause illness, disease, and death for a large group of human victims. A trained biologist or geneticist might very well make a far different and better educated assumption than mine.

- Regarding 3D printing technology, I based my risk assessment on just two possible uses: a low-consequence use, the printing of firearms, and a high-consequence use, the printing of precision-tooled parts required for the completion of the nuclear fuel cycle. A different analyst, one with a more potent imagination than mine or more of a military or intelligence background, could likely vastly expand the list of possible uses beyond just these two. In fact, now that I've put on my science fiction writer's hat, I realize that 3D printing tech could also "democratize" the availability of weapons systems such as lasers, ground-to-air missiles (perhaps based on modifications to commercially available hobbyist drones), electromagnetic pulse devices, and devices that could turn off or disrupt medical equipment implanted in patients, such as electronic pacemakers. Had I thought of this before filling in my chart above, or had an analyst with a better technical, military, or IC background filled it in instead of me, the resulting risk scores could very well have gone the other way, favoring a $20M expenditure to defend against the potential malign uses of 3D printing, rather than gene-splicing kits.

- Also, regarding 3D printing technology, I assumed a low likelihood that detailed online schematics for nuclear fuel cycle and weapons components

> would be available for malign actors to download to their printers' memories. An analyst with better knowledge than mine, perhaps an IC analyst who has familiarity with top secret intelligence regarding rogue nuclear engineers, could very well make a far different assumption, which in turn would flip the resource allocation decision I've outlined above.

So, with all these fresh caveats in mind, the notion of using the "Evil Genius" questions to create a risk assessment chart, and then basing our resource allocation decision purely on the outputs derived from this chart, now appears much less adequate than it did before. These sorts of caveats become increasingly vexing as the number of Promethean technologies under consideration grows and the consequences of making inaccurate or ill-informed assumptions snowball.

Relying upon color-coded or ordinal, numeric ranking-based risk assessment charts to guide resource allocation decision-making poses other problems that can skew the effectiveness of the decision-making process. Douglas W. Hubbard, in his book *The Failure of Risk Management: Why It's Broken and How to Fix It*, describes the basic flaws inherent in these types of tools.[73] Regarding ordinal rankings (1–2–3, Low-Medium-High), Hubbard's biggest concern is the lack of precision in these rankings and what that lack of precision can incorrectly imply. Say a risk analyst is attempting to assess the risks to an airport terminal. As part of her risk assessment chart, she ranks the severity of possible casualties. She decides that Low equals zero casualties, Medium equals 1–9 casualties, and High equals 10 or more casualties. In this model, a change of just one casualty, from 9 to 10, changes the Casualty Severity ranking of a scenario from Medium to High. If the analyst is calculating a combined risk score, Low may be assigned a 0, Medium a 1, and High a 2. So, in terms of the risk score calculation, an 11% change in the casualty variable (from 9 to 10) equates to a 100% change (from 1 to 2) in the number that is fed into the combined risk score calculation. Hubbard divides the most commonly used risk scoring

[73] Douglas W. Hubbard, "Worse Than Useless: The Most Popular Risk Assessment Method and Why It Doesn't Work," in *The Failure of Risk Management: Why It's Broken and How to Fix It* (Hoboken, New Jersey: John Wiley & Sons, 2009), 117–143.

methods into two categories, additive weighted scores and multiplicative risk matrices. He states the following types of flaws apply to both methods: (1) skewing which results from human cognitive distortions regarding perception of uncertainty and risk; (2) subjective, differing interpretations of the definitions of ordinal scores (Low-Medium-High) among users and observers of the risk matrices, despite attempts to thoroughly define what those scores mean; and (3) errors induced by the very structure of the scoring schemes, as I have illustrated above.[74]

So, were my hypothetical homeland security analyst trying to properly perform R&D resource allocation among various emerging Promethean technologies, and he or she made do merely with a risk assessment matrix developed from the "Evil Genius" questions, that resource allocation decision would be hobbled by many limitations and flaws. These include a lack of knowledge; unchallenged and possibly incorrect assumptions; potential variables that are overlooked and not considered in the decision; and a flawed risk matrix scoring scheme that can inaccurately magnify differences among variables. Not an ideal situation, to say the least, especially not when hundreds, thousands, or possibly even millions of lives may be affected by the decision.

Therefore, if we were to stop our crystal ball development program at this point, users of our crystal ball would find it to be infused with octopus ink; those black clouds would only occasionally recede enough for observers to see anything at all, and those intermittently revealed visions would be hazy and untrustworthy. Making use of a tool such as FUSE, then applying the "Evil Genius" questions as an analytical frame, are only two *initial* steps. They do not represent the entirety of a predictive analysis procedure that can effectively guide homeland security R&D efforts to counteract whatever evil toys may burst out of the devil's toy box. Our objective cannot be the fabrication of a perfect crystal ball, for perfect knowledge of future events is not attainable; however, what we must strive for is an *improved* crystal ball, with the flaws of analysts' limited knowledge, incorrect assumptions, ignored or overlooked variables, and analytical errors introduced by risk-measurement schemes *ameliorated* as best we can manage.

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[74] Ibid., 122–123.

Fortunately for the homeland security enterprise and the public that relies upon it, several sets of predictive analysis techniques have been developed since the end of World War II that we can press into service in our effort to improve the clarity and accuracy of our crystal ball. These techniques include expert analysis (the Delphi technique and the nominal group technique, which are both formal procedures for eliciting the input of subject matter experts, and futures studies/foresight studies, both a field of academic study and a set of commercial and governmental processes that utilize various techniques of eliciting expert input), red-teaming (formal analytical procedures designed to reveal and counteract inaccurate preconceptions and to allow users to "see through the adversaries' eyes"), and the use of a futures or predictions market or a prediction poll (benefiting from the wisdom of the crowd). The next seven chapters will examine how these three types of predictive analysis techniques might be used to improve our crystal ball; the strengths, advantages and limitations of each technique; factors to be considered in selecting expert analysts; and how elements of some or all the techniques might be used in conjunction by homeland security analysts. The culmination of all this consideration comes in Chapter IX, when I set forth my recommended procedure, one I have named Pandora's Spyglass. My examination of best practices derived from predictive analysis techniques starts with the set of techniques designed to elicit and amalgamate expert opinion; the first I consider is the Delphi technique.

III. EXPERT ANALYSIS (1): THE DELPHI TECHNIQUE

A. DELPHI TECHNIQUE: INTRODUCTION

Olaf Helmer, one of the inventors of the Delphi technique, had this to say in 1967: "Fatalism… has become a fatality. The future is no longer viewed as unique, unforeseeable, and inevitable; there are, instead, a multitude of possible futures, with associated probabilities that can be estimated and, to some extent, manipulated."[75]

The Delphi technique was created in the wake of history's most cataclysmic conflict, World War II. The cruel necessities of war have often served as an accelerator for new technologies. The Crimean War saw the introduction of iron-armored floating batteries for assaults on coastal fortresses. The American Civil War witnessed the first ship-to-ship clashes between armored warships, the first use of a submarine and its spar torpedo to sink an enemy warship, and the use of lighter-than-air observation platforms, balloons, to allow military scouts to describe to their commanders, using wired telegraph machines, the dispositions of enemy troops. The Russo-Japanese War introduced the widespread use of locomotive torpedoes, machine guns, and trench warfare. The static trench warfare of World War I necessitated the deployment of new weapons—poison gas, mechanized tanks, and heavier-than-air aircraft—to break the stalemate. But arguably no conflict of the past two centuries has done more to accelerate development and adoption of new technologies than World War II. This conflict prompted the development of radar, sonar, analog computers, and, perhaps most consequentially, nuclear weapons.[76] The atomic devastation of Hiroshima and Nagasaki led scientists and government leaders in the victorious Allied nations to anxiously question what the accelerating wave of technological advances would mean for the future of warfare, society, and humanity itself.

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[75] Olaf Helmer, *Analysis of the Future: The Delphi Method* (P-3558) (Santa Monica: the RAND Corporation, March 1967), 2.

[76] Alex Roland, "Chapter II: Land Warfare" and "Chapter III: Naval, Air, Space, and Modern Warfare" in *War and Technology: A Very Short Introduction* (New York: Oxford University Press, 2016), 7–83.

One field of literature, science fiction, had been exploring potential alternative futures and extrapolating the development of both existing technology and imagined technologies ever since Mary Shelley wrote *Frankenstein, or the Modern Prometheus*, arguably the first modern tale of science fiction and the extrapolation of the consequences of future technology, in 1818.[77] In the shadow of the atom, academicians and political and social scientists felt a need to predict potential future events and technological developments in a more systematic way. This led to the development of the *Delphi technique*, a systematized method for the elicitation of expert opinion, in the late 1940s. The earliest notable use of the Delphi technique for defense or homeland security-related prognostication took place in 1953, when, in a classified experiment not published in unclassified form until 1962, Norman Dalkey and Olaf Helmer used the technique to elicit the opinions of seven experts regarding likely outcomes of exchanges of nuclear weaponry with the Soviet Union.[78] Helmer notes that he helped develop the Delphi technique due to the fact that projections into the future can very rarely be based entirely upon mathematical models and instead, out of necessity, must be based upon the intuitive judgments of a number of experts spread across a variety of disciplines. He states that political, social, economic, and military leaders can either wait until such time as an adequate theory and models have been developed to project future events, or they can "obtain the relevant intuitive insights of experts and then use their judgments as systematically as possible."[79] He further notes that, prior to the development and use of the Delphi technique, the most common method for the elicitation of expert opinion from a group of experts was a roundtable discussion. He developed the Delphi technique to attempt to mitigate what he saw as the roundtable discussion's major shortcomings. These include pressure among face-to-face interactors for a compromise between divergent or opposing positions, and the undue influence of the participant(s) with the most prestige, the highest official level of

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[77] Brian W. Aldiss and David Wingrove, *Trillion Year Spree: The History of Science Fiction* (London: Victor Gollancz Ltd, 1986), 36–44.

[78] Juri Pill, "The Delphi Method: Substance, Context, a Critique and an Annotated Bibliography," *Socio-Economic Planning Sciences* 5, no. 1 (February 1971): 58–59.

[79] Helmer, *Analysis of the Future*, 4.

authority, or the most dominating or authoritarian personality. Other shortcomings of the roundtable discussion include the possible unwillingness of participants who have already publicly stated an opinion to back down on that opinion during a face-to-face interaction with their peers, and what Helmer calls the "bandwagon effect," or the tendency of members of a group to alter their own stated opinions to better fit in with the majority's opinion.[80]

Andre Delbecq, Andrew Van de Ven, and David Gustafson define the Delphi technique as "a method for the systematic solicitation and collection of judgements on a topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses."[81] Norman Dalkey, along with Helmer, one of the technique's pioneers, lists the three essential elements of the Delphi technique as (a) anonymity (none of the participants are aware of the others' identities, and they do not engage in any face-to-face interactions, for all communications from facilitators to participants are in the form of written questionnaires); (b) formulated feedback (the provision to individual participants of statistics of group responses); and (c) a finalized group statistical response resulting from a series of rounds of surveys.[82]

A. Kaplan, a philosopher employed by the RAND Corporation, gave the Delphi technique its name after the methodology was first used in an experimental setting, to test whether it could be used to improve the accuracy of horse-race betting.[83] (For those devotees of the sport of kings who wish to know whether the Delphi method can, indeed, fatten one's wallet at the track, unfortunately, the results of this early experiment appear

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[80] Ibid., 7.

[81] Andre Delbecq, Andrew Van de Ven, and David Gustafson, *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes* (Glenview, IL: Scott, Foresman and Company, 1975), 10.

[82] Norman C. Dalkey, *The Delphi Method: An Experimental Study of Group Opinion* (RM-5888-PR) (Santa Monica: the RAND Corporation, 1969), 16–17, https://www.rand.org/pubs/research_memoranda/RM5888.readonline.html.

[83] Fred Woudenberg, "An Evaluation of Delphi," *Technological Forecasting and Social Change* 40 (1991): 131.

lost in the fogs of time. The only solid reference I have been able to find regarding this experiment comes from Olaf Helmer, who reported in a 1963 RAND Corporation monograph, *The Systemic Use of Expert Judgment in Operations Research*, that the experiment, meant to determine the predictability of the winners of horse races based upon statistically-derived consensus of handicappers' predictions, was only chronicled in an unpublished study carried out at RAND many years earlier.[84] Helmer, perhaps in an attempt to protect his own advantage as a bettor—I jest—does not reveal the unpublished study's results.) During the early 1950s, the U.S. Air Force sponsored one of the earliest uses of the Delphi technique for systematic forecasting. The goal of the study was to draw on the expertise of American military planners and scientists to determine, from the imagined viewpoint of Soviet strategic planners, which U.S. industrial targets were most vital to the sustainment of American military capabilities, and how many atomic bombs the Soviets would be required to deploy to reduce U.S. outputs of munitions by various percentages.[85] Interestingly, this early, classified use of a Delphi procedure can also be viewed as an exercise in red-teaming, of seeking to see one's own vulnerabilities through an adversary's eyes (see Chapter VI for a description and discussion of red-teaming techniques).

B. DELPHI TECHNIQUE: METHODOLOGIES

Different researchers have set forth varying methodologies for Delphi procedures. Some of these variations in methodologies have stemmed from differing goals of the Delphis; this thesis considers several forms of modified Delphis in a later section. This section, however, describes alternate methodologies for what has come to be known as the classic or conventional Delphi. According to John Murry, Jr; and James Hammons, in the classic Delphi, the format originally developed at the RAND Corporation by Dalkey and Helmer to facilitate the forecasting of how technological advancements may affect future

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[84] Olaf Helmer, *The Systemic Use of Expert Judgment in Operations Research* (P-2795) (Santa Monica, CA: RAND Corporation, September 1963), 5, https://www.rand.org/content/dam/rand/pubs/papers/2008/P2795.pdf.

[85] Gene Rowe and George Wright, "The Delphi Technique as a Forecasting Tool: Issues and Analysis," *International Journal of Forecasting* 15 (1999): 354.

events, the first-round questionnaire is intended to prompt participants' brainstorming regarding the issue at hand by offering open-ended questions. The facilitator/researcher uses the participants' responses to this first questionnaire to prepare a more structured questionnaire for the next round. This second-round questionnaire asks the panel members to rank or rate the responses received from the open-ended round-one questionnaire, with rankings or ratings posted using a Likert scale. Following receipt from all panelists of their completed second-round questionnaires, the facilitator/researcher tabulates the results and calculates statistics for each questionnaire item; such statistics typically include means, standard deviations, and frequency distributions for each item. The third-round questionnaire, as well as questionnaires for any subsequent rounds, includes this statistical feedback for panelists to consider, sometimes in addition to comments that respondents have made regarding items. Panelists are offered the opportunity to use this informative feedback on the group's prior responses to change their responses in the current questionnaire from their earlier responses, if they so wish. The facilitator/researcher either halts the Delphi procedure after a pre-determined number of rounds of questionnaires or does so once group consensus or a stability of responses has been achieved.[86]

Kenneth Brooks (1979) describes eight steps for Delphi procedures as they are typically carried out in the field of educational administration research:

1. Identify a panel of experts, with the optimal number being no more than 25.

2. Determine the willingness of the prospective panelists to participate, making sure that eliminating some whose enthusiasm for the project seems marginal does not remove all representation from a key demographic.

3. Gather input from the panelists, allowing for some open-ended input; also ask for demographic data from each panelist.

[86] John W. Murry, Jr; and James O. Hammons, "Delphi: A Versatile Methodology for Conducting Qualitative Research," *The Review of Higher Education* 18, no. 4 (Summer 1995): 423–425, doi: https://doi.org/10.1353/rhe.1995.0008.

4. Amalgamate the input from the panelists into a limited number of possible future states (the basis of a second questionnaire). The researcher must take special care that his or her biases or expectations do not play an overriding role in compiling this second, more structured questionnaire.

5. The second questionnaire is sent to all the panelists, asking for their reactions, which may consist of agreement/disagreement, rankings using a scale, or modifying the questionnaire's statements.

6. The researcher analyzes the feedback received from the second questionnaire and prepares a third questionnaire, this one containing summary statistics of the group's responses, plus, for each panelist, a reminder of his or her own response to each question or item. This third questionnaire is sent to the panelists.

7. Each panelist is asked, in the context of the third questionnaire, to reconsider his or her earlier responses in the light of the group's amalgamated responses. If the panelist decides to stick to their divergent view, he or she is asked to provide a brief rationale to support this decision.

8. The researcher repeats Step 6 with a fourth questionnaire, and the panelists are asked to repeat Step 7. The process is repeated until a consensus is reached or little or no movement of opinions/responses occurs between rounds.[87]

In 1981, two years after Brooks' formulation, S. Isaac and W. B. Michael compiled their own list of steps to be undertaken in carrying out a Delphi procedure. Their steps are essentially congruent with those laid out by Brooks, but with additional methodological details added. They are as follows:

[87] Kenneth W. Brooks, "Delphi Technique: Expanding Applications," *The North Central Association Quarterly* 53 (1979): 377–378.

9. Identify the panel. If the panel does not consist of an already existing, intact group, the various publics whose interests and varying expertise are to be represented must be representatively sampled. (Note: this latter statement represents a methodological change from Brooks, as well as from other researchers, who state that representative sampling is invalid when one is seeking to compile a Delphi panel made up of experts.)

10. The facilitators prepare Questionnaire One, which asks each panelist to offer his or her list of issues, concerns, or goals. Using these responses, the facilitators then prepare Questionnaire Two, in which a summary of the responses from Questionnaire One are presented in random order, along with instructions for rating or ranking them.

11. Panelists rate or rank the items on Questionnaire Two.

12. The facilitators prepare Questionnaire Three, which is comprised of the results from Questionnaire Two along with statistical summarization of the group's responses to each item. Panelists whose Questionnaire Two responses differed substantially from the median response and who wish to retain their deviating response on Questionnaire Three, rather than change their response in accordance with the group median response, are instructed to provide a written reason or explanation for this decision.

13. The facilitators prepare Questionnaire Four in the same fashion that they prepared Questionnaire Three, building upon the responses from the previous questionnaire.

14. Results from Questionnaire Four are summarized statistically and are presented as the group's final consensus, the results of the Delphi procedure.[88] (Note: this cut-off of the Delphi procedure at Questionnaire

[88] S. Isaac and W. B. Michael, *Handbook in Research and Evaluation* (San Diego, CA: EdITS Publishers, 1981), 115.

Four represents a change from Brooks' methodology, which states the procedure is to continue until consensus or stability is achieved.)

C. DELPHI TECHNIQUE: APPROPRIATE USES AND OTHER BEST PRACTICES

Harold Linstone and Murray Turoff have considered the issue of under which circumstances use of the Delphi technique is to be preferred to the use of other techniques for the elicitation of expert opinion. They suggest that Delphi is best when the problem under consideration is not one that can be parsed using mathematical analytical techniques or models, but instead requires subjective judgment of experts. Delphi is also advantageous when the range of expertise that the researcher needs to call upon is broad and diverse, and the experts in the various fields who need to be consulted have no history of prior interactions. In terms of logistics, Delphi has much to recommend it when the number of panelists required cannot be easily accommodated within an available physical meeting space; or face-to-face interactions among them all would prove too cumbersome; or face-to-face meetings would be too expensive or otherwise too inconvenient; or the researcher wishes to supplement face-to-face meetings with an additional group communication process. Regarding psycho-social issues, Delphi is the preferable technique in situations wherein the experts the researcher wishes to engage have a history of severe disagreements, such that face-to-face meetings might devolve into unproductive personal clashes; and/or the researcher is especially concerned about the potentially outsized influence one or more participants might wield in a face-to-face discussion.[89] Regarding this thesis's "devil's toy box" analysis, Linstone's and Turoff's stipulations regarding the need for experts' subjective opinions and the need for a diverse field of experts definitely apply. Their logistical concerns may also possibly apply, depending upon circumstances. Juri Pill offers an observation regarding when use of the Delphi technique is appropriate that also applies well to a "devil's toy box" analysis: "It is the question of intuitive judgements, the marshalling of subconscious processes, dredging of half-formed ideas from the group

[89] Harold A. Linstone and Murray Turoff, eds., *The Delphi Method: Techniques and Applications* (Reading, MA: Addison-Wesley Publishing Company, 1975), 4.

memory that Delphi is most useful (for) and as such, one cannot judge it on the same basis as a concrete measurement."[90]

Also, regarding the subject of the appropriateness of the Delphi technique, Kathy Franklin and Jan Hart, in their 2006 survey of prior research on Delphi, point out that earlier researchers have suggested that use of the Delphi method may be especially desirable when any of the following situations apply:

1. The topic being considered consists of newly generated knowledge with little or no historical background.

2. The study concerns rapidly evolving, changing events.

3. The subject(s) being studied involve(s) great complexity.

4. Researchers hope to gather collective knowledge from experts regarding subjects not frequently explored.

5. Researchers hope to facilitate the surfacing of new ideas regarding a given topic.

6. Researchers hope to gather information familiar to experts but so new and timely that the information has not yet been published in the existing literature on the subject.[91]

All Franklin's and Hart's stipulations can be said to apply to a "devil's toy box" analysis to a greater or lesser extent, depending upon the specific emerging, over-the-horizon Promethean technological development in question, its level of strategic latency, and its potential for combinatorial evolution in conjunction with existing technologies or other emerging technologies.

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[90] Juri Pill, "The Delphi Method: Substance, Context, a Critique and an Annotated Bibliography," *Socio-Economic Planning Sciences* 5, no. 1 (February 1971): 62.

[91] Kathy K. Franklin and Jan K. Hart, "Idea Generation and Exploration: Benefits and Limitations of the Policy Delphi Research Method," *Innovative Higher Education* 31, no. 4 (January 2007): 238, doi: 10.1007/s10755-006-9022-8.

Several researchers have focused on identifying best practices for Delphi. Regarding optimal panel size for a Delphi procedure, Murry's and Hammons' review of prior studies finds mixed results. One study suggests a minimum size of 10 participants, with no recommended upper limit. Another set of researchers suggest a maximum size of 30. Another researcher states that little improvement in accuracy of the results will be seen once the panel size exceeds 25, and still another suggests that any increase in panel size will result in the benefits of increased reliability of results and fewer errors.[92] Regarding the optimal number of rounds of questionnaires, B. R. Worthen and J. R. Sanders suggest that, although Delphi procedures may continue past three rounds of questionnaires, "the payoff usually begins to diminish quickly after the third round."[93] Regarding feedback provided to participants between rounds of questionnaires, Gene Rowe and George Wright discovered an interesting contrast between two types of feedback provided to Delphi panelists, either statistical summaries of the group's amalgamated responses or reasons panelists provided for the answers they gave. Whereas panelists who received the latter form of feedback changed their own answers less frequently in response than they did when provided the former, when they *did* change their responses after receiving "reasons" feedback, their altered responses were more likely to tend toward improved accuracy than responses altered after receiving statistical summaries of the group's answers.[94]

Other researchers on the efficacy of Delphi offer cautionary suggestions for the technique's utilizers. Franklin and Hart, who conducted a policy Delphi regarding the future of web-based learning for metropolitan universities, note the vulnerability of Delphi procedures to weaknesses in development of the initial questionnaire. With policy Delphis, researchers base their initial questionnaire on exhaustive reviews of the existing literature. The questionnaire is a summarization of current scholarly research and theories, intended to give the Delphi panelists a framework for their thoughts on the research subject and a

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[92] Murry and Hammons, "Delphi: A Versatile Methodology," 428.

[93] B. R. Worthen and J. R. Sanders, *Educational Evaluation: Alternative Approaches and Practical Guidelines* (New York: Longman, 1987), 312.

[94] Gene Rowe and George Wright, "The Delphi Technique as a Forecasting Tool: Issues and Analysis," *International Journal of Forecasting* 15 (1999): 371.

common point of origin for their subsequent remarks; however, this key building block in the Delphi methodology is subject to researcher bias and error. The researcher may not capture the truly relevant issues at hand if those issues are currently emerging and have not yet been reflected in the scholarly literature, or if scholars have not yet recognized the significance of those issues approaching center stage from the wings. Franklin and Hart suggest that the structure of the initial questionnaire can ameliorate this vulnerability by inviting panelists to contribute qualitative input on subject matter with which they might be uniquely cognizant; they also point out that this underscores the importance of recruiting true experts in the field, those who are most likely to be aware of recent and emerging developments. They state that issues missed in the first questionnaire of a Delphi procedure are not easily recovered and addressed in later questionnaires, due to the technique's iterative nature from the second questionnaire onward.[95]

This process failure identified by Franklin and Hart may pose less of a danger for the sort of "devil's toy box" analysis considered in this thesis than it does for most policy Delphis. This is because the procedure I compiled in this thesis, Pandora's Spyglass, is intended to have its initial questionnaire generated by a computer-intelligence-driven analysis of worldwide technical literature and patent applications, performed by a software package such as IARPA's FUSE. No software program, not even one programmed to learn through iteration, will be perfect at identifying all potentially relevant emerging, over-the-horizon technological developments; however, a program such as FUSE should not be susceptible to the types of human researcher bias and error discussed by Franklin and Hart.

H. A. Linstone and M. Turoff continue in this vein of suggesting cautionary advice. They offer a list of five methodological and process mistakes that they observe have caused Delphi procedures to come to an unsuccessful, dissatisfying conclusion. Their five "deadly sins" include:

[95] Franklin and Hart, "Idea Generation and Exploration," 243.

1. The facilitators over-specify the structure of the Delphi study by imposing their own outlooks and preconceptions onto the initial questionnaire, rather than allowing open-ended feedback from panelists.

2. The facilitators assume that the Delphi process is capable of substituting for all other communication between facilitators, the experts, and among the experts themselves.

3. The facilitators do not provide questionnaire completion instructions that are adequate to remove ambiguity about the evaluation scales and ensure shared interpretation of those scales, and facilitators do a poor job of summarizing the group's responses.

4. The facilitators ignore or discard dissenting opinions, those responses that are statistically significantly different from the median responses, thereby leading those holding such dissenting opinions to abandon the Delphi procedure. This results in an artificial consensus.

5. The facilitators fail to appreciate the magnitude of the tasks being given to panelists and do not provide adequate recognition and other compensation for the expert panelists' time.[96]

D. DELPHI TECHNIQUE: ADVANTAGES

Helmer notes, in his 1967 review of several early uses of the Delphi technique for prognostication tasks, that one of the most common outcomes of a use of Delphi is a convergence of opinion towards a single judgment, evaluation, or forecast, or, in some cases, a convergence around two separate, divergent estimations. He states that this latter outcome should not be viewed as a failure of the Delphi technique to produce final consensus, but rather as a successful clarification of the steps of reasoning that led to the divergent opinions, an illustration that helps to provide improved insight into the intricacies

[96] H. A. Linstone and M. Turoff, *The Delphi Method: Techniques and Applications* (Reading, MA: Addison-Wesley Publishing Company, 1975), 6.

of an issue.[97] Certainly, given the purposes of this thesis, a convergence of opinion around two or even three emerging potential future-shock threats from a list of a dozen such threats or more would represent a great benefit.

Dalkey lists many advantages of the Delphi technique. It is a relatively quick and efficient way to elicit opinions from a group of experts. It is easier and less time-consuming for participants to respond to Delphi questionnaires than it is for them to attend conferences or write lengthy papers. A properly mounted Delphi exercise can be a stimulating, motivating experience for the participants, given the statistical feedback provided to participants following the various rounds, and participants tend to value the sense of objectivity provided using a systematized procedure such as Delphi, rather than an unstructured group exchange of opinions. Finally, and importantly, the Delphi technique's anonymity frees participants from whatever psychological or social inhibitions they might face to expressing their true opinions in face-to-face encounters.[98]

Murry and Hammons, drawing on earlier research regarding the Delphi technique, list additional advantages. Studies have suggested that decisions, forecasts, or estimations made by groups through anonymous means that feature-controlled feedback tend to be more accurate than the results of face-to-face meetings. Logistically, Delphi is a convenient method for the elicitation of expert opinions when the experts are geographically dispersed. In terms of outcomes, the results of Delphi procedures are the product of careful reasoning, because the methodology directs panelists to offer written rationales explaining the bases of their opinions and responses. Finally, Delphi procedures allow for the responses of groups of panelists to be summarized statistically.[99] Depending upon the composition of a panel of experts assembled to conduct a "devil's toy box" analysis, their other professional commitments (in academia, homeland security agencies, or scientific research establishments), and their level of geographic dispersion, the logistical advantage Murry and Hammons refer to could prove consequential. I also suspect that participants being

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[97] Helmer, *Analysis of the Future*, 9.

[98] Dalkey, *The Delphi Method: An Experimental Study*, 16–17.

[99] Murry, Jr; and Hammons, "Delphi: A Versatile Methodology," 426.

encouraged to back up their opinions with step-by-step reasoning and explanations will tend to lead to more deeply considered input.

Ruth Beretta adds the following advantages to the positive side of the Delphi ledger. Comparing the anonymity provided by the Delphi technique to a face-to-face committee process, she suggests that a Delphi procedure ameliorates common drawbacks of face-to-face committees. In a Delphi procedure, domineering personalities have less opportunity to overwhelm the opinions of less forceful members, and panelists feel less pressure to withhold their opinions until all relevant facts are known. The issue of less senior participants being unwilling to contradict the opinions of more senior participants is elided. Participants feel less pressure to remain committed to an already voiced opinion. Finally, participants cloaked in anonymity feel freer to offer opinions they consider to be well outside the mainstream; there is less fear of public ridicule.[100] All these advantages would come into play in a "devil's toy box" analysis, but I think freeing participants from being drowned out by louder or more authoritative, domineering voices might be the most significant. The very nature of the act of attempting to forecast how emerging, over-the-horizon technologies might be used for nefarious purposes by various groups of malcontents and forces, or individuals, hostile to the U.S. calls for unconventional thinking, prognostication that is "out of the box" (or "out of the devil's toy box"). Any technique that can reduce participants' anxieties about becoming subject to the ridicule of their peers adds value in such a situation.

E. DELPHI TECHNIQUE: DISADVANTAGES

The Delphi technique is not without its potential downsides, however. Murry and Hammons, drawing on earlier research regarding the Delphi technique, raise several drawbacks. Some of these drawbacks are psycho-social in nature and concern group dynamics. The questions chosen by the facilitator/researcher may unduly influence the panelists' responses. Lack of face-to-face interactions may mean that the full expertise of the participants is never completely drawn upon. Also, the remote, impersonal nature of

[100] Ruth Beretta, "A Critical Review of the Delphi Technique," *Nurse Researcher* 3, no. 4 (June 1996): 81.

the technique may contribute to a lack of motivation on the part of panelists, which can lead to attrition of participants between rounds. Other shortcomings are more logistical in nature. Depending upon the number of rounds of questionnaires in each Delphi procedure, the time required for questionnaire preparation, disbursement, completion by panelists, and statistical analysis could stretch to four or five months, making the technique inappropriate for timely or urgently needed decision support. Ad-hoc administrative difficulties with the questionnaires or the procedure cannot be easily dealt with, such as panelists' misinterpretations of the meanings of questions or the goal of the exercise. Perhaps of greatest consequence, the reliability of the results of any Delphi procedure is based largely on the facilitator's selection of experts; thus, the technique is vulnerable to less than optimal selections of panelists.[101] I would add this might include panelists chosen for convenience, political reasons, or paper credentials, rather than true expertise.

Regarding Murry's and Hammons' group dynamics-related shortcomings, their concern about the facilitator's selection of the initial research question(s) may perhaps be ameliorated by the fact that the initial step of a "devil's toy box" analysis would be a worldwide review of scientific papers and patent applications carried out by a machine intelligence program such as FUSE, rather than a literature review carried out by the researcher(s). The lack of participants' motivation the technique's remoteness may lead to and the fact that communications between participants are severely limited (just to statistical feedback of group responses and written statements of explanation and reasoning regarding the opinions and ideas presented by other participants), which may result in an incomplete elicitation of the participants' expertise, are two complaints that are more difficult to elide. These two criticisms are better addressed by a different but related procedure, the nominal group technique, which is discussed in detail in Chapter IV and that was developed, in part, as a response to these criticisms of Delphi. Regarding the logistical concern of the length of time required for the deployment of the various rounds of Delphi questionnaires, this shortcoming has been at least partly ameliorated by the advance of communications technology. Electronic communications techniques such as email, Skype,

[101] Murry, Jr; and Hammons, "Delphi: A Versatile Methodology,"426–427.

Google Docs, and others have eliminated the necessity of relying on slow, traditional mail for the exchange of questionnaires. A Delphi procedure's vulnerability to its researcher's choice of expert participants applies to any opinion solicitation technique that relies upon the participation of a relatively limited number of experts. The old saying, "garbage in, garbage out," certainly applies here, and any utilizers of the Delphi technique need to be mindful of the temptation to choose participants based on convenience rather than quality, as well as their own cognitive blind-spots, which may lead them to overlook or improperly eliminate potential participants or even whole categories of participants who could significantly add to the Delphi analysis in question. I have much more to say regarding the choice of experts in Chapter VII.

Juri Pill points out two shortcomings of the Delphi technique. The first is the problem of scaling of responses. How can numeric values properly be assigned to opinions, a methodology required to obtain a group consensus from a Delphi procedure?[102] Some of Pill's concerns in this area are addressed by Douglas W. Hubbard in his book *The Failure of Risk Management: Why It's Broken and How to Fix It*.[103] Hubbard's thinking has already been briefly discussed in Chapter II, and I consider his proposed solutions more extensively in Chapter IX. The second shortcoming Pill highlights is the likelihood that, given the Delphi technique's methodology, the opinion(s) of the most knowledgeable expert(s) on the panel regarding the issue at hand will likely be diluted by the opinions of those less knowledgeable.[104] To an extent, this shortcoming can be elided by a substitution of aspects of the nominal group technique for steps of the Delphi technique, or a combination of the two techniques, or an application of the "wisdom of select crowds" method (explored in Chapter VIII), options I address in Chapter IX.

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[102] Juri Pill, "The Delphi Method: Substance, Context, a Critique and an Annotated Bibliography," *Socio-Economic Planning Sciences* 5, no. 1 (February 1971): 60.

[103] Douglas W. Hubbard, "Worse Than Useless: The Most Popular Risk Assessment Method and Why It Doesn't Work," in *The Failure of Risk Management: Why It's Broken and How to Fix It* (Hoboken, New Jersey: John Wiley & Sons, 2009), 117–143.

[104] Pill, "The Delphi Method: Substance, Context," 62.

Beretta, drawing upon the work of earlier researchers, adds additional negative critiques of the Delphi method. Foremost among these is an absence of methodological rigor, although she states that several of the Delphi technique's defenders have pointed out that Delphi is not intended for use as an instrument of scientific measurement. A closely related criticism is Delphi's absence of statistically rigorous sampling methodology, although Beretta offers the caveat that when decision-making support requires the elicitation of expert opinion, attempts at representative sampling are generally not called for. From a methodological perspective, no agreement exists regarding the optimal size of Delphi panels; very few studies demonstrate replicability of Delphi results from one panel to another; and many of the studied Delphi procedures suffered from significant attrition of participants between rounds, which raises questions regarding the validity of the final results, since the panel of respondents to the final questionnaire is not the same as the panel of respondents to the initial questionnaire. Other methodological criticisms include the fact that each Delphi procedure's facilitator/researcher decides the level of consensus required for the procedure to come to an end, i.e.: no standard of consensus exists, and that different facilitators/researchers are free to handle outlying opinions in different ways, thus artificially shaping the group's consensus. Beretta's final methodological concern is that, as in a postal questionnaire, the facilitator/researcher has no assurance that the person who fills out the Delphi questionnaire is the person for whom the questionnaire was intended (a busy administrator who had previously agreed to be a panelist might order his assistant to fill out the questionnaire, for example).[105]

In my estimation, these misgivings concerning Delphi may be grouped under the heading of *lack of replicability/standardization*. Beretta is concerned that different sets of researchers, when making use of Delphi procedures in pursuit of their own projects, are not necessarily using *identical* procedures, which makes methodological and statistical comparisons of the resulting studies problematic. Although this is a valid concern for those who wish to consider Delphi a tool of scientific research, this is not a concern of mine in formulating an optimal procedure for a "devil's toy box" analysis, since my goal is not

[105] Beretta, "A Critical Review of the Delphi Technique," 83–87.

replicable scientific research, but rather a less-inaccurate prognostication of the likelihoods of certain malign, catastrophic events occurring. Bearing this in mind, I am free to "mix and match" whatever variations of Delphi technique (or other methods of expert opinion elicitation) I feel are most useful for the task at hand.

Catherine Powell agrees with Baretta's concern regarding a lack of a clear, uniform standard for consensus in Delphi procedures. She goes into greater detail regarding the difficulties researchers who have used the technique have faced in defining when consensus has been achieved. In her survey of research regarding standards Delphi facilitators/researchers have used to define when consensus has been reached in a Delphi procedure, Powell reports that the levels of consensus sought range from a simple majority of the respondents (50% plus 1) to 100% agreement. Other facilitators/researchers suggest that a Delphi procedure has achieved its consensus when the results achieve stability between rounds of questionnaires.[106] For my purposes, however, this flexibility in applications of the Delphi technique is a *feature*, not a bug. Different iterations of a "devil's toy box" analysis could conceivably call for different levels of precision of forecasting, and thus different standards for consensus. A short-range analysis, say for prognostications of malign uses of technology likely to occur within the next 12 to 18 months, would demand a higher level of precision and a higher standard of consensus. A longer-range analysis, say one examining a time frame of five to ten years out, necessarily becomes fuzzier, less precise. A wider range of opinion is to be expected, and thus a lower standard of consensus should be applied, perhaps one that can coalesce around two, three, or four dominant opinions.

Jon Landeta, in his review of prior research on the Delphi technique, adds the following points to the lists of shortcomings already compiled by Helmer, Pill, Murry and Hammons, and Beretta. Landeta's concerns primarily regard psycho-social, group dynamics issues. He states the anonymity and isolation of participants in Delphi procedures rob those participants of the sorts of social benefits (comradery, positive reinforcement for

[106] Catherine Powell, "The Delphi Technique: Myths and Realities," *Journal of Advanced Nursing* 41, no. 4 (February 2003): 379.

one's contributions, and increased motivation derived from the group's positive energy) sometimes available through face-to-face interactions. He also suggests anonymity lessens inhibitions against frivolous or irresponsible responses to questionnaire items. Finally, he states the Delphi technique extracts a psychic cost on the participating experts, who are asked to participate in a methodology about which many know little; who are directed to answer the same questions more than once without having an understanding of why this is necessary; who do not have the pleasure of interacting with their fellow experts, beyond receiving other participants' comments and sets of statistics on the group's responses; and who are often left with the feeling that they have contributed a good deal of time and thought and have received little of value in return.[107]

To mitigate the psychic toll that participating in a Delphi procedure can exact from the participating experts, Landeta recommends the following best practices. The institution that sponsors the exercise should demonstrate visible, preferably enthusiastic support for it, and this support should be emphasized to the participants to enhance participants' senses of pride in their involvement in a socially beneficial effort. The team that facilitates the Delphi procedure should have a good working knowledge of the subject area being studied. Expert participants should be selected, in part, in accordance with their high level of motivation. The designers of the Delphi procedure should mentally put themselves in the place of the participants and determine the number of questions per questionnaire and the number of rounds accordingly, seeking to reduce the overall burden to the lowest level that will still accommodate the needs of the study. The facilitators should thoroughly explain the study's methodology and goals to all participants before the Delphi procedure begins, and they should conduct a pilot prior to the initiation of the actual Delphi procedure to validate and calibrate the initial questionnaire. The facilitators should encourage participants' contributions of qualitative feedback to the questionnaire items and should note when elements of qualitative feedback have resulted in shifts of the statistical aggregate group response between rounds; this will grant the experts who contributed this effective, significant feedback a greater sense of being a vital part of the study. Finally,

[107] Jon Landeta, "Current Validity of the Delphi Method in Social Sciences," *Technological Forecasting and Social Change* 73 (2006): 469–470.

facilitators should send the study's final results to all participants as soon as possible, along with personalized letters of appreciation.[108] I feel that all Landeta's suggestions for ameliorations have merit. Some of them come across as simple common sense or courtesy. I should add that I would expect participants in a "devil's toy box" analysis to exhibit a relatively high level of commitment to the project, given that the organizers should take pains to emphasize that the results of the analysis will lead to R&D efforts that may prevent the deaths or injuries of dozens, hundreds, or even hundreds of thousands of innocent persons, depending upon the capabilities of the emerging Promethean technologies.

F. DELPHI TECHNIQUE: MODIFIED FORMS

Facilitators and researchers have developed variants of the Delphi technique over the years. The original form of Delphi, pioneered by Helmer and Dalkey at the RAND Corporation in the late 1940s and early 1950s and already described, has been called the conventional Delphi or the exploratory Delphi. One modified form, the normative Delphi, also called a consensus Delphi, is not used for forecasting the likelihood of future events or developments. Rather, it seeks to engage a group of experts in arriving at a shared consensus concerning the desirability of a goal or agreeing upon the ranking of the desirability of a set of potential goals. (An example of its use would be a group of city administrators trying to decide between spending an equal amount of money on a new community swimming pool, a new senior citizens' activities center, or a multi-use amphitheater in a local park.) A second modified form, the policy Delphi, also termed the focus Delphi or the decision Delphi, abandons the conventional Delphi's goal of achieving consensus within the group of experts. Conversely, its goal is the elicitation of strongly opposed views on a policy issue from a group of experts, seeking to generate divergent opinions through a series of debates, each carried out within a round of Delphi questionnaires.[109]

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[108] Ibid., 479–480.

[109] Muhammad Imran Yousuf, "Using Experts' Opinions Through Delphi Technique," *Practical Assessment, Research & Evaluation* 12, no. 4 (May 2007): 2, http://pareonline.net/getvn.asp?v=12&n=4.

Helmer conducted experiments regarding possible benefits of a refinement to the Delphi technique, that of introducing weighted opinions into the final tabulation of group judgment, based upon participants' self-assessments of their levels of expertise on the questions at hand. He found that discarding the opinions of those participants who scored themselves relatively low on expertise and basing the group's consensus result only upon the median value of responses from those participants who scored themselves relatively high on expertise tended to result in higher accuracy. This was reflected in 68% of the 20 experiments he and his colleagues conducted.[110] Helmer's modification shares elements in a common with a form of structured interaction called the Dictator or Best Member procedure, wherein final group judgment is based upon that of the group's selected representative. Presumably, under this latter procedure, group members choose their "best member" based upon his or her level of expertise. Helmer's refinement relies, instead, on participants' subjective evaluations of their own expertise, but the result is essentially the same—the discarding of opinions judged to be based upon lesser expertise.

Murry and Hammons conducted a modified Delphi procedure to elicit opinion on the best management performance audit criteria for evaluating the effectiveness of community college administrators. Their initial modification consisted of constructing the first-round questionnaire with structured, rather than open-ended questions. They then restricted sending the second-round questionnaire only to those panelists who had completed the first-round questionnaire. They reminded each panelist in the second questionnaire of his/her response to that same question during the first round by repeating that earlier response, and they included a list of all comments made regarding each questionnaire item, in addition to the standard statistical breakdowns. Finally, they provided explicit instructions to panelists that they should either alter or reconfirm their earlier responses based upon the comments provided by other panelists and the group's statistically amalgamated responses, and they encouraged panelists to provide additional comments on each questionnaire item. Each of these first two rounds took approximately 60 days to complete. After their study, the two authors sent the 33 panelists a final report

[110] Helmer, *Analysis of the Future*, 9–10.

explaining the study's methodology and summarizing its results.[111] In my judgment, the last three of these four modifications seem like generally helpful best practices, designed to hone the outcomes the Delphi technique was designed to elicit. The benefit of constructing the initial questionnaire with structured, rather than open-ended, questions, on the other hand, would seem to hinge on the purposes of the study. Under the "devil's toy box" analysis envisioned in this thesis, the basis for the first-round questionnaire would be supplied by the output of a FUSE analysis or a comparable software-driven analysis of worldwide scientific literature and patent applications, so the first-round questionnaire would, in fact, be a structured one, or more structured than not.

Advances have occurred in adapting Delphi to computerized communications technologies to overcome the time lags involved in mailing of questionnaires. In 1998, the first software package to combine Delphi procedures with communications over the World Wide Web, Professional Delphi Scan, was introduced in Finland. A third version of this software, eDelfoi, was rolled out in 2008 and has been licensed by about 30 different Finnish organizations. Approximately 300 studies have been conducted using a version of this software. In 2004, DARPA contracted with Articulate Software, Inc., for the creation of software that would allow for the use of Delphi procedures for the resolution of tactical questions on the battlefield in real time. The software was designed to allow for either synchronous or asynchronous input by participants. The DARPA-developed software is open-source and is available to the public under the heading "Delphi Blue" at http://sourceforge.net.[112] Links to additional resources regarding the Real-Time Delphi can be found at http://107.22.164.43/millennium/RTD-general.html.

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The Delphi technique is not the only widely-used structured procedure for the elicitation of expert opinion; Andrew H. Van de Ven and Andre L. Delbecq noted

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[111] Murry and Hammons, "Delphi: A Versatile Methodology," 430–433.

[112] Theodore J. Gordon, "The Real-Time Delphi Method," in *Futures Research Methodology* Version 3.0, Jerome C. Glenn and Theodore J. Gordon, eds. (Washington, DC: The Millennium Project, American Council for the United Nations University, 2009), CD-ROM article 5, 1–2, http://107.22.164.43/millennium/RTD-method.pdf.

deficiencies regarding the design of the Delphi technique and set out to create a new method to address those deficiencies. Their innovation, the nominal group technique, is the next type of expert opinion elicitation method I will examine.

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IV. EXPERT ANALYSIS (2): THE NOMINAL GROUP TECHNIQUE

A. NOMINAL GROUP TECHNIQUE: INTRODUCTION

Andrew H. Van de Ven and Andre L. Delbecq created the nominal group technique (NGT) in 1968. They intended to institute a structured procedure of group interaction that would ensure the use of differing, appropriate processes for different phases of creative thought and help to ensure balanced participation among the various participants. Like the creators of the Delphi technique, they created a process to aggregate the group's judgment through mathematical voting procedures; however, Delbecq and Van de Ven note that researchers of small group dynamics and group decision-making processes have found that, whereas group interactions *do not* promote efficient and effective idea generation, identification of problems, or elicitation of facts (the initial phase of the problem-solving process), face-to-face discussion *does* promote improved evaluation, screening, and synthesizing of ideas already generated (the latter portions of the problem-solving process).[113] With this in mind, they designed their NGT to remove face-to-face interactions from the idea generation stage of analysis, where research showed it to be counterproductive, but institute in-person social interactions in those stages of analysis where such interactions add value. This addition of face-to-face interaction in appropriate phases served to differentiate their technique from the older Delphi technique.

In their book *Group Techniques for Program* Planning, Delbecq and Van de Ven make several comparisons between NGT and Delphi procedures. (Despite being the originators of NGT, they do not act as partisans in favor of their own procedure; rather, they point out the varying situations wherein one technique might be preferred to the other.) They note a difference in task completion time burdens, pointing out that, for panelists/participants, answering the Delphi questionnaires typically takes less time than sitting through the silent idea generation, round-robin idea sharing, and structured group idea evaluation phases of an NGT procedure; however, for the researchers/facilitators,

[113] Delbecq, Van de Ven, and Gustafson, *Group Techniques for Program Planning*, 7–9.

more time is required to prepare and distribute Delphi questionnaires, analyze the results, and then prepare individualized follow-up questionnaires to participants than it does to lead an NGT procedure. They state that, based upon the number of questionnaire rounds included, completing a Delphi procedure may take up to five months, whereas preparing for, leading, and subsequently analyzing an NGT procedure typically takes about 88 man hours of work time.[114] However, they made this comparison in 1975, before the arrival of email and other computerized communications technologies, when Delphi questionnaires had to be sent to participants and returned to researchers through the U.S. Postal Service. Today, a Delphi procedure can be accomplished in a fraction of the time it could in 1975, given equally motivated participants. Thus, the overall time burden of a Delphi procedure, including that required of both facilitators and participants, is likely a lot closer to that of a nominal group technique procedure than was originally the case.

B. NOMINAL GROUP TECHNIQUE: METHODOLOGY

Delbecq and Van de Ven lay out the steps of an NGT procedure as follows:

1. The group's members, 7–10 in number, while in the same room as the other members, silently brainstorm ideas and write them down.

2. All the group's ideas are then written on a flip chart by a recorder in the following fashion. The ideas are presented one at a time, in round-robin fashion, with each participant offering one of his or her ideas at a time. No discussion occurs in this phase. The round-robin process continues until all the members' ideas have been written on the flip pad. (This portion of the procedure gives the nominal group technique its name; the group is considered "nominal" because, although the members are in one another's presence, there is only very limited communication between them.)

[114] Ibid., 29–30.

3. Members discuss each recorded idea one at a time, asking for clarifications when necessary and expressing their agreement or disagreement, and offering supporting reasons.

4. Each member privately votes on the ideas, ranking or rating each. The facilitator mathematically derives the group's decision/consensus based upon these private votes.[115]

C. NOMINAL GROUP TECHNIQUE: APPROPRIATE USES AND OTHER BEST PRACTICES

Bjørn Anderson and Tom Fagerhaug suggest that use of the nominal group technique is appropriate when one of several situations exists. NGT is helpful in facilitating productive analysis of root causes of a problem when team members are prone to blame one another for the problem's existence; the technique allows the participants to get past bitter feelings based on clashing personalities. The technique is also very helpful in coaxing ideas from valuable participants who might be too intimidated, cautious, or shy to present their ideas within another format. NGT can help bring focus to groups whose previous brainstorming sessions have resulted in overwhelming or chaotic lists of potential root causes of the problem under consideration, or in situations when the group has decided the problem may have multiple possible root causes and the members are stuck on how to decide which potential root cause to analyze first.[116]

In presenting his Improved Nominal Group Technique (INGT), to be discussed in a later section, William M. Fox states the procedure is designed for consideration, evaluation, and consensus generation for a single purpose per procedure. The technique should not be used for negotiations between opposed parties, for coordination of inter- or intra-team efforts, or for routine dissemination of information. Furthermore,

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[115] Ibid., 8.

[116] Bjørn Anderson and Tom Fagerhaug, "The Nominal Group Technique: Generating Possible Causes and Reaching Consensus," *Quality Progress* 33, no. 2 (February 2000), 144.

researchers/facilitators should anticipate that INGT meetings will likely take 90 minutes to three hours and should plan accordingly.[117]

Delbecq and Van de Ven suggest the following best practices for team leaders facilitating NGT procedures. During the initial phase of a procedure, that of the group's silent generation of ideas, they state that the leader should present the study question to the participants in writing, should disallow any queries from participants not related to process matters, should model proper behavior by silently noting ideas him/herself, and should discipline any participant who violates the group's silence once idea generation has begun.[118] For the round-robin idea-recording phase, they suggest that the leader verbally emphasize that presentation of ideas should be in brief statements, that any duplicative ideas will be eliminated, but variations on a theme are both permitted and encouraged (they term this "hitchhiking," when the recording of one participant's idea stimulates a related idea from a different participant), and that each idea will be recorded serially, with enough turns taken that each idea from each participant will be recorded on the flip chart. They also state that leaders should record ideas in the participants' own words, without abbreviations, and that all pages from the flip chart should be displayed so that they can be seen simultaneously.[119]

For the following step, that of serial clarification of each idea, they direct leaders to emphasize that clarification is not limited to what the phrase representing an idea means, but also can include questions about the reasoning process by which the contributor arrived at the idea and the relative importance that contributor places on the idea; however, no participant should feel compelled or obliged to clarify their contributed idea, should they choose not to. The authors also caution that leaders should carefully pace the discussion so

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[117] William M. Fox, "The Improved Nominal Group Technique (INGT)," *The Journal of Management Development* 8, no. 1 (1989), 25, https://doi.org/10.1108/EUM0000000001331.

[118] Delbecq, Van de Ven, and Gustafson, *Group Techniques for Program Planning*, 45.

[119] Ibid., 47–50.

that it does not become snagged on an item (depriving later items of adequate clarification time) and that it does not descend into argumentation.[120]

The next step is participants' individual, independent preliminary voting on the ideas or items that the group has generated. The authors state that the leader determines the number of ideas/items that participants will be asked to list in rank order of importance or suitability (this could be five ideas/items or another number). The authors point out that studies of decision-making behavior have indicated that individuals are typically capable of accurately ranking or rating seven items, plus or minus two items (a range from five to nine items). The leader should instruct participants to take five separate index cards (or another number of cards if the number of ideas/items to be ranked is different) and clearly mark on each both the number identifying the idea/item and a separate number indicating that participant's rank ordering of that idea/item, with higher numbers representing greater importance or suitability. The leader then randomly shuffles the participants' index cards and records the votes on a flip chart in front of the entire group.[121]

The authors state that the NGT process may conclude with step 4, the preliminary group vote; however, two optional steps may be added if the facilitators wish to pursue additional precision for the group's judgment. The first of these optional steps is a discussion of the vote just held. The objective of this step is to explore possible reasons for preliminary vote tallies appearing to be skewed: do participants have differing access to information? Have various participants understood the ideas/items differently? Or do the voting patterns accurately reflect differences in judgment, absent other confounding factors? The authors instruct group leaders to explain to the group that the objective of this step is clarification, not social pressure on any participants for a change of their votes, and for group leaders to keep the discussions brief, to not give the ideas/items discussed undue prominence in comparison with other ideas/items not requiring clarification.[122] The second optional step, step 6, is a final vote. This may be carried out in the same fashion as step 4,

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[120] Ibid., 52–53.

[121] Ibid., 57–58.

[122] Ibid., 62–63.

the preliminary vote; however, the authors strongly suggest that, in addition to ranking the top five to nine ideas/items in order of importance or suitability, with higher numbers representing increasing importance or suitability, the participants also rate each item on importance on a scale of 1–10, with low numbers indicating low importance and higher numbers indicating higher importance; this allows researchers to gain a better understanding of the magnitude of preference differences between the prioritized ideas/items. If used, this second round of voting, mathematically tabulated, represents the group's final consensus.[123]

Delbecq and Van de Ven also address situations wherein the researcher or facilitator wishes to use NGT procedures with a group of more than nine participants, such as when the viewpoints and opinions of a large advisory board or commission need to be amalgamated. The authors stipulate that the large group (they envision groups of 30 to 40) be split into separate NGT groups of nine participants or fewer. Each group has its own facilitator; these facilitators lead their groups through steps 1 through 4 of the process, as described above. The groups then adjourn for a break. During the break, the facilitators convene to compare the preliminary lists. Duplicate ideas/items are merged, along with their accompanying votes. This process leads to the assembly of a master list of prioritized ideas/items. The facilitators then reconvene the members of all the groups into a single assemblage. They instruct the amalgamated group to discuss and clarify each idea/item in turn, in round-robin fashion, and then the results of the preliminary voting are discussed. Once this is completed, a final vote is held, using the same ranking and rating procedures described for step 6 above.[124]

Freya Vander Laenen emphasizes that the research question at the heart of an NGT analysis must be concrete and avoid the pitfall being too general in nature, yet not be so restrictive that it forecloses valuable brainstorming on the part of the participants. She suggests that, given the tremendous importance of the initial question, facilitators pilot test several alternative versions of their research question. She notes that, as with all techniques

[123] Ibid., 63–66.

[124] Ibid., 70–72.

that seek to elicit opinions and knowledge from experts, sampling of experts for an NGT procedure is purposive, not random. She recommends that the expert participants (whose expertise may simply consist of the fact that they are persons that have been impacted by a problem, or who will be impacted by a decision that needs to be made) be chosen to allow for input from a variety of differing perspectives. If the number of differing perspectives (or elements of expertise) needed to be sampled exceeds the optimum number of participants in an NGT session, she suggests multiple NGT sessions should be conducted.[125] Karen H. Dening et al. provide an example of this in their NGT study of persons with dementia and their family care-takers regarding preferences for end-of-life care. The researchers conducted three separate NGT sessions, one including persons with dementia, the second with those persons' family carers, and the third consisting of dementia sufferer-caretakers' dyads.[126] Vander Laenen notes that, whereas Delbecq and Van de Ven state the optimal number of participants for NGT sessions is between five and nine, other researchers who have used the technique have achieved satisfactory results with groups ranging from six to twelve in number.[127]

D. NOMINAL GROUP TECHNIQUE: ADVANTAGES

Delbecq and Van de Ven claim many advantages for their nominal group technique. They state that having specified procedures for the accomplishment of each step means there is little variability in behavior among either group leaders or participants in different instances of NGT use, which should lead to consistency in decision making. They point out that participants derive both social-emotional benefit and task-instrumental satisfaction from NGT, as opposed to the Delphi technique, which isolates participants from one another. NGT's procedures of silent, independent idea generation, followed by round-robin discussions of each idea in its turn, generally results in a relatively high number of unique

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[125] Freya Vander Laenen, "Not Just Another Focus Group: Making the Case for the Nominal Group Technique in Criminology," *Crime Science* 4, no. 5 (2015), 3, doi: 10.1186/s40163-014-0016-z.

[126] Karen H. Dening, Louise Jones, and Elizabeth L. Sampson, "Preferences for End-of-Life Care: A Nominal Group Study of People with Dementia and Their Family Carers," *Palliative Medicine* 27, no. 5 (2012), 410, doi: 10.1177/0269216312464094.

[127] Vander Laenen, "Not Just Another Focus Group," 3.

ideas generated. The technique encourages its participants to engage in proactive search behavior for problem solutions. NGT processes have the advantage of enforcing a high level of equality of participation among participants. Finally, they point out that evaluations of NGT indicate that participants derive relatively high levels of perceived accomplishment and closure from their participation, which also inspires increased interest in further involvement in the problem-solving process.[128] This latter observation is of importance in any forecasting or problem-solving effort, such as the "devil's toy box" challenge analyzed in this thesis, which requires multiple steps or rounds and which may ask participants to devote continuing time and effort over a period of weeks or months.

Carolyn Brahm and Brian H. Kleiner point out the psycho-social benefits that may be derived from use of the nominal group technique. They note that NGT is often to be preferred for group analyses involving judgmental decisions because research suggests the technique is effective at reducing negative emotions such as hostility, resentment, and interpersonal tension that might otherwise be generated by the discussion of controversial issues and alternative choices. Additionally, it facilitates input from group members who might otherwise self-censor their own ideas due to a desire to avoid causing intragroup conflict or exacerbating such conflict.[129] Freya Vander Laenen adds to the list of psycho-social benefits of NGT by pointing out that it minimizes the power differential between researchers/facilitators and participants by placing the primary burden of idea generation on the participants. Additionally, participants in an NGT procedure are treated as subjects rather than objects—sources of opinions and specialized expertise (even if that expertise is only their subjective knowledge of their own situations or social milieus), rather than simply sources of data. These two features of NGT give the procedure added utility in generating consensus within a group whose members may experience conflict or feelings of opposition, such as community police officers and members of a crime-prone neighborhood.[130] The psycho-social benefits that accrue to participants versus facilitators

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[128] Ibid., 33–34.

[129] Carolyn Brahm and Brian H. Kleiner, "Advantages and Disadvantages of Group Decision-Making Approaches," *Team Performance Management* 2, no. 1 (1996), 35.

[130] Laenen, "Not Just Another Focus Group," 2.

are meaningful to my "devil's toy box" analysis. The facilitators will most likely be bureaucrats at homeland security agencies, rather than subject matter experts. Given this fact, far greater emphasis should be placed upon the opinions and knowledge of the participants, as opposed to that of the facilitators.

William M. Fox, prior to laying out his own Improved Nominal Group Technique, mentions the following positive attributes of the technique's original formulation. Some of his thinking mirrors that of Brahm, Kleiner, and Vander Laenen. He states the technique encourages participants to expand upon one another's ideas, a concept in group dynamics known as "coat-tailing." Additionally, NGT does not permit the facilitator or participants to remove any of the ideas due to objections or hostile feedback, which adds to the procedure's aura of fairness and equality of power among the participants. Along the same lines, NGT promotes a group focus on the quality of the ideas themselves, rather than the comparative status of the ideas' authors. The technique allows for new items to be added to the ideas list at any time prior to voting, which accommodates "late bloomers." It conserves time and preserves positive group dynamics by limiting discussion to clarification of the ideas and brief statements in favor of or against an idea, thus sidestepping digressions, uninvited repetition of talking points, hard selling tactics, and extended periods of argumentation. Finally, the technique avoids premature declaration of group consensus by allowing for the renewal of discussion following the initial round of voting, plus a second round of voting, whenever the results of the first round of voting indicate that additional deliberation and individual consideration of the ideas at hand are warranted.[131] In Chapter VII of this thesis, I discuss the selection of expert participants. For a truly thorough "devil's toy box" analysis, participants will need to be selected from a variety of disciplines, professions, and experiential backgrounds. The level of perceived authority, prestige, and expertise will necessarily vary considerably among the different participants (for example, a university professor of materials physics will likely enter a team with a higher perceived status than that granted a science fiction writer). For a "devil's toy box" analytical team to function optimally, lower-status participants should not feel

[131] Fox, "The Improved Nominal Group Technique," 21.

cowed into relative silence by those of higher status, and all participants should feel equally empowered and that their ideas will be judged on their own intrinsic quality, rather than authors' status upon entry into the group.

E. NOMINAL GROUP TECHNIQUE: DISADVANTAGES

Brahm and Kleiner note that the nominal group technique is designed to deal with only one problem at a time, which limits its flexibility. They further state that its structure deprives the technique of being able to accommodate consideration of related but separate problems or controversies that participants might be inspired to raise in the context of NGT discussions; such separate issues would need to be considered and analyzed at a later NGT meeting. Finally, they suggest that the technique is limiting in that the participants must be persons who are comfortable working within the fairly rigid structure called for by the NGT.[132] In the context of my envisioned "devil's toy box" analysis, neither of these shortcomings poses a major problem, as scheduling more than one analytical session will likely be required in any case, simply due to the complexity of the issues under consideration.

William M. Fox, in his article, "The Improved Nominal Group Technique (INGT)," precedes his description of his improved technique with a discussion of what he sees as the shortcomings of the technique's original format as developed by Delbecq and Van de Ven. Fox begins by pointing out that ideas are generated by participants only once the face-to-face NGT process has begun. This robs participants of the opportunity to take more time to deliberate pre-meeting and to examine appropriate literature and resources. Also, the lack of pre-meeting familiarization with the questions to be addressed during the NGT procedure does not allow for participants to suggest to researchers/moderators other possible panelist candidates, whom the researchers have not considered, who might be able to contribute valuable insights to the meeting. Fox points out that much time at the NGT meeting itself could be saved if participants would be allowed to generate their lists of ideas before the meeting, send them to the facilitator, and the facilitator would input them onto

[132] Brahm and Kleiner, "Advantages and Disadvantages," 35.

a flip chart prior to the meeting's start, rather than spending time doing so during the meeting. On the important issue of anonymity of idea generation, although the traditional NGT's processes do separate the ideas' authors from the ideas themselves to an extent, anonymization of the ideas is not complete, since participants can reconstruct in their minds who was responsible for which ideas by noting the order of the ideas on the flip chart and aligning this with the participants' seating order. Since anonymization is not complete, participants may still be inclined, if they are sitting at the same table with colleagues—or, worse, supervisors—to avoid sharing controversial ideas or ideas that would reflect badly on colleagues or bosses. Finally, Fox points out that the traditional NGT's procedures make holding a session with more than nine participants cumbersome; assembling an NGT group with more than nine members risks alienating the participants by extending the intervals between their contributions to tiresome lengths. This limitation on the number of participants that can be accommodated may render the NGT impracticable for certain research efforts.[133] Of course, Fox does not leave off his analysis here. He proposes a set of solutions to address the shortcomings he has identified.

F. NOMINAL GROUP TECHNIQUE: MODIFIED FORMS

Fox follows up this list of shortcomings of the original NGT procedure with a description of what he calls the Improved Nominal Group Technique (INGT). Fox's INGT replaces traditional NGT's round-robin, out-loud voicings of ideas to a shared group transcriber with the following procedure. Participants, prior to the meeting, write each of their ideas on a separate 3X5 note card. These cards are then shared with the meeting's facilitators ahead of time, allowing the facilitators to write the ideas on the flip charts prior to the meeting, thus shortening the time required for the gathering. Also, the list of ideas is shared with all participants prior to the meeting, which may generate additional ideas or refinements of ideas. Participants are encouraged to bring these newer ideas with them on 3X5 note cards to the meeting, where they are given to a team of transcribers, who add the additional ideas to the already prepared flip charts. The use of multiple transcribers also shortens the amount of time required by an INGT session. This team of transcribers may

[133] Fox, "Improved Nominal Group Technique," 21–22.

also add more new ideas, those that occur to the participants at the gathering itself, to the flip charts; participants, if so inclined, share additional 3X5 note cards with the facilitators in an anonymous fashion.[134] Fox suggests that the anonymity of ideas that participants either bring to the gathering or that they generate at the meeting be assured by the moderator, who shuffles the 3X5 notecards thoroughly before distributing them to the multiple transcribers to be added to the already prepared flip charts.[135] He states that his INGT offers the significant process improvement of allowing sessions larger than the maximum of nine set forth by Delbecq and Van de Ven; based on his experience, groups as large as 20 can be accommodated by the INGT.[136]

Fox is not the only researcher who has suggested refinements to the original nominal group technique. Dening et al., in their nominal group study of end-of-life preferences of persons with dementia and their family care-givers, modify the traditional NGT procedure by following the first round of idea discussion with a second round of idea generation, and then adding a subsequent step of generating common themes from the ideas previously generated in the two brainstorming rounds.[137] S. Gaskin has adjusted the original nominal group technique for situations wherein the initial round of voting suggests that additional idea clarification and consideration are warranted to achieve consensus; for example, when the initial voting results in votes clustering around two or more preferred ideas or options. In such situations, Gaskin adds another round of discussion, followed by a second round of voting/ranking.[138] In fact, Gaskin's suggestions are not so much modifications of the original NGT process as they are restatements of Delbecq's and Van de Ven's optional additional discussion and voting/ranking steps set forth in their book *Group Techniques for Program Planning*.

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[134] Fox, "Improved Nominal Group Technique," 23.

[135] Ibid., 24.

[136] Ibid., 23.

[137] Dening, Jones, and Sampson, "Preferences for End-of-Life Care," 410.

[138] S. Gaskin, "A Guide to Nominal Group Technique (NGT) in Focus-Group Research," *Journal of Geography in Higher Education* 27, no. 3, 341–347.

Considerable technical advances in communications have taken place since Delbecq and Van de Ven created the nominal group technique in 1968. Vander Laenen notes in her 2015 article that online variations of NGT are becoming increasingly popular with researchers. In the synchronous form of online NGT, participants utilize various forms of collaborative software to present their ideas and discuss them while online simultaneously. Alternatively, online NGT sessions can be arranged for asynchronous participation, wherein participants log in at their own convenience within a period of time set by the researcher.[139] She points out that, while these online forms of NGT extend the technique's utility and applicability by obviating the need for physical gathering and the accompanying travel on the part of participants and by allowing for much larger numbers of participants than a face-to-face session, certain advantages of face-to-face NGT sessions are lost. The online discussions typically lack the non-verbal cues that add to clarifications of ideas in face-to-face sessions and written-only communications are subject to misinterpretations. Also, synchronous online discussions are subject to being dominated by the fastest typists in the group, who can get their ideas on other participants' screens the quickest.[140] Interestingly, whereas Delbecq and Van de Ven developed the nominal group technique in part as a response to what they saw as shortcomings in the Delphi technique, the asynchronous online form of NGT is virtually indistinguishable from online forms of the Delphi technique. Technology and communications trends have caused the most technically advanced versions of the two once-disparate techniques to merge. This is in contradiction to the intentions of Delphi's and NGT's progenitors. They relied upon differing perspectives and goals—Delphi creators wanted to entirely banish face-to-face interactions between participants for a variety of reasons already discussed, and NGT creators wanted to incorporate face-to-face interactions in the idea discussion and refinement phase—in designing their separate techniques for the elicitation of expert opinion. The siblings, separated in early childhood, have now been reunited, and their parallel development during the intervening years has made distinguishing between them a difficult discernment.

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[139] Vander Laenen, "Not Just Another Focus Group," 4.

[140] Ibid., 9.

G. EVALUATIONS OF THE DELPHI TECHNIQUE COMPARED WITH THE NOMINAL GROUP TECHNIQUE, STATICIZED GROUPS, UNSTRUCTURED DIRECT GROUP INTERACTION, AND OTHER FORMS OF STRUCTURED DIRECT GROUP INTERACTION

In 1991, Fred Woudenberg performed a meta-study of 17 earlier studies that compared the accuracy of results accrued by the Delphi technique with that of results accrued from staticized groups (participants who offered inputs entirely independently, whose inputs then had means or medians calculated to determine centrality), unstructured, direct interaction, and structured, direct interaction. Structured, direct interactions are represented in this meta-study by the nominal group technique. Woudenberg finds these studies, taken in aggregate, show Delphi to be slightly more accurate in its outcomes than unstructured, direct interactions, but slightly less accurate than staticized groups. He sees no difference in accuracy between Delphi and structured, direct interactions (the nominal group technique). He cautions that all the 17 studies were performed in laboratory settings and that all but a few did not use expert participants, which is the *raison d'être* for the Delphi in the first place.[141] Regarding the efficacy of iteration (successive rounds of questionnaires) in improving the accuracy of Delphi forecasts, Woudenberg states that prior studies show the great majority of improvement takes place between the initial and second rounds of estimation (not counting the Delphi's first questionnaire, if that initial questionnaire is open-ended, as with the conventional Delphi). He also points out that successive rounds of questionnaires appear to induce participants to shift their responses toward the group's median, but rarely shift that median itself.[142] He ascribes this shift toward the group's median as due to pressures for conformity, which are exerted through the statistical feedback regarding group response provided to the individual participants, rather than an improvement in accuracy for the outlying panelists due to improved information being made available to them.[143] He states that Delphi procedures are very effective at achieving consensus; however, consensus increases far more strongly than

[141] Woudenberg, "An Evaluation of Delphi," 131–135.

[142] Ibid., 140.

[143] Ibid., 141.

accuracy. He concludes that one of the primary justifications for the characteristic features of the Delphi technique—that of preventing groupthink or the domination of expressed group opinion by the loudest or most prestigious voices, presumably accomplished through anonymity, avoidance of face-to-face interactions, and the remote, dispersed use of questionnaires—is not borne out by the experimental evidence.[144]

Eight years later, in 1999, Gene Rowe and George Wright performed another meta-study of the effectiveness of the Delphi technique versus staticized groups, interacting groups, and other structured group procedures. They included a larger number of prior studies in their meta-study than Woudenberg had, 27 to his 17.[145] In examining the lists of studies considered by Woudenberg and by Rowe and Wright, I found that the latters' meta-study includes nine studies also covered by the former meta-study; eight of the studies considered by Woudenberg were not considered by Rowe and Wright; and 18 of the studies considered by Rowe and Wright were not considered by Woudenberg.

Rowe's and Wright's findings differ from those of Woudenberg. Regarding the accuracy of Delphi procedures versus that of statistized groups, their meta-study shows that, of 14 studies permitting this comparison, Delphi procedures are shown to result in higher accuracy than the results of statistized groups in 12 of the 14 studies, although five of these studies showed the difference in accuracy failed to reach statistical significance. In two of the studies, the Delphi proved more accurate under conditions but not under others.[146] Regarding Delphi's accuracy versus that of unstructured, interacting groups, of nine studies permitting this comparison, five showed a superiority for Delphi, one showed a superiority for unstructured, interacting groups, two showed no difference in accuracy between the two techniques, and one study showed a superiority for Delphi when almanac type items were being predicted but a superiority for unstructured, interacting groups when

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[144] Ibid., 145–146.

[145] Gene Rowe and George Wright, "The Delphi Technique as a Forecasting Tool: Issues and Analysis," *International Journal of Forecasting* 15 (1999): 356.

[146] Ibid., 364.

the object was forecasting.[147] Their results for Delphi procedures versus other structured group procedures were equivocal. Three studies indicated a superiority of the nominal group technique over Delphi in terms of accuracy, quality, or number of ideas generated, one showed Delphi to be superior regarding quality, and two showed no difference in accuracy between the two procedures. Few differences were found in studies comparing Delphi to other types of structured face-to-face interaction techniques such as the Dialectic procedure (panelists are required to deliver arguments both in favor of and against their own judgments), the Dictator or Best Member procedure (final group judgment is based upon that of the group's selected representative), groups whose interactions were based upon Social Judgment Analysis, groups that were given rules on interactions prior to their exchanges, and groups whose interactions followed the Problem Centered Leadership model. Only one of these studies showed any of the non-nominal group technique procedures to be superior to Delphi, and that was the Problem Centered Leadership approach, wherein group leaders are provided training in facilitating positive exchanges between panelists.[148]

Rowe and Wright echo the criticisms offered by Woudenberg of studies conducted on the accuracy or quality of the Delphi technique. They point out that the great majority of studies they examine have used as panelists either students or professionals from a single discipline, rather than the diverse panel of experts envisioned by the developers of the Delphi technique (and often selected by researchers using Delphi in the field). They write: "Delphi, however, was ostensibly designed for use with experts, in cases where the variety of relevant factors (economic, technical, etc.) ensures that individual panelists have only limited knowledge and might benefit from communicating with others possessing different information… This use of diverse experts is, however, rarely found in laboratory situations… if varied information is not available to be shared, then what could possibly be the benefit of any group-like aggregation over and above a statistical aggregation

[147] Ibid., 365–366.

[148] Ibid., 366–367.

procedure?"[149] They further point out that "(t)he requirement of empirical social science research to use simplification and reductionism to study highly complex phenomena seems to be at the root of the problem, such that experimental Delphis have tended to use artificial tasks (that may be easily validated), student subjects, and simple feedback in the place of meaningful and coherent tasks, experts/professionals, and complex feedback."[150] They offer the final criticism that students recruited into studies of the efficacy of the Delphi technique lack the motivation and interest of experts serving on panels intended to solve problems, create forecasts, or arrive at statements of consensus relating to their fields of expertise.[151] They conclude that Delphi procedures conducted to actually produce forecasts or to support decision-making are, in all likelihood, more accurate and produce results of higher quality than those Delphi procedures conducted in laboratory settings to test the technique's efficacy.[152]

Rowe's and Wright's critiques of these studies strike me as valid, their observations that virtually none of the laboratory studies involved experts and that, in contrast to Delphi procedures carried out in the field to help support important decisions or to forecast potential events of some significance, the laboratory studies offered no real motivation for participants to do their utmost—nothing was at stake. Despite the limitations of these comparison studies, I find it of interest that the Delphi technique is often shown to be superior in terms of accuracy to staticized groups and interacting, unstructured groups, and either on par or somewhat inferior to the nominal group technique. Should the two best-known, most frequently used procedures for the elicitation of expert opinion—the Delphi technique and the nominal group technique—be shown to be roughly equivalent in their effectiveness, or with a slight edge to the latter, then the choices to be made by the facilitators of a "devil's toy box" analysis regarding process come down to factors other than predictive accuracy. These factors will likely include feasibility, timeliness, cost,

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[149] Ibid., 368.

[150] Ibid., 369.

[151] Ibid., 368.

[152] Ibid., 373.

logistics, and the value the facilitators place upon face-to-face interactions between the members of their panel of experts versus the relative sterilization from social effects offered by remote anonymity.

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In the 1960s, researchers and analysts, charged with a new sense of optimism (driven in part by the early promise of expert forecasting techniques such as Delphi) that future events in the technological, social, commercial, and political realms could be successfully forecast and that the most desirable future states could be planned for and implemented through systematized effort, developed a new field known variously as futurism, future studies, or foresight studies. Not merely a field of academic study, futurism/future studies/foresight studies also developed into an operational doctrine used in both corporate environments and governments. Over subsequent decades, practitioners of futures studies innovated new ways of prognosticating future events and trends, adding to the potential tool kit available to a "devil's toy box" analysis team. In Chapter V, I will survey these approaches and techniques that futurists have added to the basket of available predictive analysis tools.

V. EXPERT ANALYSIS (3): FUTURES STUDIES/FORESIGHT STUDIES

A. FUTURES STUDIES: INTRODUCTION

Dr. Roy Amara, President and Senior Research Fellow at the Institute for the Future in Menlo Park, California, has this to say in speaking of his own work and that of his fellow practitioners of futures studies. He states "our purpose is not to predict—much as we would dearly like to do so. Rather, our primary purpose is to generate images and to analyze and understand them so that we can act to increase the probability of producing futures that we prefer."[153] He goes on to specify that the main objectives of futures studies are:

- laying out paths of possibilities (the art of the 'possible');
- examining in detail paths and the likelihood of their occurring (the science of the 'probable');
- expressing preferences for, and implementing, paths (the politics of the 'preferable').[154]

Thomas Saaty and Larry Boone, in their book *Embracing the Future: Meeting the Challenge of Our Changing World*, echo some of Amara's thoughts regarding the field of future studies, or, as they refer to it, futurism. They begin by listing three assumptions held in common by practitioners of futurism—that the future defies prediction; that the future is in no way predetermined; and that the shape the future takes will be influenced by the choices that individuals make.[155] They go on to describe three different types of futurists:

> *Futurists of the possible* tend to be mavericks, visionaries, sometimes geniuses, and sometimes madmen. They emphasize intuition and feeling in their thought processes. *Futurists of the probable* tend to be analytically

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[153] Roy Amara, "Views on Futures Research Methodology," *Futures* 23 (July/August 1991), 647–648.

[154] Ibid., 646.

[155] Thomas L. Saaty and Larry W. Boone, *Embracing the Future: Meeting the Challenge of Our Changing World* (New York: Praeger, 1990), 15.

> oriented in one or more fields such as mathematics, statistics, or systems analysis. *Futurists of the preferable* tend to be political scientists; they emphasize specific issues such as nuclear power, women's rights, or environmental concerns. Futurists of all categories are usually effective writers who can generate mass appeal.[156]

Nicholas Rescher, in his 1967 monograph *The Future as an Object of Research*, notes that the decade of the 1960s had witnessed increasing interest in future studies. He lists books published in that decade by French, German, and American authors, such as *Art of Conjecture* by Bertrand de Jouvenel (1964), *Der Wettlauf zum Jahre 2,000* by Fritz Baade (1960), *Inventing the Future* by Dennis Gabor (1964), and Theodore Gordon's simply titled *The Future* (1965). He also points out that decade's proliferating numbers of governmental advisory commissions regarding forecasting future trends to help guide public policy formulation, including the Futuribles association in France and, in the United States, the Commission for the Year 2000, the National Planning Association, the National Commission on Automation, Manpower, and Technological Progress, and Resources for the Future. He singles out the early work of Alvin Toffler for praise, citing Toffler's article "The Future as a Way of Life" from the summer, 1965 edition of *Horizon*. He lumps these phenomena together and christens them "The Futures Industry."[157]

Various governments regularly engage in a form of futures studies called future-oriented technology analysis, which consists of institutionalized efforts to forecast disruptive, transformative technology developments. The United Kingdom, Singapore, and the Netherlands all maintain horizon-scanning centers, and the European Parliament has established a parliamentary technology assessment office, the Scientific Technology Options Assessment Unit.[158] In Japan, the Ministry of International Trade and Industry (MITI/METI), in conjunction with the Science and Technology Agency, initiated a series

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[156] Ibid.

[157] Nicholas Rescher, *The Future as an Object of Research* (Santa Monica: RAND Corporation, April 1967), 2–4, http://www.dtic.mil/dtic/tr/fulltext/u2/651425.pdf.

[158] K. Matthias Weber, Jennifer Cassingena Harper, Totti Könnölä, and Vicente Carabias Barceló, "Coping with a Fast-Changing World: Towards New Systems of Future-Oriented Technology Analysis," *Science and Public Policy* 39 (2012), 155–157, doi:10.1093/scipol/scs012.

of national Delphi forecasting studies beginning in 1969 and repeated every subsequent five years. One example, the National Delphi study conducted in 1990–1991, attempted to formulate a long-term forecast for Japanese society and the economy through 2010 by examining 101 separate emerging technologies, their predicted emergence times, and their potential impacts upon society and the economy. Japan's national Delphis have tended to encompass large numbers of participants; for example, 2,781 initial respondents in the 1990–1991 study, increasing to 4,220 first-round questionnaire respondents in the 1997 study. Considering the high value that Japanese society places on consultation and inclusion, an important side-benefit of the National Delphi studies has been their facilitation of communication between large groups of experts and the improved flow of information.[159] The Finnish Parliament's Committee for the Future conducted a series of policy Delphi surveys between 1997 and 2001. The surveys encompassed a forecasting time envelope of 5–20 years and focused upon the genetic engineering of plants, new technologies to assist teaching and learning, energy technology development, gerontechnology, and new techniques for knowledge management.[160] The European Commission established the European Foresight Monitoring Network (EFMN) to monitor European foresight studies, gather and distribute the information produced in the form of an annual report, and determine key emerging issues in the areas of science and technology policy.[161] EFMN annual reports have focused on such disparate issues as developments in cognitive science (2005), technological and medical advances regarding healthy aging (2006), issues for Europe surrounding the emerging knowledge-based economy (2007), and the future of European public health services (2008).[162]

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[159] Kerstin Cuhls, "Foresight with Delphi Surveys in Japan," *Technology Analysis & Strategic Management* 13, no. 4 (2001), 555–559, doi: 10.1080/09537320120095446.

[160] Ahti Salo and Osmo Kuusi, "Parliamentary TA: Developments in Parliamentary Technology Assessment in Finland," *Science and Public Policy* 28, no. 6 (December 2001), 453–456, doi: 032-3427/01/060453-12.

[161] Maurits Butter, Felix Brandes, Michael Keenan, Rafael Popper, Susanne Giesecke, Sylvie Rijkers-Defrasne, Anette Braun, and Patrick Crehan, *Final Report: Monitoring Foresight Activities in Europe and the Rest of the World* (EUR 24043 EN) (Brussels, Belgium: European Foresight Monitoring Network, European Commission, Publications Office of the European Union, 2009), 7, doi: 10.2777/47260.

[162] Ibid., 33–39.

The origins of both the Delphi technique and futurism/future studies as a field of operational decision support and academic study may be said to flow from the same wellspring, a monograph entitled *The Prediction of Social and Technological Events*. This was first published by the RAND Corporation in 1949, then republished in January 1950 as an article in *Public Opinion Quarterly*. The monograph's authors were A. Kaplan, an Associate Professor of Philosophy at UCLA, A. L. Skogstad, an economist employed by RAND, and M. A. Girshick, a Professor of Mathematics at Stanford. Kaplan et al. voiced many of the same questions and concerns regarding experts and their prognostications that have occupied practitioners of futures studies ever since. In dealing with questions germane to the formulation of public policy, which require that assumptions be made about future societal states and future trends, how good are experts' prognostications? Who are the best experts to listen to? How can their prognostications be improved? How can the prognosticators avoid emotional, psycho-social, and political pressures to alter their forecasts in ways favorable to their peers or superiors?[163]

In their attempt to address these questions, the authors performed an experiment in forecasting whose design helped to establish the basic procedures of the classic Delphi technique. The researchers recruited a group of 26 predictors, of whom 15 were mathematicians or statisticians, four were economists or business administrators, one was an office manager, one a secretary, and one a professional writer. Twenty-four of the 26 had a college education. These participants were asked to make predictions through the method of answering questionnaires. The questions were divided between the social sciences and natural sciences. Regarding the former, predictions to be made concerned domestic and foreign political events and economic developments. For the latter, the predictions were focused upon technological advancements and developments in physical and life sciences. In total, participants were asked 123 questions. In response, they offered 3007 separate predictions, all in the form of rating the likelihood, on a scale of 0 to 100, of an event occurring; for each question, the researchers offered four possible answers, and the participants' ratings for the four alternatives needed to add to 100 (for example,

[163] A. Kaplan, A. L. Skogstad, and M. A. Girshick, "The Prediction of Social and Technological Events," *Public Opinion Quarterly* 14, no. 1 (January 1950), 93–96, https://doi.org/10.1086/266153.

participants were asked to predict which of four possible candidates would be nominated as the Republican candidate in the next presidential election). The researchers issued the participants a new questionnaire each week for 13 subsequent weeks, and in addition to offering their likelihood ratings, participants were instructed to write down the reasoning by which they made their determination. Each participant was allotted three hours in which to complete a questionnaire. Each week, participants were broken out into three groups. The members of the control group all answered their questionnaires independently. Members of the second group were directed to discuss the questions with the other members of their group prior to answering the questionnaires separately. Members of the third group also discussed the questions, but they provided a single, consensus set of answers to the researchers. The questions asked were all the sort for which definitive answers could be obtained within the five month-long period of the study (i.e., the Republican National Convention would take place prior to the researchers performing their analysis, so the accuracy of the prognosticators' answers could be determined).[164] Thus, this experiment may be viewed as an early precursor of the forecasting tournament sponsored by the Intelligence Advanced Research Projects Agency (IARPA) beginning in 2011, which I will examine in detail in Chapter VIII.

Kaplan et al. cautioned that the experiment's design and choice of participants weighed against its replicability and pointed out that all participants were instructed to answer all the questions, not merely those questions falling within the field for which they could be considered an expert. Were such a restriction to have been made, matching experts with those questions regarding which they would have the greatest prior knowledge, the accuracy scores might have been higher. They also bemoaned the fact that time constraints on the study's completion required that only short-term prognostications could be considered, those whose results could be determined within a five-month timeframe. With these caveats in mind, the researchers derived some interesting, suggestive results. The overall success rate for prediction was 52%. For those responses the participants judged "guesses," the success rate was 40%, whereas those answers for which the participants

[164] Ibid., 96–97.

offered justifications saw a far higher success rate of 62%. Importantly for the future development of the Delphi technique, the researchers compared the accuracy of their various experimental cohorts, comparing these to the overall predictive success rate of 52%. On the low end, the worst-informed half of the respondents, answering independently, scored at 50%. By way of comparison, the best-informed half of the respondents scored at 56%; however, those results were bested by the cooperative group (those participants who conferred with their peers and then answered independently) at 62%, and the joint group (those participants who conferred with their peers and offered a consensus answer) at 67%, as well as by the mean prediction at 66% and the plurality prediction at 68%. The outlier of all the participants, the single best-performing individual predictor, scored at 71%.[165] Olaf Helmer and Norman Dalkey obviously took these results into account when designing the Delphi technique, noting the benefits of inter-participant consultation and attempting to accrue those benefits while at the same time avoiding the detrimental features of face-to-face interactions.

B. FUTURES STUDIES: METHODOLOGIES

The purpose of these sections concerning futures studies is not to offer a broad overview of the field, nor to survey and profile the thinking of prominent futurists, nor to examine the role of futurism in popular culture (such as the enormous success and influence of Alvin Toffler's book *Future Shock* with a non-specialist readership), nor to provide a portrait of the field's evolution since its initial gestation at the RAND Corporation in the late 1940s. Such topics, while of great interest, are outside the scope of this thesis. Rather, the purpose of this consideration of the field of futures studies is to examine the analytical tools commonly used by futurists and to determine whether any of those tools might be advantageously added to the tool kit I intend to assemble for the members of a "devil's toy box" analytical team.

Nicolas Rescher, along with Olaf Helmer and Norman Dalkey one of the philosophers employed by the RAND Corporation's Mathematics Division in the 1950s and

[165] Ibid., 103–109.

1960s and thus one of the pioneers of futures studies, identifies, in his 1967 monograph *The Future as an Object of Research*, three types of what he terms predictive methodologies: "the extrapolation of historical experience, the utilization of analytical models, and the use of experts as forecasters."[166] He mostly dismisses extrapolation of historical experience as a useful technique, stating that scientific progress involves so many breaks from past technological methods that simple extrapolation leads to outlandish prognostications (my own favorite in this realm is a prediction from the early 1900s that, given the projected growth in the numbers of horse stabled in New York City, by mid-century the city's streets would be enveloped by a layer of horse dung ten feet deep!). He also states that, at the time of the article's writing, the processes of scientific invention and innovation, of the diffusion of new technologies through society, and of resulting social change were too little understood to permit the creation of useful analytical models incorporating these essential feeders of the future. He concludes by opining that only the systematic use of experts as prognosticators offers much in the way of utility in forecasting future trends.[167]

In a later work, his 1998 book *Predicting the Future: An Introduction to the Theory of Forecasting*, Rescher offers the following, Table 2, illustrating when methods of prediction are appropriate:

Table 2. Conditions of Predictability (per Rescher, 1998)168

The phenomena of domain are amenable to prediction by	**provided that**	***This domain has a structure of occurrence that***
expert judgment		is learnable (orderly)
trend extrapolation		exhibits trend uniformity
pattern fitting		exhibits stable temporal patterns
analogy		maintains an actual (rather than merely apparent) analogy
indicators		exhibits stable correlations
law inference		is stably lawful (regular)
modeling		has a fixed structural *modus operandi*

[166] Rescher, *Future as an Object of Research*, 5.

[167] Ibid., 5–7.

[168] Nicholas Rescher, *Predicting the Future: An Introduction to the Theory of Forecasting* (Albany, NY: State University of New York Press, 1998), 111.

Given the natures of the various phenomena that would feed into a "devil's toy box" analysis—including, but not limited to, technological advances; technological diffusion; interplay between technologies; social, political, and ideological trends in extremism and extremist groups; evolution in homeland security practices and doctrines; and political will to support changes in security-related laws and procedures—it would appear that few of the formal techniques Rescher lists would be appropriate tools. These phenomena, for the most part, are not orderly; they do not exhibit trend uniformity; they do not exhibit stable temporal patterns, nor stable correlations; they are not stably lawful or have fixed structural modus operandi. Given all this, Rescher's stipulation that forecasters in the social and political arenas need to muddle through with judgmental techniques, rather than formalized inferential or sophisticated scientific methods, would seem to apply.

Saaty and Boone present a list of four possible ways in which to forecast the future, which overlaps some with Rescher's list and expands his list. Their first method is acquiring the consensus of experts; the best-known method in this realm is the Delphi technique. Their second method is the extrapolation of past trends, which they state is most commonly used in fields amenable to quantitative analysis, such as projecting futures in the demographic, environmental, and economic realms; they point out the basic pitfall to this approach is that it does not allow for unprecedented events of great impact (such as the assassination of an influential world leader, the crash of a major meteor into a populated area, or the emergence of a new, virulent, highly contagious disease). Their third method is historical analysis, of which they mention there are at least three subtypes, including political analyses (such as those performed by Karl Marx in his writings), analyses of problems with existing systems, and analyses that hypothesize major changes in existing systems and extrapolate the effects of those changes into the future. Their fourth method is "the systematic generation of alternative paths" using both quantitative and non-quantitative modelling to generate alternative plausible futures.[169] This fourth method is scenario building and analysis.

[169] Saaty and Boone, *Embracing the Future*, 22–24.

Roy Amara, in his survey of futures research methodologies, states that the discipline's original analytical tool kit, popular in the 1960s and 1970s, consisted of various methods of simulations and gaming, cross-impact modelling, and Delphi studies. Following what he describes as the heyday of Delphi in the 1960s and 1970s, practitioners of futures studies moved on to structured workshops (which, judging from Amara's brief description, sound much like uses of the nominal group technique) and the widespread use of scenarios for portraying potential alternate futures. He identifies the three primary objectives of futurologists as exploring the possible, the probable, and the preferable. His suggested methodologies for exploring the possible include all techniques that improve imaging of future states, including brainstorming sessions, structured workshops, focus groups, and one-on-one interviews of experts in various disciplines, as well as the panoply of imaginative tools used by artists and writers. For exploring the probable, he suggests tools that trace connections, such as flow charts, influence diagrams, matrices, and root-and-branch structure diagrams. Finally, for exploring the preferable, he directs practitioners to role-play various stakeholders and engage in the techniques of shared problem solving, including negotiation and bargaining, conflict resolution techniques, and various forms of mediation of competing interests.[170]

Earlier in this thesis, in Chapter II, I discuss Ronald Lehman's concept of strategic latency, the fact that virtually all technology can conceivably be dual-use, as effective in causing harm or multiplying the force of existing weapons systems as it is in its intended, benign civilian use. I also address Bryan Arthur's concept of "combinatorial evolution" of technology, wherein various separate technologies act like chemical elements that can be reconfigured and recombined in virtually endless combinations for new purposes, including purposes unforeseen by the technologies' original developers, some of these purposes at harsh variance to those developers' intentions. Given the mind-boggling array of potential variations, branchings, and recombinations of new and existing technologies, the challenges for a "devil's toy box" analyst team are daunting. One tool in the futurists' tool kit that can assist our poor, bedeviled team of analysts in parsing these complications

[170] Amara, "Futures Research Methodology," 645–647.

of influence and interdependencies is the cross-impact matrix. Theodore J. Gordon defines the cross-impact matrix method as "an experimental approach by which the probability of each item in a forecasted set can be adjusted in view of judgments relating to potential interactions of the forecasted items. … The systematic description of all potential modes of interaction and the assessment of the possible strength of these interactions is vastly complex but methodologically important, since these descriptions and metrics may provide new insight into historical analysis and permit greater accuracy and precision in forecasting."[171] Automated tools are available to perform the mathematical calculations involved in the analysis of a cross-impact matrix, which incorporates both the direction of change involved in the interaction between two variables and the strength of that change. Gordon provides a set of seven steps for setting up a cross-impact matrix so that the interactions between variables can be analyzed by a software program:

> 1. assessing the potential interactions (cross impacts) among individual events in a set of forecasts, in terms of:
>
> a. direction, or mode, of the interaction,
>
> b. strength of the interaction, and
>
> c. time delay of the effect of one event on another
>
> 2. selecting an event at random and "deciding" its occurrence or nonoccurrence based on its assigned probability
>
> 3. adjusting the probability of the remaining events according to the interactions assessed as likely in Step 1
>
> 4. selecting another event from among those remaining and deciding it (using its new probability) as before
>
> 5. continuing this process until all events in the set have been decided
>
> 6.. 'playing' the matrix in this way many times so that the probabilities can be computed based on the percentage of times that an event occurs during these plays; and

[171] Theodore J. Gordon, "The Current Methods of Futures Research," in *The Futurists*, ed. Alvin Toffler (New York: Random House, 1972), 180.

7. Changing the initial probability of one or more events and repeating Steps 2 to 6.[172]

Trudi Lang identifies three related futures studies methodologies for identifying and analyzing emerging issues. These are environmental scanning, issues management, and emerging issue analysis.[173] Peter Schwartz, futurist and president of Global Business Network, discusses environmental scanning in his 1991 book *The Art of the Long View*. Schwartz lists the primary targets for information gathering, as part of an environmental scanning process, to be developments in science and technology, perception-shaping events (events that receive widespread coverage in the media and that move public opinion in a new direction), new developments in music (music, with its impact upon the emotions, can be a powerful driver of public sentiment, as well as a reflection of concerns bubbling up in the larger society, as songwriters seek to connect to the zeitgeist), and what Schwartz terms the fringes.[174] Regarding the latter, Schwartz writes that "…new knowledge develops at the fringes. People and organizations often organize knowledge concentrically, with the most cherished, vital beliefs at the protected center. At the outer edge are the ideas that the majority rejects. A little closer to the center are the fringes—areas not yet legitimized but not utterly rejected by the center either. Innovation is the center's weakness. The structure, the power, and the institutional inertia all tend to inhibit innovative thinkers and drive them to the fringes. At the social and intellectual fringes, thinkers are freer to let their imaginations roam, but are still constrained by a sense of current reality."[175] As examples of players on the fringes who ended up influencing the world in striking ways, Schwartz lists Albert Einstein, Steve Jobs and Steve Wozniak, Ho Chi Minh, the creators of the Gaia hypothesis, the visionary who first conceptualized nanotechnology, the radical environmentalist group Earth First, researchers at Xerox's Palo Alto Research Center, and

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[172] Ibid., 182.

[173] Trudi Lang, "An Overview of Four Futures Methodologies" (unpublished research paper, last modified Fall, 1994), 1, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.455.1045&rep=rep1&type=pdf.

[174][174] Peter Schwartz, *The Art of the Long View* (New York: Doubleday, 1996), 62–73.

[175] Ibid., 69.

telephone network "phone phreaks," adventuresome hobbyist teenagers who were the original computer hackers.[176] P. T. Terry also created a model of environmental scanning, one focused on the needs and concerns of a commercial company or corporation. The areas he emphasizes for attention include market influences (encompassing customers, markets, competitors, and suppliers), technical influences (encompassing the availability and quality of raw materials, as well as the knowledge base concerning the company's products and production processes), social influences (values, prohibitions and constraints, environmental concerns, religious beliefs, and trends in opinions and preferences in the larger society of which the company is a part), and political/legislative influences (regulations, laws, planned legislation or legislation in progress).[177]

Howard Chase, a pioneer of the issues management methodology and at one point chairman of the Issues Management Association, offers the following definition of issues management: "the capacity to understand, mobilize, coordinate, and direct all strategic and policy planning functions, and all public affairs/public relations skills, toward achievement of one objective: meaningful participation in creation of public policy that affects personal and institutional destiny."[178] Lang points out that most practice of issues management as a methodology occurs in the corporate environment, with a near-term focus, examining issues likely to result in legislative activity within the next 18–36 months. Drawing on the model set forth by Robert L. Heath and Richard A. Nelson in their 1986 book *Issues Management: Corporate Public Policymaking in an Information Society*, she states that the three concurrent activities of issues management are foresight, development of policies, and advocacy for those policies. The six steps that support these activities are thoroughly monitoring political and legislative activity to identify those emerging issues that will most likely have an impact on the researcher's sponsoring or employing organization; prioritizing those emerging issues in terms of the significance of their likely impact;

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[176] Ibid., 69–73.

[177] P. T. Terry, "Mechanisms for Environmental Scanning," *Long Range Planning* 10, no. 3 (June 1977), 2–3.

[178] Robert L. Heath and Richard A. Nelson, *Issues Management: Corporate Public Policymaking in an Information Society* (Beverly Hills, CA: Sage Publications, 1986), 20.

evaluating the prioritized issues in terms of their likely impacts upon the operations and finances of the organization; formulating the organization's official position on the prioritized issues; based upon these official positions, formulating organizational strategies in response to the issues; and, finally, carrying out this strategy.[179]

In contrast to the short-term focus of issues management, which concentrates upon issues that have matured to the point when they appear ripe for legislative action within 18 to 36 months, the related methodology of emerging issues analysis seeks to identify and analyze issues far earlier in their developmental cycle.[180] Graham T. T. Molitor, a pioneer of emerging issues analysis, writes that the envelope of time that extends from the earliest emergence of a social issue on the fringes of society, such as in avant-garde or visionary artistic works or the writings of members of minority or outcast groups, to a focus on that issue by the popular mass media, to a scholarly consideration of the issue in academic journals and conferences, may stretch from 35 to 85 years.[181] In a later article, Molitor refines his estimation of the timelines involved in the origins, formulation, and legislation of social policy. He states the minimum amount of time required for this progression from idea to legislation is 6–12 years, although his studies have shown that the time required can extend to as much as 23–100 years.[182] As the founder of Public Policy Forecasting, a consulting firm specializing in emerging issues analysis, Molitor built his Molitor Multi-Timeline Model to predict the timing of the introduction and passage of major public policy legislation. Molitor notes that, in contrast with many of his fellow futurists, who tend to focus on discontinuities, he focuses instead on historical continuities and repeating patterns of societal evolution. His model is based upon G.K. Chesterton's notion of the "prophetic past," the observation that history encompasses observable, identifiable patterns that are

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[179] Lang, "Four Futures Methodologies," 12–13.

[180] Ibid., 13.

[181] Graham T. T. Molitor, "How to Anticipate Public-Policy Changes," *S.A.M Advanced Management Journal* (Summer 1977), 6.

[182] Graham T. T. Molitor, "Forty Year Effort to Ascertain How Public Policy Evolves," *Journal of Futures Studies* 5, issue 1 (August 2000), 80.

repeated time and again, from society to society, heralded by leading indicators.[183] He states that changes in public policy are put into motion by approximately 25 discrete "signatures of change," as he calls them, which he has incorporated into his model.[184] As an example of these "signatures of change," in his consulting practice, he looks to political developments in the Scandinavian countries as precursors to later changes that will likely take place in other European democracies, the United Kingdom, the United States, and Canada; within the U.S., he considers New York, Massachusetts, and California as the trend-setters that other American states almost inevitably follow within certain time lags.[185]

In opposition to Rescher's belief that forecasting in the social and political realms cannot be reliably based upon formalized inferential or sophisticated scientific methods, the Molitor Multi-Timeline Model incorporates elements of trend extrapolation, pattern fitting, use of analogies, leading indicators, and modeling. Molitor claims a remarkable reliability rate of 90% for use of his Multi-Timeline Model to predict the timing of what he terms public policy resolutions (introduction and passage of legislation, etc.).[186] Given the vagaries of what constitutes "public policy resolutions," however, I would need to see his definitions of these outcomes, as well as his definitions of what constitutes success in forecasting (what range of time—plus or minus six months from the date predicted by his model?), to judge the meaningfulness of this claim. In his retrospective of his forty-year-career as a futurist in the public policy realm, he provides no indication of, nor consideration of, the potential for his model to be successfully adapted to a different realm of analysis, other than the introduction and passage of public policy legislation—such as a "devil's toy box" analysis. Would G.K. Chesterton's notion of the "prophetic past" apply as well, or at all?

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[183] Ibid., 86.

[184] Ibid., 80.

[185] Ibid., 83.

[186] Ibid., 81.

I suspect it might—in part. Technologists have created theoretical models to predict the pace and extent of technology diffusion; psychologists and sociologists have developed models of individual and group behavior; scholars in the homeland security field have begun developing models of processes of radicalization and other models predicting the rise and decline of extremist organizations. I feel such models, either adapted or amalgamated to assist in predictions of malign uses of new technologies, could prove useful for a "devil's toy box" analysis. Perhaps their best use would be to remind the analytical team members of the wide range of factors that need to be considered, so that important elements do not get overlooked; however, I would lean towards using such a model or models in conjunction with other techniques, which could act as a "reality check;" too great a reliance on models of complex social phenomena, even on models that have performed well in the past, can lead to embarrassing errors in prediction. The "prophetic past" focuses analysts' attention on continuities, which certainly have been seen throughout history, but that lens on the future reveals only part of the picture. It is inadequate for the forecasting of future *discontinuities*—the Great Awakenings, revolutions, and paradigm shifts brought about by the actions of extraordinary individuals, new scientific discoveries, or the sorts of low-probability, high-impact events that have been referred to as "black swans." Folkloric wisdom is generally based upon generations of hard-won experience; in this context, the old saying that "the only constant is change" has resonance—not as a blanket denial that history embodies continuities, but as a reminder that those continuities, the reliable contract players of history, share the historical stage with the black swans, history's breakout star actors, emerging from obscurity to forever leave their mark.

Of interest for this thesis's goal of providing a more effective tool kit for a "devil's toy box" analysis team, the European Foresight Monitoring Network (EFMN) conducted a survey covering the period 2004–2008 regarding forecasting techniques used by facilitators of foresight exercises around the world. Over this five-year period, the EFMN analysts considered approximately 6000 foresight exercises.[187] Their survey determined

[187] Butter et al., *Final Report: Monitoring Foresight Activities*, 22.

that a wide range of methods were frequently used in combination within these exercises. Methods popularly used included:

- *Cross-impact analysis* (in conjunction with questionnaires/surveys and/or brainstorming)
- *Brainstorming* (in conjunction with futures workshops, Delphi surveys, individual interviews, environmental scanning, and/or Strengths-Weaknesses-Opportunities-Threats [SWOT] analysis)
- *Environmental scanning* (in conjunction with individual interviews, questionnaires/surveys, futures workshops, SWOT analysis, trend extrapolation, and/or stakeholder mapping)
- *Stakeholder mapping* (in conjunction with trend extrapolation, futures workshops, SWOT analysis, brainstorming, and/or environmental scanning)
- *Futures workshops* (in conjunction with brainstorming)
- *Scenarios analysis* (in conjunction with futures workshops)
- *Modelling and simulation* (in conjunction with megatrend analysis and/or trend extrapolation)
- *Delphi surveys* (in conjunction with futures workshops, analysis of key technologies, and/or brainstorming)
- *Expert panels* (in conjunction with brainstorming and/or futures workshops)
- *SWOT analysis* (in conjunction with questionnaires/surveys, futures workshops, and/or brainstorming)
- *Technology roadmapping* (in conjunction with futures workshops and/or key technologies analysis)

- *Trend extrapolations* (in conjunction with scenario analysis, expert panels, and/or literature reviews)
- Many methods listed above are used in conjunction with *scenario analysis*, *literature reviews*, and/or *expert panels*

The EFMN analysts determined that governments and agencies in regions tended to prefer differing forecasting techniques or combinations of techniques.[188] While my brief overview of combinations of techniques listed above is not backed up by an analysis of the comparative effectiveness of the various combinations (such an analysis could in itself be the subject of a thesis or dissertation), its value for this thesis lies in its demonstration that these techniques are very frequently used in combination and that national and regional governments and non-governmental agencies have found value in using various forecasting techniques in conjunction (otherwise, the EFMN analysts would not have observed such a high frequency of combinations, as opposed to using techniques in isolation, over the five years covered in their study). This characteristic catholic nature of governmental practitioners of futures studies, the fact that so many do not cling exclusively to a single preferred forecasting technique or even pair of techniques, certainly has implications for the development of my own blended technique, Pandora's Spyglass, for the conduct of a "devil's toy box" analysis.

C. FUTURE STUDIES: METHODOLOGIES: TECHNOLOGY SEQUENCE ANALYSIS

Technology Sequence Analysis (TSA) was first developed and utilized in the 1980s as a way to formulate probabilistic forecasts of the amount of time it would take to develop a technological system.[189] Estimating the likelihood of a Promethean technology and its enabling technologies reaching deployment or the market within a five- to ten-year time window is a key activity of a Pandora's Spyglass procedure, my proposed method for

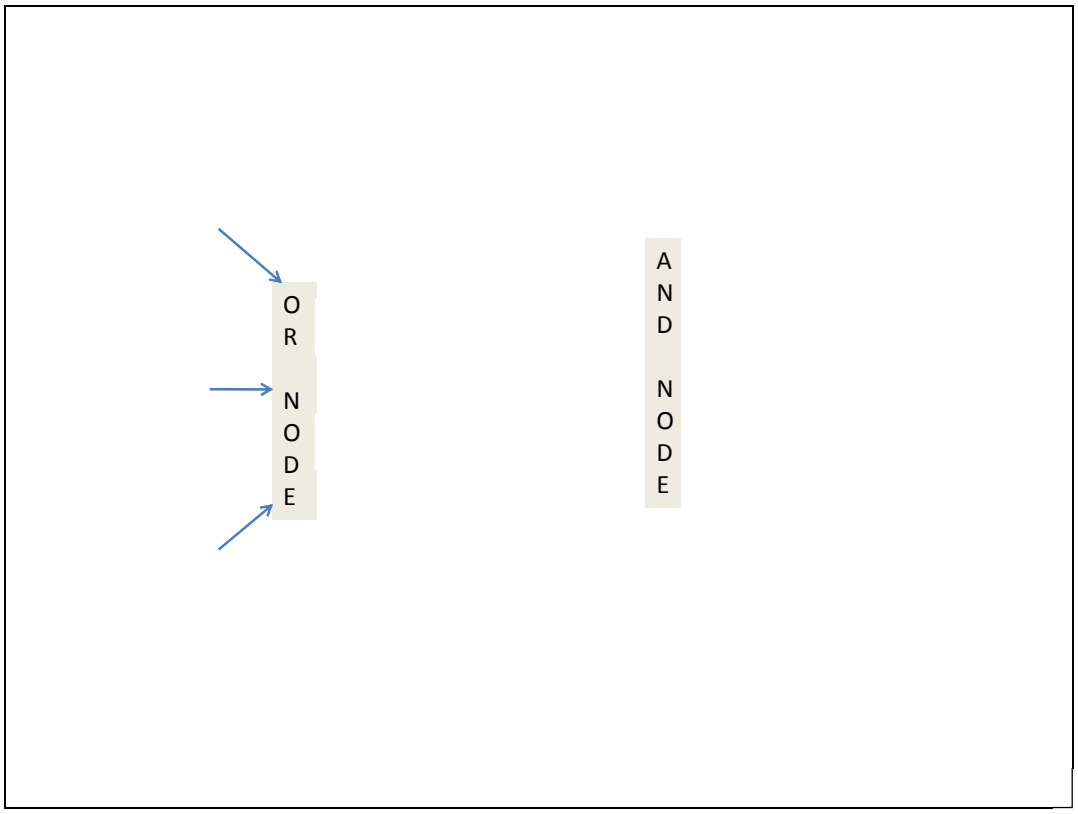
[188] Ibid., 26–27.

[189] Theodore J. Gordon, "Technology Sequence Analysis," in *Futures Research Methodology* Version 3.0, Jerome C. Glenn and Theodore J. Gordon, eds. (Washington, DC: The Millennium Project, American Council for the United Nations University, 2009), CD-ROM article 16, 1.

conducting a “devil’s toy box” analysis, which will be described in detail in Chapter IX. For this reason, a brief examination of Technology Sequence Analysis is in order.

Technology Sequence Analysis is a form of path analysis that breaks down a system into sub-systems and those sub-systems into individual components. Theodore J. Gordon provides the following example of a harvesting robot, with simple Boolean logic laid out in picture form:

Figure 1. Example of Technology Sequence Analysis (Harvesting Robot)[190]



On the left side of the figure, three alternate enabling technological sub-sub-systems, any of which could enable the Ripeness Sensing sub-system, are shown. These are called “OR nodes” because not all three of them need to be available for the Ripeness

190 Ibid., 3.

Sensing sub-system to work; only one of the three needs to be developed. Moving further to the right of the figure, five critical sub-systems are listed, Guidance, Position Sensing, Ripeness Sensing, Cleaning, and Packaging. All these sub-systems are required for the overall system of the Harvesting Robot to work properly and carry out all its necessary functions. So, each of these five critical sub-systems is termed "AND nodes," since all them must be present, and none of them can substitute for the others.

Technical experts provide their estimates of the likelihood of nodes within the network being created by a certain date (an example might be, "Node XXY has a 65% likelihood of being developed within five years"). Gordon explains that several hundred nodes leading up to the completed system on the right might need to be included in a full Technology Sequence Analysis diagram. He states that "(a) typical network may consist of 600 to 800 nodes and 700 to 1,000 associated 'and' paths and 'or' paths," and that some charts become so complicated that special software must be used to simulate the Monte Carlo simulations necessary to assign the ranges of probabilities opened up by the paths involving alternate enabling technologies or components.[191] Gordon then describes the process of Technology Sequence Analysis in greater detail:

> The process begins with the technologies at the left side of the matrix. Using a random number generator, the time of occurrence of each of the downstream technologies is determined. Suppose, for example, that a given path from one node to another is judged to have a 25 percent probability of taking three years, a 50 percent of taking five years, and a 75 percent of taking ten years or less. These estimates form a probability versus time curve. A random number between 0 and 100 is chosen; this number is used to enter the curve and produce a single estimate of the required time. If the node being considered is at an "and" point in the network, the latest date of the contributing technologies determines when the development occurs. Similarly, the earliest date of the possible technologies determines when an "or" node is assumed to occur. When this process is completed for all paths, a single scenario will result. In this scenario, the anticipated sequence of events is the path through the network; in turn, this path leads to an estimate of the time of availability of the end system.[192]

[191] Ibid., 4.

[192] Ibid., 5.

If the entire path from the most basic components on the left to the finished system on the right consisted only of AND nodes, with no alternate OR nodes, Monte Carlo simulations would not be necessary; rather, the sequence of contingent probabilities could be calculated simply. In Gordon's example from above, since the five critical sub-systems are all AND nodes, if their estimated probabilities of being completed within five years are Guidance (80% likelihood), Position Sensing (95% likelihood), Ripeness Sensing (78% likelihood), Cleaning (93% likelihood), and Packaging (54%), the estimated probability of a Harvesting Robot being completed within five years is the product of these dependent probabilities, or about 30%—only if those critical sub-systems are not themselves dependent upon enabling technologies, for which several alternative solutions are available; however, since most notional technological systems may be actualized through various alternate combinations of components or technical solutions for sub-systems, Monte Carlo simulations are almost always necessary as a part of Technology Sequence Analysis.

D. FUTURES STUDIES: METHODOLOGIES: SCENARIO ANALYSIS

I have chosen to give scenario analysis more extensive attention than I have provided other futures studies methodologies discussed thus far because, of these methodologies, scenario analysis, along with the Delphi technique, the nominal group technique (NGT), and Technology Sequence Analysis, holds the greatest promise as a part of the tool kit for a "devil's toy box" analysis. Developments in technologies are only a portion of what a "devil's toy box" analytical team must consider. Equally as important are the human motivations that drive the uses and misuses of those emerging technologies—the religious, political, ideological, and emotional desire factors that could influence human actors to seek to harm or threaten to harm their fellow men and women using new tools and new strategies. These factors are better considered through a scenario analysis than any of the more formalized techniques mentioned earlier.

Nicole Rijkens-Klomp and Patrick Van Der Duin, in their review of local and national public foresight studies, define scenario analysis as "the systematic analysis of a

variety of uncertainties combined into distinctive stories about the future."[193] Amara praises the use of scenarios as a form of descriptive, qualitative forecasting. He defines a scenario as "nothing more than a description of an internally consistent, plausible future," one that does not make a claim to be a prediction.[194] Herman Kahn and Anthony J. Wiener, two futurists associated with RAND who made prolific use of the scenario analysis technique in their writings, have this to say regarding the technique: "The scenario is suited to dealing with events taken together—integrating several aspects of a situation more or less simultaneously. Using a relatively extensive scenario, the analyst may be able to get a feeling for events and the branching points dependent upon critical choices. These branches can then be explored more or less systematically or the scenario itself can be used as a context for discussion or as a 'named' possibility that can be referred to for various purposes."[195] They go on to caution that "if a scenario is to seem plausible to analysts and/or policy-makers it must, of course, relate at the outset to some reasonable version of the present, and must correspond throughout to the way analysts and/or policy-makers are likely to believe decision-makers are likely to behave. Since plausibility is a great virtue in a scenario, one should, subject to other considerations, try to achieve it. But it is important not to limit oneself to the *most* plausible, conventional, or probable situations and behavior." Since history is replete with surprises, "…we should expect to go on being surprised."[196] Along those lines, they list as a key advantage of the scenario analysis technique that it helps to "illuminate the interaction of psychological, social, economic, cultural, political, and military factors, including the influence of individual political personalities upon what otherwise might be abstract considerations, and they [scenario

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[193] Nicole Rijkens-Klomp and Patrick Van Der Duin, "Evaluating Local and National Public Foresight Studies From a User Perspective," *Futures* 59 (2014), 18, http://dx.doi.org/10.1016/j.futures.2014.01.010.

[194] Roy Amara, "A Note on What We Have Learned About the Methods of Futures Planning," *Technological Forecasting and Social Change* 36(1989), 44.

[195] Herman Kahn and Anthony J. Wiener, "The Use of Scenarios," in *The Futurists*, ed. Alvin Toffler (New York: Random House, 1972), 161.

[196] Ibid., 163.

analyses] do so in a form that permits the comprehension of many such interacting elements at once."[197]

This last point is especially pertinent to my "devil's toy box" analysis, which must bring social, political, religious, and psychological elements into cognitive play to have any success whatsoever. The mere existence and availability of a new technology that offers the potential for malign uses are not enough, by themselves, to cause that technology to be used for harm. Other questions must be asked to get a better notion of the likelihood of such harmful use—are there aspects of the technology that make it especially appealing to the adherents of an extremist ethnic, religious, or political group? Would use of the technology fit within an extremist group's ideology, worldview, and goals, or would using the technology violate a taboo sacred to that group? What are the levels of skill and technical expertise required to make effective, malign use of the technology, and are such skill levels and expertise found among members of the extremist groups under consideration? These are questions not easily framed within the other methodologies used by futurists; however, they may easily be accommodated within the bounds of a detailed scenario analysis.

A recent example of governmental scenario analysis in an American context is the Federal Emergency Management Agency's Strategic Foresight Initiative of 2010–2011, which resulted in a monograph entitled *Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty*. In attempting to project the sorts of environments that may be faced by emergency response planners and operatives in 2030 and the needs of those future emergency responders, the Strategic Foresight Initiative focused upon social and technological drivers, including technological innovations and resulting societal dependencies. The Initiative also considered changing U.S. demographics; environmental drivers, including potential climate changes; and economic and political drivers, including the likelihood that future budgets made available for government programs will be lower than present-day budgets. The Strategic Foresight Initiative Scenario Workshop developed five different scenarios for the possible world of

[197] Ibid., 161.

2030. These included "Quantum Leap" (the U.S. economy is strong and vibrant, but the country is challenged by severe climactic changes and malign uses of new technology), "Bet on the Wrong Horse" (the U.S. economy is lethargic, with frequent recessions; climate change has stabilized, but federal and state governments are under constant fiscal pressure made worse by a massive population migration from rural to urban areas), "Dragon vs. Tiger" (following a depression, the U.S. economy has strongly rebounded, and the country has fully modernized its infrastructure following a series of federal bailouts of state governments, but foreign crises threaten, including the possibility of nuclear war breaking out), "Treading Water" (a worst-case scenario, with the U.S. economy in its worst shape since the Great Depression, worsening climate change, and social unrest caused by poverty, dissention, and pandemics), and "Dude, Where's My Sovereignty?" (the U.S. economy chronically lags behind that of its competitors, climate events are severe, the federal government is weak, and regions are influenced both by powerful state governments and by foreign influences). Over a four-day period, 60 members of the emergency management community, drawn from federal, state, and local agencies, were divided into five teams and then immersed in one of the five scenarios, wherein they role-played their own roles as they would be impacted by these varying imagined environments of 2030. The scenario exercises resulted in a list of 15 common strategic needs, formulated in post-workshop analysis sessions.[198]

Peter Schwartz, who has used scenario building and scenario analysis extensively throughout his career as a futurist, offers the following eight steps for constructing scenarios:

- Step One—Identify the primary focal issue around which the scenario will revolve. What challenges are faced by your organization or company? What are the looming decisions that will need to be made? (For a "devil's

[198] Federal Emergency Management Agency, *Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty—Progress Report Highlighting the 2010—2011 Insights of the Strategic Foresight Initiative* (Washington, DC: Federal Emergency Management Agency, 2012), 1–12, https://www.fema.gov/media-library-data/20130726-1816-25045-5167/sfi_report_13.jan.2012_final.docx.pdf.

toy box" analysis, this would be selecting one over-the-horizon technology of concern, or a cluster of emerging and existing technologies which might be combined in a new and malign way.)

- Step Two—Identify the environment factors that will influence the success or failure of your organization's or company's strategy. This could include the availability of budgetary and material resources, the capabilities of competitors, the regulatory environment, the overall economic climate, and the political climate. (For a "devil's toy box" analysis, the team would want to consider whether the political climate might contribute to the rise of new extremist groups or the rebirth of old ones, and whether changes in the economy and in social acceptance of technologies might be creating new societal vulnerabilities; for example, the Internet-of-Things making household appliances, climate controls, and security features vulnerable to hacking.)

- Step Three—Identify those specific driving forces that will have a significant impact on your organization or company. (For a "devil's toy box analysis, the team would explore whether any formerly exclusive and expensive technologies of interest have recently become affordable for the typical consumer or soon will become affordable, transforming restricted technology formerly only available to well-funded scientists, universities, or government or military agencies into Promethean technology. The team could also research whether any new extremist groups are gaining traction domestically or internationally, and what those groups' goals might mean for homeland security.)

- Step Four—Rank key factors and driving forces on the criteria of the strength of their relationship to the success or failure of your organization's or company's strategy, and on the degree of uncertainty of those key factors and driving forces. The aim in this step is to identify a

small group of factors and forces that are high on significance to success/failure *and* on uncertainty.

- Step Five—Select the logics of the scenarios by arraying the key factors and driving forces that are high in both significance and uncertainty along a spectrum (one axis), a matrix (two axes), or a volume (three axes). If you chose three axes, you end up with eight possible scenarios, assuming each separate scenario will be either high or low on each axis (High-High-High, High-High-Low, High-Low-Low, High-Low-High, Low-Low-Low, Low-Low-High, Low-High-High, or Low-High-Low). The number of possible combinations would be extended if key factors and driving forces are arrayed along more axes or Low-Moderate-High rather than just Low-High. Do not assemble the scenarios mechanically, however. You want to keep the number of scenarios manageable, so decide which ones make the most sense in terms of internal consistency and plausibility. In the FEMA Strategic Foresight Initiative exercise discussed earlier, the axes selected by the analysts included the state of the U.S. economy, climate/weather, the state of infrastructure, the health of states and localities, and major threat vectors.

- Step Six—Flesh out the selected scenarios. Create plots that realistically bring the story forward from the present situation to the future situation portrayed by the scenario. Decide whether any key personalities or leaders might facilitate the progress from the present situation to the situation of the scenario.

- Step Seven—Determine the implications of the scenarios for your organization or company. Will your organization thrive or wither in the future world of the scenario? What are the implications of the scenario for the success or failure of your organization's strategy and goals?

- Step Eight—Select leading indicators that will indicate that a scenario is on its way to becoming actualized. These leading indicators will typically consist of a movement in one of the key factors and driving forces identified in Steps Three and Four. Then monitor those leading indicators.[199]

E. FUTURES STUDIES: BEST PRACTICES

Scenario Analysis: Peter Schwartz offers the following suggestions regarding best practices for scenario analysis. He cautions against identifying only three scenarios to work with, as participants in the analysis will tend to identify the one in the middle as the most likely scenario and then treat that scenario as a single-point forecast, which, in Schwartz's mind, defeats the whole purpose of scenario analysis. He suggests four scenarios as an optimal number for a single session of scenario analysis, saying that five or more scenarios tend to blur together in participants' minds; however, the facilitators of FEMA's Strategic Foresight Initiative chose to use a range of five scenarios. Schwartz also strongly recommends that facilitators avoid assigning probability figures to the different scenarios, as this will tend to lead participants to pay their full attention only to that scenario with the highest assigned probability. He further suggests that, in a group of four selected scenarios, two be of equally high probability and the other two be what he terms "wild card" scenarios, low-likelihood but high-impact. Interestingly, Schwartz focuses on the importance of coming up with memorable, evocative names for each scenario. He points out that well-named scenarios are more likely to attract the attention of upper management and are more likely to be adopted into the organization's collective memory and planning culture. Regarding choosing members of the scenario analysis team, Schwartz recommends that members of upper management be included, that a wide range of organizational units and functions be represented on the team, and that members, overall, be selected for their supple imaginations and their ability to work well with others in a team setting.[200]

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[199] Schwartz, *Art of the Long View*, 241–247.

[200] Ibid., 247–248.

Identifying and Analyzing Emerging Issues: Trudy Lang compiled a list of suggested best practices for the related activities of environmental scanning, issues management, and emerging issue analysis, drawn from her own observations and those of a range of futurists. She notes that the scanning team should be highly multi-disciplinary in its composition, to allow for the broadest possible range of vision, and she echoes Schwartz's view of the importance of the support and participation of upper-level managers. She suggests that the practice of scanning be routinized throughout the organization, rather than limited just to the time periods of a formal scanning and forecasting exercise or analysis, so that the participants become well-practiced in the activity and learn how to better recognize their own personal biases in selecting those signals they deem to be important. Additionally, she points out that an organization's environmental scanning practices tend to improve with time and that organizations develop systems and processes that work well for them, but that often cannot be directly copied by other organizations with success, due to those processes being interwoven with the originating organization's culture and personnel. Since different organizations will conduct scanning activities differently and likely identify different signals of interest, Lang suggests that organizations partner with one another and exchange their scanning reports on a regular basis. Also, recognizing that scanning is an inherently subjective activity, she strongly recommends that participants, when making their reports, clearly state up front their values and preconceptions that have influenced their scanning process.[201]

Cognitive Biases in Forecasting: Nicholas Rescher points to many cognitive biases that, if uncorrected for, tend to warp forecasts, resulting in false-positives, false-negatives, and omissions. The first of these is the tendency of prognosticators to exaggerate both the immanency and the scale of a predicted change or event—forecasters tend to pull predicted events closer in time to the present and to grant them greater magnitude. Another cognitive bias, which may be viewed in partial contradiction to the bias just mentioned (human beings are not necessarily notable for their internal consistency), is conservatism, or the tendency to assume that present conditions are more durable and lasting than they

[201] Lang, "Four Futures Methodologies," 16–17.

are, that the distinctive social, political, and economic features and patterns of the present will persist into the future. A related cognitive bias is what Rescher terms wishful or fearful thinking. Prognosticators tend to predict a future they prefer, either because they feel they ought to express such an opinion or because they hope that making such a prediction of a preferred future will increase the likelihood of that future becoming actualized. The flip side of wishful thinking is fearful thinking, or the tendency of prognosticators to have greater confidence in their expectation that what they most dread will come to pass. Rescher adds to his list of cognitive biases errors in judgments of probabilities, classing these as mistaken evaluations and mistaken combinations. As an example of the former, he provides the example of a coin-tosser who predicts the next toss will result in a "heads" because the last three flips have all resulted in "tails." Regarding the error of mistaken estimates of probabilistic combinations, Rescher points out the bettors (predictors) tend to overestimate the chances of long-shots becoming actualized, which is an overestimation of the likelihood of conjunctive events, while underestimating the likelihood of small-probability/large-consequence events happening, which is an underestimation of disjunctive events (as an example of the latter, he points out the repeated willingness of town planners and homeowners to build homes and businesses in flood plains).[202] Only by recognizing such common human cognitive biases can members of a "devil's toy box" analytical team take such biases into account and attempt to adjust for such biases in their predictions.

Putting the Pieces Together: Amy Webb, founder of the Future Today Institute, offers in her popular 2016 book, *The Signals are Talking*, a road map to lead prognosticators from environmental scanning to scenario development and refinement to scenario analysis. Her steps alternate between what she calls "flaring" and "focusing," the former being a widening of vision to encompass as much information and as many signaling indicators as possible, and the latter being a narrowing of vision to the specific environmental factors most pertinent to one's organization. Her six steps include:

[202] Rescher, *Predicting the Future*, 218–222.

- *Flaring at the fringe*—analysts are directed to brainstorm, consider many alternative points of view, and seek out views outside the mainstream (carry out Peter Schwartz's environmental scanning described in an earlier section).

- *Focusing to spot patterns*—Webb uses the acronym CIPHER (which stands for "contradictions, inflections, practices, hacks, extremes, and rarities") to suggest how an analyst should sift through the huge amount of material gathered in the "flaring at the fringe" step to focus on the most important signals, which are phenomena that correspond to the elements of her acronym.

- *Flaring to ask the right questions*—the analyst is directed to confront all his or her own beliefs and biases and to brainstorm counter-arguments to his or her own original assertions.

- *Focusing on the timing of trends*—analysts must try to determine how far along on their trajectories significant trends have progressed and when they might be expected to produce major changes in society.

- *Flaring to brainstorm scenarios and their accompanying action strategies*—in this step, analysts produce their scenarios based upon probable, plausible, and possible future states, determining likely consequences for their organizations under the conditions described in each scenario and developing strategies to mitigate or take advantage of those scenario-based consequences.

- *Focusing to pressure-test (or red team) their chosen strategies*—analysts game-play their chosen strategies within the worlds of each scenario to better understand the potential outcomes of taking these actions, to brainstorm possible second-order and third-order consequences, and to

construct a well-reasoned prediction regarding whether taking the chosen actions will lead to a desired future.[203]

F. HOW ACCURATE CAN EXPERT PROGNOSTICATION BE? THE 1964 RAND CORPORATION STUDY OF FORECASTING TECHNOLOGICAL AND SOCIAL TRENDS (A CASE STUDY)

Despite Roy Amara's qualification, quoted at the beginning of the introductory Section on futures studies, that prediction is not the objective of the futurist, the methods of futurism/futures studies have been used in attempts to forecast the likelihood of future events occurring within certain timeframes. Some of these studies were conducted decades ago, which grants a present-day reviewer the benefit of being able to judge the accuracy or inaccuracy of such studies' predictions. In 1949, Kaplan and his associates at the RAND Corporation, in testing the ability of their new technique to predict future social and technological developments, felt compelled to limit themselves to considering only those events whose occurrence could be verified within a five-month timeframe; however, fifteen years later, their colleagues at RAND carried out a more ambitious study of the ability of experts, when their opinions were amalgamated and honed by the Delphi technique, to successfully predict a wide range of technological and social developments over a long-term time envelope. Given our more than half a century of hindsight since that study, how well did those experts perform?

In 1964, the RAND Corporation carried out an experimental use of the Delphi technique to perform a long-range forecast of technological and social trends in six key areas of inquiry. These areas included weapons systems; techniques of war prevention; developments in space exploration, exploitation, and colonization; automation; population control; and general scientific breakthroughs. Six Delphi procedures were conducted, corresponding to the six areas of forecasting inquiry, and for each of six procedures, facilitators recruited a separate set of experts. In total, the facilitators approached 150 experts, of whom 82 chose to respond to at least one Delphi questionnaire. Although the

[203] Amy Webb, *The Signals are Talking: Why Today's Fringe is Tomorrow's Mainstream* (New York: PublicAffairs, 2016), 264–266.

participants were instructed to only respond to those questionnaires relating to their field of forecasting inquiry, all the questionnaires from all six areas of inquiry were shared with all participants. Each panel of experts was asked to respond to four sequential Delphi questionnaires, which were shared with the participants at two-month intervals, approximately. Thus, 24 Delphi questionnaires were addressed in total, and the aggregate group of 82 expert participants submitted 348 completed questionnaires.[204]

A few years later, in 1967, Brownlee Haydon wrote a monograph, *The Year 2000*, which compiles and discusses two lists of the predictions produced by Gordon's and Helmer's 1964 Delphi study, one for developments to have taken place by 1984 (20 years out from the time of the study) and the second for developments to have taken place by 2000 (36 years out from the time of the study).[205] As we are well past both 1984 and 2000 and thus have the benefit of hindsight, an examination of these lists of date-anchored prognostications provides an illuminating opportunity to roughly gauge the accuracy of a set of long-range forecasts produced by the Delphi method *under the set of conditions for which it was designed*—those conditions including the recruitment of panels of technological experts and the provision of sets of questions that are intellectually challenging and that call directly upon the expertise of the participants, as opposed to a laboratory setting using participants recruited for convenience, rather than expertise, and posing questions of limited interest to the participants (see the earlier Section of this thesis that summarizes Rowe's and Wright's criticisms of laboratory tests evaluating the accuracy of predictions of Delphi procedures versus other opinion-elicitation techniques). The following two Tables, Table 3 and Table 4, list the 1984 and 2000 predictions discussed by Haydon and evaluate how accurate those predictions have proven.

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[204] T. J. Gordon and Olaf Helmer, *Report on a Long-Range Forecasting Study* (*P-2982*) (Santa Monica, CA: RAND Corporation, September 1964), 2–6, https://www.rand.org/content/dam/rand/pubs/papers/2005/P2982.pdf.

[205] Haydon, *The Year 2000*, 8.

Table 3. Accuracy of Predictions from 1984 Long-Range Forecasting Delphi Study

COLOR KEY:	Accurate Within + 5yrs	Accurate Outside + 5yrs	Inaccurate

Prediction	Category	Predicted by Date	Occurred by Date	Comment on Accuracy
Organs commonly transplanted; artificial organs used	Scientific advances	1984	1982	Jarvik-7 artificial heart implanted[206]
Wide use of personality-altering medications	Scientific advances	1984	1987	Approval of Prozac, the first SSRI antidepressant[207]
Wide use of sophisticated teaching machines in schools	Scientific advances	1984	1983	Apple computers in wide use in schools as learning aids[208]
Automated libraries	Scientific advances	1984	1990	Invention of first web browser[209]
Automatic translating machines	Scientific advances	1984	2006	Introduction of Google-sourced translating service for web pages[210]
Universal satellite communications, worldwide coverage	Space exploitation	1984	1969	Global satellite coverage achieved[211]
Permanent lunar base	Space exploitation	1984	N/A	Has not occurred
Manned fly-bys of Venus and Mars	Space exploitation	1984	N/A	Has not occurred
Space laboratories	Space exploitation	1984	1973	Skylab, Mir, International Space Station
Directed energy weapons (lasers)	Weapons	1984	1985	Test laser successfully downs a Titan missile booster[212]
World population of 5.1 billion	Population	1984	About 1988	Actual 1984 world population was 4.85 billion[213]
Large-scale ocean farming	Scientific advances	1984	N/A	Has not occurred
Large-scale production of synthetic proteins	Scientific advances	1984	N/A	Has not occurred
Commercial nuclear fusion	Scientific advances	1984	N/A	Has not occurred
Regional weather control	Scientific advances	1984	N/A	Has not occurred
General immunization against viral and bacterial disease	Scientific advances	1984	N/A	Has not occurred
Primitive forms of artificial life produced in labs	Scientific advances	1984	2010	First synthetic bacterium[214]
Correction of genetic defects through genetic engineering	Scientific advances	1984	About 2017	Being developed currently
Deployment of a universal language	Scientific advances	1984	N/A	Has not occurred
Mining of propellant elements on the Moon	Space exploitation	1984	N/A	Has not occurred
Manned landing on Mars	Space exploitation	1984	N/A	Has not occurred
Permanent unmanned research stations on Mars	Space exploitation	1984	N/A	Has not occurred
Commercial transport by ballistic missile	Space exploitation	1984	N/A	Has not occurred
Military weather manipulation	Weapons	1984	N/A	Has not occurred
Anti-ballistic missile defense by ABM missiles and directed energy	Weapons	1984	2010	Successful American tests of modern ABM missile systems[215]
World population of 7.4 billion	Population	2000	About 2020	Actual 2000 world population was 6.08 billion; projected 2020 population is 7.58 billion[216]

Table 4. Statistical Breakdown of Accuracy of Predictions from 1984 Long-Range Forecasting Delphi Study

Predictions Category	Accurate Within + 5yrs	Accurate Outside + 5yrs	Inaccurate	TOTALS
Scientific Advances	3 (21.4%)	5 (35.7%)	6 (42.9%)	**14 (100%)**
Space Exploitation	1 (12.5%)	1 (12.5%)	6 (75%)	**8 (100%)**
Weapons	1 (33.3%)	1 (33.3%)	1 (33.3%)	**3 (100%)**
Population/Ecology	2 (50%)	1 (25%)	1 (25%)	**4 (100%)**
Automation	2 (66.6%)	1 (33.3%)	0 (0%)	**3 (100%)**
War/Politics	2 (66.6%)	0 (0%)	1 (33.3%)	**3 (100%)**
TOTALS	**11 (31.4%)**	**9 (25.7%)**	**15 (42.9%)**	**35 (100%)**

For purposes of analysis, I will lump together the "accurate within + 5 years" and "accurate outside + 5 years" figures as "success" or "accuracy;" the success rate is seen to be 57.1% for predictions made for 1984 (20-year window) and for 2000 (36-year window). My reason for doing so is the nature of a "devil's toy box" analysis. Given that the ultimate purpose of such an analysis is to support the selection of research and development projects that will likely take three to five years to bring countermeasures to operational fruition and deployment, it does not matter that the analysis team predicts that a malign use of technology will eventuate in five years, and then that threat does not actualize for nine years. In terms of Table 4, "accurate outside + 5 years" still counts as a "win." The countermeasure would be in place and available when the anticipated threat finally makes its nasty debut.

Most of the predictions categories have too few data points to allow for meaningful comparison between them; however, the fact that the predictions category of space exploitation stands out from both the other categories and from the overall results in terms of its relatively high inaccuracy rate suggests a factor that bears consideration. The experts were wrong in this area three-quarters of the time. This points to a key weakness in trend extrapolation. Clearly, none of the assembled experts could foresee the dramatic shift in political support for the manned space program following the completion of the successful Apollo landings on the Moon. Apparently, all the respondents assumed that the massive governmental effort that culminated in the Moon landings and America's victory over the Soviet Union in the Space Race would continue well into the future; however, a combination of political, social, and economic shifts caused NASA to shrink to a shadow

of its former self less than a decade after the 1964 RAND forecasting study. The intensification of the America's involvement in the Vietnam War combined with the fiscal consequences of Lyndon Johnson's Great Society and its expansion of the welfare state to produce high inflation and budgetary pressures, making NASA's expensive manned space program a tempting target for deficit hawks. The social movements of the 1960s—racial equality, women's rights, environmentalism, the drug culture, the anti-war movement, and the self-actualization movement—resulted in a cultural shift, wherein an increasing portion of voters questioned why America should be spending such enormous sums in space when so many social problems needed to be solved on Earth. The Oil Shock of 1973 caused many Americans to question the country's national paradigms of continual economic and technological progress, and the Watergate crisis of 1974 reduced many American's faith in the trustworthiness and competence of their federal government. These various shifts and trends, all "black swans" from the perspectives of the prognosticators of 1964, combined into a "perfect storm" for America's manned space program. From 1973 on, the best NASA could accomplish on its limited budgets and shrunken mission scope was to cobble together a short-lived space laboratory, Sky Lab, from the left-over parts of the Apollo Program, and launch its expensive and unreliable fleet of "space buses," the Space Shuttles, into low Earth orbits. The 1964 RAND prognosticators were not the only futurists to fail to see the coming diminishment of America's manned space program, however. Out of the many dozens of science fiction writers active in the late 1960s and early 1970s, only two foresaw NASA's diminution. These were British author J. G. Ballard, who predicted in numerous short stories that America would abandon space exploration due to boredom (perhaps not too far from the truth), and American author Barry N. Malzberg, who wrote that America's national space program would be undone by a plague of astronaut mental illnesses brought about by a combination of the harshness of the space environment and NASA's bureaucratic pathologies.

Robert H. Ament, a member of the Institute for the Future, performed an analysis like mine of the 1964 RAND study five years after the study's conclusion; his analysis focused on the accuracy of the study's short-term forecasts and was published in the March 1970 edition of the journal *Futures*. His primary finding was that, of the 22 events predicted

by the RAND study's participants as having at least a 50% likelihood of occurring by 1970, 15 had occurred (68.2%), five had not (22.7%), and the occurrence of two events was uncertain (9.1%).[206] A comparison of the higher accuracy rate Ament found for the five-years-out forecasts to the lower rate I determined for the 20–years-out and 36–years-out forecasts makes intuitive sense; the closer a prognosticator is in time to a predicted future, the better/weightier the available data is, since current data points will have less time to be affected by change than they would in a longer-term prognostication.

To put these figures into perspective, in Table 5, I compare the 57.1% success rate I have calculated for the 1984 and 2000 RAND 1964 Delphi study predictions (long-term) and the 68.2% success rate Ament calculated for that study's predictions within a five-year envelope (medium-term) with the results Kaplan et al. reported from their 1949 study of short-term (five-month envelope) predictions of social and technological developments:[207]

Table 5. Accuracy Rates of Various Experiments in Prediction of Social and Technological Events and Developments, Short-Term, Medium-Term, and Long-Term, Ranked (Ascendant) by Accuracy

Experimental Cohort Type	Prediction Period Covered	Success Rate
1949 Kaplan, Worst-informed predictors (bottom half)	Short-term	50%
1949 Kaplan, Independent group	Short-term	52%
1949 Kaplan, All predictors	Short-term	53%
1949 Kaplan, Best-informed predictors (top half)	Short-term	56%
1964 RAND Delphi	**Long-term**	**57.1%**
1949 Kaplan, Cooperative group (predictors conferred, then made independent estimates)	Short-term	62%
1949 Kaplan, Mean prediction	Short-term	66%
1949 Kaplan, Joint group (predictors conferred, then delivered consensus estimates)	Short-term	67%
1949 Kaplan, Plurality prediction	Short-term	68%
1964 RAND Delphi	**Medium-term**	**68.2%**
1949 Kaplan, Best individual predictor	Short-term	71%

[206] Gordon, "The Current Methods of Futures Research," 174.

[207] Table figures for the 1949 Kaplan et al. study taken from Kaplan, Skogstad, and Girshick, "Prediction of Social and Technological Events," 104.

My assumption is that accuracy of prediction becomes more and more difficult the longer the time envelope is stretched, since knowledge currently held, even that held by experts, becomes progressively less pertinent with the passage of time and the intervention of fresh events. Given the relative levels of difficulty of their tasks, the improvement in predictive accuracy associated with the participants in the 1964 Delphi study seems notable. In making predictions within a five-year envelope, the 1964 Delphi participants performed on par with the accuracy displayed by the most accurate group cohort of the 1949 Kaplan study, who only had to make predictions within a five-month envelope, one-twelfth the length; and the accuracy rate for the 1964 Delphi participants on long-range forecasts, those with a 20–year envelope and a 36–year envelope, was not too far behind at 57.1%.

As mentioned above, an analytical team working a "devil's toy box" analysis should be operating within a forecasting envelope with a minimum of five years, the approximate amount of time required for a HSARPA-type R&D project to reach fruition and achieve deployment (HSARPA's Homeland Innovative Prototypical Solutions, or HIPS, projects, those with a moderate to high risk of failure, were expected to deliver significant new capabilities in prototype form within two to five years).[208] Achievement of a prediction success rate of 68%, better than two-thirds accuracy, equivalent to the medium-term (five-year envelope) success rate of the 1964 Delphi participants, would be a laudable accomplishment for a "devil's toy box" analysis team. Given the advances in automated information-gathering, amalgamation, and analysis tools since 1964, represented by innovations such as IARPA's FUSE tool and recently deployed commercial Big Data analysis tools (to be discussed in Chapter 9)—also taking into consideration improvements in judgment quality over a standard Delphi procedure promised by my amalgamation of "best-of-kind" features of existing forecasting techniques—a present-day

[208] Department of Homeland Security, *The Science and Technology Directorate's Processes for Selecting and Managing Research and Development Programs* (OIG-08-85) (Washington, DC: U.S. Department of Homeland Security, Office of Inspector General, August 2008), 8, https://archive.org/details/241114-oig-08-85-the-science-and-technology.

“devil’s toy box” analysis team should be able to *better* the predictive performance of the 1964 Delphi group.

* * * * *

How can a “devil’s toy box” analytical team avoid or ameliorate the cognitive biases in forecasting identified by Nicholas Rescher? How can such an analytical team follow the dictates of Herman Kahn and Anthony J. Weiner to pay as much attention to subjective human factors—the political, ideological, cultural, religious, and psychological drivers that influence human actors to seek to harm or threaten to harm their fellow men and women—as they do to trends in emerging technological capabilities and those capabilities’ availability to members of the general populace? How can such a team follow Peter Schwartz’s and Amy Webb’s recommendations to consider a broad range of perspectives and “flare at the fringe” to capture ways of thinking outside the mainstream? Red-teaming, a discipline originally developed for military organizations, offers a “devil’s toy box” analysis team, an additional set of analytic tools, and cognitive correctors that are useful for analyses of competitive situations involving attackers and defenders… such as the ever-crafty devil and ever-bedeviled shield-makers who populate the parable at the heart of this thesis.

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VI. RED TEAMING

A. RED TEAMING: INTRODUCTION

The concept of red-teaming has become central to U.S. military operations. In Army doctrine, red teams are expected to provide alternative analysis (adding the "red view of red" to traditional intelligence products' "blue view of red"), decision support, and threat emulation. The U.S. Army established a school at the University of Foreign Military and Cultural Studies, located at Fort Leavenworth in Kansas, to teach red-teaming techniques. When carrying out large-scale red-teaming operations and analysis, unified commands may call upon red team members from a variety of sources, including the Defense Intelligence Agency (DIA), the Navy Warfare Development Command, the Army Directed Studies Office, the National Defense University, the various service academies, and the Center for Strategic and International Studies, in addition to graduates of the University of Foreign Military and Cultural Studies.[209]

Colonel Gregory Fontenot (U.S. Army, Retired), defines red-teaming as "a structured and iterative process executed by trained, educated, and practiced team members with access to relevant subject matter expertise" that "provides the commander with an independent capability to continuously challenge OE [operational environment] concepts, plans, and operations from partner and adversary perspectives … emphasiz(ing) technical issue and vulnerability analysis, focusing on capabilities rather than the enemy's potential use of those capabilities … (and) provid(ing) a means to build intellectual constructs that replicate how the enemy thinks."[210] He traces the practice's origin to the *kriegspeils* (wargames) instituted by the nineteenth century German army to train its officers.[211] The U.S. Marine Corps defines red-teaming as "role-playing the adversary."[212]

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[209] *Armed Forces Journal*, "A Better Way to Use Red Teams."

[210] Gregory Fontenot, "Seeing Red: Creating a Red-Team Capability for the Blue Force," *Military Review* 85, 5 (September–October 2005): 4-5.

[211] Ibid., 5.

[212] Longbine, *Red Teaming: Past and Present*, 6.

From a look at these definitions, the reader can see that red-teaming introduces something new to the tool kit I have been seeking to assemble for a "devil's toy box" analysis team. The uses described so far for techniques such as Delphi, the nominal group technique, and even futures studies techniques such as scenario analysis have tended to regard the development of technology and its uses from a scientist's, engineer's, or technologist's point of view, asking such questions as, what are the antecedents of these technologies? What are the physical and operational constraints of the technologies? What are the likely diffusion curves throughout society? What aspects of society are likely to portend greater acceptance for a technology or cause it to be rejected? The focus is on the technological development and society's reaction to that technological development, or the relationship between society and a new technology; that relationship may be harmonious and a source of societal happiness, or it may introduce unwelcome disruptions (oftentimes both simultaneously). Red-teaming, however, focuses on conflict, the ever-shifting balance between attackers and defenders. When analysts look at new technologies through a red-teaming lens, they focus on the advantages or disadvantages that those new technologies may offer to attackers and defenders within a sector of interest. The answers may not always be straightforward, for the gifts of technology are often two-sided (or multi-sided). For example, whereas the introduction of the Internet of Things offers security managers of facilities new abilities to remotely control defensive features of the facilities for which they are responsible, at the same time it brings new vulnerabilities stemming from the new potential for attackers to remotely hack into control systems that they formerly would have needed to directly physically access.

Also, the red-teaming lens encourages defenders to look at the sector of interest through the eyes of potential attackers, taking the antagonists' motivations, fears, and strengths and weaknesses into account. Conversely, attackers are encouraged to look at the sector through the eyes of the defenders. Questions that can be addressed include: why is a target more attractive to a certain type of attacker than another? What makes a type of weapon or mode of attack more attractive to a certain type of attacker? Given the cultural, social, and psychological background of a certain type of attacker, how might a mode of defense be adjusted or improved to take advantage of that attacker's vulnerabilities, taboos,

or fears? (Bob Kane, creator of Batman, intuitively recognized this aspect of red-teaming. In the Batman origin story from the November 1939, issue of *Detective Comics*, Kane has Bruce Wayne mull to himself, "Criminals are a superstitious cowardly lot, so my disguise must be able to strike terror into their hearts." Just then, in one of the most famous coincidences in popular culture, a bat flies through Wayne's open window, inspiring him to create and don his iconic costume.[213] Thousands of Batman stories published or filmed since 1939 have focused upon the great advantage Batman, who, unlike Superman or Wonder Woman, lacks any superpowers, derives from his criminal enemies' superstitious fears, exploited by Batman's ghastly uniform and aspect. Stepping outside of one's accustomed frame of reference allows for otherwise non-obvious insights to surface. Had Bruce Wayne not been striving to see through the eyes of his antagonists, he would have simply shooed the bat back through the window with a broom, or more likely yelled for his butler Alfred to do it.)

Dr. Mark Mateski, in his *Red Teaming: A Short Introduction*, provides nine definitions of red-teaming from various military, government, and scholarly sources. In comparing them, he points out that their common elements are bringing to the fore an adversary's or competitor's point of view, and they are assisting decision makers to make the best possible choices or to optimize systems.[214] Mateski asserts that red-teaming is a type of alternative analysis whose function is to assist leaders in making good decisions by aiding them in avoiding rigidity and countering surprise. He states that red-teaming does this through drawing on the benefits of a variety of alternative analysis techniques, including "key assumptions checks; devil's advocacy; Team A/Team B; red cell exercises; contingency 'what if' analysis; high-impact/low-probability analysis; [and] scenario development."[215] He divides red-teaming activities into two categories, passive and active, assigning each category two purposes. Passive red-teaming encompasses the purposes of helping decision makers better *understand*—how adversaries think; how adversaries view

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[213] Bob Kane and Bill Finger, "The Batman Wars Against the Dirigible of Doom," *Detective Comics* no. 33 (November 1939).

[214] Mateski, *Red Teaming: A Short Introduction*, 22-31.

[215] Ibid., 1–7.

the defending organization; what sorts of biases and assumptions are held by the defending organization—and better *anticipate*—adversaries' potential courses of action; which of defender's vulnerabilities are most likely to be exploited; potential surprises to be avoided. Active red-teaming encompasses the purposes of *testing* (probing/penetrating defender's systems or security; identifying vulnerabilities and determining how far those vulnerabilities can be exploited; demonstrating adversaries' likely moves and the defender's countermeasures interactively) and *training* (teaching defenders how potential adversaries think and how those adversaries might operate; preparing defenders to deploy effective countermeasures).[216]

Major David F. Longbine of the U.S. Army describes the key roles of red-teaming as challenging stale, outdated, or false thinking in an organization through filling the role of "devil's advocate," strongly challenging what is accepted as "conventional wisdom," plus providing a set of alternative analyses. Red-teaming grants decision makers with alternative perspectives by describing the operational environment as it might be seen through the eyes of allies and partners, adversaries, or other actors within the environment. The goal of red-teaming, in his view, is to avoid common perceptual errors such as mirror imaging (assuming that one's adversaries or allies share one's own motives, values, and cultural concepts) and ethnocentrism (the belief in the superiority of one's own culture), which can lead a decision maker to underestimate an adversary's skills, abilities, or determination.[217] Additionally, red-teaming helps decision makers avoid falling into the pernicious trap of group think, wherein a group of experts, all sharing a similar world view and coming from similar backgrounds, tend to reinforce one another's viewpoints and solidify a group sense that the right decisions are being made.[218]

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[216] Ibid., 40-41.

[217] Longbine, *Red Teaming: Past and Present*, 8-15.

[218] Ibid., 67.

B. RED TEAMING: METHODOLOGIES

The U.K. Ministry of Defence, in its *Red Teaming Guide*, divides red-teaming activities into a framework with three phases—diagnostic, creative, and challenge—that produce a final red team product. The diagnostic phase concentrates upon the identification of flawed assumptions and gaps in existing knowledge. The creative phase emphasizes brainstorming and various types of alternative analyses (that may include "what if?" and alternative futures analyses, as well as outside-in thinking). The challenge phase seeks to compare competing views, as well as challenge commonly held assumptions, and may include the analytical techniques of devil's advocacy, high impact/low probability analysis, wargaming, or team A/team B analysis. Red teamers may move back and forth between these three phases throughout the process.[219]

According to the University of Foreign Military and Cultural Studies' *Red Team Handbook* (version 6.0, April 2012), the key questions for a red team to ask themselves at all stages of their operations and analyses include:

What if…?	alternative analysis
What are the objectives of…?	consideration of enemy, partner, and others on the battlefield
What about…?	identification of gaps, seams, vulnerabilities
What are we missing…?	identification of gaps, seams, vulnerabilities
What happens next…?	identification of branches and sequels
What should we assess…?	identification of measures of effectiveness
How can we assess…?	
How do we know success…?	
What worked and why?	enables a learning organization
What did not work and why?	avoid patterns of operations[220]

[219] United Kingdom Ministry of Defence Development, Concepts and Doctrine Center, *Red Teaming Guide*, 3-1 – 3-7.

[220] University of Foreign Military and Cultural Studies, *Red Team Handbook* (version 6.0), 10-11.

Additionally, the UFMCS's *Red Team Handbook* describes numerous types of structured analytical techniques that may be used during the process of red-teaming, several of which are especially appropriate for a "devil's toy box" analysis. All the following techniques can be useful in answering the "Evil Genius" questions listed earlier. These techniques may be separated into *brainstorming techniques* and *techniques to challenge conventional wisdom and group think*. The results of these various analyses are then summarized in a *threat matrix*.

1. Brainstorming Techniques

- ***Pre-mortem Analysis***: Developed by Dr. Gary Klein, this technique involves red team members imagining a fiasco, then brainstorming all the possible reasons as to why the catastrophic failure occurred.[221]

- ***Indicators or Signposts of Change***: Red teamers assemble a list of significant, observable events that would indicate that a trend likely to have an impact upon homeland security is occurring or about to occur. They identify competing hypotheses or scenario, then separate out lists of happenings, statements, or publications that would be expected for each to occur, and regularly review the lists of indicators to see which of the signifiers has experienced change or a shift in the direction predicted. The team then decides upon the most likely hypothesis or scenario based upon the number of indicators that have experienced the predicted change.[222]

- ***High-Impact/Low-Probability Analysis***: This is a brainstorming technique that seeks to analyze events which the red team members consider highly unlikely but which, should they occur, would result in catastrophic consequences. Members are called upon to identify potential ways in which the unlikely event could be actualized, possibly triggered as the unforeseen second- or third-order consequence of another occurrence

[221] Ibid., 163-165.

[222] Ibid., 180-182.

(such as a natural disaster). They then identify mitigations that could be undertaken to avert the catastrophe.[223]

- ***Brainstorming***: This is a structured method for eliciting unstructured, uncensored analysis. It involves a divergent thinking phase (six steps for the generation and collection of diverse, oftentimes conflicting ideas), followed by a convergent thinking phase (six steps involving the clustering of similar ideas, winnowing out of unreasonable outliers, and coming to agreement on which ideas will require further analysis).[224]

- ***Alternative Futures Analysis***: This technique is especially useful when examining a situation encompassing both many "known unknowns" and "unknown unknowns." Once a focal issue or threat vector is selected through interviews with experts, varying sets of critical or uncertain influencing forces are chosen to be placed on sets of axes, forming a series of futures matrixes that can be used to analyze potential alternative futures.[225]

2. Techniques to Challenge Conventional Wisdom and Groupthink

- ***Analysis of Competing Hypotheses***: Particularly effective when large amounts of data must be considered, this method involves the red team identifying all possible reasonable alternative hypotheses. They then prepare a matrix of supporting evidence for each alternative hypothesis, focusing on disproving as many hypotheses as possible, rather than proving one true. Additionally, they analyze how sensitive various hypotheses are to pieces of evidence (if an evidence node is removed, does the hypothesis then become unreasonable?), as well as analyze what types

[223] Ibid., 191-192.

[224] Ibid., 195-198.

[225] Ibid., 202-205.

of evidence not currently evident would need to be present for various hypotheses to be proven true.[226]

- ***Devil's Advocacy***: This technique allows a red team to challenge a strongly held consensus view by constructing the strongest possible case for a competing explanation, avoiding the pitfalls of groupthink and confirmation bias. It involves two activities: disproving the strongly held consensus view by uncovering evidence that was either faulty or ignored in the original analysis and proving the assertion opposite to the consensus view.[227]

- ***Team A/Team B***: This technique is suggested for occasions when two factions of a red team each hold competing views of a problem. It involves separating the team into two debating sub-teams, each of which assembles evidence for its own hypothesis and then presents that evidence in an oral debate format.[228]

- ***Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis***: The team, after settling on a situation or threat vector to analyze, creates a four-quadrant diagram (strengths, weaknesses, opportunities, and threats) and brainstorms entries for each quadrant.[229]

Most of these exercises will be discussed in greater detail in Chapter 9, the chapter in which I describe my fused predictive analytical technique, Pandora's Spyglass. In that chapter, I will explore adaptations of these exercises that make them more useful to a "devil's toy box" analysis.

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[226] Ibid., 184-186.

[227] Ibid., 186-189.

[228] Ibid., 189-191.

[229] Ibid., 2010-212.

3. Threat Matrix

As shown in Table 6, Sandia National Laboratories published a report, entitled *Categorizing Threat: Building and Using a Generic Threat Matrix*, which provides a graphical tool for ranking potential threat vectors/malign actors on a scale that combines seven measures of capability (divided between commitment and resources) into an overall, comparative level of threat.

Table 6. Generic Threat Matrix, Sandia National Laboratories230

THREAT LEVEL	THREAT PROFILE						
	COMMITMENT			RESOURCES			
					KNOWLEDGE		
	INTENSITY	STEALTH	TIME	TECHNICAL PERSONNEL	CYBER	KINETIC	ACCESS
1	H	H	Years to Decades	Hundreds	H	H	H
2	H	H	Years to Decades	Tens of Tens	M	H	M
3	H	H	Months to Years	Tens of Tens	H	M	M
4	M	H	Weeks to Months	Tens	H	M	M
5	H	M	Weeks to Months	Tens	M	M	M
6	M	M	Weeks to Months	Ones	M	M	L
7	M	M	Months to Years	Tens	L	L	L
8	L	L	Days to Weeks	Ones	L	L	L

In this matrix, "Intensity" refers to the level of dedication to his cause that the antagonist brings to an attack (is he willing to die for the cause, go to jail for the cause, or merely suffer minor inconvenience?). "Stealth" refers to the ability of the antagonist to keep his activities hidden. "Time" refers to the period required to plan, organize, supply, and carry out an attack and to the amount of time an antagonist is willing to commit to such

230 David P. Duggan, Sherry R. Thomas, Cynthia K. K. Veitch, and Laura Woodard, *Categorizing Threat: Building and Using a Generic Threat Matrix* (*SAND2007-5791*) (Albuquerque, NM: Sandia National Laboratories, September 2007), 23.

efforts. “Technical Personnel” refers to the number of subject matter experts (SMEs) who are required to carry out an attack successfully and to the number of SMEs the antagonist group can assemble on its behalf. “Cyber Knowledge” refers to the antagonist’s level of expertise in computer systems, computer networks, and computer security. “Kinetic Knowledge” refers to the antagonist’s level of expertise in the defender’s physical barriers and the methods with which to defeat those (explosives, firearms, camouflage, etc.). Finally, “Access” refers to an adversary’s level of accessibility to the target (if the target is a military base, does the antagonist work there as a contractor?).[231]

Members of a “devil’s toy box” analysis team would likely want to modify this generic threat matrix, since they need to be concerned not only with classifying the threat level from a universe of potential hostile actors, but, more crucially for their purposes, also with classifying the threat level from a universe of potential future technologies and combinations of future (and existing) technologies. They might opt to keep the seven measures of capability highlighted in the Sandia Laboratories generic threat matrix, but add the following measures taken from the “Evil Genius” study discussed earlier: (a) consequences of prompt effects that could result from a malign use of the identified technology/threat vector; (b) consequences of human response effects; (c) ease of use of the identified technology/threat vector; and (d) affordability of the identified technology/threat vector for a selected antagonist group or malign actor. When categorizing levels of threats, the following would indicate higher levels of threat: higher consequences of prompt effects; higher consequences of human response effects; higher level of ease of use; greater affordability.

I have already discussed, near the end of Chapter 2, “Beginning the Winnowing Process,” some of Douglas W. Hubbard’s reservations regarding ordinal rankings used in common forms of risk management matrixes, which he sets forth in detail in his book *The Failure of Risk Management: Why It’s Broken and How to Fix It*. In Chapter 9, which outlines my suggested blended technique for a “devil’s toy box” analysis, I will apply some of Hubbard’s suggested correctives. In the meantime, regarding the Sandia National

[231] Ibid.

Laboratories' Generic Threat Matrix, I would caution that analysts should not rely upon a tool of this sort to be determinative. They should not plug their "High-Medium-Low" estimations into this chart (or even an expanded chart) and expect that it will then grind away like some mechanical engine of decision and tell them which threats should be granted highest priority for research and development attention. For now, this tool could be most useful as a repository for the insights the analytical team has surfaced during its red-teaming process. It can neatly summarize the team's thinking at various stages, too, if it is regularly updated throughout the process and successive iterations of the matrix are retained; in this way, it can also help to preserve a record of the team's work and the evolutions in its collective consideration. A filled-out generic threat matrix can also serve as a jumping-off point for additional analytical exercises using tools from the tool kit we have been assembling, for the relative placement of various identified threats on the matrix will very likely spark renewed discussions and debates among members of the analytical team.

C. RED TEAMING: BEST PRACTICES

The editors of *Red Team Journal* list seven "musts" for a system of red-teaming analysis to be effective within an organization. (1) The red team participants must acquire an adequate understanding of the defensive technology, system, or method that is to be tested. (2) The red team must acquire an adequate understanding of potential adversaries' culture(s), motivations, likely technologies, and rules of engagement. (3) The red team must apply red-teaming best practices during its simulated attack or probe. (4) The red team must effectively communicate what they have learned to their customers. In turn, those customers must (5) pay attention to what the red team is telling them, (6) understand what is being communicated, and (7) be willing and authorized to act in response to the red team's findings. The *Red Team Journal* editors state that, should any of these factors not be present, the red-teaming effort will not produce the desired results within the organization.[232]

[232] *Red Team Journal*, "Red Teaming Myth #5," last modified February 23, 2016, http://redteamjournal.com/2016/02/red-teaming-myth-5/.

The RAND Corporation suggests additional factors that should be kept in mind by red teamers. Their monograph, *Breaching the Fortress Wall: Understanding Terrorist Efforts to Overcome Defensive Technologies*, examines the continual dynamic of measure-countermeasure, move-countermove that takes place between defending organizations within the homeland security enterprise and their opponents, either individual terrorists/criminals or terrorist organizations. The authors review the tactics and strategies of four prominent terror groups or aggregations. They focus on Palestinian terror organizations; Jemaah Islamiyah and its allies; the Liberation Tigers of Tamil Eelam; and the Provisional Irish Republican Army. They identify four ways that these groups have attempted to defeat defensive technologies or measures put into place by homeland security organizations. These include altering operational practices, which might include incorporating camouflage, deception, or forgery into their tactics; switching their own chosen technologies (surveillance tools, communications systems, or weapons) to foil defensive technologies; avoiding the defensive technology altogether by, for example, changing the target or zone of attack; and, finally, directly attacking the defensive technology. The authors assert that homeland security defensive systems should always be designed with the likely reactions of opponents in mind. They suggest that these systems' designers utilize red-teaming techniques to test the resilience of such systems, including assessing potential adversaries' information requirements (what attackers would need to know to successfully defeat the system and how those attackers might acquire such information) and attempting to foresee how attackers may adjust to the defensive system and responsively change their own technologies and tactics. The authors further suggest that in the realm of counterterrorism, flexible systems are of more value than inflexible ones, for opponents' countermoves may swiftly render a defensive system's initial mode of operation obsolete. They additionally suggest that defensive system designers take into consideration the relative costs of the system they are designing and those of foreseeable efforts to defeat that system. They point out that one goal of some terror groups is to drain defenders' ability and will to defend themselves by subjecting them to very high relative

expenditures. In other words, a billion-dollar system that can be defeated by a ten-thousand-dollar countermeasure is not a wise expenditure of homeland security dollars.[233]

D. RED TEAMING: DISADVANTAGES AND WAYS TO OVERCOME THOSE PITFALLS

Red-teaming can be an expensive and time-consuming process. Defensive systems may be potentially confronted by a multitude of different opponents who may field a wide variety of opposing technologies and counter-methods. The facilitators of a "devil's toy box" analysis might not want to invest in gathering the various groups of subject matter experts needed to analyze various technological threat vectors and employ those SMEs for the extended periods of time required for thorough red-teaming efforts. How might the red-teaming methodology be applied in a more cost- and time-effective fashion, given the wide range of potential threats?

Michael J. Skroch of Sandia National Laboratories offers a potential answer: virtual red-teaming through modeling and simulation. Skroch points out that human beings and computers have differing relative advantages and strengths when it comes to red-teaming. Whereas human beings are effective in the realms of creativity and intuition, computers are good at crunching numbers, dealing with complexity, and exhausting a range of potential alternatives.[234] In parsing out these differences between human analysts and computers, Skroch delineates three realms for which red-teaming methods are used to highlight strengths and vulnerabilities: the physical space (defensive measures such as walls, gates, fences, sensors, and weapons); the cyber space (computers and networks, information systems, codes); and the behavioral space (the homeland security organization being attacked, the political and cultural environments that organization inhabits, as well as the policy and organizational restraints faced by the operators of the defensive system

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[233] Brian A. Jackson, Peter Chalk, R. Kim Cragin, Bruce Newsome, John V. Parachini, William Rosenau, Erin M. Simpson, Melanie Sisson, and Donald Temple, *Breaching the Fortress Wall: Understanding Terrorist Efforts to Overcome Defensive Technologies* (Santa Monica, CA: RAND Corporation, 2007), xviii-xxii, http://www.rand.org/content/dam/rand/pubs/monographs/2007/RAND_MG481.pdf.

[234] Skroch, *Modeling and Simulation of Red Teaming*, 2-4.

and the employees and managers of the organization fielding the system).[235] Skroch states that red teams composed of human beings are superior when it comes to red-teaming the behavioral space, whereas virtual red teams are superior at red-teaming the physical space, due to the advantages offered by computer red team modeling and simulation. These advantages include the ability of programmers to create a wide variety of attack modes quickly and at relatively low cost; the ability of modeling and simulation systems to run 24/7; the ability to easily and cheaply capture all data; the ability to replicate past environments and events; superior verification and validation [V&V] across multiple simulations; and the fact that virtual red-teaming's easily generated large numbers of varying attack scenarios are extremely useful for sensitivity analysis. He suggests that, when it comes to red-teaming the cyber space, neither human red teams nor virtual red teams have a clear advantage over the other, since both bring valuable and unique strengths to bear.[236] Skroch concludes that virtual red teams should not be considered a replacement for red teams composed of human beings, but rather a complement to them, providing a cost-effective extension of the coverage of red-teaming analysis in the physical and cyber realms.[237]

The DETER Cybersecurity Project offers the members of a "devil's toy box" analysis team a powerful, government-run tool for their use when they need to red team emerging cyber threats. Initially established by the Department of Homeland Security and the Space and Naval Warfare System Center as a "basic hardware-focused network security testbed," the DETER Cybersecurity Project has since evolved into a laboratory for cybersecurity experimental science, which allows researchers to observe actual malware products introduced from live environments, determine their properties through observation, modeling, and simulation, and test various approaches for neutralizing them. Prior to the establishment of the DETER Project in 2004, entrepreneurs and other actors who sought to develop counter-malware products often fell short of their goals due to the

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[235] Ibid., 6. Skroch uses the term "cyber space" in this context, rather than the accepted usage "cyberspace," to match his use of the terms "physical space" and "behavioral space."

[236] Ibid., 5.

[237] Ibid., 7.

lack of testing facilities. Since then, DETER has allowed for the development of much more effective cybersecurity tools.[238]

Yacov Y. Haimes and Barry M. Horowitz of the University of Virginia, thinking along the same lines as Sandia Laboratories' Skroch, introduced in 2004 an Adaptive Two-Player Hierarchical Holographic Modeling (HHM) Game for counterterrorism intelligence analysis, "a repeatable, adaptive, and systemic process for tracking scenarios" meant to model the actions of a blue team and a red team and quantify threats to and vulnerabilities of a defensive system.[239] HHM, further defined as "a structured approach to organizing a team effort for performing a risk analysis," addresses the following three questions: "*What can go wrong? What are the consequences? What is the likelihood?*"[240] The methodological frameworks that form the basis of this technique of table top or computer-simulated red-teaming are:

- Hierarchical Holographic Modeling (HHM)—for scenario structuring and risk identification,
- Risk Filtering, Ranking, and Management (RFRM)—for adding priorities to the generated scenarios and intelligence database,
- Bayesian analysis—for corroboration and adding credibility to intelligence, and
- Building blocks of mathematical models and the centrality of state variables—for identifying, in conjunction with the HHM, the critical elements that are of interest to the terrorist networks. These form the basis for collecting intelligence. Such knowledge

[238] Terry Benzel, "The Science of Cyber Security Experimentation: The DETER Project" (paper presented at 2011 Annual Computer Security Applications Conference, Orlando, Florida, December 5–9, 2011), https://www.acsac.org/2011/program/keynotes/benzel.pdf.

[239] Yacov Y. Haimes and Barry M. Horowitz, "Adaptive Two-Player Hierarchical Holographic Modeling Game for Counterterrorism Intelligence Analysis," *Journal of Homeland Security and Emergency Management* 1, no. 3, art. 302 (June 2004), i, doi: https://doi.org/10.2202/1547-7355.1038.

[240] Ibid., 3.

> can result in *a priori* likelihoods of attacks using specific classes of weapons.[241]

Both the blue team and the red team perform Hierarchical Holographic Modeling analyses on their own "side," with levels of analysis including the following: organizational, narrative, doctrinal, technological, and social.[242] The authors outline the game's steps as:

> 1. Select classes of potential terrorist threats to be tracked (e.g., meat poisoning, water poisoning, nuclear power-plant attacks).
>
> 2. For each class conduct an HHM analysis … The results are sets of attack elements; when combined in various ways, these can be the basis for coherent attack scenarios. For example, some elements could be (a) gain employment at the target location, (b) steal weapon for an attack, and (c) bribe an employee at the target location.
>
> 3. Combine elements into packages of potential attacks. For each package, evaluate the consequences and likelihood, …
>
> 4. Rank the attacks and attack elements in order of concern, …
>
> 5. For the highest-ranking attacks, evaluate the potential observables that could result if a terrorist were to undertake such a plan of action.
>
> 6. For the attack elements and combinations that provide the most unusual observations, … consider setting up an

[241] Ibid., 18.

[242] Ibid., 6-7.

intelligence-collection capability; then evaluate actual collections based on observing these elements in isolation and in combination.

7. When defined thresholds of observation are exceeded, raise the level of likelihood for the corresponding terrorist attack.[243]

At the time of the article's publication (June 2004), the authors were amid writing a software program to permit gamers to use computers to conduct multiple sessions of Hierarchical Holographic Modeling swiftly and inexpensively, allowing for successive iterations of large numbers of attack and defense combinational scenarios.[244]

Haimes and Horowitz have not been the only computer scientists or systems analysts to tackle the problem of countering terror attacks. In response to what they felt were critical flaws in DHS's 2006 exercise in bioterrorism risk assessment, which relied upon subject matter experts (SMEs) and an eighteen-stage risk assessment tree to determine probabilities of various potential bioterror attacks, Gerald G. Brown, Matthew Carlyle, and R. Kevin Wood of the Naval Postgraduate School developed a "Defend-Attack-Mitigate risk-minimization model" and a "tri-level 'Defender-Attacker-Defender risk-minimization model.'" Their contention was that, contrary to DHS's Bioterrorism Risk Assessment exercise, the likelihood that the attackers (terrorists deploying biological weapons) would adjust their tactics in response to whatever defensive methods DHS deployed could not be captured purely by statistical analysis. In their model, the defender (blue team) develops its best mitigation/protection strategy against a mode of attack (the example given is a biological agent attack, with the defender investing in a supply of emergency vaccines). Then the attacker (red team) adjusts its plan of attack as best it can to adapt to the defender's countermeasures. In response, the defending blue team puts its selected countermeasure(s) into play as effectively as it can. The authors assert that this

[243] Ibid., 3–4.

[244] Ibid., 15.

method of analysis allows homeland security intelligence analysts to focus on attacks of the highest likelihood and highest lethality.[245] Their model is laid out mathematically and appears to me suitable for transposition to a computer software program; it has been validated through more than a hundred assessments of vulnerability conducted by students and instructors at the Naval Postgraduate School.[246]

In 2005, the same group of authors, joined by Javier Salmerón, applied earlier versions of their bi-level programming models to the problem of protecting critical infrastructure. They selected electric power grids, oil pipelines, the Washington, DC Metro system, and the Los Angeles International Airport for their analysis.[247] They drew the following lessons from this series of simulations:

> The attacker has the advantage. …
>
> Some systems are naturally robust, while others are not. …
>
> Hardening an infrastructure system from attack can be expensive. …
>
> The data are out there, and if we can get them, anybody can. …
>
> The answers are not always obvious. The most damaging coordinated attacks, or the most effective defenses, can be nonintuitive. …
>
> Malicious, coordinated attacks can be much more damaging than random acts of nature. …
>
> Reliability is not the answer. We must protect the most critical components in our infrastructure systems, rather than backing up the least reliable components. …
>
> The right redundancy may be the answer. …
>
> Secrecy and deception may be valuable. …

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[245] Gerald G. Brown, W. Matthew Carlyle, and R. Kevin Wood, "Optimizing Department of Homeland Security Defense Investments: Applying Defender-Attacker (-Defender) Optimization to Terror Risk Assessment and Mitigation," Appendix E of *Department of Homeland Security Bioterrorist Risk Assessment: A Call for Change* (Washington, DC: National Research Council, National Academies Press, 2008), E-1—E2.

[246] Ibid., E-3.

[247] Brown et al., *Analyzing the Vulnerability of Critical Infrastructure*, 110-117.

> Worst-case analysis using optimization is key to a credible assessment of infrastructure vulnerability, and to reducing that vulnerability.[248]

The members of a "devil's toy box" analysis will not have unlimited resources with which to proceed. They will face limits on their staff size, their funding, their equipment, and their time. They could potentially economize on those limited resources and maximize their utility by using computerized modeling and simulation of red team-blue team interactions. Certain types of future-shock threats presented by emerging technologies may be more appropriate subjects for computerized modeling and simulation. Cyber attacks and kinetic attacks whose success depends upon physical or software properties that can be accurately mathematically modeled are the most appropriate for computerized modeling and simulation. Conversely, threats whose outcomes depend heavily upon cultural and emotional human factors—for example, an apocalyptic extremist religious group's willingness to use a new type of man-made biological agent in an attack—would be the least appropriate. Additionally, the managers of a "devil's toy box" analysis could hone the products of human red-teaming analyses by performing sensitivity analyses of various key factors, using massive numbers of base scenario iterations generated by a computer program, getting "more bang for their buck."

* * * * *

To sum up, red-teaming is not an optional part of a "devil's toy box" analytical effort. It is the *heart* of that effort. Technological implements do not use themselves and attack office buildings, shopping malls, trains, aircraft, festive gatherings, religious processions, or entire cities of their own volition (the issue of future artificial intelligence systems going "rogue" aside). They are used by human beings with human motivations, fears, hatreds, loyalties, honor codes, religious or ideological aspirations, and lusts, as well as hunger for destruction and its accompanying glory or infamy. Only the analytical frameworks provided by a thorough red-teaming process can provide members of a "devil's toy box" analysis team with those types of insights into the minds and hearts of potential adversaries to be faced by the homeland security enterprise. Additionally, the proponents of red-teaming recognize the range of personal cognitive fallibilities that

[248] Ibid., 120-121.

analysts must consider when performing any sort of attacker-defender analysis (of which a “devil’s toy box” analysis is certainly an example), such as groupthink, mirror imaging, or the tendency to surrender to the lure of conventional wisdom, offering exercises that help analysts overcome such cognitive biases.

Thus far, I have considered a range of techniques that can be used to amalgamate, sift, hone, and rank the opinions or forecasts of experts and arrive at a group consensus, as well as red-teaming techniques that can help those experts overcome their cognitive biases and see matters through the eyes of their potential antagonists; however, one question I have not yet addressed is this: for the purposes of a “devil’s toy box” analysis, just who *are* the “experts”?

VII. WHO ARE THE EXPERTS? A CASE FOR THE INCLUSION OF SCIENCE FICTION WRITERS AS PART OF A "DEVIL'S TOY BOX" ANALYTICAL TEAM

A. THE CONCEPT OF EXPERTISE: BACKGROUND

Delphi panels, nominal group technique procedures, and conclaves of futurists all rely upon the participation of experts. What are experts? For the purposes of a "devil's toy box" analysis, experts may be persons possessing specialized knowledge, not typically dispersed among the public, which can be of aid to the analytical task. Or they may be individuals with life experience or personal knowledge that has specific bearing on the analytical task, or persons who have benefitted from training that is necessary for the completion of the analytical task.

Olaf Helmer points out the difficulties inherent in selecting the right experts for a foresight exercise, defining those experts' qualifications, and separating high performing forecasters from low performing forecasters.[249] Catherine Powell has surveyed the literature regarding best practices for choice of expert panelists in Delphi procedures. She reports that E. Rowe, Andre Delbecq et al., and M. K. Murphy et al. all agree upon the importance of heterogeneity to the composition of an effective Delphi panel, and that panels featuring participants having a wide variety of perspectives, backgrounds, and specializations tend to produce higher quality results than those that are produced by more homogenous panels. She also points out that most Delphi users she has surveyed agree upon the importance of selecting experts having high levels of credibility with the Delphi report's target audience; otherwise, the report faces the danger of becoming "shelfware," never seriously read and considered by the decision-makers whose actions the report was intended to guide.[250]

Her recommendations focus on *diversity of perspectives* and *credibility* with the consumers of the group's outputs. Powell's emphasis on the importance of panelists'

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[249] Helmer, *Analysis of the Future*, 5.

[250] Powell, "The Delphi Technique: Myths and Realities," 379.

credibility with the final report's intended target audience, to ensure buy-in of the report's recommendations at the highest levels of the organization, suggests that one best practice would be to include in the analytical team persons who would be considered representative of the sponsoring organization's mission. For a law enforcement agency, this would mean senior officers; for a homeland security agency, it would likely mean special agents, senior analysts, and/or members of top management. Ideally, such "in-house" participants would have a familiarity with red-teaming techniques, to also serve Powell's other recommendation, that diversity of perspectives be well accommodated and sought after. The danger exists, however, that too large an "in-house" representation on a "devil's toy box" analytical team would lead to organizational group-think and counterproductive steering of results in directions amenable to the sponsoring organization's existing initiatives and priorities. In other words, the old aphorism applies—when one's only tool is a hammer, every problem conveniently looks like a nail. Outside expertise must also be sought to ensure diversity of perspectives, but that outside expertise also needs to be credible to the sponsoring organization's management.

Credibility is oftentimes based upon credentials, educational or experiential background, or status within a group; however, it can also be based upon possession of specialized or local knowledge that is not generally perceived by the public as expert knowledge. For example, a Delphi panel having the goal of arriving at consensus regarding crime reduction strategies in a Chicago neighborhood would benefit from having among its members neighborhood residents who have been victims of crimes, and, if possible, persons who have committed crimes in that neighborhood and then gone on to reform. Such individuals would not typically be regarded as "experts," but they are experts when it comes to knowledge of conditions in their neighborhood and motivations underlying the commission of crimes. A resident could speak to broken streetlights that make her feel unsafe and businesses that attract unruly or threatening clienteles. The reformed criminal could speak to the availability of a customer base desperate for illicit drugs, networks of criminal activities (gambling, prostitution, protection rackets) embedded in the neighborhood, gang rivalries, and the most advantageous locales from which to ambush

victims. Such input, while not recognized as "expert input" by those who place heavy emphasis on professional credentials, would be invaluable for this Delphi panel.

B. EXPERTISE IN THE CONTEXT OF A "DEVIL'S TOY BOX" ANALYSIS

What sorts of experts with which types of backgrounds would be most useful for a "devil's toy box" analysis? What areas of expertise are required? An answer that immediately comes to mind is persons who are expert in the scientific or technical fields relevant to the over-the-horizon Promethean technologies initially flagged by a system such as IARPA's FUSE. The facilitators of a "devil's toy box" analysis would want to include geneticists to judge emerging gene-splicing technologies; explosives and firearms experts to judge emerging 3–D printing technologies; robotics, machine intelligence, and radio spectrum communications experts to judge emerging automation technologies; and cybersecurity experts to judge the vulnerabilities of new personal medical implant technologies connected to the Internet of Things. Uber hopes to test its planned Uber Elevate service, "ride sharing in the air," in the Dallas-Fort Worth and Los Angeles markets by 2020 and get approved for inter-city flying taxi rides by 2023.[251] An evaluation of the security vulnerabilities of this gargantuan expansion of civil aviation at low altitudes would require experts in civil aviation, air traffic control systems, and guarding aviation assets from terror attacks. Regarding all such emerging technologies, experts in appropriate fields would be called upon to help predict the levels of training, technical expertise, and support that would-be malign exploiters of such innovations would require five years down the line, and to extrapolate the outer boundaries of their potential destructiveness.

Yet a focus on the future development of technologies is not enough. A gun, by itself, does not murder. Nor will an automated laser rifle, a micro-drone carrying a payload of poison, or a software worm written to turn off Internet-connected pacemakers. Each of these tools, to contribute to a killing or an act of destruction or disruption, must be used or set into motion by a human actor. Human actors choose the various attack options—mode,

[251] Eric Auchard, "Uber in Deal with NASA to Build Flying Taxi Air Control Software," *Reuters* website, November 8, 2017, https://www.reuters.com/article/us-portugal-websummit-uber/uber-in-deal-with-nasa-to-build-flying-taxi-air-control-software-idUSKBN1D81AE.

time, place, and target; indeed, the choice of whether to engage in destructive or murderous activity at all, rather than expressing negative emotion in a different, less violent fashion. Ideally, a "devil's toy box" analytical team will include experts on the human motivations that lead to decisions to engage in acts of terror, as well as the desires, aspirations, fears, hatreds, taboos, loyalties, rivalries, social or religious traditions, and cultural imperatives that shape the behaviors and goals of terrorists.

Which emerging Promethean technologies will prove especially attractive to which terror groups? Conversely, which technologies will be shunned by certain terror groups as anathema to aspects of their practices or ideology? Looking through a different lens, which technologies may prove irresistible to young home hobbyists but lead to unintended accidents with huge negative consequences for the surrounding community? Regarding the first question, a terror group or individual terrorist whose ideology centers around hatred and loathing of dark-skinned peoples and Jews would very likely be tremendously attracted to a gene-splicing technology that allows for the creation of pathogens tailored to be deadly to victims with substantial African genetic heritage or Ashkenazic Jewish genetic heritage. Regarding the second question, a notional fundamentalist Jewish terror group in Israel, whose goal is to "cleanse" all Jerusalem of Arab residents and "rededicate" it for Jewish use, would likely not want to use a weapon of mass destruction that would cause physical obliteration of the sacred spaces or render those spaces uninhabitable (through radiation contamination, for example); its members would seek a weapon that would cause the deaths or flight of Arab residents in Jerusalem but spare the physical surroundings.

Regarding the third question, that of new technologies that might lead to accidental deaths or major disruptions, fans of bleeding-edge immersive, massively multiplayer online gaming will likely swarm, like moths around a tiki torch, toward a gaming system that combines shareable virtual reality environments with direct neural connections (either wired or wireless) into players' brains. Conceivably, groups of irresponsible (but not murderous) teenagers or individual teens could intend to "prank" one of their fellow players with a psychological/physiological shock through the mode of the shared network, only to see this "prank" result in the unintended neurological impairment or death of their target(s). Milder forms of Internet-facilitating pranking and targeted revenge/disruption that have

entered common parlance include doxxing, or the intentional release of a targeted individual's phone number(s), email address(es), IP address(es), and other identifying information in the hopes of facilitating widespread harassment; and swatting, the making of false claims of a person committing a serious crime to trigger a zealous law enforcement response, such as the dispatch of a SWAT squadron to the target's home. These forms of pranking sometimes also result in consequences more severe and lasting than the pranksters may have originally intended. The speculative scenario I mention above is nothing more than an extrapolation of the contemporary phenomenon of social media-based bullying, which sometimes induces its victims to attempt or successfully commit suicide. Face-to-face bullying between young people has taken place since the time of the founding of the first social units in prehistoric times; the invention of online social media extended the reach of bullying from school or public environments into a victim's own home. Similarly, irresponsible teens' pranks leading to injuries or deaths are not a new phenomenon. What the technology described above would accomplish would be to extend the reach of such terrible accidents from any point in the world to any other point, with no geographical limits or boundaries, and facilitate such accidents occurring between pranksters and victims who will likely never know one another's true identities. Such extended range will vastly complicate the efforts of local law enforcement agencies, schools, social service agencies, religious and pastoral organizations, and families to prevent, stem, or punish such destructive behavior.

The attacks on the Twin Towers and the Pentagon in 2001 by a cadre of al Qaeda suicide terrorists spurred the development of terrorism studies and homeland security studies as academic fields of interest. Early attempts by analysts and researchers to explain the behavior of terror groups and individual terrorists either focused on individuals' psychopathology as a motivator, or recycled Cold War-era analytical frames derived from political science and international relations, such as the Rational Choice/Rational Actor Model, to parse out the motivations of terror organizations and to try to predict those groups' future operations.[252] More recently, some academics in the field of terrorism

[252] David Brannan, Kristin Darken, and Anders Strindberg, *A Practitioner's Way Forward: Terrorism Analysis* (Salinas, California: Agile Press, 2014), 28–33.

studies have adopted a sociological model developed in the 1970s, Social Identity Theory, to provide a more effective set of analytical frames through which to compare and contrast varying terror groups across different societies and time periods, and to better understand why superficially similar groups sometimes compete or clash rather than cooperate, or why groups with identical goals and overlapping constituencies will sometimes opt to operate in very different fashions.[253] Social Identity Theory is centered upon four analytical markers derived from studies of traditional Eastern Mediterranean societies. These are the centrality of relationships between patrons and their clients; a focus upon desired attributes and resources as limited goods; social interactions being shaped by a common desire to accrue honor and to avoid shame; and both interpersonal and inter-group interactions following a challenge-and-response model.[254] Terrorism analysts practiced in the use of Social Identity Theory as an analytical framework could serve as useful additions to a "devil's toy box" analytical team. Their mode of analysis could provide greater insight into why terror organizations may be especially attracted to emerging Promethean technologies, and thus why the analytical team should consider certain technologies as more likely to be used in malign ways than others. More so than the scientific and technical experts embedded in the notional analytical team, terror analysts using a Social Identity Theory framework could further one of the principle goals of red-teaming—that of "seeing a situation through the enemy's eyes."

An ideal addition to a "devil's toy box" analytical team would be a person who combines the horizon scanning habits of a futurist or a technology forecaster with the conflict- and mayhem-inclined mindset of a terrorist. Such an individual would be able to speak not only to the feasibility of use of a Promethean technology for malign purposes, but also to the human, emotional factors that prompt such use—the symbolic, religious, and psychological attractants inherent within certain technologies and how and why those attractants appeal to persons of a terroristic bent. These notional ideal team members exist. They are called science fiction writers.

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[253] Ibid., 40–49.

[254] Ibid., 65.

C. ANOTHER SOURCE OF EXPERTISE: THE SCIENCE FICTION MINDSET

Thus far, virtually all researchers into the efficacy of various forecasting methods have emphasized the importance, for the success of a forecasting effort, of a diversity of outlooks, backgrounds, and analytical frameworks. What other analytical framework might be especially helpful in determining the intersections between emerging Promethean technologies and the motivations, aspirations, and goals of human actors who seek to cause mayhem, disruption, and terror? I propose that the mode of creative extrapolation of scientific and social possibilities inculcated in writers of commercial science fiction is especially useful for a "devil's toy box" analysis.

The science fiction mindset is not a random trait based upon personal characteristics inherent in the science fiction writer. This mindset arises from modes of thinking, planning, plotting, and writing that are inculcated into science fiction writers by the demands of their marketplace. These modes of imagining, extrapolating, planning, and plotting what are essentially futurist scenarios centered around conflict between persons (or in the case of aliens, beings) with intelligible and compelling motivations allow science fiction writers insight into, in the terms of this thesis's central parable, the devil's mindset—his desires, his preferred goals, and which of his many, many gestating toys he will tend to favor. Having a mix of science fiction writers on a "devil's toy box" analytical team is the next best thing to having as members former terrorists who brainstormed new weaponry and new modes of attack for their terror groups.

While a great deal has been written about the socio-economic backgrounds of terrorists and the possible psychological, sociological, and even physiological factors that may contribute to terroristic behavior, few academicians have focused their attentions on parallel studies of science fiction writers or the science fiction readership they serve. Some socio-economic surveys have been performed of the latter, and a handful of scholars have attempted more in-depth study, but much of what is known about science fiction writers and the science fiction readership is based upon literary memoirs and reminiscences. Thus, while I base my attempt to illuminate parallels between terror group leaders and members and the science fiction readership on existing studies and analyses, I also make use of more

subjective materials. In part, I base my postulation of the similarities between the two groups, which underlies my insight regarding the utility of the science fiction writer's mindset to a "devil's toy box" analysis, on my own personal experience as both a lifelong reader of science fiction and as a writer of commercially published science fiction. Since 1994, I have written 17 novels, most them science fiction, fantasy, or horror, along with a similar number of short stories. Of the novels, three have been published by commercial publishers, and I have self-published several others through the Amazon Kindle and CreateSpace platforms. I have worked with a succession of literary agents since 2001, who have submitted all my books to a wide variety of commercial publishing houses. Both my successes and my disappointments from this part-time career/full-time avocation over the past twenty-five years, when added to my collegial relationships with numerous fellow science fiction writers, have taught me a great deal about the needs and proclivities of the commercial marketplace for science fiction, that market being made up of acquiring editors, writers, and readers and fans.

1. The Constraints of Commercial Science Fiction as a Shaper of the Science Fiction Mindset: (Commercial Science Fiction = Future Technology + CONFLICT)

Many persons with only a passing familiarity with the science fiction field have assumed that the primary goal of writers of science fiction is to successfully predict future developments in science and technology, to serve as literary crystal balls. This impression was furthered by the accurate prognostications of two of the science fiction field's earliest and most prominent writers, Jules Verne and H. G. Wells. The former predicted electricity-powered submarines (*Twenty Thousand Leagues Under the Sea*), manned flight to the Moon (*From the Earth to the Moon*), and round-the-world travel by air (*Around the World in Eighty Days*). The latter foresaw the development of armored tanks ("The Land Ironclads"), genetic engineering of animals (*The Island of Dr. Moreau*), and nuclear weaponry (*The World Set Free*). Also, during the decades leading up to the First World War, Robert Louis Stevenson foresaw the use of powerful psychotropic drugs to radically alter a person's personality and behavior, with his very popular *The Strange Case of Dr. Jekyll and Mr. Hyde*, whose story has been widely disseminated by multiple film versions.

Additionally, the founder of science fiction as a commercial genre of American fiction, Hugo Gernsback, original editor of the pulp fiction magazine *Amazing Stories*, intended that one of the goals of his periodical, first published in 1926, would be to accurately predict future technological developments for its readership. Yet as John Clute and Peter Nicholls, editors of the authoritative *The Encyclopedia of Science Fiction*, point out, the record of science fiction writers as accurate soothsayers is decidedly mixed. Since the first publication of *Amazing Stories*, the most consequential scientific prediction by a major writer of commercial science fiction has been Arthur C. Clarke's 1945 article about the potential for communications satellites, and perhaps the most amusing has been Robert Heinlein's accurate prognostication of the invention of the water bed. Clute and Nicolls point out that many science fiction writers have never set out to predict what *will* happen; instead, they predict, then dramatically envision, what *could* potentially happen, either to warn their readers about possible dire developments in the future or, less frequently, to provide a beacon to an attractive possible future.[255]

So, if science fiction writers have not demonstrated a widely shared talent for accurately predicting future technological developments, what do they have to offer a "devil's toy box" analysis? Their most valuable contribution would be their mindset, inculcated in them by a career spent chasing opportunities to sell stories and novels to a type of readership—a mindset that combines conflict-seeking (within the realm of storytelling) with continual horizon-scanning in search of innovative technological extrapolations upon which to base their fictions.

Conflict lies at the heart of any story or novel. Absent conflict (which can be between persons, between a protagonist and society, or conflicting impulses within a protagonist), a story or novel is no more than a character sketch, a philosophical or sociological essay, or an excursion into speculative psychology. Although a relative handful of science fiction stories and novels have been accepted into the literary canon as works of literary art, and science fiction has made inroads in recent decades into the

[255] Peter Nicholls, "Prediction," in *The Encyclopedia of Science Fiction*, second edition, ed. John Clute and Peter Nicholls (New York: St. Martin's Press, 1995), 957–958.

academy as an object of study, science fiction is primarily a *commercial* genre of fiction, subject to the same marketplace pressures and influences as other popular fiction genres, such as romances, mysteries, suspense thrillers, and Westerns. If acquiring editors do not judge a story or novel as having the potential to earn a profit, they will not buy the piece, no matter how much they may personally like it. (Exceptions to this marketplace rule exist for media that are not primarily profit-driven, such as academic publications, subsidized publishing, self-publishing, or agenda-focused publishing).

2. Extrapolated or Novel Technology as an Element of the Science Fiction Mindset

The science fiction field has traditionally been an iterative one, like jazz music and Modernist painting, wherein subsequent writers build upon the concepts and tropes developed by earlier writers. In the science fiction genre (as opposed to the related commercial genres of fantasy and horror, which rely more heavily on repeated, well-worn tropes and effects), freshness of approach to the material is highly sought after. Writers who can provide fresh, novel approaches are highly thought of by their colleagues (and often the recipients of prestigious awards) and are lauded by discriminating readers. Some (not all) acquiring editors in the science fiction field seek freshness and novelty and will immediately reject what they perceive as the "same-old, same-old" story (unless that "same-old, same-old" story is written by a highly marketable author with a huge built-in readership, but that is a subject for a different thesis). Thus, science fiction writers, or at least those who write what is called "hard science fiction," which is science fiction based in supportable, plausible extrapolations of science and technology ("hard sf" is defined by Allen Steele as "imaginative literature that uses either established or carefully extrapolated science as its backbone"[256]), compete with one another to offer fresh takes on rigorous extrapolations of evolving science and technology, often cutting-edge or highly notional.

In terms familiar to Social Identity Theory practitioners, publishing billets are a limited good. Less than two dozen commercial science fiction magazine markets, those that pay at least 5 cents per word, exist as of 2017, as well as a limited number of science

[256] Allen Steele, "Hard Again," *New York Review of Science Fiction*, June 1992, 1–4.

fiction novel publishing imprints that have a limited number of publication slots each year. Also, "hard sf" is always in danger of getting pushed aside by the commercially more popular science-fantasy, "soft sf," science fiction romance, and fantasy stories and books, which sell in far greater numbers than most anything classified as "hard sf." The competitive pressures of commercial science fiction publishing thus push writers of more technology-oriented science fiction to offer "hot takes" on plausible extrapolations of current or foreseen developments in science and technology AND to present those extrapolations in the form of exciting conflicts that induce readers (most especially acquiring editors) to swiftly turn the pages. The commercial market trains a successful writer of "hard sf" (someone who is able to make, if not a comfortable living, at least some level of steady income from his or her writing work) to continually scan available sources for new information on scientific and technical developments with story potential; to furiously extrapolate the potential implications (both good and bad implications, but the latter typically make for better, more exciting plots) of said developments before a competitor writes the same or similar extrapolation, sells it to one of the limited number of acquiring editors, and renders the more tardy author's work unmarketable; and to extrapolate the scientific or technical development in the most thrilling, reader-engaging way possible, meaning ramping up the levels of conflict inherent in the work's plot, characters, settings, and themes.

In short, the successful writer of "hard science fiction" has been trained to regularly and extensively exercise a mindset of special value to a "devil's toy box" analysis. These authors, to sell their work often enough to produce even a modest income, must continually ask themselves:

- What are the NEWEST developments in science and technology?
- What developments are anticipated in the foreseeable future?
- What are theorists of science speculating about as possibilities?
- What might happen because of these developments in science and technology?

- What is likely to happen? What might plausibly happen?
- What trends currently exist in science and technology and societal adjustments to science and technology? What would happen if those trends were extrapolated into the future and greatly exaggerated?
- What are the possible social impacts of these trends and developments? Political implications? Cultural implications? Religious implications? Psychological impacts? Impacts on behaviors? Impacts on health and longevity? Impacts on the physical environment?
- What are the *scariest* things that might result?
- What are the most interesting, exciting *conflicts* that might arise because of these potential, extrapolated trends and developments in science and technology?

3. Exciting Conflict that Appeals to Young Men as an Element of the Science Fiction Mindset

Throughout much of its existence as a genre of popular fiction, science fiction has been marketed as reading material for teenage boys and young men of approximately college age. It is for good reason that a saying common within the field cynically states that "the Golden Age of Science Fiction is 14."[257] (Varying versions of the epigram peg the Golden Age as 12.) With this primary audience in mind, authors of science fiction who hope to have a commercially remunerative career have traditionally loaded up their stories and novels with plenty of conflict, oftentimes the sorts of conflict of most interest to teenage boys and young men. These include stories of future military conflicts, invasions by alien beings, or underground rebel movements using new technologies or social doctrines. Stories about the exploration and conquering of new frontiers, primarily outer space, have always been popular with boys. Another set of story possibilities with proven appeal to the target audience is the acquisition of vast new personal capabilities, such as

[257] Peter Nicholls, "Golden Age of SF," in *The Encyclopedia of Science Fiction*, 506.

machine-enhanced intelligence or physical strength and dexterity; similar improvements provided through genetic engineering; or the development of esoteric abilities such as telepathy or telekinesis. Since many science fiction writers, writers of "hard sf," write their works with this audience in mind—not only out of careerist motives, but because many them were readers and fans themselves prior to beginning their professional writing careers, and most writers write what they themselves want to read—an examination of this readership should prove illuminating. This is especially true to the extent that such data and observations allow for parallels to be drawn with another audience of interest to "devil's toy box" analysts: potential followers and acolytes whom terror leaders attempt to recruit.

Looked at from a certain vantage point, both science fiction writers and terror group leaders are purveyors of dreams and fantasies for similar audiences of young men. Appendix B of this thesis, "Drawing Parallels Between Two Audiences—The Science Fiction Readership and Potential Memberships of Terror Groups," illustrates that science fiction writers and terror group leaders are pitching their adventuresome, testosterone-laden "products" to intriguingly similar audiences, young men having very similar educational and socio-economic backgrounds and some of the same emotional and social needs. This kindred nature of the two audiences being served suggests that science fiction writers with their science fiction mindset can offer valuable insights into the mindsets of technophile terror leaders and followers. (Appendix B includes a case study of Aum Shinrikyo, an apocalyptic terror cult whose leader was a science fiction devotee and who based portions of his cult's end-of-days scenario on Isaac Asimov's classic science fiction trilogy, the *Foundation* novels. He successfully recruited dozens of Japanese scientists, technologists, and graduate students of the sciences to develop doomsday weapons for the cult, which resulted in the use of a weapon of mass destruction in the Tokyo subway system in 1995.)

4. Science Fiction Writers' Focus on Rebels, Insurgents, Subversives, and Terrorists

Of value to the customers of the outputs of a "devil's toy box" analysis, science fiction writers, seeking to service an audience composed of young men who oftentimes view themselves as an oppressed, overlooked, certainly unappreciated "secret elite,"

frequently focus on insurgents and rebels as their heroes (thus flattering their reading audiences and providing them with the power fantasies they crave). H. G. Wells may have begun this trend with his *The War of the Worlds*, the second half of which centers on the actions of isolated resisters against a successful invasion of Great Britain by colonizing Martians and their irresistible war tripods. Popular writers Robert Heinlein, A. E. van Vogt, Fritz Leiber, and L. Ron Hubbard, during what has been termed the Golden Age of Science Fiction (1938 to 1946, corresponding with the most innovative period of editor John W. Campbell Jr.'s helming of *Astounding Science-Fiction*), often wrote about future insurgencies against various types of political or religious tyrannies. Emblematic works of this type during this period include Heinlein's *Sixth Column* and *Revolt in 2100*, van Vogt's *Slan*, *The Weapons Shops of Isher*, and *The Weapon Makers*, Leiber's *Gather, Darkness!*, and Hubbard's *Final Blackout*.

The sub-genre of science fiction called cyberpunk, popularly launched by William Gibson's innovative novel *Neuromancer* (1984), became the dominant sub-genre within the field during the 1980s and part of the 1990s and remains popular and influential to the present day, both in written and filmed forms. Cyberpunk fiction focuses, as the portmanteau suggests, on both "cyber"—the impact on individuals and their societies of computer networks, highly advanced information technologies, machine intelligence, and the fusion of computers/machines with human biology—and "punk"—resistance to authority, convention, control, and The Establishment. In cyberpunk stories, novels, and films, hackers are the heroes, and they struggle against oppressive, authoritarian constructs, either governmental or corporate (or a malign fusion of both). Their struggles, often highly romanticized, take place in both the physical realm and realms of virtual reality and cyberspace. The cyberpunk movement within science fiction was praised in some quarters as having restored a missing element of swagger, avant-gardism, romanticism, fashion sensibility, and sexiness to science fiction, qualities that, according to some critics, had been missing in the field's products since the work of the New Wave cohort of writers in the 1960s, then a leading part of the counterculture. Writers associated with the cyberpunk movement include Gibson, Bruce Sterling (the movement's primary propagandist/writer of manifestos), Greg Bear, Elizabeth Hand, and Jack Womack. Key early cyberpunk films

include *Blade Runner* (1982, based on Philip K. Dick's novel *Do Androids Dream of Electric Sheep?*) and David Cronenberg's *Videodrome* (1982).[258] The cyberpunk work that has arguably enjoyed the greatest mass popularity and cultural impact is *The Matrix* (1999) film trilogy, which prominently features the cyberpunk tropes of humanity enslaved by technology (in this case, literally—intelligent machines have subjected humanity to virtual reality suspended animation in which individuals unknowingly serve as biological batteries to power their machine oppressors); a charismatic group of heroes, possessed of otherwise hidden knowledge (they have taken the Red Pill, which allows them to perceive that what they thought to be reality is merely virtual reality, the Matrix), serving as the vanguard of a revolution; a long-prophesized, technocratic messiah (Neo); dynamic conflicts within cyberspace; and vertiginously shifting, seemingly psychedelic environments. Recent films and television productions, including a sequel to *Blade Runner*, *Blade Runner 2049* (2017), which was nominated for five Academy Awards, and a 2018 Netflix series based upon Richard K. Morgan's popular 2002 cyberpunk mystery-thriller *Altered Carbon*, illustrate the continuing relevance and popular appeal of the sub-genre.[259]

5. Case Study: Eric Frank Russell's *Wasp*

An extraordinary example of the results achievable through the science fiction mindset is Eric Frank Russell's novel *Wasp*, first published in 1957. This astoundingly prescient work—not predictive of future technologies, but rather of doctrine, strategy, and tactics—serves as a fictionalized how-to manual for a low-resource, low-personnel insurgency or terror campaign. Russell's accomplishment is especially noteworthy because he wrote *Wasp* near the beginning of the Algerian War between the Algerian National Liberation Front (FLN) and France (1954–62), but prior to the Viet Cong's insurgency against the government of South Vietnam and its American allies in the 1960s, Palestinian

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[258] Peter Nicholls, "Cyberpunk," in *The Encyclopedia of Science Fiction*, 288–290.

[259] "*Blade Runner 2049*," *BoxOfficeMojo*, accessed February 12, 2018, http://www.boxofficemojo.com/movies/?id=bladerunnersequel.htm; Sam Machkovech, "*Altered Carbon* Somehow Nails the Sci-fi Book-to-TV Landing on Netflix," *ArsTechnica*, February 11, 2018, https://arstechnica.com/gaming/2018/02/altered-carbon-somehow-nails-the-sci-fi-book-to-tv-landing-on-netflix/.

terror campaigns against Israel beginning in the late 1960s, various leftist and Maoist terror campaigns in the U.S; and Europe in the late 1960s and 1970s, the Liberation Tigers of Tamil Eelam's insurgency in Sri Lanka as of the mid-1970s, leftist insurgencies and terror campaigns in Latin America in the 1980s, and the current wave of Islamist terror, arguably begun with the 1979 Iranian Revolution and the subsequent rise of both Hezbollah and an array of Sunni terror organizations. Russell likely drew upon accounts of the French Resistance during World War II and the anti-Nazi partisans in Eastern Europe in working out his fictional terror campaign, but he used his science fiction-trained imagination to extrapolate new tactics that would allow a single individual with no actual followers to appear to be the secret leader of an insurgency of hundreds or thousands of operatives. Best-selling British author Terry Pratchett, in a back-cover blurb for a reprinting of Russell's book in 2000, writes, "I'd have given anything to have written *Wasp*. I can't imagine a funnier terrorists' handbook."[260]

The central conceit of the novel is that, like a tiny, half-ounce wasp that flies through the window of a car loaded with passengers, stings the driver, and causes the destruction of a two-ton automobile and the deaths of five human beings, each of whom outweighs the wasp by orders of magnitude, a single secret operative, with tactics that make him seem far more numerous and powerful than he actually is, can goad the government and military forces of an entire world into ruinous overreactions and tie down a force of thousands of police and soldiers. The book's protagonist is James Mowry, an Earthman who was born and raised in Masham, capitol city of Diracta, home-world of the Sirian Combine. Mowry is recruited by the special operations division of the Terran defense forces, which have been engaged in a long interstellar war with the Sirian Combine. They want Mowry as their operative because of his Sirian language skills and knowledge of Sirian culture and his presumed ability, following plastic surgery procedures to make him appear Sirian, to infiltrate a Sirian planet al. though the Terrans are in some ways technically superior in their war-making capabilities to the Sirians, the Sirians outnumber the Terrans by twelve-to-one; the Terran qualitative edge is cancelled out by the Sirian

[260] Terry Pratchett, back cover material for *Wasp*, by Eric Frank Russell (London: Victor Gollancz, 2000).

quantitative advantage. The Terran defense forces hope to overcome this stalemate through a campaign of sabotage, subversion, propaganda, recruitment of local criminals, and what a present-day reader would recognize as carefully targeted acts of terror. Mowry agrees to becoming involved, and a stealthy spacecraft inserts him in a backwoods area of Jaimec, the ninety-fourth planet of the Sirian Combine, along with a large cache of supplies and equipment, which Mowry hides in a secluded cave. He uses the cave as his base of operations as he travels between various cities on Jaimec, sowing confusion, misdirection, targeted murders, and terror.

In several ways, Mowry's tactics have him acting like a pufferfish, a small, vulnerable creature that, when threatened by a predator, expands to many times its normal size, using intimidation—the implication of offensive and defensive capabilities far more than what it possesses—to make actual physical combat unnecessary. The initial tactic Mowry deploys is very simple, yet extremely effective in spreading a sense of unease and apprehension both among Jaimec's population and its law enforcement cadres. He uses a machine in his cave hideout to print up hundreds of stickers with slogans that purport to be messages from an indigenous insurgent group opposed to the Sirian involvement in the war with Terra and highly dismissive of claimed Sirian successes in the war. These stickers are designed to be applied to glass surfaces; while affixed to glass, chemicals in the sticker etch the printed slogan into the glass, making removal of the slogan impossible, short of replacing the entire pane. Mowry surreptitiously affixes these stickers to phone booths, restaurant windows, storefronts, and the windows of public facilities. The resulting effects are twofold: not only does Mowry spread fear that a widespread underground organization exists that is in opposition to the war, but the fact that owners of buildings and businesses are unable to remove the slogans from their properties, at least not quickly or easily, spreads suspicion among the populace and law enforcement that these owners are supporters or even members of this organization. Mowry's use of this "sticker campaign" can be viewed as a precursor of today's Islamist terrorists' use of the Internet, in part, to make it appear that their support, reach, and capabilities are greater, perhaps, than they truly are. On the Internet, no one knows you're a dog; equally, no one knows a group of a dozen active malcontents is not actually a force of hundreds or thousands.

Mowry focuses his initial terror campaign on high-ranking officers of the Kaitempi, the Sirian secret police who are his chief foes. After he manages to insinuate himself with a mid-ranking Kaitempi, killing him, and stealing his credentials, including a list of fellow Kaitempi officers, Mowry hires a trio of local criminals and murderers to assassinate a more prominent Kaitempi officer, not telling his hirelings the identity of the man they are to kill. Simultaneously, he mails hundreds of threatening notes to other top-ranking Kaitempi, signed only with the name of his imaginary insurgent organization, *Dirac Angestun Gesept* (the Sirian Freedom Party), which personally threatens each of them with assassination. He also mails copies of the letters to members of the Sirian media and government so that his terror message will be disseminated even more widely. Mowry knows that his few hirelings will not succeed in killing more than a handful of Kaitempi leaders, at most. But he also intuits that this mail-facilitated information-terror campaign (in our times, much more efficiently carried out through the medium of the Internet) will cause the Kaitempi to "circle the wagons" and assign a goodly portion of their manpower to protecting their own leaders, rather than searching for Mowry and his imaginary followers. He ratchets up this terror campaign by mailing fake but realistic-looking bombs through the mail to Sirian governmental leaders, each with a message warning that the phony bomb they just opened could just have easily been a genuine one, and that if two of the working versions of these bombs were to be brought together in a public square, hundreds could be killed at once. Mowry operates off the assumption that fake bombs are more effective for his purposes than genuine bombs; explosive killings of government officials would be covered up in the media by the security forces but warning of the type Mowry sends will be spoken of throughout the governmental and security spheres, spreading terror through personal networks. Taking advantage of only four targeted murders (the victim of one being an unreliable hireling who had tried squealing to the Kaitempi), plus claiming credit for killings carried out by the Sirian security forces, Mowry is able to provoke his foes into declaring restrictive regimes of martial law in Jaimec's largest cities and drawing military forces away from the primary campaign against the Terrans.

The climax of Mowry's "wasp" campaign of terror involves Jaimec's merchant fleet, a key piece of Sirian infrastructure that allows for transport of both military and civilian goods across the primarily ocean-covered planet. Mowry deploys a small fleet of inexpensive, small, automated sea craft that travel just beneath the surface and randomly extend periscope-like devices above the waves, thus (to surface observers) appearing to be enemy submarines. He then infiltrates Jaimec's largest commercial harbor and attaches a mine to the side of a merchant ship, timing its explosion to occur when the vessel is out on the open sea, so that it will appear the ship has been attacked by a submarine. Mowry reasons that this will result in vast military forces being deployed to hunt enemy submarines, which are Mowry's cheap, harmless drones. Similarly, in the present day, one can envision terrorists provoking huge expenditures of manpower and resources from America's or Europe's homeland security institutions simply by flying a few drones into the airspace of stadiums packed for championship athletic contests and then bragging on the Internet that they had done so; the drones need not even be armed to provoke such a reaction.

Although no evidence exists that I am aware of that the leaders of the Palestinian Liberation Organization ever read *Wasp*, the PLO of the late 1960s and early 1970s carried out a *Wasp*-like campaign with such near similarities to Mowry's tactics on Jaimec that Eric Frank Russell seemingly could have written their operations manual. Just as Mowry monopolized the attention of Jaimec's governmental and security leadership by threatening a key transportation system, so did the PLO gain the world's headlines by threatening the viability of commercial aviation with their campaign of hijacking passenger airliners. Just as Mowry made his imaginary organization seem far, far larger and more consequential than it truly was through a handful of carefully chosen and targeted assassinations, so did the PLO succeed in forcing their cause to the center of the international community's agenda by assassinating a handful of Israeli athletes at the 1972 Summer Olympics in Munich, Germany; a few years later, PLO Chairman Yassir Arafat was invited to address the United Nations General Assembly regarding the Palestinian situation, achieving a legitimacy few world leaders would have anticipated him and his cause achieving prior to the massacre at the Olympics. The PLO, however, was (and remains) an actual organization

with a leadership structure and cadres of armed operatives. What Russell foresaw with *Wasp* was a more advanced terror apparatus—a *virtual* terror organization consisting of a single operative, a limited supply of physical assets, and imagined impressions and expectations of potency spread person-to-person through interpersonal, governmental, and media networks, a terror organization whose primary weapons are the psychology of fear and the power of suggestion, rather than capabilities to inflict physical harm and destruction. The science fiction mindset contributed to Russell's development of this concept of a virtual terror organization. A commercial writer seeking to sell his novel in competition against other commercial science fiction writers, he envisioned a thrilling story of a highly resourceful and daring individual pitting himself against overwhelming numbers and daunting odds of survival, both subliminally flattering his readership (male social pariahs who believed/hoped they possessed unappreciated inherent qualities and skills the world would someday value) and impressing his acquiring editors with fresh, inventive takes on both technology (espionage technology, drones, and personal disguise) and military tactics.

6. The Intersection of the Science Fiction Mindset with Homeland Security: The Career of Jerry E. Pournelle and the Formation of SIGMA, the Science Fiction Think Tank

The career of the late Dr. Jerry E. Pournelle (he passed away due to heart failure in 2017 at the age of 84) exemplifies the fertile intersection, rife with potential, of the science fiction mindset with the needs of the U.S. military and homeland defense communities. Dr. Pournelle (he earned a Ph.D. in political science) was a well-known, best-selling science fiction writer whose first novel, *Red Heroin*, appeared under a pseudonym in 1969. His best-known and most-read books are his collaborations with fellow science fiction writer Larry Niven, including *The Mote in God's Eye* (1975), *Lucifer's Hammer* (1977), and *Footfall* (1986), among others. He also wrote a popular monthly column for the computer industry magazine *Byte*, which he continued after the column's demise as a series of frequent blog posts on the technology industry, science fiction, and politics. Less well-known is Pournelle's lengthy and consequential involvement with the aerospace and defense industries and with the evolution of strategic concepts that contributed to

America's victory in the Cold War and its global military dominance during the subsequent two decades. Following service in the U.S. Army during the Korean War, Pournelle took advantage of the G.I. Bill to acquire several degrees at the University of Washington, after which he went to work for aerospace giant Boeing. Among his many projects at Boeing was a study of the heat tolerances of the space suits Boeing's engineers were fabricating for NASA and the tolerances of the men who would be wearing them. Regarding this segment of his career, Pournelle is known to have joked to prolific fellow science fiction writer Robert Heinlein that at Boeing, Pournelle wrote far more science fiction than Heinlein ever managed, only his did not require any character development.[261]

Yet Pournelle's most influential book, in terms of its impact upon the world's military balance of power, written in collaboration with Dr. Stefan T. Possony and Col. Francis X. Kane, remains virtually unknown outside the small world of military colleges, the Pentagon's strategic planning offices, and military contractors. This is *The Strategy of Technology*, written between 1968 and 1970, a time when, as Pournelle notes in his Preface to the book's 1997 electronic edition, many U.S. strategists and political scientists, influenced by American setbacks in Vietnam and elsewhere around the world, feared that the United States was losing the Cold War to the Soviet Union and that our best option would be to vigorously pursue Henry Kissinger's preferred path of strategic détente and make the best situation possible from our gradual retreat and decline. The book was used as a textbook at the U.S. Service Academies for many years and was also on offer for a time as a text at the Air War College and National Defense University. *The Strategy of Technology* is notable for its recognition of the nature of inexorable technological progress as seen from a military vantage, as well as its description of how technology could be used as a decisive force multiplier, allowing for the United States to overcome the Soviet Union's advantages of a preponderance of military manpower, armor, aircraft, and other equipment through a decisive qualitative edge that would allow for strategic surprise. It laid down the conceptual framework that led the administration of President Ronald

[261] Neil Genzlingersept, "Jerry Pournelle, Science Fiction Novelist and Computer Guides, Dies at 84," *New York Times* website, September 15, 2017, https://www.nytimes.com/2017/09/15/obituaries/jerry-pournelle-science-fiction-novelist-and-computer-guide-dies-at-84.html.

Reagan to pursue the Strategic Defense Initiative, a move that proved a factor in the bloodless defeat of the Soviet Union in the Cold War. Its influence also helped pave the way for U.S. development of stealth technology, electronically networked weapons systems, and the revolution in battlefield command and control systems, all which contributed to the dramatic U.S. victory in the first Iraq War and to the subsequent two decades of U.S. military superiority over its geopolitical rivals.[262]

Later in his career, Pournelle would become a member of SIGMA, the science fiction think tank founded by science fiction writer and environmental engineer Arlan Andrews in 1992 to provide the insights of the science fiction community to U.S. defense, intelligence, and homeland security institutions. In 1992, Andrews, a member of the American Society of Mechanical Engineers, was serving as a White House Fellow and staffer in the White House Science Office when he witnessed his boss, Dr. Alan Bromley, President H. W. Bush's Science Advisor, suffer humiliating laughter from a room full of scientists and bureaucrats for mentioning that virtual reality could potentially become an important aspect of future computer systems. This followed close on the heels of Andrews witnessing another forward-looking scientist, Dr. Joe Bordogna, the National Science Foundation's Deputy Director for Engineering, being made the butt of jokes from his National Science Foundation colleagues for suggesting that a decade hence, nanotechnologies and micromachines would become prominent on the scientific horizon. In response to these experiences, which indicated a crippling lack of imagination within the federal science establishment, Andrews founded SIGMA, whose membership he initially limited to science fiction writers with doctorate degrees in science or engineering, or medical degrees, to not provoke giggles from the federal partners with whom they hoped to work as *pro bono* consultants. SIGMA's founding manifesto summed up Andrews's complaints and aspirations: "The Future is too important to be left to the futurists. I have heard more appropriate and realistic forecasts of technology and the future at any given science fiction convention than in all the forecasting meetings I have attended here in Washington, D.C., … (W)e science fiction writers have spent our literary careers exploring

[262] Stefan T. Possony, Jerry E. Pournelle, and Francis X. Kane, *The Strategy of Technology* (self-published electronic edition, last revised 1997), https://www.jerrypournelle.com/slowchange/Strat.html.

the future, we owe it to the rest of humanity to come back and report on what's out there."[263]

Andrews's initial recruits for SIGMA included fellow science fiction authors Doug Beason, who also served as an Air Force Lieutenant Colonel assigned to the President's Office of Science and Technology Policy, Dr. Charles Sheffield, Dr. Yoji Kondo (who wrote SF under the pen name Eric Kotani), Dr. David Brin, Dr. Gregory Benford, Dr. Stanley Schmidt (then editor of *Analog Science Fiction & Fact*), Dr. Robert Forward, Dr. Geoff Landis, and Greg Bear. Although in its early years, SIGMA's efforts to engage with the government as a group were rebuffed, individual members managed to brainstorm educational technology ideas for DARPA, deliver a lecture to a standing-room only audience at Sandia National Laboratories, and serve as paid consultants; also, Andrews contributed an endorsement of nanotechnology to the April 1993 edition of *The President's Report to Congress on Science and Technology* (a response, perhaps, to the humiliation he had seen heaped upon his colleague Dr. Bordogna). The organization's first formal interaction with a sector of the federal government occurred in 1999, when the group offered a day and a half long discussion seminar to the Sandia National Laboratories' Advanced Concepts Group entitled "Future National Threats." However, it was not until nearly eight years later, in May 2007, that the group held its second formal interaction with the federal government, this time an invitation of six of SIGMA's members to participate in the Department of Homeland Security Science & Technology East Coast Stakeholders' Conference. SIGMA member Dr. Jerry Pournelle chilled the audience by leading them in a discussion of what sorts of mitigations the government should have ready to roll out in response to an attack on the United States that left the country's twenty largest cities devastated and all communications systems inoperable. Other SIGMA participants offered DHS S&T officials ideas regarding post-disaster resilient communications and how DHS might best deploy the cell phone-installed chemical/biological agent detectors that S&T teams were developing.[264]

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[263] Andrews, Sr., "SIGMA: Summing Up Speculation," 39–40.

[264] Ibid., 40–41.

SIGMA's participation in this event led to a flattering interview of SIGMA members by a reporter from *DoD*, which opened the gates for other federal agencies to invite SIGMA members to advise them regarding potential future developments in fields as diverse as demography, sociology, computer science, politics, communications, and culture. Clients for SIGMA's no-cost consultations, lectures, and panel or round-table discussions have included the U.S. Army's Tech 2025 Conference (also called the "Mad Scientist" conference), the North Atlantic Treaty Organization's NATO 2030 conference, other conferences sponsored by DHS S&T, the Joint Services Small Arms Program, and the 2012 Global Competitiveness Forum.[265]

As of December 2017, SIGMA was comprised of 43 members, including most of the original nine recruited by Arlan Andrews. Members are no longer required to have a doctoral degree in science or engineering or a medical degree, although a professional background in the sciences or engineering is highly valued within the group. Current members who have achieved notable success in the science fiction field (some of science fiction's most popular living authors) include Dr. Catherine Asaro, John Barnes, Greg Bear, Dr. Gregory Benford, Dr. Ben Bova, Alan Dean Foster, Kathleen Goonan, Joe Haldeman, Nancy Kress, Dr. Geoffrey A. Landis, Larry Niven, Elizabeth Moon, Dr. Stanley Schmidt, Bruce Sterling, Steve Sterling, Michael Swanwick, and Walter Jon Williams.[266] According to the SIGMA Forum website:

> With sufficient notice, SIGMA can provide a panel of distinguished science fiction authors with real-world expertise ranging over physics, astrophysics, nuclear science, advanced weaponry, engineering, nanotechnology, biomedicine, human factors and a common element of practical futurism. Other members can be recruited as needed; a large pool of potential SIGMAns exists within the professional science fiction community. SIGMA members have each committed to consult with Federal authorities for taskings on vital national issues for several days, for travel and lodging

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[265] Ibid., 41–43.

[266] "SIGMA Members," *SIGMA Forum* website, accessed December 22, 2017, http://www.sigmaforum.org/?page_id=117; http://www.sigmaforum.org/?page_id=125; http://www.sigmaforum.org/?page_id=134; http://www.sigmaforum.org/?page_id=140.

> expenses only. For extended effort or research, compensation may be based on individual contracts, as appropriate.[267]

Thus, the homeland security enterprise has already benefitted from a Proof of Concept for the involvement of science fiction writers having professional backgrounds in science and technology for brainstorming and advisory efforts. The work of SIGMA collectively and the work of its members independently, prominent among them the late Dr. Jerry Pournelle, should help break down any remaining resistance on the part of homeland security professionals to incorporating science fiction writers, with their vital science fiction mindset, into a "devil's toy box" analytical venture.

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Each of the forecasting methods considered to this point has assumed the participation of experts as prognosticators; however, not all forecasting methods in use today operate from the premise of expert participation. Relying upon eighteenth century economist Adam Smith's notion of the "invisible hand" that guides markets to the most efficient outcomes, and the more recent "dumb agent theory" of economics, which states that intelligent markets arise from the trading decisions of even "dumb," or relatively uninformed, traders, forecasting methods such as prediction markets and prediction polls eschew the notion of the desirability of restricting participation to experts. Going even a step further, predictive analytics largely pushes human analytical effort to the side, relying on sophisticated algorithms and computing power to find correlations in massive sets of seemingly random data to create forecasts. In the following chapter, I will consider whether any of these techniques may be of use to a "devil's toy box" analytical effort.

[267] Ibid., http://www.sigmaforum.org/?page_id=107.

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VIII. THE WISDOM OF CROWDS: PREDICTION MARKETS, PREDICTION POLLS, THE WISDOM OF SELECT CROWDS, AND PREDICTIVE ANALYTICS

A. PREDICTION MARKETS: UNDERLYING THEORIES AND EARLY DEVELOPMENTS

In 1948, British economist Friedrich Hayek published his elaboration on earlier economist Adam Smith's notion of the "invisible hand," the amalgamation of tendencies that guide unregulated markets in goods and services such that the averaged welfare of all participants is increased. Hayek called this his Efficient-Market theory, which stipulates that markets act to aggregate otherwise separate bits of knowledge concerning the environment within which a market operates and the forces acting upon that market, and that they do so through the mechanism of prices. The market, by amalgamating vast amounts of scattered pieces of information, can be collectively far more intelligent than any of its individual participants are. A little less than half a century earlier, in 1906, the British statistician Francis Galton made use of an already existing betting game to demonstrate in striking fashion the existence of the collective intelligence of a crowd of ordinary persons (non-experts and non-specialists). Approximately 800 persons participated in a betting game wherein they were asked to guess the weight of an ox; betters placed their names and best guess of the beast's weight on a slip of paper, and the person who came closest to the animal's actual weight would win a prize. Galton borrowed the 800 slips of paper and averaged all the guesses. This average varied from the ox's actual weight by less than one percent.[268] Similarly, in 1968, Dr. John Craven of the U.S. Navy's Special Projects Division was assigned to head up the search for the Navy's missing nuclear submarine, the *U.S.S Scorpion*. Craven gathered a team composed of submarine officers, salvage specialists, and scientists, then organized an internal prediction market for them to participate in. Eventually, the *Scorpion* was discovered to be resting 220 yards from where Craven's team predicted it would be found.[269]

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[268] Weigle, *Prediction Markets*, 5.

[269] Ibid., 7.

Michael Abramowicz, Professor of Law at George Washington University, is more in accord with Dr. Craven than with Galton regarding the most appropriate participants in a prediction market, clearly preferring expert or specialist participants. He describes prediction markets as

> a tool for aggregating the views of people who many have used sophisticated methodologies, such as the tools of econometrics, to make individual estimates. Prediction markets provide financial incentives for the best-situated individuals to apply the best available tools to predictive problems, and to test the depth of conviction of those who have done detailed analyses themselves, as well as those who have studied the work and reputations of such expert analysts. Thus, they can effectively identify a consensus position.[270]

In 1988, researchers at the University of Iowa obtained a legal exemption from federal and state laws banning gambling to set up the Iowa Electronic Markets, a pioneering attempt to appropriate market principles for a futures market to predict elections outcomes. The Iowa Electronic Markets offer contracts regarding federal elections, selected state and foreign country elections, and various types of economic events, such as decisions made by the Federal Reserve Open Market Committee. Although the researchers' agreement with the Commodities Futures Trading Commission limited accounts to $500 and only allows academics to participate in buying and selling futures contracts regarding economic events, members of the public have been allowed to participate in the elections markets. Trade prices must fall within a range of $0.00 to $1.00 and reflect predicted probabilities between 0% and 100% (for example, a trade valued at $.45 means that the trader has a 45% confidence level/expectation that a candidate will win the election). The elections markets have performed as well as or slightly better than averages taken of major national elections polls, with error rates tending to fall between 1.37% and 3.44%.[271]

Inspired by the success of the Iowa Electronic Markets, Robin Hanson, an early Silicon Valley researcher into artificial intelligence and the design of the World Wide Web,

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[270] Michael Abramowicz, "The Politics of Prediction," *Innovations: Technology, Governance & Globalization* 2 (Summer 2007): 90.

[271] Ibid., 11–12.

originated the concept of "idea futures," wherein market principles could be harnessed to predict a wide range of political, social, and technological outcomes. Working with Mark James and Sean Morgan, Hanson developed the Foresight Exchange in 1994, the world's first web-based betting market, which elided U.S. anti-gambling laws by using play money (which could be exchanged for prizes) rather than real money.[272]

B. PREDICTION MARKETS: DARPA'S POLICY ANALYSIS MARKET

Michael Foster, program manager for the quantum computing research program sponsored by the National Science Foundation, learned of Hanson's "idea futures" experiments and the work of the Iowa Electronic Markets and convinced colleagues at DARPA that their agency should fund research into how prediction markets could potentially be used to guide public policy decision-making.[273] DARPA viewed the "dumb agent theory" (markets are collectively "smart" even when their participants may be individually "dumb") regarding markets' powers to uncover previously hidden information as a possible solution to the counterproductive siloing of vital information, within the various agencies of America's intelligence community. Many observers had suggested that siloing of information in the months leading up to the 9/11terror attacks had abetted the terrorists' movements in and out of the United States. DARPA's managers believed a prediction market could serve as an aggregation mechanism capable of bypassing bureaucratic and political obstacles to information sharing.[274] In May 2001, DARPA requested proposals under the project heading "Electronic Market-Based Decision Support." DARPA awarded two companies, Neoteric Technologies and Net Exchange, the initial two small business independent research grants. Robin Hanson, then a professor at George Mason University in Virginia, was subcontracted to perform research work as a system architect for Net Exchange, whose project came to be known as the "Policy Analysis Market," or PAM.[275] Hanson describes the goals of the Policy Analysis Market

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[272] Hanson, "The Policy Analysis Market: A Thwarted Experiment," 76.

[273] Ibid., 75.

[274] Looney, "DARPA's Policy Analysis Market," 411.

[275] Hanson, "The Policy Analysis Market:A Thwarted Experiment," 75.

as having been "to forecast military and political instability around the world, how U.S. policies would affect such instability, and how such instability would influence U.S; and global aggregates of interest, such as growth rates or oil prices."[276] When PAM's designers discovered the high prices that The Economist Magazine's Economists Intelligence Unit would charge Net Exchange to determine what levels of instability actually developed in each nation of interest, the designers economized by focusing their attention exclusively on eight key nations of the Middle East.[277] The eight nations selected for analysis were Turkey, Syria, Israel, Saudi Arabia, Iraq, Iran, Jordan, and Egypt.[278]

The initial test period was scheduled to extend for two years. Every three months, participants would engage in trading activities to determine prices (probabilities) regarding five parameters for each of the eight nations, to include U.S. financial involvement in each, U.S. military activity in each, that nation's economic growth, level of political instability, and its own military's activities. In addition, traders would predict expected values for economic indicators such as world trade and U.S. Gross Domestic Product (GDP) and security indicators such as aggregate Western casualties from terror events and total U.S. military casualties. Participants would also be permitted to trade futures on future events occurring within the eight nations of interest, and buyers and sellers would be allowed to exchange money placed on bundled, contingent predictions, what Hanson terms combinatorial market trades. Net Exchange's original plan for PAM was to run the prediction market with a pool of participants drawn from the full range of federal intelligence agencies, with "winnings," rather than being granted directly to traders, instead being distributed to fund those winning traders' agencies' research projects; however, federal laws erected too many barriers against conditional transfers of funds between federal agencies. That idea was dropped, and Net Exchange attempted to recruit a single large agency whose analysts could serve as traders. They found no takers, and so they were forced into the fallback position of running a market open to the public, being able to do

[276] Ibid., 77.

[277] Ibid.

[278] Looney, "DARPA's Policy Analysis Market," 407.

so because serving as agents of the Department of Defense shielded the company from anti-gambling laws. The designers laid out a schedule wherein PAM would begin test operations with a hundred test traders on September 1, 2003, each tester being given $100 with which to trade. Full operations were scheduled to begin on January 1, 2004 with a thousand initial traders. This was actually a nominal schedule, since Congress had earlier introduced significant financial uncertainty by cancelling all current funding for DARPA's Information Awareness Office (IAO), under which the Policy Analysis Market operated, due to political concerns with privacy issues regarding another of IAO's projects, the Total Information Awareness project (formerly called the Terrorism Information Awareness project).[279]

Regarding the fate of the Policy Analysis Market and the overarching FutureMAP project (Future Markets Applied to Prediction, the renamed Electronic Market-Based Decision Support project), worse was soon to come. In the midst of the overheated political environment caused by the debate over the 2003 invasion of Iraq and the justifications for the invasion provided by the George W. Bush administration, Democratic Senators Byron Dorgan and Ron Wyden held a joint press conference on July 28, 2003 to denounce DARPA's FutureMAP project as a "terror market" that would allow members of the public to bet on the likelihood of terror attacks.[280] To bolster this assertion, the senators referred to one of the DARPA webpages, which explained how the Policy Analysis Market worked. This page listed various miscellaneous events whose probabilities participants would be able to make trades against; these events included the king of Jordan being deposed or overthrown, a North Korean missile strike, and whether Palestinian Authority Chairman Yassir Arafat would be assassinated within a timeframe. The senators strove to make the FutureMAP project appear more "Strangelove-ian" by highlighting the fact that former Admiral John Poindexter, a Reagan Administration figure infamously connected with the Iran-Contra scandal of the 1980s, had been appointed supervisor of the project. Dorgan and Wyden had chosen to present their press conference at a time when DARPA's public

[279] Hanson, "The Policy Analysis Market: A Thwarted Experiment," 77–79.

[280] Ibid., 79.

relations manager was out of the office and unreachable, thus depriving that agency of a chance to offer a timely and informed response to the senators' allegations.[281] The highly emotional tone of their press release is epitomized by this quote: "Spending millions of dollars on some kind of fantasy league terror game is absurd and, frankly, ought to make every American angry. What on Earth were they thinking?"[282]

The following day, approximately fifty negative articles appeared in the Nation's press regarding FutureMAP. The Washington Post declared that the project reflected the Bush Administration's extreme, "near religious" belief in the applicability of market-based solutions to all problems and chided the administration for seeking a dubious short-cut to knowledge that could only be gained through painstaking intelligence work. Joseph Stiglitz, a Nobel Prize-winning economist, in an editorial written for the Los Angeles Times ridiculed the notion that an operation such as the Policy Analysis Market could successfully unearth information regarding terrorist activity that had not earlier come to the attention of the CIA or FBI. He also stated that anonymous markets would be subject to manipulation by malign parties, and non-anonymous markets would fail to attract participants holding the desired information. On July 29, 2003, the day after Dorgan's and Wyden's press conference, Deputy Secretary of Defense Paul Wolfowitz announced to the Senate Foreign Relations Committee that the FutureMAP program had been terminated. This decision had been made without any input being solicited from the Policy Analysis Market project team regarding the truth of the allegations and whether the project could be adjusted to make it more politically palatable.[283]

Hanson has pointed out that, based upon his analysis of approximately 500 articles written about FutureMAP and/or the Policy Analysis Market, those written by more

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[281] Robin Hanson, *The Informed Press Favored the Policy Analysis Market* (Fairfax, VA: Department of Economics, George Mason University, August 8, 2005), 2, http://mason.gmu.edu/~rhanson/PAMpress.pdf.

[282] Senators Ron Wyden and Byron Dorgan, "Wyden, Dorgan Call for Immediate Halt to Tax-Funded 'Terror Market' Scheme," (press release, Washington, DC: Offices of Senators Ron Wyden and Byron Dorgan, July 28, 2003), http://wyden.senate.gov/media/2003/print/print_07282003_terrormarket.html.

[283] Hanson, "The Policy Analysis Market: A Thwarted Experiment," 79–82.

informed analysts, who took time to contemplate the economic theories the program was based upon and to accurately describe the program's intended purposes, tended to be more favorable to the program than those writers who reacted from a less-informed stance.[284] As an illustration of this, Charles Seife, a writer for Science, wrote admiringly in an August 3, 2003 article that the designers of FutureMAP had attempted to "essentially creat[e] a social-science supercomputer out of flesh rather than silicon."[285] Yet the damage had already been done.

C. PREDICTION MARKETS AND PREDICTION POLLS: THE GOOD JUDGMENT PROJECT

However, the potential promise of prediction markets for improving intelligence forecasts of significant world events proved too alluring for the subject to be permanently consigned to the garbage heap of failed governmental initiatives. Beginning in 2011, the Aggregative Contingent Estimation (ACE) program of IARPA, the Intelligence Advanced Research Projects Activity, sponsored a four-year-long forecasting tournament that sought to substitute numerical estimates of probability for the vague, qualitative estimates that had predominated in intelligence estimates to that point. Slippery words such as "May" "could," "might," and "maybe" had been found to imply vastly different levels of probability when expressed by different intelligence analysts; studies had shown that such hedging words could indicate an implied probability of occurrence as low as 0.08 for some forecasters and as high as a 0.59 probability of occurrence to other forecasters, a range of variations that rendered the hedging words typically found in intelligence estimates essentially meaningless. Within the constraints of such qualitatively-based estimates, individual intelligence analysts could not be scored on their accuracy, for the definition of accuracy was elastic, due to the elasticity of the hedging words upon which the forecasts were based ("I only said that the U.S. sending arms to the Ukrainians *might* provoke a hostile Russian response to the U.S., not that it *would*"). Since analysts could not be scored

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[284] Hanson, *The Informed Press Favored the Policy Analysis Market*, 14.

[285] Charles Seife, "´Terrorism Futures' Could Have a Future, Experts Say," *Science*, August 8, 2003, 749.

or ranked on accuracy, any efforts to train them for improved accuracy would be futile, due to the inability to measure improvements (or any change) in their performance over time, rendering feedback impossible.[286]

The IARPA forecasting tournament, originally encompassing five teams, each from a different university, sought to elicit quantitative probability predictions for a wide range of sociopolitical, military, and economic events that were resolvable—which would either occur or not occur within a stipulated time. Forecasters' accuracy was measured using Brier scores, wherein events that occur are coded as 1 and events that do not occur are coded as 0, and the Brier score is calculated as the sum of squared errors between what occurs and the probability forecast. To provide an example, a participant might predict a 70% chance that the fourth quarter growth rate in U.S. gross domestic product (GDP) would be 3.0% or higher (and accordingly, the chance that the growth rate would be less than 3.0% would be predicted as 30%). Actual GDP growth rate is later seen to be only 2.5%. This participant's Brier score would be calculated as $(0.7–0)^2 + (0.3–1)^2 = 0.833$. The best possible Brier score is 0, representing perfect forecasting ability, and the worst possible score is 2, representing complete failure at forecasting. Had the participant predicted the reverse set of probabilities, that there was only a 30% chance of GDP growth hitting or exceeding 3% and a 70% chance that growth would fall short of 3%, the Brier score would be calculated as $(0.3–0)^2 + (0.7–1)^2 = .18$. This would represent a large improvement in the Brier score, and, more importantly, a *measurable* improvement that would allow for individual accountability and learning.[287]

Only one of the five university teams, dubbed the Good Judgment Project, continued beyond the end of the second year of the tournament; its members' accuracy proved so superior to that of the members of the other four teams that the managers of IARPA's Aggregative Contingent Estimation project deemed it unnecessary for the other four teams to continue their participation. During the first three years of the tournament,

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[286] Philip E. Tetlock, Barbara A. Mellers, and J. Peter Scoblic, "Bringing Probability Judgments in Policy Debates Via Forecasting Tournaments," *Science* 355 (February 3, 2017), 481, doi: 10.1126/science.aal3147.

[287] Ibid.

encompassing predictions of future events that could be determined to have actualized or not by the end of the fourth year of the study, the Aggregative Contingent Estimation project presented the Good Judgment Project participants with 344 different forecasting questions, which were responded to by 2,860 GJP respondents, for a total of 494,552 forecasts. Good Judgement Project facilitators recruited their 2,860 participants through science blogs, research centers, professional societies, alumni associations, and through word-of-mouth referrals. Participants received minimal financial compensation. For those who lasted at least one full year of the competition and submitted at least 25 forecasts, the facilitators provided $150; for those who made it through years 2 and 3 and who continued providing at least 25 forecasts per year, payments of $250 were provided at the end of each of those years. Participants could also collect $100 bonuses for continuing from one year's efforts to the next. Researchers observed that participants tended to devote at least two hours per week on research to support their forecasts while engaged in the tournament, while some devoted more than ten hours per week to research. Prior to making their initial forecasts, participants engaged in two hours of psychological testing and training on compensating for biases in forecasting. This training focused upon various techniques through which individual forecasters could benefit from "the wisdom of the crowd" (their fellow team members); suggested use of statistical methods for amalgamating forecasts; overviews of the relative frequencies of events actualizing that were similar to those that would be forecast; and instruction regarding the dangers of forecasting overconfidence, on the one hand, and an excess of caution, on the other.[288]

During the second and third years of the forecasting tournament, the facilitators of the Good Judgment Project randomly assigned their forecasters to participate in either prediction markets or prediction polls (also called competitive forecasting), to allow for comparisons to be made regarding the benefits to be derived from each method. Prior laboratory experiments, far smaller in scale than the Good Judgment Project, had indicated

[288] Don A. Moore, Samuel A. Swift, Angela Minster, Barbara Mellers, Lyle Ungar, Philip Tetlock, Heather H. J. Yang, and Elizabeth R. Tenney, "Confidence Calibration in a Multiyear Geopolitical Forecasting Competition," *Management Science, Articles in Advance* (August 22, 2016): 2–4, https://doi.org/10.1287/mnsc.2016.2525.

that the two methods achieved approximately equal levels of forecasting accuracy. During the two years covered in this phase of the Aggregative Contingent Estimation project, the facilitators chose a continuous double auction design for their prediction market, wherein traders who place bids, or buy orders, are matched with traders who place sell orders; trades, which set prices for contracts, take place when the highest buying price on offer is equal to or higher than the lowest selling price. No actual money exchanged hands during this part of the ACE study; simulated currency was used, instead. Prediction polls differ from election polls or policy preference polls in that participants offer a numerical probabilistic likelihood forecast of an event occurring, in lieu of informing a pollster of how they intend to vote in an upcoming election or whether they agree or disagree with a policy prescription. In the prediction polls used in this study, forecasters could update their forecasts as often as they wished, forecasters were given feedback on their performance using the Brier scoring system I earlier described, and the forecasters were placed in a state of competition with one another regarding accuracy. The Good Judgment Project utilized two forms of prediction polls: polls of individuals, wherein all the participants competed individually against one another, and team poll competitions, wherein teams of approximately 15 members were encouraged to pool their information, discuss competing rationales for differing forecasts, and offer social encouragement to one another. For the team polls competitions, each team's numerical probabilistic forecast was devised as the mean of the team members' individual forecasts. The Good Judgment Project facilitators refined these mean forecasts through two methods: exponential discounting, wherein more recent forecasts are given heavier weighting than older forecasts, and through granting heavier weighting to those forecasts by participants whose prior forecasting records had shown them to be more accurate than the mean.[289] The researchers determined that individual participants' forecasting skill level could be established through their participation in a "seeding poll" of 20–25 questions.[290] In both the prediction market and

[289] Pavel Atanasov, Phillip Rescober, Eric Stone, Samuel A. Swift, Emile Servan-Schreiber, Philip Tetlock, Lyle Ungar, and Barbara Mellers, "Distilling the Wisdom of Crowds: Prediction Markets vs. Prediction Polls," *Management Science* 63, no. 3 (March 2017): 693–695, https://doi.org/10.1287/mnsc.2015.2374.

[290] Ibid., 704.

the two types of prediction polls, participants, while mostly of advanced educational background (having at least a bachelor's degree) and at least somewhat informed on the subjects for which they were entering forecasts, could not be considered subject matter experts, mainly due to the great range of differing subjects and specialties (economics, geopolitics, national and local politics, military campaigns, and social developments) covered by the questions posed by IARPA.[291]

The results seen by the Good Judgment Project were as follows. Regarding accuracy, simple mean results of the team prediction polls outperformed the results of prediction markets, which in turn outperformed simple mean results of the individual prediction polls. Furthermore, when the researchers refined the amalgamation algorithm using increased weightings for the most recent predictions, increased weightings for forecasts offered by participants with the best prior records of forecasting accuracy, and recalibration to account for excess caution of forecasts (under confidence), the team prediction polls outperformed prediction markets by significant margins, and the independent prediction polls mostly tied for accuracy with the prediction markets. Regarding the correlation of participants' self-confidence levels with their accuracy, the researchers found that prediction markets reflect systematic under confidence, like prediction polls when results are aggregated; prediction poll results at the individual, non-aggregated level were seen to be slightly overconfident. The researchers hypothesize that the lesser accuracy seen by participants in prediction markets versus prediction polls may have been due to the former's lack of a sophisticated, strategic knowledge of the workings of markets and how to best prevail in such a setting. The researchers also speculate that team prediction polls offer superior inducements to share information among participants than do prediction markets; in the latter environment, the competition is viewed by participants as a zero-sum game, wherein one trader loses when another gains, whereas in the former environment, improvements spread among some or all team members result in an improved result for the team overall. Team prediction polls offer a bit of "the best of both worlds"—intra-team cooperation, pooling of information, and social encouragement,

[291] Ibid., 693.

combined with inter-team competition. Finally, the researchers point out that the advantage offered by a team prediction poll over a prediction market is especially large when the number of available participants is relatively small, as markets can suffer from "thin market syndrome," or an inability to set prices, when the number of traders is so low that not all possible trades accrue a willing buyer and seller.[292] Impressively, the most accurate results achieved by the Good Judgment Project outperformed, by about a 30% margin, a prediction market whose participants were all subject matter experts in their fields, intelligence analysts drawn from across the U.S. intelligence community who had access to classified information, whereas the Good Judgment Project participants did not.[293]

D. THE WISDOM OF SELECT CROWDS

Albert E. Mannes, Jack B. Soll, and Richard P. Larrick have suggested an alternative to prediction markets and prediction polls, what they have termed the select-crowd strategy. In a select-crowd forecasting procedure, participants are ranked in terms of forecasting ability using an available indicator of ability (such as performance on recent forecasts), and the group's amalgamated output is the average of the inputs of the top five ranked participants. The researchers contrast the select-crowd strategy with what they call the whole-crowd strategy (the averaged or otherwise amalgamated opinions of all the members of a crowd, such as in a prediction poll) and with what they term the best-member strategy (participants on a forecasting team or panel select the opinion of the single member they collectively judge to be the best or most accurate as the group's consensus opinion; the basis of the group's selection of their best-member representative may be that person's credentials, status in an organization, or expressed confidence). They point out that in varying types of environments, one of these three strategies will lead to the best or most accurate outputs. For example, in an environment in which participants' forecasting abilities vary widely and unambiguous indicators of those abilities are readily available, the best-member strategy tends to perform the best. Contrarily, in an environment

[292] Ibid., 703–704.

[293] Tetlock et al., "Bringing Probability Judgments in Policy Debates Via Forecasting Tournaments," 482.

distinguished by small differences in forecasting ability and frequent bracketing (i.e.: participants' forecasting errors show an approximately equal likelihood of being either above or below the true value by approximately equal amounts), the whole-crowd strategy is preferable. The difficulty in selecting the appropriate procedure comes in determining what type of environment applies in each situation. Given this indeterminacy of environments, the researchers indicate that the select-crowd strategy is the most robust, due to the fact that in two types of environments (a low bracketing/low dispersion in expertise environment and a high bracketing/high dispersion in expertise environment), the select-crowd strategy is optimal, and in the other two types of environments (a low bracketing/high dispersion in expertise environment and a high bracketing/low dispersion in expertise environment), the select-crowd strategy is second best out of three strategies that might be chosen.[294]

As part of their experiments, Mannes et al. tested varying numbers of most highly ranked participants to serve as part of their select-crowd strategy. They found that, depending on the type of environment, select crowds varying in size between three and eight in number could be optimal, but that in situations where the type of environment is unknown, selecting five high-ranking judges serves as a "best compromise" optimal number. They found that only short histories of prior forecasting performance (one to five prior forecasts, with the higher number being preferred for environments of high dispersion of levels of expertise) are required to productively rank participants by ability. This is due to their findings that in a situation of high dispersion of expertise, minimal testing is all that is required to differentiate between participants, whereas in a situation of low dispersion of expertise, when all participants are approximately equal in their ability, no amount of testing would reveal significant differences.[295]

The authors illustrate that in previous research regarding how acceptable/plausible various types of judgment aggregation are to recipients of the aggregated judgments, the

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[294] Albert E. Mannes, Jack B. Soll, and Richard P. Larrick, "The Wisdom of Select Crowds," *Journal of Personality and Social Psychology* 107, no. 2 (2014): 277–279, doi: 10.1037/a0036677.

[295] Ibid., 281–286.

best-member strategy was consistently shown to have the highest popular appeal and acceptance, whereas the whole-crowd strategy rated considerably lower, due to the typical person's suspicion that averaging all responses, those provided by experts and non-experts alike, counterproductively dilutes the input provided by experts and results in a less accurate amalgamated output. Mannes et al. performed a trio of experiments that indicated that observers find the select-crowd strategy to have strong appeal when compared to the other two strategies, since it allows them to combine their instinctive, intuitive preference for a best-member strategy with an effective hedge against the possibility that they have improperly chosen the best-skilled participant (based on available social cues such as credentials or status in a group). The authors point out that the primary significance of the high acceptability/plausibility of the select-crowd strategy is to be found in the reactions of upper management to forecasting reports conducted by lower-level staffers. If bosses tend to be dismissive of forecasts based on the whole-crowd strategy, and the best-member strategy is only optimal in one of four environment types, then the select-crowd strategy combines the best of all possible worlds—acceptance from higher management *and* highest or second-best accuracy of the three possible strategies in virtually any environment.[296]

Most interestingly in the context of this thesis's overview of the development and evolution of forecasting techniques over the past seventy years, the select-crowd strategy presented by Mannes et al. as a refinement of the prediction poll technique has, in some ways, circled back to the early roots of forecasting as a field of academic study and corporate/governmental use. This refinement of "the wisdom of the crowd" philosophy, a philosophy that initially disregarded the input of selected experts in favor of the amalgamation of widely dispersed bits of knowledge held by non-experts, looks a good bit like a Delphi panel.

E. PREDICTION MARKETS AND PREDICTION POLLS: SUGGESTED BEST PRACTICES

Training: Philip Tetlock, author of *Superforecasting: The Art and Science of Prediction*, and his fellow researchers with the Good Judgment Project have expressed

[296] Ibid., 286–292.

gratified surprise at the longevity of the beneficial effects of the initial, brief training sessions they provided for participants. These trainings' subject matter included reducing overconfidence in predictions, avoiding common cognitive biases, and using Bayesian statistical methods to refine or change their forecasts over time as new information becomes available. They found that the benefits of the training regarding avoiding the pitfalls of overconfidence, stuck with the participants throughout entire forecasting years. They hypothesize that the regular feedback on performance that participants were given helped to "cement" in their minds what they had learned from their training.[297] Additionally, the researchers found that training in group dynamics was helpful for those participants assigned to work on team prediction polls, specifically training in how to question one another's assumptions and reasoning in a clear, logical, non-emotional fashion—i.e.: "how to disagree without being disagreeable."[298] They compared the benefits of scenario training (teaching participants to envision a broad range of possible futures, how to use decision trees, and how to avoid biases in forecasting such as fabricating incoherent scenarios, overpredicting patterns of change, or assigning probabilities that exceed a sum of 100% to a range of mutually exclusive and comprehensive outcomes) with those of probability training (the use of Bayesian statistical methods as mentioned above). The researchers found that the benefits of probability training outweighed those of scenario training, but the provision of scenario training resulted in higher levels of forecasting accuracy by its recipients than the accuracy shown by participants who received no training at all.[299]

Prior to Tetlock et al.'s work on the Good Judgment Project, George Wright and a team of researchers in the United Kingdom conducted a study on the connections between forecasters' self-estimated level of expertise, their understanding of the workings of

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[297] Moore et al., "Confidence Calibration in a Multiyear Geopolitical Forecasting Competition," 10.

[298] Tetlock et al., "Bringing Probability Judgments in Policy Debates Via Forecasting Tournaments," 482.

[299] Barbara Mellers, Lyle Ungar, Jonathan Baron, Jaime Ramos, Burcu Gurcay, Katrina Fincher, Sydney E. Scott, Don Moore, Pavel Atanasov, Samuel A. Swift, Terry Murray, Eric Stone, and Philip E. Tetlock, "Psychological Strategies for Winning a Geopolitical Forecasting Tournament," *Psychological Science* 25, no. 5 (March 2014): 1107–1109, doi: 10.1177/0956797614524255.

probability estimations, and their calibration/accuracy in their forecasts. Although their experiment showed only a weak correlation between forecasters' coherence (their knowledge of and ability to apply mathematical probability axioms) and their accuracy on forecasting tasks, the researchers recommended that providing training in the laws of probability to forecasters prior to their making their predictions would likely provide some improvement to their performance, for those forecasting tasks involving compound probabilities (the probability of both A **and** B occurring) or contingent probabilities (the probability of A occurring once B has already occurred, or the probability of A occurring once B has not occurred).[300]

Teaming and Stratifying: During the first year of the IARPA forecasting tournament, the Good Judgment Project researchers found that having participants work collaboratively, on team prediction polls, resulted in more accurate forecasts than having the participants work separately. During the second year of the tournament, the researchers discovered that forecasting accuracy could be boosted even further by grouping the best forecasters, those whom the researchers dubbed "superforecasters," together on the same team. The elite super forecaster teams far out-performed all the other groupings, as well as individual forecasters and prediction markets. From these results, they postulated that forecasting is a learned skill and that the learning of this skill is accelerated when the very best performers are directed to collaborate with one another.[301]

Selection of Forecasters for Cognitive Style and Abilities: Researchers found that those participants whom they classified as superforecasters scored at least one standard deviation higher on measures of fluid intelligence than the general population; these measures included the Cognitive Reflection Test, the Shipley-2 Abstraction Test, and the Raven's Advanced Progressive Matrices. Superforecasters also scored higher than the

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[300] George Wright, Gene Rowe, Fergus Bolger, and John Gammack, "Coherence, Calibration, and Expertise in Judgmental Probability Forecasting," *Organizational Behavior and Human Decision Processes* 57 (1994): 22–23.

[301] Barbara Mellers, Eric Stone, Terry Murray, Angela Minster, Nick Rohrbaugh, Michael Bishop, Eva Chen, Joshua Baker, Yuan Hou, Michael Horowitz, Lyle Ungar, and Philip Tetlock, "Identifying and Cultivating Superforecasters as a Method of Improving Probabilistic Predictions," *Perspectives on Psychological Science* 10, no. 3 (2015): 269, doi: 10.1177/1745691615577794.

general population on tests of knowledge of both domestic and foreign political affairs, as well as on the Shipley-2 Vocabulary Test. Researchers found that superforecasters scored high on measures of competitiveness and displayed high levels of desire for intellectual challenges. Their enjoyment of the problem-solving process was reflected by their high scores on the Need for Cognition scale. The researchers stress that one of their most important findings regarding the cognitive style of superforecasters was a high level of open-mindedness, a willingness to change one's views in response to fresh information and reasoned arguments from peers.[302] The superforecasters tended to be more likely than the general population to hold to a secular, science-centered worldview, to "treat their beliefs more as testable hypotheses and less as sacred possessions—and to be warier of overinterpreting coincidences by attributing them to supernatural mechanisms such as fate."[303] Superforecasters put more emphasis on the value of deliberate practice for improvement of forecasting accuracy than did their less-accomplished peers. Within the milieu of the team prediction polls, they updated their forecasts more frequently than any other cohort of participants, and this frequency of belief-updating was determined by researchers to be the strongest correlator of accuracy. Finally, within the context of intra-group interactions, the researchers found that superforecasters were more willing than others to dig into the knowledge and opinions of their teammates, asking more questions of them, on average, than did the less accomplished participants.[304]

Selection of Forecasters for Diversity of Opinion, Background, and Knowledge: *The Wisdom of Crowds* author James Surowiecki emphasizes that one of the requirements for a crowd to be collectively smart is that it be diverse, containing a diversity of opinions, backgrounds, and localized or specialized knowledge. He states that, on average, better decisions will be made by a cognitively diverse crowd than by two or three very intelligent experts. He supports this by pointing out that expertise tends to be very narrow, whereas complex decisions are broad in their contributive factors; expertise in one area is rarely

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[302] Ibid., 273.

[303] Ibid.

[304] Ibid., 277.

transferrable to another area (expertise is not fungible); studies have shown that experts' forecasts are neither internally consistent (regarding different forecasts made by the same expert forecaster) nor consistent across a given area of expertise (experts within the same field often disagree, even on very technical matters relating to their field); and expert forecasters working independently have an overall poor record of accuracy.[305]

Weighting Forecasters' Contributions by Their Self-Estimated Levels of Expertise and Confidence: Mannes et al., in their research regarding the select-crowd strategy, examined the validity of various alternative cues to forecasting expertise, other than the results of past performance on forecasting tasks. They found that participants' self-evaluations of confidence could serve as a valid and reliable alternative judgment factor for facilitators to use in selecting the five preferred participants from a crowd, then averaging those five participants' inputs as the group's output. Based on their experiments, they found that selecting five participants based on those participants' self-evaluations of confidence resulted in group average forecasting outputs about as accurate as those derived from a select-crowd made up of participants chosen by facilitators based on five past forecasts. They suggest that using self-evaluated confidence as an alternative selection cue is especially appropriate in situations where the forecasting task involves an unprecedented or unique event, such as the anticipated remaining tenure for a foreign dictator.[306] Clearly, this latter stipulation applies in the instance of a "devil's toy box" analysis, which, by its nature, attempts to forecast unprecedented and mostly unique events involving technological innovations.

George Wright and his team of researchers in the United Kingdom conducted an experiment that indicated that forecasters' levels of self-reported expertise prove to be a reliable predictor of subsequent accuracy on forecasting tasks. They recruited 35 students attending Bristol Polytechnic to complete a forecasting questionnaire that encompassed 272 statements regarding the upcoming World Snooker Championships. The questionnaire items were all expressed in binary answer form (Yes/No; Will/Will Not). Slightly less than

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[305] Surowiecki, *The Wisdom of Crowds*, 31–33.

[306] Mannes et al., "The Wisdom of Select Crowds," 295.

half of the questions were conditional, questions about players' predicted performances that were contingent upon other players' prior accomplishments. Before they answered any questions, participants were asked to rate, on a 7–point scale (with "1" indicating very knowledgeable and "7" indicating no knowledge whatsoever), their level of prior knowledge, or expertise, regarding the game of snooker. The participants were also directed to rate each individual question regarding how difficult to answer they perceived that question to be, also on a 7–point scale (with "1" indicating extremely easy and "7" indicating extremely difficult). The researchers found that the participants who rated themselves as being more expert proved to be less overconfident, better calibrated, and likely to achieve higher accuracy scores than those participants who self-rated as less expert.[307] They contrast their finding of a strong correlation between self-rated expertise and subsequent forecasting performance with findings of earlier studies that found no correlation between socially-defined expertise (the aura of expertise granted an individual due to their position within an organization, their educational background, membership in professional associations, or other social factors) and forecasting performance.[308] The implication of their research for a "devil's toy box" analysis is that expert participants will need to be selected more for self-reported expertise than for paper credentials, or that the responses of those participants who rate themselves as more knowledgeable and more confident about the subject matter of a question should somehow be weighted more heavily than those respondents who rate themselves as less knowledgeable and confident, when the results for that question are amalgamated.

Optimal Number of Forecasters for a Prediction Pool: Ville A. Satopää and his fellow researchers, performing a study connected with IARPA's forecasting tournament, found that although aggregated accuracy of forecasts showed continual improvement as the number of forecasts aggregated increased, the majority of the improvement in accuracy occurred as the number of forecasters increased from 10 to 20, with the bulk of improvement having been obtained when the number of forecasters reached 20, and only

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[307] Wright et al., "Coherence, Calibration, and Expertise in Judgmental Probability Forecasting," 8–10.

[308] Ibid., 21.

small increases in accuracy seen as more forecasters were added. Additional moderate improvements tapered off significantly after the number of forecasters reached 40.[309]

Accountability: David R. Mandel and Alan Barnes, in their study of the accuracy of 1,514 forecasts provided by the Socio-Cognitive Systems Section of the Defense Research and Development Canada agency, hone in on the importance of a sense of personal accountability to improving individual forecasters' accuracy. They point out that a sense of the social, organizational, and personal/professional costs of getting an important forecast wrong, accentuated by the necessity to present one's forecasts to multiple, skeptical audiences, leads to reduced overconfidence on the part of forecasters, more thorough processing of information, and a deeper understanding and appreciation of the various determinants contributing to one's forecasting choices and decisions. Additionally, a higher sense of accountability leads to reduced over attribution bias, or the tendency to attribute more weight to a factor's causality effects than is warranted.[310]

F. PREDICTION MARKETS AND PREDICTION POLLS: POSSIBLE PITFALLS

Robert E. Looney, in his evaluation of DARPA's FutureMAP project as a potential intelligence and counter-terrorism tool that may have been abandoned by the Department of Defense too soon, examines several criticisms that were leveled against the program when Senators Dorgan and Wyden brought it to public light. Robin Hanson, one of PAM's designers, has also written extensively regarding the criticisms aimed at his project and has attempted to respond to them. I will focus on those criticisms that could be leveled against a use of prediction markets for the purposes of a "devil's toy box" analysis.

The problem of insider information: Could a system such as the Policy Analysis Market provide would-be terrorists with an incentive to purchase large numbers of shares

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[309] Ville A. Satopää, Jonathan Baron, Dean P. Foster, Barbara A. Mellers, Philip E. Tetlock, and Lyle H. Ungar, "Combining Multiple Probability Predictions Using a Simple Logit Model," *International Journal of Forecasting* 30 (2014): 351, doi: 10.1016/j.ijforecast.2013.09.009.

[310] David R. Mandel and Alan Barnes, "Accuracy of Forecasts in Strategic Intelligence," *Proceedings of the National Academy of Sciences (PNAS) of the United States of America* 111, no. 30 (July 29, 2014): 10988, doi: 10.1073/pnas.1406138111.

in a futures contract for a terror event, so they could then profit when they carry out the act? Intelligence analysts have speculated that Saddam Hussein profited from investing in oil futures prior to his invasion of Kuwait, which drove up prices, and others have observed that the stock market declined substantially following the 2001 attacks on the World Trade Center and Pentagon, leading to speculations that al-Qaeda profited by shorting the market; however, Looney points out that the small size of trades permitted under PAM's operating rules would have made it extremely unlikely that any terrorist could substantially profit by betting on the impact of his own destructive acts.[311] Similar rules governing the use of a prediction market for a "devil's toy box" analysis could also minimize the likelihood of insider information being used for nefarious purposes. Also, given the very specialized nature of a "devil's toy box" analysis versus the more generalist analyses envisioned under PAM, it is highly likely that facilitators would limit participation to vetted experts in various scientific, military, sociological, homeland security, and literary disciplines, greatly lessening the potential for participation by terror operatives who would seek to amass trading profits from their own destructive actions. Robin Hanson points out that, rather than fearing that would-be terrorists might try to profit from betting on their own activities, we should welcome such behavior. After all, he says, law enforcement agents would be delighted if they could pay a would-be bank robber $10 for that robber to tell them which bank he and his gang had selected to rob next.[312] He additionally observes that, regarding attempts to manipulate a market by spreading rumors or falsified information, participants who deliberately lie are another sort of "noise trader," which Hanson defines as someone who trades based upon mental mistakes, insufficient information, or emotional reasoning. The opportunity to bet against "noise traders" and make a profit is one of the prime motivators for more informed and rational traders to participate in a market, thus increasing a market's overall precision. Therefore, Hanson views "noise traders" as a plus, rather than a detriment, to market functioning.[313]

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[311] Looney, "DARPA's Policy Analysis Market," 412–413.

[312] Hanson, "Designing Real Terrorism Futures," 269.

[313] Robin Hanson, *Foul Play in Information Markets* (Fairfax, VA: Department of Economics, George Mason University, 2004): 5–6, http://mason.gmu.edu/~rhanson/foulplay.pdf .

Changes in futures prices may be driven in the short-term by emotional reactions and the herd instinct: Looney points out that the market efficiency theories underlying the FutureMAP project were dominant in the 1970s but since then have lost much of their luster in economics due to the emergence of newer behavioral theories. Chief among these is the observation that "dumb," or emotional, agents May in fact, lead to dumb or emotional markets, at least in the short-term.[314] He provides an example of this phenomenon in action. Following the 1986 space shuttle Challenger disaster, the stock market uncovered hidden information far faster than NASA's scientists who were investigating the cause of the explosion. Securities traders punished the stock price of the contractor (the Morton Thiokol Company, one of four primary space shuttle contractors) who had manufactured the faulty part far sooner than the official investigative panel of experts was able to determine the technical cause of the failure following the Challenger's launch; however, several years later, when a second space shuttle, the Columbia, was also destroyed by a catastrophic failure, the market once again punished the Morton Thiokol Company—actually, the company's new owner, Alliant Techsystems, Inc.—even though the investigation eventually determined that the Columbia disaster had nothing to do with components manufactured by Alliant. Looney ascribes this premature, inaccurate judgment of the market to emotional reactions based upon memories of the earlier event.[315] This is a criticism that applies to the "smart markets, dumb agents" theory in general and so could be leveled against any use of a prediction market. Looney suggests that this potential deficiency of prediction markets used for government intelligence purposes could be countered by limiting participation is such markets to government intelligence analysts within a multi-agency setting, perhaps with the additional participation of selected outside businessmen and academics.[316]

Michael Abramowicz points out another, closely related pitfall public participation in prediction markets, the cognitive-distorting impact of the availability heuristic. This is

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[314] Looney, "DARPA's Policy Analysis Market," 413.

[315] Ibid., 410–411.

[316] Ibid., 416.

the tendency of individuals to place greater emphasis on events with which they have greater and/or more recent familiarity; they tend to express greater fear of, and predict a higher likelihood for, the type(s) of events recently publicized in the media and/or discussed within their circles of friends, relatives, neighbors, and coworkers.[317] This tendency, in essence, makes "dumb agents" even "dumber" and ends up distorting collective predictions. The availability heuristic phenomenon is especially relevant to the use of any prediction market that is open to public participation for a "devil's toy box" analysis. This heuristic could either benefit or disadvantage such an analysis, depending on whether would-be terrorists select their Promethean technologies based upon media "hype" or not. Conceivably, both the public participants in a "devil's toy box" analysis prediction poll and would-be terrorists could react in the same fashion to popular media hyping emerging, over-the-horizon technologies—the predictors acting on the availability heuristic to increase their forecasts of the likelihood of hyped technologies being used for nefarious purposes, and would-be terrorists being attracted to those same technologies by all the hype and attention; however, it is just as conceivable that predictors and would-be terrorists would act in opposite ways, with the predictors reacting to the availability heuristic as noted above, but the would-be terrorists avoiding "hyped" technologies because of a fear that homeland security and law enforcement agencies would be more likely to prepare countermeasures against those technologies.

Government actions, taken in response to information unveiled by a prediction market, would cause the predicted event to become far less likely and would thus prevent any pay-offs on the trades that resulted from the original information: This is the "self-negating" prophecy issue, which I will discuss in greater detail in Chapter 9. Looney provides the example of a prediction market indicating a rising probability of the assassination of a foreign leader; in response, the U.S. government passes along this information to the foreign government, whose security forces then raise their level of precautionary security measures, preventing the assassination, but also preventing any pay-off to the traders who had predicted the threat in the first place. Looney responds to this

[317] Abramowicz, "The Politics of Prediction," 90–91.

criticism by stating that the sorts of contracts that the Policy Analysis Market intended to offer to traders would not encompass the sorts of events or developments that are vulnerable to swift, decisive government interventions or manipulations, and for those trades that could be affected by government intervention, the problem of self-negating prophecy could be addressed through conditional datives (payouts that take into account how government action on or beyond a certain date has altered events).[318]

By continuously revealing prices on contracts for events or developments, and thus the government's best available estimates of the likelihoods of those events or developments, a prediction market would provide intelligence to terrorists regarding what the government knows and what the government anticipates regarding those terrorists' activities: Hanson recognizes this potential problem of a prediction market aiding terrorists' planning, and he states that this problem can be sidestepped by hiding the most problematic or delicate pricing information from the public. He points out that in existing markets, traders have learned to deal with the reality of not knowing what the market price will be once their trade is entered into the system, due to the delay between their making their trade known and their trade becoming effective, and the market price moving in the meantime. The markets have adopted conditional or limited trades to deal with this situation, whereby traders can protect themselves against sudden, drastic swings in prices between the time they commit to a trade and the time that trade is made effectual.[319]

In the context of a "devil's toy box" analysis, however, informing would-be terrorists of the government's degree of knowledge of their intentions regarding use of a Promethean technology is a *feature*, not a bug (this will be discussed further in the "Assumptions" Section of Chapter 9). This is because the primary goal of the homeland security enterprise's development of countermeasures against Promethean technologies is not to *deploy* those countermeasures against actual attempted uses of such technologies by malign actors, but rather to *deter* malign actors from ever planning to use those Promethean

[318] Looney, "DARPA's Policy Analysis Market," 414.

[319] Hanson, "Designing Real Terrorism Futures," 270.

technologies in the first place. Operating under the assumption that it will never be possible, short of all-encompassing, population-wide mind control by the government, for the homeland security enterprise to prevent all malign actors from acting upon destructive or murderous impulses, the task of the defenders must always be to nudge malign actors towards less consequential and deadly techniques by closing off avenues—or by promulgating the widespread assumption that they have already closed off or will soon close off avenues—to deadlier, more consequential instrumentalities. In other words, better a knife attack than the release of a CRISPR-created, virulent biological poison in a subway station. Better one or two deaths, however, regrettable, rather than hundreds.

Prediction markets are limited in that "futures contracts can be written only for events that are explicitly anticipated:"[320] Looney does not refute this criticism, but rather pushes it off to the side by stating that the Policy Analysis Market would not have offered contracts on highly unique events of terrorism, such as a pair of jetliners being hijacked to be rammed into the World Trade Center towers.[321] Yet in the context of a "devil's toy box" analysis, this criticism of the use of a prediction market has great validity. Let's take the example of an attempt to use a prediction market to determine the probability of a CRISPR-type genetic manipulation kit being used to cause a mass casualty event. All sorts of definitional problems come to the fore, since pay-offs would be based upon such definitions. What level of proof would be required to show that a CRISPR-type kit had been used to produce the malign biological entity that caused the casualties? Such biological entities could have several different origins, including government or university labs that the terrorist infiltrated or from which he stole material. Proof of the origin of the biological entity might take many months or years to uncover, and such proof might never come to light. Furthermore, what constitutes a "mass casualty event"? A hundred casualties? Five hundred? How many of those casualties must lead to deaths for a contract to be paid against? Are economic losses that are secondary or tertiary to the immediate injuries and deaths to be counted in any way as fulfilling the prediction? What about deaths

[320] Looney, "DARPA's Policy Analysis Market," 415.

[321] Ibid.

that take a long time to occur? What sort of time limit would be applied? Only deaths that occur within a year of the initial attack? One could fill pages with potential conditional stipulations that might be required for a pay-off. In my opinion, this is a significant drawback to using prediction markets for forecasting hard-to-define-ahead-of-time events and developments. As Charles Polk, the president of the Net Exchange company, has stated, "Nobody's going to trade in bushels of corn if you can't define what a bushel of corn is."[322]

Robin Hanson and his colleagues have shown that combinatorial markets can be deployed that take such combinations of eventualities in account; however, allowing participants to trade on such large numbers of potential combinations (billions, in some instances) can lead to a thin market problem—too few participants trading against combinations to set prices for those combinations.[323] Hanson states this problem is most acute in the case of a traditional double auction market design; this is because when a simple double auction is used, each asset must attract many traders, due to the fact that traders will not make offers that are not likely to be quickly accepted, and thus double auctions require several times as many active traders as the number of assets available for trade.[324] Hanson and his fellow PAM researchers developed a combinatorial market maker to address this problem. Their experiments indicated that six traders could set 255 different prices for independent combinatorial predictions in a period of only three minutes. Still, he indicates that just storing the number of potential combinations on a computer would require enormous computing power and storage, as well as software programs still to be developed.[325]

Prediction markets are online gambling parlors: This is a moral criticism of prediction markets, not a logistical or conceptual criticism. In some religious communities and among some individuals, gambling is considering sinful. Additionally, Robin Hanson

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[322] Seife, "'Terrorism Futures' Could Have a Future, Experts Say," 749.

[323] Hanson, "Designing Real Terrorism Futures," 265.

[324] Hanson et al., *An Experimental Test of Combinatorial Information Markets*, 2.

[325] Hanson, "Designing Real Terrorism Futures," 265–267.

suggests that the visceral outcry against the Policy Analysis Market among certain politicians and the press was based upon a moral taboo having been crossed—the program had transgressed against the moral intuition that "none of us should intend to benefit when some of them hurt some of us."[326] Responding the "gambling parlor" objection, Looney points out that the Policy Analysis Market was granted special legal status through regulatory allowances granted by the Internal Revenue Service and the Securities and Exchange Commission. He further points out that, in essence, all speculation in any market is a form of gambling, and American society has come to accept (and legalize) many forms of speculation over the last hundred and fifty years, some of them extremely complex.[327] Hanson observes that all forms of stocks and commodities trading and arbitrage, including stock trading, life and property insurance, and stocks and commodities futures and options, were at one time considered illegal gambling, and the relevant industries needed to invest enormous public relations efforts over many decades to convince the public to accept such transactions as legitimate.[328]

Prediction markets will be unable to do a better job of revealing terror-related information than the agents and intelligence analysts of our existing intelligence agencies and so are superfluous: Looney points out that the Policy Analysis Market was not created with the intention of predicting or forecasting likelihoods of terrorism events. Rather, PAM was meant to focus on broader issues of economic and social import, the types of events and developments that could broadly impact foreign nations and thus have significant effects on American foreign and domestic policy. Looney states that, in the broader social and economic realms, a considerable amount of valuable information escapes American intelligence analysts, simply due to the overwhelming volume of such information and the difficulties individual analysts have in discriminating between signal and noise. He suggests that a system such as PAM would be a relatively low-cost, effective mechanism for surfacing such useful information that otherwise might get lost or

[326] Ibid., 261.

[327] Looney, "DARPA's Policy Analysis Market for Intelligence," 415.

[328] Hanson, "The Policy Analysis Market: A Thwarted Experiment," 84.

overlooked.[329] Robin Hanson responds to a related criticism that was leveled against the Policy Analysis Market, which was that PAM sought to replace professional intelligence analysts with a loose network of amateurs. Hanson states that this criticism misrepresents the purpose of PAM, which was not to replace existing intelligence arrangements, but to supplement them. He feels that existing intelligence-gathering systems have not extracted anywhere near the maximum amount of useful information from amateur observers of events, and a mechanism such as PAM could more effectively and efficiently gather information from the pool of amateur informants. He further states that PAM-type mechanisms could provide a new and more efficient forum within which the numerous agencies of the intelligence community could merge their intelligence estimates into consensus products.[330]

The ultimate payoffs for participants in prediction markets or prediction polls can only be granted once the predicted event(s) has either occurred or not occurred and can be verified: Hanson has pointed out this basic requirement for the operation of prediction markets—they may only involve predictions of events that are capable of being verified after their occurrence or non-occurrence.[331] This presents a perhaps insurmountable obstacle to the use of prediction polls in , and perhaps to prediction markets as well, for the purposes of a "devil's toy box" analysis. The goal of such an analysis is to guide decision-making on the best allocation of research and development resources to various emerging, over-the-horizon, future-shock threats in a timeframe of an estimated five years before such threats would most likely become actualized. In other words, the decision must be made about half a decade earlier than the predictors expect the threat will materialize. Participants in the Good Judgment Project were predicting events that would either occur or not occur within a year's time. Since the project extended over a three-year period, rewards for accuracy of predictions could be distributed within the project's timeframe. I assume that (and this will be discussed at greater length in my Section on

[329] Looney, "DARPA's Policy Analysis Market," 415.

[330] Hanson, "The Policy Analysis Market: A Thwarted Experiment," 82.

[331] Robin Hanson, "Decision Markets," *IEEE Intelligent Systems* 14, no. 3 (May/June 1999): 16–19.

"Assumptions" in Chapter 9) any "devil's toy box" analysis will be conducted in support of resource allocations based upon the federal government's annual appropriations cycle; such analyses would be affected on an annual basis to ascertain which research and development projects would be included in the budget request for the next upcoming budget cycle. Thus, if a prediction poll were to be utilized to support this effort, participants would need to continue to participate in the prediction poll over five successive cycles before most of their predictions could be validated and associated rewards distributed. This very lengthy separation between prediction effort and reward would, in my opinion, negate the motivational effects of group competition and group awards observed by the moderators of the Good Judgment Project. With such beneficial motivational effects neutralized, the cost-benefit ratio of setting up and maintaining ongoing prediction polls or markets presumably sinks into negative territory.

G. COMPARISONS OF PREDICTION MARKETS TO DELPHI, NOMINAL GROUP TECHNIQUE, AND OTHER METHODS

Kesten C. Green, J. Scott Armstrong, and Andreas Graefe, in their 2007 review of the scholarly literature regarding the Delphi technique and prediction markets, summarize points in favor of and against use of each method for generating aggregations of forecasts. Overall, in weighing the various advantages and disadvantages, they come out mostly in favor of Delphi. In prediction markets' favor, they note that prediction markets can be run continuously and thus generate continuously updated results, whereas Delphi panels are typically one-time affairs, resulting in a single set of data points, although conducting several separate rounds of questionnaires does generate changing results that may reflect changing external circumstances (national or world events, for example). They also note that, in an unrestricted prediction market, with no barriers to involvement, individuals are motivated to participate by potential profit if they feel they have unique or better information upon which to base their bids, whereas the facilitators of Delphi panels may face difficulties in recruiting a suitably expert and diverse set of panelists.[332]

[332] Kesten C. Green, J. Scott Armstrong, and Andreas Graefe, "Methods to Elicit Forecasts from Groups: Delphi and Prediction Markets Compared," *Foresight*, no. 8 (2007): 4, http://repository.upenn.edu/marketing_papers/157.

On the other hand, they point out that the Delphi technique may be used to address a wider range of problems and decisions, since, unlike the case regarding prediction markets, the outcome of the future event in question does not need to be ascertained to arrange for payouts to market participants. They note the difficulty of formulating contracts for certain types of questions to be addressed through prediction markets. They observe that the Delphi technique allows for transparent exchanges of information between participants and thus allows for learning. Furthermore, Delphi panels, unlike participation markets, are generally immune to cascades, or situations in which certain traders react strongly to what they perceive as new information being indicated by price shifts in the market, and their strong reactions are then reacted to and mirrored by other traders, in a process like falling dominoes. Also, Delphi panels generally can be quite effective with between five and 20 expert participants, whereas prediction markets require far higher numbers of participants to function effectively, or else the markets are confronted with the thin market problem, wherein sellers for contracts are unable to hook up with buyers and trades fail to occur, resulting in prices not being set. They also reiterate some of the potential problems I have already discussed regarding prediction markets, including the perceived moral inappropriateness of certain types of contracts involving violent acts and deaths, the need, on the part of market participants, for a fairly sophisticated understanding of how markets work and how traders profit, and the possible vulnerability of prediction markets to speculative attacks by traders intending to cash in on their own malign behaviors or those of persons known to them.[333]

Andreas Graefe and J. Scott Armstrong later followed up this literature review with a 2011 experiment comparing performance on a quantitative judgment task among 227 participants assigned to either traditional face-to-face meetings, Delphi panels, nominal group technique panels, or prediction markets. The participants were divided into 11 groups per method, for a total of 44 groups under comparison. The assigned task consisted of participants providing numerical percentage estimates of likelihood for ten factual

[333] Ibid., 4–5.

questions.[334] The participants were all University of Pennsylvania students. In addition to a $10 show-up fee, participants were offered small financial inducements for superior predictive performance, ranging from $15 to $50 per group for face-to-face meeting, Delphi, and nominal groups, and between $4 and $6 pay-offs per trade to individuals participating in the prediction markets.[335]

The researchers found that overall differences in accuracy between the four methods did not rise to the level of statistical significance. Some differences were seen between methods on the level of individual questions, however, the study found that Delphi panels were never less accurate on their predictions than the nominal group technique panels, and Delphi panels outperformed face-to-face meetings on two out of ten questions. Few differences were seen in performance between nominal groups and face-to-face meetings. The researchers were surprised to find that prediction markets failed to outperform face-to-face meetings on any of the questions and under-performed them on three questions. They observe that in their experimental design, participants drew upon the same pools of knowledge, so information exchanges would have little value, compared to real-world problem-solving and decision-support situations, wherein exchanges of disparate information can be of great added value. From this, they speculate that the structured methods studied may not have displayed as much of an improvement over face-to-face meetings and staticized individual results as those methods would in an environment where exchanges of information result in accretions of new and useful knowledge within the forecasting groups. Regarding participants' levels of satisfaction with the four methods, participants expressed a clear preference for those methods that involved the most social interaction (face-to-face meetings and nominal groups). They indicated that they found participating in prediction markets the most complex and least

[334] Andreas Graefe and J. Scott Armstrong, "Comparing Face-to-Face Meetings, Nominal Groups, Delphi and Prediction Markets on an Estimation Task," *International Journal of Forecasting* 27 (2011): 183, doi: 10.1016/j.ijforecast.2010.05.004.

[335] Ibid., 187.

satisfying; however, the researchers did not observe that high levels of satisfaction with participation correlated with improved accuracy of forecasts.[336]

H. APPLICABILITY OF ELEMENTS OF PREDICTION MARKETS AND PREDICTION POLLS TO A "DEVIL'S TOY BOX" ANALYTICAL PROCESS

Regarding their potential applicability within the context of a "devil's toy box" analysis, I feel that the key shortcoming of both prediction markets and prediction polls is the fact that the events and developments to be predicted by participants will not be seen to actualize/non-actualize until long after the participants' forecasts have been amalgamated into a recommendation. Given that the goal of a "devil's toy box" analysis is to recommend which emerging Promethean technologies most require countermeasures against them to be prepared, and the research, development, testing, and fielding of such countermeasures is estimated to take approximately five years, the forecasters participating in a "devil's toy box" analysis will be looking ahead to potential developments five years down the line. Thus, payouts in a prediction poll or a prediction market could not be distributed until years after the conclusion of the initial analysis. For those participants in a prediction poll, the performance feedback so essential for learning and improvement could not be provided in a timely fashion. For those participants in a prediction market, not only would the final pay-out on contracts be extended several years beyond the necessary operating period of the market, but the vast range of possible combinations of technologies, targets, and types of assailants would likely result in a severe thin market problem. Also, as has been previously discussed, several researchers have pointed out the great difficulty involved in formulating contracts for types of events. The farther away from a binary "yes/no, will/will not" outcome a future event or development is seen to be, the more difficult it becomes for the facilitators of a prediction market to formulate an applicable contract.

However, researchers in the areas of prediction markets and prediction polls have spotlighted various best practices that could potentially be applied within the context of a

[336] Ibid., 193–194.

"devil's toy box" analysis. In training of participants prior to their engagement in forecasting exercises is both feasible and desirable. Various researchers have discovered the usefulness of providing training in the areas of the statistics of probabilities, the cognitive biases involved in prediction, productive group dynamics, avoiding the pitfalls of overconfidence, and effective use of future scenarios. Potential participants could be screened using measures of open-mindedness, an important predictor of forecasting accuracy. All the researchers I encountered in my readings in this area stressed the importance of diversity of backgrounds, knowledge, and opinions among participants for any sort of "wisdom of the crowd" approach to work properly. I have already addressed this issue in Chapter 7, "Who Are the Experts?" I have suggested that the ideal panel of participants for a "devil's toy box" analysis would include scientists and technologists familiar with the basic principles involved in the emerging Promethean technologies under consideration, managers who are centrally involved with the research and development program to be utilized, persons who have studied the social and cultural dynamics of terror and insurgent groups and the motivations of those groups' supporters, and science fiction writers whose work has focused on malign uses of future technology, unintended harmful consequences of future technology, or social, political, or economic developments that lead to societal conflict.

Two groups of researchers have suggested factors that could be usefully applied as weighting factors for participants' input into a "devil's toy box" analysis. Tetlock et al. of the Good Judgment Project, in seeking ways to stratify their participants by forecasting skill level prior to those individuals' participation in prediction polls, found that they could determine participants' forecasting skill level through involvement in a "seeding poll" of 20–25 questions.[337] Such a "seeding poll" could be used prior to a "devil's toy box" analysis, with the stipulation that facilitators select questions that can be resolved in a two-week to one-month time envelope (so that the initiation of the analysis process would not be unduly delayed; resolution of these seeding questions could take place concurrently with the participants' involvement in the "devil's toy box" analysis, with the results of the

[337] Atanasov et al., "Distilling the Wisdom of Crowds," 704.

seeding poll being used only when the facilitators are calculating and weighing the participants' inputs after the panelists' involvement). Wright et al. found that participants who rated themselves as being more expert proved to be less overconfident, better calibrated, and likely to achieve higher accuracy scores than those who self-rated lower.[338] Presumably, participants' self-rated levels of expertise will vary from question to question, depending upon that question's subject matter and level of difficulty. (A biologist might feel very confident answering a question about future developments in genetic engineering but much less confident answering a question about future developments in home metallurgy kits.) Should self-rated expertise be used as a weighting factor, participants should be directed to rate their own expertise separately for each question posed. Thus, Participant A's responses would be weighed differently by the facilitators on Questions 1, 2, 3, etc., depending upon Participant A's self-ratings of expertise and confidence.

Unfortunately, I see no way to apply either the profit motive inherent in prediction markets or the team competition motivation of prediction polls to a "devil's toy box" analysis, for the reason already stated, that the outcomes of participants' forecasts will not be actualized until years after their group recommendations are made; however, this is not to say that participants in such an analysis will lack for motivation. Facilitators should continuously stress to panelists the importance their work holds for national security. Participants should be encouraged to imagine the additional security benefits that will accrue to the United States because of their efforts, as well as the potentially catastrophic consequences for their own communities, friends, and families should the ultimate products of their "devil's toy box" analysis fail to deter, counter, or mitigate future malign uses of emerging Promethean technologies.

I. PREDICTIVE ANALYTICS

Vast increases in computational power and decreases in the costs associated with that computational power since the beginning of the twenty-first century have driven the development and widespread use of a new type of forecasting technique, predictive

[338] Wright et al., "Coherence, Calibration, and Expertise in Judgmental Probability Forecasting," 8–10.

analytics. Predictive analytics take the "wisdom of the crowd" concept to a new level; not only are expert inputs not sought as the basis for forecasts, but intentional human intellectual discernment is not brought into play at all. Rather, the "footprints" and "fingerprints" left behind by individuals' past decisions and behaviors are used to predict current patterns and future occurrences. Predictive analytics are the up-to-date, data-driven version of G.K. Chesterton's "prophetic past."

Individuals' use of smartphones and computers, for online browsing, shopping, physical navigating/positioning, social media, and other activities, results in a vast trove of data detailing both individual and group behaviors online. This data, when combined with data regarding offline behaviors and occurrences that are input into computer databases, can become the basis for remarkably detailed and precise forecasts of present and future behavior when analyzed by computer algorithms, either parametric or non-parametric. The basis for such forecasts is the observation that people tend to be creatures of habit in many aspects of their daily lives. Predictive analytics are used by commercial companies to foresee trends regarding consumer purchases, the uses to which consumers put the products they buy, and other forms of consumer behavior that have a bearing on companies' planning for future product development, production, pricing, and marketing. Police forces and other homeland security agencies have also productively used predictive analytics, following their insight that criminals act, in many ways, just like consumers do—creatures of habit who tend to prefer conducting their "business" with familiar associates or in familiar surroundings and neighborhoods, often sticking to the same standard operating procedures.[339] Thus, in an attempt to deter or proactively respond to many types of crimes that are characterized by continuities or habits in criminal behavior (such as drug dealing, burglaries, automobile thefts, and vandalism, for example), police forces, by making use of predictive analytics, can distribute their personnel and resources in an informed fashion to those neighborhoods most afflicted with such crimes.

Seen in this light, predictive analytics offer their greatest usefulness to those members of the homeland security enterprise engaged in that enterprise's systemic mission,

[339] Lozada, "The Emerging Technology of Predictive Analytics," 119–120.

what Rodrigo Nieto-Gómez has described as preparing for and responding to *known threats* of either a natural or man-made origin; however, a "devil's toy box" analysis seeks to grapple with potential future-shock threats, the malign co-mingling of emerging Promethean technologies with bad actors who intend to use the new capabilities provided by those technologies in creative, innovative fashions. Some emerging Promethean technologies may be used by bad actors simply to add greater convenience and operational secrecy to existing, familiar attack modes. An example of this would be using 3D printers to home manufacture firearms or bomb parts, rather than taking the risks of purchasing such implements on the black market, using fronts to legitimately purchase such items, or stealing them. Other bad actors, however, may be inspired by the new capabilities made possible by emerging Promethean technologies to plan radically new modes of attack, breaks from past terroristic behavior—discontinuities rather than continuities. Predictive analytics, by focusing on the continuities revealed within masses of amalgamated data, are significantly less useful to those agents of the homeland security enterprise who focus on the discontinuities of the counter-future-shock mission than those focused on the continuities of the systemic mission.

This is not to say, however, that predictive analytics play no role in a "devil's toy box" analysis. In fact, they play a key role. I have already discussed how IARPA's Foresight and Understanding from Scientific Exposition (FUSE) Program, or a similar tool that facilitates systematic horizon scanning for technical emergence (several similar systems are now available commercially, as will be discussed in Chapter 9), could be used to perform the initial step of a "devil's toy box" analysis, that of identifying those emerging technologies that are most likely to be developed into products available to consumers, consumers other than governments or large corporations with deep pockets. FUSE and its commercially available equivalents are predictive analytics tools. Rather than being used to predict consumers' buying behavior or criminal activity, however, they are used to forecast which larval technologies are most likely to end up in consumers' hands in product form within a given time, based upon past and current patterns of the interplay between basic research, applied research, product development research, patent applications, and commercialization of new products. Just as with consumers' purchasing behavior and

criminals' illegal activities, enormous quantities of data are available regarding scientific research activities worldwide, patent applications, and product development activities, and these predictive analytics software packages enable timely sifting, correlating, and the drawing of patterns.

* * * * *

In preparation for the fabrication of a crystal ball for use with a "devil's toy box" analysis, we have conducted a sweeping examination of forecasting methods that are currently in use, covering a span of seventy years. We began with the Delphi technique, birthed shortly after the close of World War Two, a conflict during which triumphs of systems analysis had led to the invention and war-winning deployment of radar, sonar, precision bomb sights, computers, and atomic weaponry, resulting in enormous social and scientific prestige for experts who could claim the mantle of scientific legitimacy. The Delphi technique was intended to provide a systematic, replicable method for the amalgamation of expert opinions on a given question and for the establishment of consensus among those opinions, a consensus presumably freed from the distortions caused by social pressures and groupthink but still benefiting from the exchange of information between panelists. Experimental research into the efficacy of use of the Delphi technique for forecasting indicated deficiencies inherent to the technique, and so a group of social scientists developed a related but alternative technique, the nominal group technique, meant to correct Delphi's perceived shortcomings. Confidence in the capability of expert analysis as harnessed by the Delphi technique, the nominal group technique, and related methods led to the establishment of a new field of the social sciences, futures studies. Practitioners of future studies, working in the service of governments, think tanks, universities, or commercial companies, expanded the range of forecasting tools that could be used by groups of experts in various fields, introducing the use of trend extrapolation, scenario analysis, cross impact analysis, and modeling and simulation. Concurrently, Western militaries were developing and expanding training methods first used by the Prussian Army in the nineteenth century into the doctrine of red-teaming, a set of exercises meant both to allow military commanders to "see through the enemy's eyes" and to counter various cognitive biases that are counterproductive to effective forecasting efforts. The techniques of red-teaming have been found to be applicable to realms beyond that of

military planning; they can help hone the efforts of participants involved in a “devil’s toy box” analysis by allowing those participants greater insight into “the devil’s mindset.” The development of Efficient-Market or “dumb agents, smart markets” theory in the post-WWII period, combined with the deployment of electronic communications networks in the 1980s, led to renewed interest in an idea first put forth by pioneering economist Adam Smith in the eighteenth century, that of “the wisdom of the crowd.” Various attempts to adapt the techniques of stock, commodities, and futures markets to types of forecasting other than price forecasting led to the creation of prediction markets and prediction polls, both of which have been tested by the American intelligence community for use in predicting economic, social, and military developments worldwide (although not without some political setbacks). These methods represent a turning away by some forecasters from a reliance on the input of experts. The leading edge of this trend is represented by the field of predictive analytics, a new set of computerized tools centered on machine learning and pattern recognition facilitated by Moore’s Law and the resultant vast increases in computational power, combined with lowered costs. Predictive analytics remove instrumental human judgments nearly entirely from the equation, drawing patterns and resultant predictions from massive quantities of data regarding past behaviors and events, correlated by time and location.

Even as a notional, conceptual, imaginary device, a crystal ball is a complex technology. This is true for a crystal ball/spy glass that will be required to accomplish the tasks inherent in a “devil’s toy box” analysis—seeing what will be inside the devil’s toy box five years into the future; determining which of those future toys are capable of causing the greatest harm; predicting which future toys the devil is most likely to select for use; and supporting a decision regarding which of the potentially numberless toy gestation boxes within the devil’s toy box most need to be sealed shut.

I have performed my due diligence as a fabricator of crystal balls. As an apprentice, I have sat at the feet of past and current master crystal ball makers, observing their methods, evaluating the strengths and weaknesses of those methods as they relate to a “devil’s toy box” analysis, and gathering a tool kit of what, judged by either experimental or real-world experience, are regarded as best practices regarding the use of various types of crystal balls.

My next step? I will seek to fuse together the best practices from the full range of forecasting techniques that are most suitable for a “devil’s toy box” analysis.

A glass blower about to fabricate a crystal ball does not work in a vacuum—literally. He assumes the known physical qualities of sand, heat, and glass will hold, that he is working within Earth’s gravity and atmosphere, and that his workshop is maintained at a temperature that lies within the human comfort zone. If that glass blower were to operate in a workshop located in an orbiting space station, he would need to start from a different set of assumptions; molten glass will behave differently in conditions of null gravity than it will in a glass blowing workshop at the edge of New Orleans’ French Quarter. Prior to picking up my metaphorical blow torch and glass-blowing straw, before I can fuse the pieces I have gathered thus far into a new whole, I first need to lay out all the assumptions upon which I will base my prospective “devil’s toy box” analysis.

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IX. PUTTING THE PIECES TOGETHER: PANDORA'S SPYGLASS

A. ASSUMPTIONS

When constructing a methodology for an analysis, the designer must work from a foundation of assumptions. Therefore, before unveiling the blueprints of my proposed methodology, I need to list those assumptions that have guided the choices I have made. A different designer working from a different set of assumptions would come up with a different set of blueprints (as would I, were I working from a different set of assumptions). What follows are the foundations of my thinking, upon which I hope to erect a sturdy, useful edifice of methodology. I believe these assumptions to be reasonable, but any of them are open to challenge. Changing any of the following assumptions would likely necessitate a change in the subsequent methodology.

Assumption 1: Defenders within the homeland security enterprise will not be able to prevent every attack by malign actors. Intelligence of the enemies' intentions can never be complete. Defensive measures can never be made infallible. Despite the defenders' best efforts, their antagonists will still be able to achieve surprise on occasion. So, some attacks will succeed, at least in part. Realistically, the job of the homeland security enterprise is not to prevent all possible attacks. In an environment of limited resources and capabilities, the best the homeland security enterprise can hope to achieve is to seek to deter those attacks with the most onerous consequences, or, should such attacks not be deterred, to seek to counter those attacks, or, should such attacks not be successfully countered, to seek to best mitigate the effects of those attacks on the Nation. In rank order of preference, the defenders' goals are to *deter*, to *counter*, or to *mitigate*.

Assumption 2: The purpose of a "devil's toy box" analysis is not to predict which over-the-horizon malign technologies will be used to harm America, nor when. Such is the job of the intelligence agencies. Rather, the purpose of the analysis we have been discussing is to decide which doorways to destruction most urgently need to be closed, then to support decisions leading to actions to bar those doorways. In the terms of our parable, the devil's toy box contains many smaller gestational boxes, each of which contains a

different malign toy, growing toward possible effectiveness and deployment. In seeking to peer inside the larger toy box before the malign toys are selected for the devil's use, the defenders want to know which of the interior gestational boxes most urgently need to have their lids sealed, since the defenders realize they will not have time to seal the lids of all them before the devil reaches inside to make his selection.

In arenas of forecasting other than a "devil's toy box" analysis, the following prevails—the higher the percentage of forecast events or developments that come to pass, the greater the forecasters' success. Within the arena of a "devil's toy box" analysis, however, witnessing previously forecasted events or developments become actualized represents *failure*, not success. Unlike the goal of IARPA's forecasting tournament and the Good Judgment Project, which is to determine techniques to improve the sharpness and accuracy of forecasts of worldwide political and social events, with such events being considered independently of one another, the goal of a "devil's toy box" analysis is for a team of experts to rank a universe of potential future-shock threats *relative to one another*. Likelihood of actualization is only one factor that needs to be considered. In an environment characterized by a nearly infinite combination of over-the-horizon malign technologies, existing malign technologies, and groups and individuals with motivations to inflict harm, and these near-infinite combinations confronted by a homeland security establishment with limited resources, staff, and time, the most imperative task is to decide which doorways to destruction most urgently need to be closed, which gestational boxes most need to have their lids sealed.

Assumption 3: Most, but not all, groups that seek to harm America are made up of rational actors or are individuals who are rational actors. The rational actors will tend to be the most dangerous, because they are most capable of teamwork, extensive planning, and maintaining operational security and secrecy. *Rational actors are capable of being deterred*. The threat of incarceration or death may not deter the most committed, not those for whom death in the service of their cause is a good to be ardently sought after; however, a high likelihood of failure to achieve their goal through a strike modality will tend to either redirect them to use a different strike modality or to wait until a more fortuitous time arises. This is because, just like defenders, attackers have limited resources (personnel, equipment,

funding, and time), and, just like the defenders, the rational actors among the attackers will not want to unnecessarily waste any of those limited resources.

Irrational actors are far less deterrable, if they are deterrable at all; however, they will tend to exhibit less self-control than rational actors and will act more impulsively. They are far more likely than rational actors to boast of their malign intentions to friends, relatives, or anonymous crowds on the Internet, and thus are more likely to appear on the radars of law enforcement authorities. The irrational actors will tend to be shunned by most groups because of their unpredictability, unreliability, and potential for breaking operational secrecy. Being less likely to extensively plan and being more impulsive than rational actors (not true in all individual cases, but I am assuming this in true in most cases), they are far less likely to seek to use innovative, future-shock attack modalities and are more likely to pursue imitative attacks using conventional weapons; however, should a Promethean technology with great malign potential emerge that is easy-to-use, inexpensive, and widely available, and thus, due to high convenience, more likely to be used by irrational lone actors, such factors should be taken very seriously into account by a "devil's toy box" analysis team, who should elevate that Promethean technology to the top of their list for R&D attention.

Assumption 4: The members of a "devil's toy box" analytical team and the universe of groups and individuals who seek to harm America will have a dynamic, interactive relationship. That is, the actions of one group will influence the decisions and actions of the other. The extent to which this dynamic relationship exists in the "real world" would need to be studied. But my decision-support methodology design assumes that efforts made by a "devil's toy box" analytical team to promulgate defensive measures against a threat modality will result in a reactive shift by potential attackers away from that threat modality to a different modality less well defended against. In other words, a forecast made by a "devil's toy box" analytical team is expected (and hoped) to have a "self-denying prophecy" effect.

This is the deterrence effect discussed in Assumption 3 above. For deterrence to work, the antagonist must be aware of the defenders' efforts. To quote Peter Sellers's Dr. Strangelove at the climax of the classic dark comedy *Dr. Strangelove, or How I Learned*

to Stop Worrying and Love the Bomb, when he is informed by the Soviet ambassador that the accidental dropping of an atomic bomb on Russian territory by an American bomber crew will result in the automatic triggering of a hitherto secret doomsday device, meant by the Russians to be the ultimate deterrent, he shouts in a confounded voice, "Of course, the whole point of a Doomsday Machine is lost, if you *keep* it a *secret*!"[340]

The Israeli experience with terrorism this century is instructive in this regard. Following their loss of hundreds of civilians to Palestinian suicide bombers crossing into Israeli territory from the West Bank during the Second Intifada, the Israelis erected a very visible separation barrier between their population centers and the West Bank. In more recent years, Palestinian terror operatives have been forced by the success of the separation barrier at keeping Palestinians from the West Bank from infiltrating into Israel proper to resort to a far less effective form of terrorism, encouraging Arabs who reside within Israel to attack Israeli Jews with whatever weapons are immediately at hand, such as knives or vehicles. While still capable of causing deaths and disruption, this newer generation of Palestinian terrorists causes far fewer deaths or injuries per incident than the suicide bombers of the Second Intifada. By successfully deterring the skilled bomb makers and terror infiltrators from the West Bank, and by doing so with a well-known defensive system that discourages those bomb makers and infiltrators from attempting new operations, the Israelis have channeled Palestinian terrorism into much less destructive modalities than formerly.[341]

With the goal of deterrence in mind, the "devil's toy box" analytical team will operate under a different set of secrecy constraints than gatherers of conventional intelligence. The latter seek to keep their sources and methods confidential, to not "tip off" their targets before those targets can be arrested or killed. They do not want their antagonists to know what the defenders know. Conversely, members of a "devil's toy box"

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[340] *Dr. Strangelove, or How I Learned to Stop Worrying and Love the Bomb*, directed by Stanley Kubrick (1964: Los Angeles, CA: Sony Pictures Home Entertainment, 2001), DVD.

[341] Simon Perry, Robert Apel, Graeme R. Newman, and Ronald V. Clarke, "The Situational Prevention of Terrorism: An Evaluation of the Israeli West Bank Barrier" (original paper, *Journal of Quantitative Criminology*, June 20, 2016), 19–20, doi 10.1007/s10940-016-9309-6.

analysis team will want potential antagonists to know or to *believe* that effective countermeasures are being developed to negate dangerous Promethean technologies. Whereas the technical specifications of countermeasures being designed, tested, and deployed should be kept confidential, general information about the government's R&D efforts should be widely promulgated in the news media, those media that cover government procurement operations and government support for science and technology. To do otherwise would be to ignore Dr. Strangelove's wise counsel!

Assumption 5: Here I am assuming that the instrumental R&D agency sponsoring the "devil's toy box" analysis will not take the results of the analysis—an ordinal ranking of the relative risks posed by a range of emerging, over-the-horizon technology threats—and decide that even the highest-ranked threats do not merit R&D attention. I am assuming that the decision-makers at the instrumental agency will not use some arbitrary threshold of threat- or risk-score below that they will not commit R&D funding. Rather, I assume that a budget, one intended for application to R&D projects intended to counter future-shock threats *as a generic threat category*, has already been appropriated by Congress and programmed by the sponsoring agency. The purpose of the Pandora's Spyglass analysis (as construed in this chapter) is not to justify a funding level; rather, it is to guide how already appropriated funds will spent—to suggest which potential projects should receive any level of funding at all, and to act as a decision-making support tool regarding allocating funding among potential projects. An alternative assumption, but one that fits the Pandora's Spyglass model just as well, is that the instrumental agency will have already committed itself to applying R&D resources to a certain number or top percentage of the highest ranked threats, perhaps with the list of threats to receive attention expanding with increased availability of funding.

I can easily imagine, however, the temptation that might exist for the heads of a sponsoring agency to run a Pandora's Spyglass analysis prior to the appropriation and allocation of any funding for counter-future-shock R&D programs, to justify a budget request or the inclusion of a line-item in the President's Budget Request. Such a use of Pandora's Spyglass would be roughly equivalent to forecasting efforts carried out by commercial firms, predictive analyses that ask questions such as "What level of investment

in my physical plant can be justified, given this range of anticipated demand for the resulting product and this range of estimated profit per unit?" Or "If I spend one million dollars on equipment and another million dollars on the annual lease for a building in which to house it, what are the chances of my at least breaking even during my first year of operation, given this range of anticipated demand for my new product and this range of estimated profit per unit, assuming the maximum number of units I can produce in one year with this equipment is 3 million?" These forecasting, or risk assessment, questions are meant to help managers of commercial firms avoid losing money by overspending on cost inputs. Ideally, the estimated ranges of such variables as profit per unit, demand for the product, up-time percentage for the equipment, etc., are based upon either actual observations of identical measures in prior projects or observations of closely-correlated measures in prior projects. Highly desirable, too, are efforts at validating the forecasting models, either by comparing forecasted values to actual values once those values become actualized and then gauging measures of fit and adjusting the models, as necessary, or by backward-fitting, trying to apply the models to earlier events with known actual values and asking, "If I had applied this model to this set of variables in this earlier event prior to the event being actualized, how well would the model have predicted the values that actually occurred?"

Therefore, I would caution any agency heads who might consider running a Pandora's Spyglass analysis to justify a budget request that they have the procedure's facilitators first carry out the difficult task of trying to validate the forecasting assumptions, selections of variables, and weightings of variables that I will lay out in the following sections of this chapter. I am working under the assumption that Pandora's Spyglass will be used to narrow down and then rank a set of possible, plausible catastrophic uses of emerging Promethean technologies *relative to one another*. The goal is to rank the possible, plausible catastrophic uses in descending order of risk, risk being defined in this case as "the estimated likelihood of a Promethean technology not only coming to market but also being used for a malign purpose, multiplied by the dollar value of the worst possible consequences." In the case of the underlying assumptions having not been validated, the accuracy of these risk forecasts may individually be wide of the mark; however, for the

purpose I have just outlined, assuming that the forecasting participants use a consistent set of assumptions across their forecasting and estimation efforts applied to different scenarios, the errors in accuracy, whether due to over-confidence, under-confidence, or some other factor, should be mostly consistent and will not affect an *ordinal ranking* of scenarios. In other words, if all the mistakes made in forecasting are made in the same direction for each scenario being judged, the relative placements of these scenarios on a ranked list of risk (as defined above) will not change from a situation in which perfect knowledge of the impacts of various variables and their interactions and a complete lack of cognitive distortions apply.

Validation of the underlying assumptions of the Pandora's Spyglass analytical procedure is made very difficult by the nature of the analysis itself—a judgment of the consequences and likelihoods of types of events that have not yet occurred. To date, virtually all terror attacks have used well-known, conventional technologies, such as firearms, explosives, or vehicular attacks. For the most part, the use of emerging Promethean technologies for catastrophic ends is a notional threat. The closest example we have of the type of attack envisioned in a Pandora's Spyglass analysis is the attack by Aum Shinrikyo acolytes on the Tokyo subway system using sarin (please refer to the final Section of Appendix B for a full description of this event). This attack could be retroactively subjected to a Pandora's Spyglass analysis to test the procedure's assumptions and variables. Also, even though terror attacks carried out with conventional weapons are not exact analogues of a "devil's toy box" attack, they are similar enough, in many ways, to be retroactively put to a Pandora's Spyglass analysis to validate most of the variables (those not directly concerned with the likelihood of emerging Promethean tools being successfully developed and coming to market). After all, most of the variables I have assigned as limiting factors on the probability of a Promethean technology coming to market AND then being used for malign purposes are adapted from Sandia National Laboratories' Generic Threat Matrix, previously discussed in Section B of Chapter 6, which was developed with conventional terror attacks in mind. Facilitators or researchers who wish to use Pandora's Spyglass for more precise risk analysis in support of budget requests to counter specific emerging Promethean technology threats could validate most

elements of the procedure by running retroactive analyses comparing actual terror attacks that were carried out successfully with those that were planned but failed to be carried out with the intended malign impacts. When the results of these analyses of past attacks are staticised, which of the limiting factors was most consequential in distinguishing between successful attacks and failed attacks? Which limiting factors were consequential than others?

Apart from validating the variables in the process, another way that agency managers who wish to use Pandora's Spyglass to justify budget requests to counter specific emerging Promethean technology threats would be to apply a type of sensitivity analysis to the results. In their executive summary of the results of the Pandora's Spyglass analysis used as a budget request justification, managers should state that the probability figure for likelihood of a Promethean technology not only coming to market but also being used to promulgate worst-case scenario consequences is probably inaccurate; however, they should then indicate how low the probability figure would need to be lowered to make the risk figure, expressed in dollar terms, equivalent to the budget line item being requested (in other words, how unlikely would the potential catastrophe need to be to make the budget amount requested fail a cost-benefit analysis?). The difference between the probability figure needed to make the budget request a waste of money from a risk avoidance perspective and the probability figure calculated by a panel of experts will likely in itself prove to be a powerful justification for the budget requested.

B. APPLYING PANDORA'S SPYGLASS TO A "DEVIL'S TOY BOX" ANALYSIS

Before walking through the steps of what I call the Pandora's Spyglass method of carrying out a "devil's toy box" analysis, let me turn for just a moment back to our parable, to which I have added a character from classical Greek mythology, Pandora. In the classical story of Pandora's box (which may be considered a direct sequel to the Prometheus story), Zeus, king of the gods, is wroth with humanity for its having accepted Prometheus' illicit gift of fire and for then having tricked Zeus into accepting a sacrifice of inferior meat. To secure his revenge on both mankind and the family of Prometheus, Zeus has Hephaistos create a woman of irresistible beauty, Pandora, who combines the graces of a goddess with

a backstabbing and deceitful nature. This is the alluring but dangerous creature that Zeus sends to Prometheus's brother on Earth as a bride, supposedly as a gift. Zeus includes an additional wedding present, an alluring box held shut by a large padlock. Pandora cannot resist her curiosity. She finds a way to open the box, and all the previously unknown ills and evils of Earthly existence fly out, defying Pandora's frantic attempts to recapture them and bedeviling mankind ever since.[342]

In terms of the parable I set forth at the beginning of this thesis, I will make Pandora, with her inexhaustible curiosity, a member of the team of defenders. Welcome to the team, Pandora! Her fellow defenders have come up with a not-so-reliable crystal ball, whose best images of what will transpire in the future are fuzzy and indistinct, but still instructive. From those images within the crystal ball, Pandora and her teammates can see that, at some point in the future, the devil will fling open his malign toy box, which contains many smaller boxes—almost too many to count—and that these smaller boxes will begin popping open and releasing the dreadful toys that have been incubating inside. Pandora and her teammates see that these smaller boxes inside the big toy box will not open all at once, but in a random, unpredictable sequence. They also see that they will have time to seal shut only some of those smaller boxes, not all them, before they can pop open. Despite their best efforts, they will be unable to trap the terrible contents of all the interior boxes inside their incubators.

Pandora is intensely curious about what is inside each of those interior boxes. But, unlike the Pandora of the classical story, she channels the energy of her inexhaustible curiosity into beneficial action. She wants so much to know what is inside each of the boxes, but she also knows that if she opens their lids to peek inside, she will release the malign toys within to wreak havoc in the world. So, she invents a fabulous spyglass that allows a viewer to see through walls, allowing her to assuage her irresistible curiosity without opening the lids of the boxes. Just as with the crystal ball, the images that Pandora's spyglass allows a viewer to see are fuzzy and indistinct, but they are also very suggestive

[342] N. S. Gill, "The Meaning of Pandora's Box," *ThoughtCo*, last modified August 26, 2017, https://www.thoughtco.com/what-was-pandoras-box-118577.

and illuminating. When they train Pandora's spyglass on the devil's toy box, the defenders can see through the outer wall the big toy box and then through the walls of the interior boxes with their gestating toys. They are then able to note to themselves which of those many, many interior boxes hold the worst, most destructive toys, the ones most likely to delight the devil. Those are the boxes they vow to seal shut during the highly dangerous assault on the devil's toy box. Realizing that the defenders' best efforts at sealing shut even just a portion of the interior gestational boxes, those holding the most dangerous toys, will not result in complete success, the shield makers among the defenders dedicate their labors to creating specialized shields against each of those toys deemed the most dangerous… all the while praying that those shields will never need to be used.

C. PHASE ONE: ENVIRONMENTAL SCANNING

To the great benefit of the facilitators of a Pandora's Spyglass analysis, recent advancements in machine learning and big data analysis have made the process of environmental scanning for emerging, over-the-horizon technologies, technologies with Promethean potential, and emerging extremist groups far more efficient and comprehensive than before. In Chapter 2, I have already mentioned IARPA's FUSE, the Foresight and Understanding from Scientific Exposition Program, an automated tool for tracking technical emergence that was developed beginning in 2011. Subsequent iterations of FUSE should be available to the Pandora's Spyglass analysis facilitators as a GOTS (government off-the-shelf) product, assuming the facilitators are employees of a federal agency such as DHS. Alternatively, since the time FUSE was created, at least one commercial firm has developed a comparable product. This is Quid, a software platform developed specifically to facilitate technology scouting by government agencies. From the Quid.com website:

> Quid is a platform that searches, analyzes and visualizes the world's collective intelligence to help answer strategic questions. Quid is a web-based platform that leverages proprietary algorithms to read millions of text-based documents for fast insight by visualizing relationships in the underlying language. … The platform can analyze public and private company data, news and blog articles, patent data, academic research as well as myriad custom text-based datasets. … Quid leverages natural language processing algorithms to analyze large text-based datasets and

> automatically extracts relevant metadata. The software employs unsupervised machine learning to automatically compare and identify semantic similarities between documents. … Government stakeholders utilize Quid to identify near (6–12 months), medium range (1 - 5 years), and extended (5–10 years) technology scouting trends. Leveraging Quid's integrated datasets consisting of news/blogs (2,000,000 news articles indexed in near real time daily), companies (information on 1,800,000 companies - including funding and M&A data), and patents (worldwide patents both applied for and granted dating back to the mid-1960s), augmented with custom data integration including academic papers, government tech scouts can analyze thousands of data points to understand evolution and emergence of certain technologies and postulate about future development.[343]

Should they opt to use Quid, facilitators would want to take time to thoroughly familiarize themselves with the product and its reporting options, and then should focus on the platform's outputs regarding medium range (1–5 years) and extended range (5–10 years) emerging technology trends. Although the facilitators would be wise to not rely entirely upon Quid (or a comparable platform) for establishing the "universe" of emerging technologies and potential Promethean technologies, the product's ability to mine news and blog articles, company data, worldwide patents, and academic papers at scale eclipses any human team's ability to examine and sift through such gargantuan amounts of material; however, the possibility exists that specialists in various technical fields may be aware of embryonic developments that have not yet surfaced in patent applications, academic papers, or companies' R&D reports. Thus, the facilitators would be wise, once they have assembled their team, to solicit additional input regarding the "universe" of emerging technologies and potential Promethean technologies from team members. This will be addressed further in the following sections.

Another commercial firm, Recorded Future, facilitates data mining from Dark Web sources to allow for scouting of emerging behaviors of criminal, terror, and extremist groups. From the Recorded Future corporate website: "Recorded Future arms threat analysts, security operators, and incident responders to rapidly connect the dots and reveal

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[343] "What is Quid?" and "Use for Government Technology Scouting," Quid website, accessed August 10, 2017, https://quid.com/.

unknown threats. Our patented technology automatically collects and analyzes threat intelligence from technical, open, and dark web sources to provide invaluable context for faster human analysis…"[344] The Recorded Future platform mines data from over 750,000 sources encompassing more than 20 billion different data points; these sources include the open World Wide Web, social media sites, the Deep Web, and Dark Websites. The firm employs its own team of intelligence analysts who continuously locate new onion sites on the Dark Web. These analysts develop data dictionaries that allow clients to develop searches that are both highly targeted and that cast a wide net.[345] The facilitators of a Pandora's Spyglass analysis, having previously used a platform such as FUSE or Quid to surface over-the-horizon, emerging technologies with Promethean potential, should work with Recorded Future's analysts (or their counterparts at another service or firm) to have social media, Deep Web, and Dark Web searches performed using terms of interest related to the identified emerging technologies, to determine whether malign elements (terror groups, extremist groups, criminal organizations, or lone wolves) are already fixating upon and brainstorming future uses of emerging technologies. The facilitators should additionally use Recorded Future and its analytical team (or a similar product/firm) to identify those malign elements, including organizations or ideologies, which are responsible for increasing levels of "chatter," indicating that they are on the rise, attracting new adherents and generating increasing levels of enthusiasm and commitment.

D. PHASE TWO: ASSEMBLE THE TEAM

Step One—Recruit Team Members: Based upon the results of their environmental scanning efforts, the facilitators of a Pandora's Spyglass analysis should strive to recruit for their team technical experts and researchers who have collectively worked within all the fields from which emerge the identified over-the-horizon technologies with Promethean potential. They should make sure to "cover the map" as best as possible, keeping in mind financial and logistical constraints, as the analytical effort will encompass a three- to four- week face-to-face portion that will incur support costs such as

[344] Recorded Future corporate website, accessed August 10, 2017, https://www.recordedfuture.com/.

[345] Ibid., accessed February 5, 2018, https://www.recordedfuture.com/services/.

travel and per diem. Relying upon guidelines for panel sizes put forth by researchers who have sought to optimize Delphi procedures, nominal group technique procedures, and wisdom of the crowd procedures (summarized below), I suggest that the facilitators aim to assemble a team of 25–40 participants. I provide my recommended proportions of the makeup of various members of the team in Table 7. Should these constraints prove unable to accommodate enough technical experts to cover all the areas of technical subject matter expertise indicated by the environmental scanning phase, the facilitators may opt to expand the size of the team by recruiting additional technical expert members for the latter remote portions of the analysis, the assignation of estimated consequence and probability scores to scenarios, which will be based upon consensus Delphi panels. The same environmental scanning procedures that surfaced over-the-horizon technologies with Promethean potential should also present facilitators with lists of researchers and technologists who have applied for applicable patents and academics who have published papers in the fields of interest. The facilitators would be well advised to use such lists as the basis for their recruitment effort, additionally relying upon the recommendations of such identified persons, should they themselves be unavailable to serve, regarding colleagues who would be available and willing to join the Pandora's Spyglass analytical team. Recruitment efforts, no matter the mode(s) of communication used, should include a full description of the purpose and goals of a "devil's toy box" analysis; in all stages of the analytical effort, facilitators should take the time to explain the effort's methodology to participants (per Landeta, 2006).

To ensure institutional support (again, per Landeta, 2006) from the organization sponsoring the Pandora's Spyglass analytical effort, the facilitators should include as participants representatives from upper management, persons I will refer to as homeland security institutional insiders. Their inclusion will greatly facilitate the "selling" of the analytical effort and its resulting recommended R&D projects to the powers-that-be and will help counter trepidation on the part of institutional management that the Pandora's Spyglass analytical effort is too "far out," too disconnected from reality, or superfluous to the sponsoring organization's primary mission set. Another category of experts from which the facilitators should seek to recruit members is terror group analysts. The environmental

scanning phase may have indicated that certain types of groups are growing in prominence and influence, and that these groups are expressing interest in pursuing technically or operationally innovative modes of attack. In such cases, the facilitators will want to try to recruit researchers who have studied these groups. The facilitators may reach out to the management of the Center for Homeland Defense and Security at the Naval Postgraduate School for assistance with identifying and recruiting suitable experts of this type.

Finally, as I have discussed in Chapter 7, the facilitators need to include members who engage in regular use of the science fiction mindset—writers of hard science fiction. The most efficient way for facilitators to recruit such members would be to reach out to SIGMA, the science fiction think tank, and its director, Arlan Andrews. This group, whose mission is to assist homeland security, defense, and intelligence agencies with conceptualizing future vulnerabilities, threats, and opportunities stemming from technological advancements, would consider participation in a "devil's toy box" analysis to fall squarely within its reason for being. Should SIGMA prove unable to provide from within its own membership an adequate number of science fiction writers to the facilitators (perhaps due to preexisting commitments to other organizations), its leadership and members, being familiar with the science fiction community, will be able to provide referrals to other suitable writers. The number of science fiction writers that will need to be included in the team depends upon the team's overall size and the number of scenarios that will be fully fleshed out (as described in an upcoming section). During the scenario fleshing-out phase, the science fiction writer members of the team will serve as the lead scenario writers; each scenario writing sub-team will consist of a scenario lead (a science fiction writer), who will be supported by between one and three technical experts (depending on how many emerging technologies are encompassed within the scenario) and at least one non-technical expert, either a terror group expert or an institutional homeland security insider. Depending upon the overall size of the analytical team, each sub-team may be assigned two scenarios to work on, or possibly three. Facilitators should base the scenario assignment load per sub-team on the number of science fiction writers available. For example, if the overall team contains five science fiction writers, since the top 12 "deadly dozen" scenarios will require fleshing out, three of the sub-teams would be

assigned two scenarios to flesh out and two of the sub-teams would be assigned three. Since 12 scenarios will need to be fleshed out, the ideal number of science fiction writers on the team would be six, so that each sub-team could be assigned two scenarios.

Other rules of thumb can be adapted from those researchers who have sought to optimize various forecasting procedures. Regarding nominal group technique panels, the inventors of the technique recommend that primary panels number 7–10 members, while a consolidated NGT panel may number up to 40 members (per Delbecq, Van de Ven, and Gustafson, 1975). William Fox, the creator of the Improved Nominal Group Technique, states that, with his procedural adjustments in place, panels may productively be sized up to 20 members (per W. Fox, 1989). Regarding Delphi panels, researchers have recommended that panel sizes do not exceed 30 members (per Murry and Hammons, 1995). The facilitators of the Good Judgment Project state that, in terms of the wisdom of crowd's effect, there is no need to increase the number of forecasters beyond 20, since the bulk of the improvement in accuracy from increasing crowd size comes from increasing the number of participants from 10 to 20 and any improvements are minimal after that (per Satopää, Baron, Foster, Mellers, Tetlock, and Ungar, 2014). The Pandora's Spyglass analytical effort will encompass both a face-to-face portion that will make use of the modified nominal group technique and two remote portions that will make use of Delphi procedures. Thus, a reasonable rule of thumb would be to aim for a team size of 25–40 members (see Table 7).

Table 7. Makeup of a Pandora's Spyglass Analytical Team

Overall Team Size: 25–40 members (may be expanded during the remote Delphi portion)	
Technical Experts	**Between 50% and 60%** (this portion may be expanded during the remote Delphi portion if the initial team did not adequately cover all the areas of technical subject matter expertise indicated by the environmental scanning phase)
Science Fiction Writers	**Between 20% and 25%** (ideally 6)
Mix of Terror Group Analysts and Homeland Security Institutional Insiders	**Between 20% and 25%**

Step Two—Administer a Forecasting Pre-Test: Once the members of the analytical team have been recruited, but prior to their physically being brought together for the face-to-face portion of the Pandora's Spyglass analysis, members should be presented with a forecasting skills pre-test, the results of which will be used to weigh individual responses during the latter remote portions of the analysis, the assignation of estimated consequence and probability scores to the "deadly dozen" scenarios, which will be based upon consensus Delphi panels. Some researchers suggest that a prior history of just five forecasts is needed to establish a performance history to use as a differentiator (per Mannes, Soll, and Larrick, 2014), whereas other researchers state that a forecasting pre-test of 20–25 forecasts is necessary to establish a performance differentiator (per Atanasov, Rescober, Stone, Swift, Servan-Schreiber, Tetlock, Ungar, and Mellers, 2017). I suggest that facilitators "split the difference" and assign a pre-test of 12–15 forecasts, all regarding events that will be actualized prior to the latter remote portions of the Pandora's Spyglass analytical effort, when the facilitators will be required to assign weights to individual members' assignation of estimated consequence and probability scores to the "deadly dozen" scenarios and will need to calculate Brier scores for each member, scores that indicate comparative levels of accuracy in forecasting. The pre-test may consist of questions regarding any event that will become actualized within the required time and that can be predictively responded to in a binary, yes/no fashion, with participants being asked to respond how confident they are in their answers by stating they believe there is a XX% chance of that answer being correct. Examples might include questions such as: "Will Candidate X achieve the nomination of Party Y for the upcoming Iowa gubernatorial election?" "Will the closing Dow Jones Industrial Average equal or exceed 25,000 points on date XX-XX-XXXX?" "Will General Motors sell more than 4,000 Malibu sedans during the month of XX-XXXX?" "Will the opening weekend theatrical gross ticket sales of soon-to-be-released film *Revenge of the Fast and Furious Jedi* exceed $80 million?" For each question, the respondents would offer a Yes or a No, along with a statement, "There is a XX% chance this answer will prove correct."

Along with the 12–15 questions of the pre-test, facilitators should share written, audio, or video links to brief training sessions for participants regarding reducing

overconfidence in predictions, self-calibrating their predictions, avoiding common cognitive biases, and using Bayesian statistical methods (starting with a hypothesis of probability and then updating this hypothesis as new data becomes available, allowing for continuous refinement of forecasts) (per Tetlock, *Superforecasting*, 2015), as well as on the laws of probability, including compound and contingent probabilities (per Wright, Rowe, Bolger, and Gammack, 1994). Participants should be instructed to read, listen to, or watch the training materials prior to their answering the pre-test questions and submitting their answers electronically to the facilitators. These same topics will be covered in greater depth during the face-to-face portion of the analytical effort, so that participants will have opportunities to ask questions regarding the materials and to discuss any implications that arise.

E. PHASE THREE: BRAINSTORM SCENARIOS

Phase Three of the Pandora's Spyglass analytical effort, that of brainstorming scenarios, is split between the initial remote portion of the analysis and the middle, face-to-face portion. The analytic effort is separated into a face-to-face portion sandwiched between two remote portions, to avail the analysis's customers of the benefits of both the nominal group technique and the Delphi technique. The choice to split the brainstorming process between a remote environment, in which participants work individually, and a face-to-face environment, where participants interact as they work, is based upon Delbecq's and Van de Ven's analysis of the work of prior researchers of small group dynamics and group decision-making processes, who found that individual work is better suited to certain phases of the brainstorming and problem-solving process and group interaction is better suited to other phases. Specifically, individual work is preferred to group interaction during the phases of idea generation, identification of problems, and the elicitation of facts (the initial phase of the problem-solving process, during which group interaction may actually prove counterproductive), whereas face-to-face discussion is better at promoting improved evaluation, screening, and synthesizing of ideas already generated (the latter portions of the problem-solving process) (per Delbecq, Van de Ven, and Gustafson, 1975).

Step One—Push Out the Results of Environmental Scanning: Facilitators should share the reports generated by the environmental scanning activities with participants (depending on the lengthiness of these reports, some reformatting or summarization may prove necessary); however, some participants may have specialized knowledge to add to the generated lists of over-the-horizon technologies with Promethean potential and of rising extremist or terror groups. As mentioned in the Section on the environmental scanning phase, certain team members may be aware of embryonic developments that have not yet surfaced in the public or semi-public sources accessible to the software platforms that mine big data. Solicit their input, and then share their input as an addendum to all participants.

Step Two—Distribute Questions to Promote Brainstorming: At this stage, the objective is not to solicit fully developed scenarios from participants regarding the various emerging technologies with Promethean potential that have been identified. Rather, at this point in the process, when divergent thinking needs to be encouraged, facilitators should instruct participants to provide "stub" scenarios, brief, one-paragraph descriptions of potential outcomes that would result from the dispersion, marketing, adoption, and potentially malign use of the technologies. Per Schwartz and his *The Art of the Long View*, encourage participants to brainstorm at least four "stub" scenarios that play out of each of the identified technologies or combinations of technologies. For each of the technologies or combinations of technologies they are assigned, suggest that participants aim to brainstorm two scenarios that they judge to be high-likelihood, high-probability scenarios and two that they consider wild-card, black swan, low-likelihood/high-impact scenarios (per Schwartz, 1996). Four scenarios from each participant per technology or combination of technologies would be ideal, but participants should not feel forced to come up with four for each if they are unable to, nor should they be discouraged from providing more than four if they are feeling especially inspired or creative.

The facilitators should seek to avoid, however, overwhelming the analysis with far too many scenario stubs to be considered, sorted, and either discarded or subjected to further development. The numbers can quickly grow daunting; if the team consists of 30 members, and the environmental scanning process identifies 10 strands of technological

development with malign Promethean potential, and each participant is encouraged to provide at least four scenario stubs for each technology considered, this would result in a minimum of 1,200 scenario stubs! Rather, facilitators should distribute the identified emerging technologies among the participants so that each team member has at least one from which to create a minimum of four scenario stubs. Facilitators should strive, as best as possible, to match the identified emerging technologies with the technical experts in those fields; emerging technologies may be randomly distributed to the remaining team members. Depending upon the number of emerging technologies that need to be assigned, if this number is fewer than the number of team members, more than one participant will be assigned a technology; conversely, if the number of emerging technologies is greater than the number of team members, some or all the participants will be assigned more than one technology from which to brainstorm scenario stubs. Since this stage of the analysis emphasizes divergent thinking, the facilitators do not want to inadvertently foreclose the development of divergent scenarios connected to technologies by assigning technologies to team members only, and disallowing inputs regarding those technologies from other team members who might have equally creative ideas (or more highly creative and insightful ideas) regarding potential scenarios. Therefore, all participants should be supplied with the full list of emerging technologies with Promethean implications and told that, although they are primarily responsible for generating scenario stubs for just one technology that they are assigned (or two, or three), they are free to volunteer scenario stubs for other technologies on the list, as well, should they choose to. This should result in a more manageable number of scenario stubs. For the sake of illustration, let us assume that the team consists of 30 members, and the number of identified emerging technologies equals the number of members, 30. Each participant is told to generate four scenarios for the one technology they are assigned. Half the team members, 15, opt to also generate four scenarios for one additional technology on the list (or to provide two scenario stubs apiece for each of two additional technologies). This would result in an amalgamation of 180 scenario stubs that the team will be responsible for sorting and sifting through; still a large number, but much more manageable than 1,200!

Facilitators should provide the following lists of questions to participants to assist with their brainstorming of scenario stubs. These are not questions for participants to answer and submit; facilitators should explain that these are questions meant to prompt creative thinking and the use of imagination. Facilitators would be wise to provide a brief explanation of the differences between creative thinking and critical thinking. This is the phase for creative thinking, and participants should be advised to put critical thinking aside for the moment, although they will be called upon to use their critical thinking skills in later phases. The following "Evil Genius" questions provide a good starting place to jump-start creative thinking about scenarios:

- What are the *prompt effects* that could result from a malign use of the identified technology/threat vector? What *magnitude of consequences* could result? (Explain prompt effects.)

- What are the *human response effects* that could result? What could be the *magnitude of consequences*? (Explain human response effects.)

- How *accessible* to potential malign actors are the products of the identified emerging technology? How much *technical skill or training* would be required to use them? How much *manpower*? How much *planning*?

- How *expensive* are the products of the identified emerging technology? How *affordable* are they for individual malign actors? For international terror groups?

- Encourage participants to think through these questions from the vantage points of the three categories of malefactors identified in the *Thwarting an Evil Genius* study: jihadists, nihilists, and thrill seekers; briefly identify the goals and inhibitions inherent to each group (per Boyd et al., 2009). I would suggest adding the following three categories of malefactors to the list: leftwing terrorists, rightwing terrorists, and adherents of apocalyptic cults.

In addition to the "Evil Genius" questions, the facilitators should provide to the participants the following list of "science fiction mindset" questions:

- What trends currently exist in science and technology and societal adjustments to science and technology? What would happen if those trends were extrapolated into the future and greatly exaggerated?
- What are the possible social impacts of these trends and developments? Political implications? Cultural implications? Religious implications? Psychological impacts? Impacts on behaviors? Impacts on health and longevity? Impacts on the physical environment?
- What are the *scariest* things that might result?
- What are the most interesting, exciting *conflicts* that might arise because of these potential, extrapolated trends and developments in science and technology?
- What *precursor developments* are required for the technologies to be used in malign ways to produce conflict? (In plotting terms, what is the "back story" of the conflict, the steps that led to the malign use of the technology?)
- What *new vulnerabilities* in society, infrastructure, and individuals' lives might be created by these emerging technologies? In what ways do these emerging technologies make society *more fragile*, less resilient? What *new threats* could result from those vulnerabilities?

Facilitators should emphasize to participants that they should avoid self-censoring in this phase. At this stage of the analysis, there are no "bad," "stupid," or "crazy" ideas. Participants should allow their imaginations to run free and follow their imaginations wherever they may lead. Facilitators should also emphasize that all scenario stubs will be submitted on an anonymous basis. The facilitators will not identify the scenarios' originators when they distribute the list of generated scenario stubs, and the originators will

not be required to identify themselves during the face-to-face portion of the analysis, unless they choose to do so to clarify certain points about the scenario or to answer questions about the thinking that fed into the creation of that scenario. Thus, no participants should fear being stigmatized for submitting “wild” or “far-out” scenario stubs.

At this point, per William Fox and his Improved Nominal Group Technique, the facilitators will gather together all the scenario stubs created by the participants and remotely disseminate the full list of stubs to the entire group. Facilitators should inform the participants that they may choose to submit additional scenario stubs if their reading of the consolidated list results in further brainstorming. If additional scenario stubs are submitted, the facilitators should re-disseminate the full list, identifying those new scenario stubs that have been added. Facilitators should at this point inform the participants that they will continue to have the opportunity to submit any additional scenario stubs they wish, either remotely or in person at the face-to-face session, up until the first day of the in-residence meeting of the full group (per W. Fox, 1989).

Step Three—Train the Science Fiction Writer Members of the Team in Small Group Processes and Optimally Facilitating Small Group Interactions: The science fiction writer members of the team will serve as the facilitators of the fleshing-out of the “deadly dozen” scenarios, and they will also serve as the lead writers for the 12 fleshed-out scenarios. Although they will have all had copious experience with the latter task, many, if not most, of them will not have had experience leading small groups. The facilitators of the overall effort should bring the science fiction writer members of the team in to the face-to-face meeting location a day earlier than the other members. They should provide the science fiction writers with a three- to four-hour training on small group processes and behaviors. This training should include ways to discourage counterproductive group behaviors such as non-productive argumentation, repetitious restatements of the same inputs by participants, withdrawal of the less-confident or assertive members from offering input, and domination of the group by one or two of the loudest or most aggressive members; and ways to get the best, most productive interactions out of the participants. The main goal of the training session will be to teach the science fiction writers how to

allow for disagreement without it becoming disagreeable. (The facilitators of the overall Pandora's Spyglass effort should have gone through this training themselves previously.)

Step Four—Bring the Participants Together for the Face-to-Face Portion of the Analysis and Begin with an Emphasis on Personal Accountability and the Importance of the Mission: Now the face-to-face portion of the Pandora's Spyglass analysis begins. David Mandel and Alan Barnes, in their study of the accuracy and effectiveness of national security forecasts, found that positive outcomes were increased for those forecasters who were encouraged to accept personal accountability for their forecasts (per Mandel and Barnes, 2014). The facilitators, at the outset of the face-to-face portion, should emphasize the importance of the Pandora's Spyglass analysis for the Nation's future safety and the personal well-being of its citizens and the participants' own families, neighbors, and friends. They should fully explain how the participants' input will guide that R&D projects get funded and which future malign uses of emerging technologies may be averted by the outputs of those projects. Facilitators should share with the assembled group the parables of the devil's toy box and Pandora's spyglass to spur group discussion of the unique challenges inherent in this type of forecasting effort and future threat analysis.

Prior to having all the participants introduce themselves and describe their professional and personal backgrounds, facilitators should share the fact that virtually all researchers who have studied the effectiveness of various forecasting methods, both those methods that rely upon the elicitation of expert opinion and those that rely upon the wisdom of crowds, emphasize the importance of gathering a diverse set of participants. Also, facilitators should provide a brief overview of the usefulness of the science fiction mindset to a "devil's toy box" analysis, to help convince those participants who may be initially skeptical of the inclusion of science fiction writers on the team of the latter's legitimacy as members.

Jon Landeta, in his consideration of the current relevance of the Delphi method, emphasizes the importance of facilitators fully explaining the methodology to participants (per Landeta, 2006). This is a good rule of thumb for the facilitators of Pandora's Spyglass to follow. During the lengthy face-to-face, in-person portion of the analysis, participants will make continuous, extensive use of consensus Delphi procedures and nominal group

technique procedures. In the introductory session that kicks off the in-person portion of the analysis, facilitators should take time to explain these procedures and the rationales behind them, and then respond to any questions participants may pose. Participants should not be told to "just trust the process." They should receive explanations of the theories behind the techniques and the laboratory and field evaluations of these analytical processes.

Step Five—Apply Convergent Thinking to the Scenario Stubs: The University of Foreign Military and Cultural Studies' *Red Team Handbook* recommends that the final stage of a brainstorming effort be to apply convergent thinking to the brainstormed ideas by having the team remove duplicate ideas and group the most similar ideas together, and that they do this in a way that is visible to the entire team (per UFMCS *Red Team Handbook*, 2012). The facilitators should edit down each scenario stub to its basic elements, such that each can be printed on a large sticky note, the type that can be stuck onto a surface, removed, and placed again without losing its adhesiveness; ideally, each note should be about the size of one-quarter of a standard-size sheet of paper, or about 5.5" by 4.25." Let us assume the group situation posited in Step Two of this phase: 180 scenario stubs generated by 30 team members. Having the full team initially sort the full list of 180 scenario stubs would be cumbersome, ineffective, and time-consuming, since it would be very difficult for individual team members to try to sort such a lengthy list of items. Facilitators should ameliorate this difficulty by following this procedure:

1. Divide the full team into five sub-teams of six members apiece. Similarly, randomly divide the 180 scenario stubs into five sets, each set having 36 scenario stubs which that sub-team will sort. Assign a facilitator to each of the sub-teams.

2. Provide each sub-team with its own work/discussion space, either a separate room or widely dispersed parts of a large common room (perhaps split up by temporary divider panels). Additionally, provide each sub-team with two portable, large easel boards, both big enough to accommodate all 36-scenario stub sticky notes without overlapping.

3. The facilitator should use a method of random assignment of order of turns to the members of the sub-team. The person assigned the first turn silently goes to the easel board holding all 36 sticky notes and moves any or all the sticky notes to the second, initially empty easel board, grouping scenario stubs that are either duplicates, are strongly similar, or share features that would allow them to be logically combined into a larger scenario. The participant may opt to move all the sticky notes, some of them, or none.

4. Each of the other participants, one at time, is given the opportunity to question why the currently active team member chose to move a sticky note in the way he/she did. The questioning participants may pose only one query at a time. The active team member is not obligated to provide his/her reasoning if he/she does not wish to do so. The rounds of questions continue until no non-active participants have any more questions to pose. These procedures follow guidance laid out by the creators of the Nominal Group Technique (per Delbecq, Van de Ven, and Gustafson, 1975).

5. Instructions 3 and 4 are followed for each member of the sub-team. Team members are not limited to only one turn at the easel boards. Turns will continue until no member of the sub-team wishes to move any of the sticky notes any further; this state of play represents the sub-team's consensus. If the sub-team deadlocks regarding the placement of any of the sticky notes—if successive rounds, after all members have had two chances, result only in sticky notes going back and forth between previous placements—the facilitator will put those sticky notes of contention aside from the grouped sticky notes and will make this lack of consensus known to the full team when it reconvenes.

6. Each sub-team brings its easel board holding the sorted scenario stub sticky notes back into the shared discussion/work space (in the current example, five easel boards would be placed side by side in a single room,

viewable by the entire team). The shared space should include a large display board, most likely wall mounted, big enough to hold all 180-scenario stub sticky notes without overlap and with enough spare space to allow for separation of grouped items. The members of each of the sub-teams select a single representative who will serve as their sorter during this consolidation round. Just as in instruction 3 above, the facilitators use a method of random assignment of order of turns to the representatives from sub-team. The person assigned the first turn silently goes to the easel boards holding all 180 sticky notes and moves them to the large display board. The active sorter should be told it is strongly preferable that already sorted groups of sticky notes be moved as groups, which may be consolidated with other groups of sticky notes with which there is overlap/duplication, which has strongly similar elements, or that share features that would allow them to be logically combined into a larger scenario; however, active sorters are not forbidden to move individual sticky notes from one previously assigned grouping to a different grouping, if they can articulate to themselves, and potentially to the full team, why they are making this change. The active sorter should also consider which of the existing groups the "contentious" sticky notes, not assigned to any groups in the earlier stages, should be assigned to; however, the active sorter may choose to leave the "contentious" sticky notes as outliers, off on their own, but they still need to be moved to the large display board. The first active sorter needs to move all the 180 sticky notes from the individual easels onto the large display board, even if he/she decides to leave the pre-assigned groupings exactly as they were on the individual easels and chooses not to amalgamate any of the pre-assigned groupings with one another.

7. Just as with instruction 4 above, each of the members of the full team, one at time, is given the opportunity to question why the active sorter chose to move a group of sticky notes (or any individual sticky note) in the way

he/she did. The questioners may ask only one question at a time. The active sorter is not obligated to provide his/her reasoning if he/she does not wish to do so. The rounds of questions continue until no team members have any more questions to pose.

8. As with instruction 5 above, instructions 6 and 7 are followed for each of the sub-teams' representatives. These representatives are not limited to only one turn at the display board. Turns will continue until no representative wishes to move any of the sticky notes any further; this state of play represents the full team's consensus. If the representatives deadlock regarding the placement of any of the sticky notes—if successive rounds, after all representatives have had two chances, result only in sticky notes or groups of sticky notes going back and forth between previous placements—the facilitators will print out duplicates of the sticky notes in contention and will place these duplicate sticky notes within each one of the groupings that the various sub-team representatives have indicated through their lack of consensus.

9. The facilitators will take photographs of the final groupings of the sticky notes on the display board. While the remaining team members are on break or are done for the day, the facilitators will then work with the science fiction writer members of the team to amalgamate each grouped set of scenario stubs into consolidated scenario stubs, removing duplicate ideas and arranging the non-duplicative elements into logical progressions. Ideally, this process will have narrowed down the original number of scenario stubs (180 in this example) to a more manageable number, perhaps between a third and one-half the original number (in this case, somewhere between 60 and 90 scenario stubs).

F. PHASE FOUR: RED TEAM THE SCENARIO STUBS

Phase Four of the Pandora's Spyglass analysis, that of red-teaming the consolidated scenario stubs, takes place entirely during the face-to-face portion of the process. This

phase not only assists the participants with their critical thinking during the following phase of winnowing the scenario stubs into a smaller list (the "deadly dozen"), it also provides them with practice at applying critical thinking and red-teaming skills generally, skills they will need during the forthcoming phase of fleshing out the selected "deadly dozen" scenario stubs.

Step One—Introduce the Concept of Red-Teaming to the Full Group and Provide Training on Avoiding Cognitive Biases: Using introductory material from either (or both) the University of Foreign Military and Cultural Studies' *Red Team Handbook* or the United Kingdom Development, Concepts and Doctrines Center's *Red Teaming Guide*, introduce the full team to basic concepts of red-teaming, its major goals, the goals of learning to see situations from multiple vantage points (those of the defender, the attacker/antagonist, and key allies) and learning about common cognitive biases that affect decision making and how to avoid or ameliorate these biases. Discuss the varied characteristics (goals, motivations, taboos and boundaries, and typical educational and socioeconomic backgrounds) of various types of terrorists—jihadists, nihilists, and thrill seekers (per Boyd et al., *Thwarting an Evil Genius*, 2009), and right-wing terrorists, left-wing terrorists, and members of apocalyptic cults (per Hudson, *The Sociology and Psychology of Terrorism*, 1999)—focusing on the characteristics that tend to make members of the various categories distinctive and different from the others. Review the cognitive distortions training given earlier to participants during the remote portion of the analytical effort, going into more detail and allowing for questions and discussion. Teach participants to avoid the pitfalls of mirror imaging (imagining that an opponent's desires, goals, limitations, and moral taboos are the same as yours and those of people raised in your own society and culture) and ethnocentrism (assuming the superiority of your own culture) (per Longbine, 2008). Train participants to consider the cognitive distortion caused by the availability heuristic, or the tendency for people to assign higher levels of risk and consequence to the types of malign events with which they have the greatest familiarity, or those recently highlighted in the news media (per Abramowicz, 2007). Other examples of cognitive biases that participants should be familiarized with and taught to countermand include anchoring, status quo bias, confirmation bias, sunk-cost bias, the framing trap, the

halo effect, the narrative fallacy, and self-fulfilling prophecy bias; *The Applied Critical Thinking Handbook*, the latest version of University of Foreign Military and Cultural Studies' *Red Team Handbook*, contains information on all these.[346] Nicholas Rescher also provides a useful overview of the cognitive biases most applicable to forecasting efforts in his book *Predicting the Future: an Introduction to the Theory of Forecasting* (per Rescher, 1998).

Step Two—Divide the Full Team into Groups of Four: At the start of each day spent in this phase, the facilitators will randomly assign participants to groups of four. Each group will be responsible for red-teaming randomly assigned scenario stubs. If the size of the full team is not divisible by four (such as our working example, a team of 30), an adequate number of facilitators will act as participants to fill out the group that otherwise comes up short (in the current example, there would be eight groups of four, with two facilitators taking on the role of participants). Existing groups break up at the end of a working day, and new, randomly assigned groups are formed at the beginning of the next working day. Facilitators should try, as best as is practicable, to ensure that each team member serves on groups with fellow team members with whom they have not previously worked in this phase; this will help familiarize each team member with as many of his/her fellows as possible.

Step Three—Randomly Assign a Scenario Stub to Each Group to Red Team; Also Assign Each Group a Red Teaming Method to Use: At the beginning of each day worked in this phase, facilitators assign each of the working groups one of the following seven red-teaming techniques to use in critically examining each of the scenario stubs that group will be responsible for red-teaming that day. Facilitators (a different one is assigned to assist each of the groups) will spend fifteen minutes explaining to a group its assigned red-teaming technique and will answer any questions regarding how the technique is to be

[346] University of Foreign Military and Cultural Studies Center for Applied Critical Thinking, *The Applied Critical Thinking Handbook* (formerly the *Red Team Handbook*) (version 8.1), (Leavenworth, KS: University of Foreign Military and Cultural Studies, September 2016), 101-102, http://usacac.army.mil/sites/default/files/documents/ufmcs/The_Applied_Critical_Thinking_Handbook_v8.1.pdf.

used. These facilitators will also briefly check in with the working groups to which they are assigned, to make sure any difficulties or questions that arise during the red-teaming process are addressed. If there are more groups than there are red-teaming techniques, more than one group will be assigned the same red-teaming technique, and the red-teaming technique that gets "double coverage" will change from day to day. One goal of this phase is to familiarize as many team members with the use of as many different red-teaming techniques as possible. The red-teaming techniques include:

- **Team A/Team B**: The group separates itself into two debating sub-teams comprised of two members apiece. One sub-team will argue that the scenario stub will become actualized, and the other will argue that the scenario stub will never actualize. Each sub-team assembles evidence for its own hypothesis and then presents that evidence in an oral debate format. The two sub-teams spend the first five minutes brainstorming evidence for their hypotheses. Then each group is given five minutes for a first-round oral presentation to the other. This is followed by five minutes for sub-teams to come up with rebuttals of the other sub-team's evidence. Then there is a second round of oral presentations, five minutes apiece for each sub-team. This is followed by three minutes for the sub-teams to assemble closing arguments. Each sub-team takes two minutes to present a closing argument. The last eight minutes of the red-teaming procedure are given over to an open discussion period, during which group members may offer their opinions regarding the strengths of the arguments presented, and time to make notes for the presentation on the debate and the points it raised to the entire team. (Adapted from UFMCS *Red Team Handbook*, 2012)

- **Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis:** The group separates itself into two sub-teams comprised of two members apiece. Each sub-team, based upon the scenario stub, creates a four-quadrant diagram (strengths, weaknesses, opportunities, and threats) and brainstorms entries for each quadrant. One sub-team does so from the

viewpoint of attackers using the Promethean technology to cause mayhem, and the other sub-team does so from the viewpoint of homeland security defenders. After each sub-team has spent 30 minutes preparing their SWOT analysis, they spend the last 15 minutes of the session comparing their notes with one another and preparing a brief presentation for the entire team. (Adapted from UFMCS *Red Team Handbook*, 2012)

- **Devil's Advocacy**: The group spends the first ten minutes of the session deciding upon the member's shared conventional wisdom regarding the scenario stub, the most widely-held and strongly-held consensus view. They then spend the next 30 minutes constructing the strongest possible case for a competing explanation that contradicts the consensus view, striving to disprove the consensus view by uncovering evidence that was either faulty or ignored in the original analysis and proving the assertion opposite to the consensus view. The group spends the last five minutes of the session preparing a brief presentation for the entire team. (Adapted from UFMCS *Red Team Handbook*, 2012)

- **Measure-Countermeasure, Move-Countermove**: This exercise is meant to explore the secondary and tertiary impacts of malign uses of emerging Promethean technologies. The group plays this in rounds, each round taking ten minutes. At the beginning of the first round, the group "plays" the attackers and decides upon the use of the Promethean technology, per the scenario stub. Then the group brainstorms what might be the prompt/primary, secondary, and tertiary effects of this attack, including impacts upon the economy, vital infrastructure, politics, social psychology, and individual liberties. At the beginning of the second round, the group "plays" the defenders and decides upon what would be the most likely countermove or countermeasure that the homeland security enterprise would put into place in response to the attack. Then the group brainstorms what might be the prompt/primary, secondary, and tertiary

effects of putting this defense into place, focusing on impacts in the same areas mentioned above. At the beginning of the third round, the group shifts back to "playing" the attackers, brainstorming how the attackers would most likely respond to the defenders' initial countermove(s), and otherwise replicating the same processes as were followed in the first round. In the fourth and final round, the group once again "plays" the defenders. The group spends the final five minutes of the session preparing a brief presentation for the entire team. (Adapted from Brian A. Jackson et al., *Breaching the Fortress Wall: Understanding Terrorist Efforts to Overcome Defensive Technologies*, 2007)

- **Alternative Futures Analysis**: At the beginning of the exercise, the group will spend eight minutes deciding which two sets of influencing forces they wish to apply to the scenario stub. Two sets of critical or uncertain influencing forces are chosen to be placed on sets of axes, forming a matrix of two forces at varying combinations of strength or intensity, facilitating analysis of four potential alternative futures (in more elaborate and longer Alternative Futures exercises, as many as four or five axes might be selected, resulting in an expanded number of combinations of forces at varying combinations of strength or intensity). For example, the two axes chosen might be economic health (recessionary economic climate vs. vigorous economic growth) and environmental stability (a period of violent weather events and drought versus a period of climate stability). In this example, the group would consider four quadrants and how the scenario stub being played out within each of those quadrants would impact that scenario; the four quadrants would be (a) recessionary economic climate/severe weather events; (b) recessionary economic climate/environmental climate stability; (c) vigorous economic growth/severe weather events; and (d) vigorous economic growth/environmental climate stability. A different example would be if the two axes chosen were domestic political stability (severe domestic

political conflict and violence vs. stable, cooperative domestic political environment) and international political stability (numerous international conflicts and high instability vs. relative peace and international stability). In this second example, the four quadrants would be (a) severe domestic political conflict and violence/numerous international conflicts and high instability; (b) severe domestic political conflict and violence/relative peace and international stability; (c) stable, cooperative domestic political environment/numerous international conflicts and high instability; and (d) stable, cooperative domestic political environment/relative peace and international stability. Whichever set of axes the group chooses, the group will spend eight minutes per quadrant brainstorming how the scenario stub playing out within that quadrant would impact the use and consequence of the Promethean technology. Would the likelihood of use of the Promethean technology be increased or decreased by the quadrant's characteristics? Would the likelihood of malign use be increased or decreased? Would the resulting severity of a malign use be increased or decreased? Would the defenders' tasks be made difficult by the quadrant's characteristics? The group spends the final five minutes of the session preparing a brief presentation for the entire team. (Adapted from UFMCS *Red Team Handbook*, 2012)

- **Analysis of Competing Hypotheses**: The group spends the first five to ten minutes of this exercise identifying three or four plausible or compelling hypotheses relating to the scenario stub (possible examples might include, "Use of the Promethean technology in a malign way will result in a severe curtailment of civil liberties in the United States," or, "Repeated use of the Promethean technology in a malign way will result in a U.S. economic recession, due to increased fear surrounding use of the Internet and a growing reluctance by members of the public to engage in economic activities online"). The various hypotheses may conflict with one another. Depending upon the number of competing hypotheses to be

dissected, the group will spend between seven and ten minutes on each one. For each hypothesis, two members brainstorm a matrix of supporting evidence for that hypothesis and factors that would need to be present for the hypothesis to come true, and two members brainstorm a matrix of disproving evidence and factors whose presence would make it highly likely for the hypothesis to be false. If time allows, members analyze how sensitive various hypotheses are to pieces of evidence or supporting or negating factors (if an evidence node or factor is removed, does the hypothesis then become unreasonable?). The group spends the final five minutes of the session preparing a brief presentation for the entire team. (Adapted from UFMCS *Red Team Handbook*, 2012)

- **Through the Terrorist's Eyes:** The group spends the first fifteen minutes of this exercise "trying on the shoes" of various types of terrorists—jihadists, nihilists, or thrill seekers (per Boyd et al., *Thwarting an Evil Genius*, 2009), or right-wing terrorists, left-wing terrorists, or members of apocalyptic cults (per Hudson, *The Sociology and Psychology of Terrorism*, 1999)—and discussing which groups and what types of adherents/sympathizers would be most likely, or less likely, to seek to use the type of Promethean technology embedded in the scenario stub, and various reasons why. The group decides upon one category of terrorist whose viewpoint will be adopted for the remainder of the exercise. Then the group spends 25 minutes filling in Sandia National Laboratories' Generic Threat Matrix, keeping in mind the type of terrorist or terror organization selected for analysis. The group will assign ratings of High, Medium, or Low to matrix categories including (a) *intensity* (level of dedication to his cause that the antagonist brings to an attack); (b) *stealth* (ability of the antagonist to keep his activities hidden); (c) *time* (period required to plan, organize, supply, and carry out an attack); (d) *technical personnel* (number of subject matter experts who are required to carry out an attack successfully); (e) *cyber knowledge* (antagonist's level of

expertise in computer systems, computer networks, and computer security); (f) *kinetic knowledge* (antagonist's level of expertise regarding the defender's physical barriers and the methods with which to defeat those); and (g) *access* (adversary's level of accessibility to the target). The group spends the final five minutes of the session preparing a brief presentation for the entire team. (Adapted from David P. Duggan et al., *Categorizing Threat: Building and Using a Generic Threat Matrix*, 2007)

Step Four—Red Team Each Scenario Stub, Then Present Results to Entire Team and Allow for Questions: Each group (in our current example, eight in number) red teams one randomly assigned scenario stub, spending 45 minutes on its red-teaming exercise. Then all the groups reconvene for a plenary session. Each group takes five minutes to present a summary of its findings to the assembled team, and each presentation is followed by up to ten minutes of questions. Facilitators should compile notes of the groups' findings regarding each scenario stub, as well as clarifications provided and answers to questions posed; they will distribute these notes in conjunction with a list of all the scenario stubs to the participants, prior to the participants' ranking of the scenario stubs.

In our current example, red-teaming sessions of eight scenario stubs, complete with sharing of results and questions and answers, takes about 165 minutes or 2.75 hours (45 minutes for the red-teaming exercises themselves, 40 minutes for eight presentations, and 80 minutes for eight Q&A sessions). With breaks and a 45–minute lunch, three such sessions could be accomplished in a work day, for a total of 24 scenario stubs red teamed per day. In our current example, which envisions an initial set of between 60 and 90 scenario stubs, red-teaming all them would take either three or four work days.

G. PHASE FIVE: RANK THE SCENARIO STUBS

This phase takes place entirely during the face-to-face portion of the process. The goal of Phase Five is for the participants to collectively rank, in ordinal fashion, the scenario stubs in terms of severity of potential consequence and likelihood of being actualized. The desired output is a "deadly dozen" of scenario stubs, those 12 scenarios that participants, in the terms of this thesis's central parable, have judged to be the very

worst of the gestating toys that may eventually spring forth from the devil's toy box. During this phase, due both to the relatively large number of scenario stubs to be ranked and to the participants' relative lack of familiarity with the scenarios (the participants will become far more familiarized with the "deadly dozen" scenarios, since those will be fully fleshed out), the facilitators will not ask participants to judge themselves on their levels of expertise and confidence in their ability to answer questions, and the facilitators will not use the results of the forecasting pre-test to weigh responses or to assist with eliminating lower-scoring participants' responses from the amalgamated results. Such statistical refinements will be used in a later phase, when the participants are ranking the Dirty Dozen scenarios, but in this phase, I believe application of such refinements would be nonproductive.

I do not recommend that each participant individually attempt to rank all the scenario stubs in ordinal fashion, due to the large number of stubs to be considered. Research has shown that individual judges are typically capable of productively ordering no more than nine items or ideas at one time (per Delbecq, Van de Ven, and Gustafson, 1975). Instead, I suggest use of the consensus Delphi technique, described in Section F of Chapter 4 of this thesis, in this phase to facilitate participants arriving at collective judgments of the scenario stubs' potential consequences and likelihoods of being actualized.

Many online tools have been developed to facilitate Delphi procedures. As of the time of this writing, such tools include the Delphi Learning Package for Moodle, which can either be installed as a module in the Moodle group communications software package or as a stand-alone module (https://sourceforge.net/projects/delphilearningpackage4moodle/?source=directory); the Mesydel package, developed at the University of Liège (https://mesydel.com/en#vision); Delphi Decision Aid, developed by J. Scott Armstrong with financial backing from the International Institute of Forecasters and the Ehrenberg-Bass Institute at the University of South Australia (http://armstrong.wharton.upenn.edu/delphi2/); Delphi Blue, an open source, Java/JSP version of the Delphi technique, originally developed by DARPA (https://sourceforge.net/projects/delphiblue/); and Calibrum, a commercial product that allows users to select different variations of the Delphi technique (https://calibrum.com/). Additionally, online polling software such as SurveyMonkey

(https://www.surveymonkey.com/mp/online-polls/) or Sli.do (http://www.slido.com/) can be adapted by facilitators to quicken the pace and ease the administration of consensus Delphi procedures. (Please be aware that, due to the swift pace of software development and the rise and fall software firms and open source development efforts, these links may no longer be functional by the time these instructions are accessed, and the software packages mentioned above may have been superseded by other products.)

A very large number of consensus Delphi procedures will need to be conducted during this phase, given the high quantity of scenario stubs that need to be rated and the fact that participants will rate each scenario stub nine times—once on severity of consequence, once on the likelihood of the emerging Promethean technology being developed and marketed within a five- to ten-year window, six times on six different limiting or retarding factors that influence the likelihood of the come-to-market Promethean technology being used to promulgate the catastrophic outcome(s) envisioned (potential retarding factors influencing the likelihood of the scenario being actualized), and once on overall probability of the scenario's being actualized. To not lengthen the face-to-face portion of Pandora's Spyglass inordinately, facilitators should randomly divide the full team into two half-teams at the beginning of each work day spent in this phase. Each scenario stub will be rated by half the full team, and each participant will be tasked with rating half the scenario stubs. Research regarding the wisdom of crowds suggests the bulk of improvement in accuracy of forecasting through increasing the size of the crowd comes when crowd size is increased from 10 participants to 20 (per Satopää et al., 2014). Since the Pandora's Spyglass team will be made up of between 25 and 40 members, dividing the full team into two halves will not substantially reduce the quality or accuracy of the estimates provided. Dividing the team into two halves, with each half performing its consensus Delphi procedures simultaneously in two separate rooms, will decrease the time that needs to be spent in this phase by fifty percent, an appreciable time savings.

Step One—Facilitators Provide Participants with List of Scenario Stubs: All participants receive a complete list of the scenario stubs. A summary of the results of the red-teaming exercise and answers or clarifications that resulted from Q&A sessions is included with each stub description.

Step Two—Participants Rate Each Scenario Stub Regarding Severity of Potential Consequences: Rather than using a numeric scale (1–10 or 1–100, etc.) for severity of potential consequences, participants should be instructed to consider severity in dollar terms. This will help them distance themselves from emotional reactions when contemplating the relative weights of various malign consequences (for example, due to our human sympathies, many participants' snap judgments will tend to assign a higher severity of consequences score to the violent deaths of a group of ten victims than to an event that shuts down the Nation's airports for three days straight, even though the economic cost to the Nation is far higher for the second event than for the first). Although the assignment of a dollar value to a human life may strike some participants as cold-blooded or even offensive, for the purposes of the current analysis, it is necessary. Various estimates of the dollar value of the life of an American have been calculated by different insurance companies and governmental institutions; for use with the current analysis, selection of any of these would be acceptable. The U.S. Department of Transportation utilizes a value of a statistical life (VSL) of $4.4 million for its cost-benefit analyses of proposed new traffic safety regulations.[347] For ease of calculations by participants, I suggest rounding this figure down to a VSL of an even $4 million.

Participants should be instructed to also consider the dollar values of secondary and tertiary consequences. Some of these secondary and tertiary consequences May like the prompt, primary consequences, involve loss of human life, injuries, or illnesses, but many will have effects more of economic impact, such as losses to local, regional, or the National economy. Since participants may feel overwhelmed by this task, facilitators should tell them that these are "back of the envelope" estimates, and that no participants are expected to perform as professional econometricians, certainly not in the limited time provided and with the limited data available. For the first round of the consensus Delphi to collectively decide severity of potential consequences, participants should be allotted 20 minutes to calculate an economic estimate of the primary, secondary, and tertiary impacts they see arising from the scenario stub. They should also be encouraged to provide brief statements

[347] John Mueller and Mark G. Stewart, *Terror, Security, and Money: Balancing the Risks, Benefits, and Costs of Homeland Security* (New York: Oxford University Press, 2011), 56.

of why they settled on their dollar figure, providing their rationales and a bullet-type list of the factors they considered. Participants should be assured that their responses will be anonymous, as they will enter both their dollar value estimates and their brief rationales through a software package that allows for anonymous online polling and/or Delphi procedures.

Facilitators should take a moment to urge participants, prior to their beginning their rating procedures in this step and future steps, to be consistent with their assumptions from scenario to scenario. In other words, if a participant judges that a secondary impact of both Scenario C and Scenario F is that the Nation's airports all get shut down for one week to allow for additional security measures to be put into place, that participant should assign the same dollar magnitude of cost to the economy for this secondary impact for both scenarios (such as $20 billion). So long as individual judges remain consistent with their assumptions from evaluation to evaluation, any errors they may make in estimating costs will be uniformly applied across their range of ratings for scenarios and will thus not affect their ordinal rankings of those scenarios. Facilitators should instruct participants to build for themselves a personal "assumptions dictionary," either in a Word file or an Excel file, adding to it as they come up with fresh assumptions to apply. This will allow judges to go back to assumptions they have made use of earlier and reuse them, allowing for both consistency and for increased speed and convenience of judging. These collected "assumptions dictionaries" will also provide facilitators with a valuable source of data should they, at some point, opt to attempt a validation of the variables contained within Pandora's Spyglass, or for researchers who wish to examine correlations between individual participants' sets of assumptions and their forecasting scores (results of the forecasting pre-test) or self-ratings of confidence/expertise on questions.

For the second round of the consensus Delphi, each participant should be electronically provided with the following pieces or sets of information: (a) their own previously submitted dollar value estimate; (b) the full team's median dollar value estimate (a mean or average should not be used in this instance, due to the likelihood of outliers pulling the mean up or down); (c) additional summary statistics, including standard deviation, mean, mode, and minimum and maximum values; and (c) a list of the rationales

anonymously submitted by the full team. Participants should be allotted 15 minutes to consider these materials and to reassess their initial dollar value estimate. They may opt to either stick with their initial estimate or adjust their estimate based upon the materials they have read. Again, all responses to the second round of the consensus Delphi are submitted anonymously. During this second round, participants are not asked to submit rationales for either sticking with their initial estimate or changing that estimate.

The facilitators calculate the median dollar value of the full team's estimates from the second round. This median value is the consensus value for this scenario stub. The facilitators share the consensus value with the participants. In the interest of conserving time, discussion is not permitted. Then this process is repeated for each of the remaining scenario stubs in turn. The facilitators should schedule stretching, snacks, and bathroom breaks, as appropriate.

Step Three—Participants Receive Refresher Training in the Laws of Probability and How to Calculate Probabilities: At this point, the facilitators should provide a more in-depth version of the training they provided in an on-line format back during Phase Two. This training session, between two and three hours, should include material on the laws of probability, including compound and contingent probabilities (per Wright, Rowe, Bolger, and Gammack, 1994) and on how to use Bayesian statistical methods to refine or change probability estimates in response to new information (per Tetlock, *Superforecasting*, 2015). Douglas W. Hubbard provides a helpful set of calibration tests and answers that may be included as part of this session (per Hubbard, Appendix, *The Failure of Risk Management*, 2009). Facilitators should allow adequate time throughout for questions and clarifications.

Step Four—Participants Rate Each Scenario Stub Regarding the Likelihood of Its Becoming Actualized: At the beginning of this step, which is broken out into multiple sub-steps, facilitators should instruct participants that when they estimate the probability of a scenario stub becoming actualized, they will consider not only the likelihood of the key enabling technologies reaching market within the next five to ten years, which is the independent base probability, but also the magnitude of the following six probability limiting or retarding factors that influence the likelihood of the come-to-

market Promethean technology being used for malign purposes. These limiting or retarding factors are: (a) affordability of anticipated acquisition cost of the Promethean technology or its enabling components in five to ten years' time; (c) appeal of the Promethean technology to the various types of terrorists and terror groups (jihadists, nihilists, thrill seekers, rightwing terrorists, leftwing terrorists, and acolytes of apocalyptic cults) compared with alternative modes of attack; (d) logistical complexity—the amount of time required to plan, organize, supply, and carry out an attack using the Promethean technology and the number of personnel required; (e) the level of cyber knowledge or other scientific/technical expertise required to make malign use of the Promethean technology,(i.e.,) the level of expertise in computer systems, computer networks, and computer security required, or in chemistry, biology, physics, or engineering; (f) the level of kinetic knowledge required to carry out a successful attack using the Promethean technology,(i.e.,) the level of expertise regarding the defender's physical barriers and the methods with which to defeat those; and (g) the level of access an attacker requires to a target to successfully carry out an attack using the Promethean technology. The team will collectively rate on a Low-High scale each of these probability limiting factors in turn, working one scenario stub at a time.

The <u>likelihood of the key enabling technologies reaching market within the next five to ten years</u> is the independent base probability. The probability figure calculated for this measure also represents the highest possible probability of the Promethean technology not only coming to market but also being used to promulgate the catastrophic consequences envisioned in the scenario. In other words, if the team calculates that the likelihood of Promethean Technology X coming to market within a five- to ten-year window is 45%, the ceiling, or the absolute maximum, probability of Technology X being used for the malign purpose envisioned in the scenario in question is 45%. The highest value (which represents the lowest retarding effect) that can be assigned by the team to any or all the probability limiting factors is 1.00 or 100%. If all six probability limiting factors are assigned scores of 1.00 or 100%, the likelihood of Technology X being used for the malign purpose envisioned in the scenario would be 45%, the same probability estimated for Technology X coming to market within a five- to ten-year window. As their name implies, the

probability limiting factors act to drive the probability of malign use of an actualized Promethean technology *lower*. The stronger the limiting factors are judged to be, the more they will tend to drive the probability of malign use downward. The probability limiting factors, expressed as percentages, are stronger in their impact the lower their percentages are estimated to be (i.e.: a probability limiting factor of .25 or 25% is stronger in its impact of lowering the likelihood of an actualized Promethean technology being used for a malign purpose than a probability limiting factor of .75 or 75%, since the limiting factors are applied through multiplication). Each of the probability limiting factors is judged by team members on a scale ranging between 0 and 1, inclusive of 1, with a score just above 0 representing the highest limiting or retarding impact of that factor and a score of 1 representing a complete absence of limiting or retarding impact. (I have chosen to not allow a score of 0 for a probability limiting factor because this would imply an infinite retarding power for that factor, rendering the malign use of an actualized Promethean technology an impossibility, rather than extremely, extremely unlikely; and I assume that once a technology is invented, there is always at least *some* level of likelihood, no matter how small, that it will be used for destructive purposes.)

Scores get converted into percentages. By not assigning participants a three-point, five-point, or ten-point scale to use, but rather allowing them to choose any decimal (percentage) figure between 0 and 1, inclusive of 1, I avoid several problems that Douglas W. Hubbard has identified with such scales when used for evaluation of risks. These problems include range compression, presumption of regular intervals, the tendency of a large proportion of respondents to select either 3 or 4 as their responses when offered a five-point scale, and the fact that different respondents interpret qualitative descriptions associated with a five-point (or three-point, or ten-point) scale differently.[348] I do include qualitative descriptions of various ranges of possible responses, but only as a guide for participants.

Regarding <u>likelihood of the key enabling technologies reaching market</u> within the next five to ten years, since this is the independent base probability that will be used in

[348] Hubbard, *The Failure of Risk Management*, 122–134.

calculating the likelihood of a Promethean technology not only coming to market but also being used for malign purposes, participants will assign a probability score of any number between 0% (no possibility of the enabling technologies being developed within the next five to ten years and the Promethean technology being brought to market) and 100% (certainty that the enabling technologies will be developed within the next five to ten years and the Promethean technology will be brought to market). Facilitators should provide the participants with following adjectival scale to help guide their selection of a probability score: Impossible = probability of 0%; Extremely Unlikely = probability between 0% and 19%; Unlikely = probability between 20% and 44%; About Equally Unlikely as Likely = probability between 45% and 54%; Likely = probability between 55% and 79%; Extremely Likely = probability between 80% and 100%; Certain = probability of 100%. The same consensus Delphi procedure as described in Step Two above is followed, but participants are given 15 minutes to make their first round estimate and to submit supporting rationales, and ten minutes during the second round to review their fellow team members' rationales, the mean of the full team's responses (rather than the median value), and the additional summary statistics, and then consider whether to stick with their original estimate or to adjust their estimate based on the information reviewed. The facilitators calculate the mean value of the full team's estimates from the second round. This mean value is the consensus value for the likelihood of the key enabling technologies reaching market for this scenario stub. The facilitators share the consensus value with the participants. In the interest of conserving time, discussion is not permitted.

For the first scenario stub, the participants use the same consensus Delphi procedure for each of the six probability limiting factors that influence the likelihood of the come-to-market Promethean technology being used for malign purposes. The only change is that participants are given five minutes to make their first-round estimate and to submit supporting rationales, and five minutes during the second round to review their fellow team members' rationales, the mean of the full team's responses, and the additional summary statistics, and then consider whether to stick with their original estimate or to adjust their estimate based on the information reviewed. Rating scales for the six probability limiting factors are provided below. Once again, please be reminded that qualitative descriptions

are to be used by participants merely as guides in their selection of values between 0 and 1, inclusive of 1. Facilitators should provide participants with the full set of guidelines in writing (or pixels) for participants' reference.

Also, facilitators should provide this instruction regarding the scoring of probability limiting/retarding factors: "You will judge the strength of each probability limiting/retarding factor individually for each scenario, in isolation from consideration of any of the other limiting/retarding factors. As you are judging each factor, do so under the presumption that it is the *sole* retarding factor impacting the likelihood of a developed technology being used for the malign purpose envisioned in the scenario. If you feel this factor makes it virtually impossible that the developed technology will be used for the malign purpose envisioned, score the factor close to 0. If you feel this factor exerts very little or no retarding influence on the likelihood of the use of the developed technology for the malign purpose envisioned—that you can pretty much say that if the technology exists, it *will* be used for this destructive purpose, so the probability of the technology coming to market AND being used for the malign purpose is the same as the probability of the technology coming to market—score this factor close to 1.0 (hardly any retarding influence) or score it 1.0 (no retarding influence at all). If you feel the influence of the limiting/retarding factor falls somewhere between these two extremes, please use the provided descriptions as a guide to your rating."

Affordability of anticipated acquisition cost of the Promethean technology or its enabling components five to ten years in the future:

0–.19 = Highly Unaffordable, Save for Well-Funded Organizations ($200 thousand or more)

.2–.49 = Mostly Unaffordable, Save for Well-Funded Organizations (between $50 thousand and $200 thousand)

.5–.79 = Affordable for Organizations, Mostly Unaffordable for Individuals (between $10 thousand and $50 thousand)

.8–.94 = Somewhat Affordable for Individuals (between $1000 and $10 thousand)

.95–1.0 = Highly Affordable for Individuals (less than $1000)

(If the scenario involves use of the technology by an individual, the participant should score the Affordability retardant more strongly, (i.e.,) numerically lower, than if the scenario involves use of the technology by an organization. If a team member estimates that the acquisition cost falls near one of the extremes of a suggested dollar range, that team member should select a fractional value close to the top or bottom of the suggested range. This stipulation applies to all the remaining limiting factors, as well.)

Appeal of the Promethean technology to the various types of terrorists and terror groups, compared with alternative modes of attack:

0–.19 = Extremely Unappealing (use of the technology conflicts with the attacker's religious precepts, morality, or ideology AND/OR attacker judges that use of the technology promises much lower likelihood of success than use of alternate attack modes AND/OR use of the technology will very likely bring condemnation from the attacker's allies and potential supporters AND/OR use of the technology will very likely incite a powerfully disproportionate punitive response from a nation state or coalition of nation states… the technology is judged to be "too hot to handle" and/or "more trouble than it is worth")

.2–.79 = Unappealing (attacker judges use of the technology promises at least some marginal decrease in likelihood of success than use of alternate attack modes AND/OR use of the technology is more likely than not to bring condemnation from the attacker's allies and potential supporters AND/OR use of the technology is more likely than not to incite new punitive measures of increased severity from targeted nation state(s) and powerful enemies, representing a risk that the attacker's use of the technology will retard the attacker's goals more than the use advances those goals)

.8–.89 = Neither Especially Unappealing or Especially Appealing (attacker judges that use of the technology suffers no significant disadvantages or offers no significant advantages when compared with alternate modes of attack; choice to use technology over alternate modes of attack most likely due to availability or convenience rather than any real preference)

.9–.94 = Appealing (attacker judges use of the technology promises at least some marginal increase in likelihood of success than use of alternate attack modes AND/OR use of the technology is more likely than not to bring approbation from the attacker's allies and potential supporters AND/OR attacker judges use of the technology will reduce the morale and will to resist of target nation state(s) and powerful enemies and advance the attacker's goals)

.95–1.0 = Extremely Appealing (use of the technology is an excellent fit with the attacker's religious precepts, driving narrative, or ideology AND/OR attacker judges use of the technology promises much higher likelihood of success than use of alternate attack modes AND/OR use of the technology will very likely bring great approbation from the attacker's allies and potential supporters AND/OR attacker judges use of the technology will very likely significantly cow and intimidate target nation state(s) and powerful enemies and significantly advance the attacker's goals)

Logistical Complexity—time required to plan, organize, supply, and carry out an attack using the Promethean technology and the number of personnel required:

>0–.19 = Very High Complexity (three years or more; 50 personnel or more)

.2–.39 = High Complexity (one to three years; 20–50 personnel)

.4–.69 = Medium Complexity (two months to one year; 10–20 personnel)

.7–.94 = Low Complexity (two weeks to two months; 3–10 personnel)

.95–1.0 = Very Low Complexity (days to two weeks; 1–2 personnel)

Level of cyber knowledge or other scientific/technical expertise required:

>0–.19 = Very High (post-graduate level skills and expertise needed, and/or five years or more of professional experience in the field)

.2–.49 = High (baccalaureate level skills and expertise needed, and/or three years or more of professional experience in the field)

.5–.69 = Moderate (associate's level or certificate program level skills and expertise needed, and/or one year or more of professional experience in the field)

.7–.94 = Low (skills and expertise can be easily acquired and absorbed through books or Internet research, and/or three months or more of professional experience in the field)

.95–1.0 = Very Low (no special skills or expertise are required, nor is any work experience in the field; Promethean technology is consumer-grade and comes with instructions that the average user can follow, with assistance, if needed)

Level of <u>kinetic knowledge</u> required:

>0–.19 = Very High (to carry out a successful strike, attackers must penetrate or bypass highly sophisticated defensive systems WITH multiple layers of defense, including both automated or passive defenses AND manned defenses)

.2–.39 = High (to carry out a successful strike, attackers must penetrate or bypass a sophisticated defensive system OR multiple layers of defense, including automated or passive defenses and/or manned defenses)

.4–.79 = Moderate (to carry out a strike, attackers must penetrate or bypass ordinary, unsophisticated barriers such as might be found at a special event or a school, which might include fences, walls, locked entrances, bollards or traffic barriers, or areas with restricted access, AND avoid detection by law enforcement or security guards assigned to protect the site)

.8–.94 = Low (to carry out a successful strike, attackers must penetrate or bypass ordinary, unsophisticated barriers such as a fence, a wall, and/or locked entrances, and avoid detection by patrolling law enforcement not specifically assigned to the site of the attack)

.95–1.0 = Very Low (to carry out a successful strike, attackers must access a space normally open to the public with no restrictions, that is not normally patrolled by law enforcement or security guards)

Level of access an attacker requires:

>0–.29 = Very High (to carry out a successful strike, attackers need to become vetted employees or contractors of an institution that uses vigorous background checks in its hiring process and requires at least a public trust clearance level, or its equivalent AND significant surveillance is necessary)

.3–.79 = High (to carry out a successful strike, attackers need to be vetted visitors, getting permission to access a facility from a security staff AND having to pass through a metal detector and have one's belongings be searched or electronically scanned, OR significant surveillance is necessary)

.8–.89 = Moderate (to carry out a successful strike, attackers need to enter a facility with no restrictions on entrance, without raising suspicions from employees, security guards, or other visitors, AND moderate surveillance is necessary)

.9–.94 = Low (to carry out a successful strike, attackers do not need to enter a facility or site but only require physical proximity, such as from a street or sidewalk; moderate surveillance may be necessary)

.95–1.0 = Very Low (attackers can carry out a strike remotely, from a secure base of operations, and do not require any access or proximity to the site of the attack)

Only after team members have performed consensus Delphi procedures for the independent base probability and all six probability limiting factors for a scenario stub will they then estimate the probability of that scenario becoming actualized. Facilitators provide participants with 20 minutes for this procedure. They should provide participants with the following examples of ways that the six probability limiting factors may be used in conjunction with the independent base probability to estimate a probability of malign use. Additionally, they should provide participants with the group's amalgamated mean for the independent base probability and for each of the six probability limiting factors, the participants' own second round scores for the independent base probability and each of the six probability limiting factors, and summary statistics for each of the seven calculated figures.

I do *not* recommend that facilitators provide participants with a mathematical formula that assigns weights to the various probability limiting/retarding factors and mechanically outputs an overall probability figure. My primary reason for not recommending this is that terror attacks are highly individualistic events, each driven by the psychology of the group's leaders and followers or that of the individual terrorist; local environmental factors; and chance. Any such model the facilitators might come up with could only be validated by examining many diverse terror attacks and working backwards, trying to estimate as best as possible what the levels of the various probability factors were prior to attacks being carried out. I suspect that models constructed and validated in this fashion would only be valid for a combination of terror group/category of terrorist, attack mode, type of target, and environment of target (overall levels of security precautions; level of governmental corruption; local weather and terrain; density of population; etc.). A model judged to have very high validity, or measure of fit, for one such combination might have next to no validity for other combinations, and thus a staggering number of varying models

would need to be constructed and validated to cover all possible combinations… that defeats the purpose of modeling, that of simplifying predictions by providing standardization; however, my supposition in this regard can be tested and validated, to an extent. I will speak more about this in a later section.

My reservations about facilitators providing participants with a recommended or assigned model must not be misconstrued to imply that participants should be forbidden from creating and using their *own* models. Participants act as judges, and formulating their own models, with the six probability limiting/retarding factors weighted individualistically (or not assigned any weights at all), is itself a judgment activity, just as vital to the estimation process as the assigning of the base probability figure for the Promethean technology coming to market within a five- to ten-year window.

The simplest method for making use of the six probability limiting factors would be for a participant to weight them all equally and calculate a simple mean of their scores. (The limiting factor scores are averaged, rather than being multiplied together, because probability limiting factor scores are not themselves contingent probabilities,(i.e.,) this is *not* a situation of, "In order for Z to occur, W AND X AND Y all need to occur, and the probability of W is 50%, the probability of X is 70%, and the probability of Y is 65%, so the probability of Z occurring is 50% x 70% x 65% = 22.75%"). An example of this simple model is provided below.

<u>Scenario Stub XYZ</u>

Likelihood of Reaching Market (independent base probability) = 74%

Affordability = .92

Appeal = .96

Logistical Complexity = .82

Cyber Knowledge/Scientific-Technical Expertise = .66

Kinetic Knowledge = .94

Access = 1.0

In this example, the probability score of the Promethean technology not only coming to market but also being used for malign purposes would be .74 x ((.92 + .96 + .82 + .66 + .94 + 1.00) / 6) = .65 or 65%. In this instance, none of the retarding factors had a very strong effect, with the highest strength limiting factor being Cyber Knowledge/Scientific-Technical Expertise. (Please note that the probability score of the Promethean technology coming to market AND being used for malign purposes never exceeds the independent base probability of the enabling technologies coming to market, no matter what the weighting of the probability limiting factors may be.)

Should participants decide to create a weighted formula using the six probability limiting factors, they should first decide which factors are more important than others and arrange them in order of descending importance. For the example above, the selected order might be (1) Appeal ("if the attackers are not emotionally motivated to use the technology rather than alternative modes of attack, none of the remaining factors matter"); (2) Cyber Knowledge/Scientific-Technical Expertise; (3) Logistical Complexity; (4) Affordability; (5) Kinetic Knowledge; and (6) Access. Then participants should select one of the factors to use as a "base value" against which to weight the others. Is there a factor that should be weighted twice as heavily as another? If so, assign the latter factor a weight of "1" and assign the former a weight of "2," then work from there, gauging the weights of the remaining factors relative to the weights assigned to those two factors. I provide an example below:

Scenario Stub XYZ (Weighted Example)

Likelihood of Reaching Market (independent base probability, no weighting) = 74%

Appeal: (raw score = .96) (weight = 4)

Cyber Knowledge/Scientific-Technical Expertise: (raw score = .66) (weight = 2)

Logistical Complexity: (raw score = .82) (weight = 2)

Affordability: (raw score = .92) (weight = 1)

Kinetic Knowledge: (raw score = .94) (weight = .5)

Access: (raw score = 100%) (weight = .5)

In this example, my two "base values" are Appeal and Affordability; the former is judged to be four times as important as the latter. Both Cyber Knowledge/Scientific-Technical Expertise and Logistical Complexity are judged to be half as important as Appeal and twice as important as Affordability. Both Kinetic Knowledge and Access are judged to be half as important as Affordability. The following formula shows how to calculate the weighted mean of the example above. The denominator (in this example, 10) is the sum of all the six weights.

.74 x (((.96 x 4) + (.66 x 2) + (.82 x 2) + (.92 x 1) + (.94 x .5) + (1.00 x .5)) / 10) = .64 or 64%

Now let's have a look at the same example, but with different estimates for some of the retarding/limiting factors. Let's say that both Logistical Complexity and Affordability are significantly retarding factors, rather than having hardly any limiting effects at all. Logistical Complexity, formerly scored at .82, is now scored at .12, and Affordability, formerly scored at .92, is now scored at .21.

Scenario Stub XYZ (Alternate Weighted Example)

Likelihood of Reaching Market (independent base probability, no weighting) = 74%

Appeal: (raw score = .96) (weight = 4)

Cyber Knowledge/Scientific-Technical Expertise: (raw score = .66) (weight = 2)

Logistical Complexity: (raw score = .12) (weight = 2)

Affordability: (raw score = .21) (weight = 1)

Kinetic Knowledge: (raw score = .94) (weight = .5)

Access: (raw score = 100%) (weight = .5)

.74 x (((.96 x 4) + (.66 x 2) + (.12 x 2) + (.21 x 1) + (.94 x .5) + (1.00 x .5)) / 10) = .49 or 49%

With the retarding power of two of the probability limiting factors significantly increased, even for two variables that are not weighted the most heavily, the probability of malign use of the Promethean technology declines by more than a third of its earlier value, from 74% to 49%.

Whatever weights participants opt to assign to the six probability-limiting/retarding factors, facilitators should encourage participants to play with their weightings in a spreadsheet, so that they can see how altering weights affects the overall probability of malign use. This will help participants decide whether the formula they have created passes the "smell test" of plausibility. Alternatively, participants may opt to consider the group's aggregated means of the six probability limiting factors separately and individually, without any weighting at all, to guide their intuitive judgment of probability of the scenario described in the stub becoming actualized. Whatever method is used, participants should perform a "gut check" regarding whether the probability result they end up with seems reasonable, based upon the information they have absorbed thus far regarding the scenario in question. If their gut tells them the result is *not* reasonable, they should reexamine the assumptions they have made in coming up with that result and alter those assumptions, if necessary.

The final, consensus probability score of a scenario stub becoming actualized, of the Promethean technology not only coming to market but also being used in a malign fashion per the scenario, is the mean of the group's overall probability scores. Once the facilitators calculate this probability value, they share the consensus value with the group. Then the group moves on to performing the same set of consensus Delphi procedures for rating probability for the next scenario stub, and so on, until participants have ascertained consensus probability ratings for all the scenario stubs.

Step Five—Facilitators Calculate Estimated Risk Levels for Each Scenario Stub: Estimated risk levels are all expressed in dollar terms, to allow for easy ranking and comparisons. The formula for risk in this instance is:

Risk = (Consensus Estimated Dollar Value of Scenario's Consequences) x (Consensus Estimated Probability of the Scenario Becoming Actualized)

Facilitators then provide participants with a list of all the scenario stubs ranked in descending order of risk, with the risk formula figures provided for each. They inform participants that only the 12 scenario stubs at the top of the risk estimation list will be further worked on and fleshed out into full scenarios for a final ranking process.

Step Six—Finalizing Determination of the "Deadly Dozen" Scenarios: At this point in the process, some participants, when exposed to the ranked list of all the scenario stubs, may feel that vital elements of threat scenarios are being discarded by the cut-off that leaves only the top twelve. Facilitators should ask whether any participants feel this way, allowing participants to indicate this through anonymous electronic means. Should any participants express such reservations with the preliminary "deadly dozen" list of scenario stubs, the full group will then follow a nominal group technique process to arrive at a consensus resolution of a revised list.

Facilitators should inform the group that the preferred option for incorporating scenario stubs or elements of scenario stubs that are ranked below the "deadly dozen" is to combine the excluded elements with one of the top twelve scenario stubs, should such amalgamations be logical, in that the newly incorporated elements are congruent and complementary with the elements in the top-ranked scenario stub. The preferred outcome is that the list of scenarios to be fleshed out should remain at 12, in the interests of expediting the analytical effort; however, should the group decide this outcome is impractical yet still want to include certain scenario stubs excluded in the preliminary list, the group, using NGT processes, may opt to expand the list of scenario stubs to be further worked with from a "deadly dozen" to a "threatening thirteen," a "frightening fourteen," or a "ferocious fifteen."

Following the nominal group technique procedure, any participants who wish to may anonymously electronically submit their ideas for amalgamation of a lower ranking scenario stub with one of the top twelve, or for adding a lower ranking scenario stub to the list of "survivors." Submitting participants should also provide a brief rationale supporting their suggested change. Facilitators should allot ten minutes for this part of the procedure, if called for. Then the round-robin questions and answers session begins. One suggestion is considered at a time. One participant speaks at a time, asking one question or making one observation regarding the suggestion, or offering a reason to support or disagree with the suggestion. Facilitators should instruct participants to keep their round-robin inputs brief and to the point. The suggestion's contributor, anonymous until now, may opt to respond or may decline to answer. After a full round of Q&A, the facilitators should ask

whether another round is needed. The facilitators then ask for anonymous Yes/No electronic votes. Round-robin Q&A and follow-on voting takes place first for amalgamation suggestions. If an amalgamation suggestion is voted YES by the group and that amalgamation integrates a lower ranking scenario stub into one of the top twelve, no round-robin Q&A or follow-on voting is done for a suggestion that this same lower ranking scenario stub be separately added to the list of top twelve scenarios. Round-robin Q&A sessions and follow-on voting are carried out last for suggestions to add additional scenario stubs to the list of "survivors."

H. PHASE SIX: FLESH OUT THE "DEADLY DOZEN" SCENARIOS

Phase Six of the Pandora's Spyglass analysis, that of expanding the "deadly dozen" scenario stubs into full-fledged scenarios, is the last phase that takes place during the face-to-face portion of the process. Our bedraggled participants are begging to go home! But I have saved perhaps the best, most fun part of the face-to-face portion of Pandora's Spyglass for last. Participants get to apply the scenario development and red-teaming skills they have learned thus far in a creative, interactive fashion. Earlier, in my chapter examining Futures Studies/Foresight Studies, I discussed the work of Amy Webb, author of the book *The Signals are Talking*, in which she offers a procedural road map for prognostication, whose six steps alternate between what she terms "flaring" and "focusing." "Flaring" is a widening of vision to encompass as much information and as many signaling indicators as possible, while "focusing" is a narrowing of vision to the most pertinent environmental factors impacting one's organization. Pandora's Spyglass also alternates between sets of flaring phases and sets of focusing phases. Phase One, Environmental Scanning, Phase Two, Assembling the Team, and Phase Three, Brainstorm Scenarios, are all flaring phases that seek to cast a wide net to gather disparate knowledge, insights, and opinions. The end of Phase Three, which involves grouping and amalgamating of similar or related scenario stubs, shifts the team's efforts into focusing. Focusing continues into the next phase, Phase Four, Red Team the Scenario Stubs, during which team members apply various critical thinking exercises to the assembled scenario stubs. Focusing grows sharper in Phase Five, Rank the Scenario Stubs, during which participants individually calculate estimates of dollar values of consequences and estimate probabilities of scenario stubs becoming

actualized, then use consensus Delphi and nominal group technique procedures to arrive at team consensus risk scores for each scenario stub, and finally rank the scenario stubs in order of those risk scores, discarding all but the "deadly dozen," those with the top-ranked risk scores; however, in Phase Six, the remaining scenario stubs are expanded into full-blown scenarios, a flaring activity that adds detail, depth, richness, and relatability to each of the "deadly dozen." This will allow for more in-depth and sophisticated forecasting and ranking procedures than have been employed thus far, for when Pandora's Spyglass shifts back to its focusing phases.

Step One—Divide the Full Team into Scenario Expansion Sub-Teams: Facilitators should aim to assemble half as many sub-teams as there are surviving scenario stubs, so that each sub-team will be responsible for fleshing out two scenarios. Sub-teams do not have to all consist of the same number of members; however, facilitators need to assign a science fiction writer as the lead scenario writer/scenario expansion facilitator, and they should also strive to match team subject matter experts (scientific, technical, academic, or homeland security practitioners) with appropriate scenarios (match biologists with scenarios involving gene manipulation, for example).

Step Two—Select the Three Key Axes of Driving Environmental Forces Most Significant to Facilitating Malign Uses of the Scenario's Promethean Technology: Sub-team leads (all science fiction writers) need to emphasize to their teammates that the primary goal of Phase Six is to promulgate the *worst-case scenario* out of each stub addressed. In fleshing out each scenario, participants, when choosing between alternative, branching plot lines ("what happens next?"), should aim to pave the path that leads to the most catastrophic outcomes. Make it as bad as possible! Remember, the goal of a "devil's toy box" analysis is not to judge which of the many, many gestating toys are most likely to jump out of the box first, but rather to decide which of those gestating toys are the most terrible in their potential impacts, and thus the most important to devise a shield against (or seal up inside the box). Participants, in devising worst-case scenarios, should strive for plausibility, but a "devil's toy box" analysis does not call for devising *probable* futures.

Peter Schwartz, in his book *The Art of the Long View*, describes selecting key axes of driving environmental forces as one of the essential steps of developing scenarios of

various plausible futures (per Schwartz, 1996). The traditional view of scenario analysis is that it is not a tool for making predictions, but rather for gaming a variety of plausible futures and exploring how different decisions made in various sectors might shift the unfolding pathways of those futures. In this phase of Pandora's Spyglass, however, participants select key axes of driving environmental forces with a different purpose in mind—they try to judge, within a volume (three axes), which combination of points along the three intersecting axes results in the worst-case scenario for use of the Promethean technology under consideration, so that this *most malign* combination of points along the three axes can be used as the scenario's enabling background. This *most malign* combination should be plausible and internally consistent, but it need not be probable.

Earlier, in Step Three of Phase Four (Red Team the Scenario Stubs), one of the red-teaming exercise techniques participants might be assigned was *Alternative Futures Analysis*, in which participants selected two sets of critical or uncertain influencing forces to be placed on sets of axes, forming a matrix containing four quadrants of combinations of forces having various strengths or intensities. The participants then brainstormed how the scenario playing out within each of these quadrants would impact the scenario. The difference between this earlier phase and the current step is that, rather than two axes of influencing forces, participants are now to consider <u>three</u> axes of influencing forces. Rather than four quadrants, participants consider eight possible combinations, if the choice along each axis is restricted to Low and High (possible combinations include High-High-High, High-High-Low, High-Low-Low, High-Low-High, Low-Low-Low, Low-Low-High, Low-High-High, or Low-High-Low).

First, the sub-team lead facilitates brainstorming of different influencing forces to possibly assign to the three axes. Since the time frame being considered is the next five to ten years, participants should keep this time frame in mind, considering that trends that are apparent or are emerging in the present may continue into that near-term future (or may not, if the participants collectively decide to insert a black swan into the scenario's timeline). Then the sub-team decides which three influencing forces are most relevant to the use or non-use of the Promethean technology at the heart of the scenario. Health of the economy? Level of political unrest? Activity level of Terror Group X? Level of conflict in

the Middle East? In Asia? Rate of societal diffusion and adoption of the Internet of Things? The sub-team lead, working with the assistance of a facilitator, creates a volume of eight possible combinations of the three influencing forces at either Low Strength/Intensity or High Strength/Intensity. Then the sub-team members vote on which of the eight possible combinations is most conducive to catastrophic malign use of the Promethean technology under consideration. This "backdrop" of influencing forces is then used to help guide the development of the full scenario.

Since the sub-teams are relatively small face-to-face groups, I encourage the sub-team leads to use nominal group technique procedures during this phase. I suggest that voting on the most malign combination be undertaken in this fashion: participants take five minutes to anonymously select their top three choices, with first choice receiving three points, second choice two points, and third choice one point. Facilitators sum the points received by each alternative combination, with the combination receiving the most points being the sub-team's consensus choice. Sub-team leads should strive to have their team complete the entirety of Step Two, including the round-robin discussion session, within an hour.

Step Three—Apply "Through the Terrorist's Eyes" Exercise to the Scenario: Earlier, in Step Three of Phase Four (Red Team the Scenario Stubs), participants applied a variety of different red-teaming exercises to the scenario stubs. In that step, each scenario stub was matched with only one of the exercises. Now that the team has narrowed down the list of scenario stubs to a "deadly dozen," the surviving scenario stubs benefit from applications of each of the exercises that are appropriate for the fleshing out process.

In this application of *Through the Terrorist's Eyes*, participants aim to select the terror group or category of terrorist (to reiterate, the list includes jihadists, nihilists, thrill seekers, rightwing terrorists, leftwing terrorists, and acolytes of apocalyptic cults) that they judge to have the greatest affinity for the Promethean technology under consideration, as well as the group or category of terrorist that is most likely to make the worst-possible, most catastrophic use of the Promethean technology. Once again, the goal is to formulate the worst-case scenario. In working this exercise, participants should build upon the results of the previous exercise, *Alternative Futures Analysis*, making use of the "backdrop"

previously developed to add detail and verisimilitude to this look "through the terrorist's eyes." This will be the case for all subsequent exercises carried out during this phase. Each exercise adds a new layer to the scenario. At this stage of Pandora's Spyglass, participants benefit from having had prior exposure to and experience using the red-teaming exercises, which should serve to make the sessions during the current phase more productive (and, I hope, more *enjoyable* for the team as a whole). Sub-team leads should ensure that the full "library" for this scenario, all the products produced by the team for the scenario stub in all earlier phases and steps, is available for members of the sub-team to refer to, either in electronic or hard-copy form (preferably both, to accommodate differing working styles).

Again, I recommend that the sub-team leads use nominal group technique procedures to facilitate discussions and deciding upon the terror group or category of terrorist to feature in this scenario. I suggest that voting on the featured terrorist(s) be undertaken in this fashion: participants take three minutes to anonymously select their top two choices, with first choice receiving two points and second choice one point. Facilitators sum the points received by each, with the option receiving the most points being the sub-team's consensus choice for the scenario's protagonist from that point forward. Sub-team leads should strive to have their team complete the entirety of Step Three, including the round-robin discussion session, within an hour.

Step Four—Brainstorm Precursors: What events or developments lead up to the malign use of the Promethean technology? What needs to happen for the worst-case scenario to actualize? What are world leaders doing in the months and years leading up to the worst-case use of the technology? What are technology and business leaders doing? Based upon the materials collected and created so far by the sub-team, do any wars occur during the five- to ten-year period leading up to the worst-case use of the Promethean technology? Do any revolutions occur? Any insurgencies or terror campaigns? Have there been any major environmental disasters that have significantly impacted the world of the scenario? Are people's standards of living rising or falling? What social changes take place in the five to ten years leading up to the catastrophic use of the technology?

I advise use of nominal group technique processes during this step. The sub-team leads should decide which brainstormed precursors enjoy consensus support following the

round-robin idea submission round and the round-robin discussion round, and which brainstormed precursors have less than unanimous support and so require voting. Sub-team leads should strive to have their team complete the entirety of Step Four within an hour.

Step Five—Apply Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis to the Scenario: In this application of SWOT analysis (see Step Three of Phase Four for details on how to carry out the analysis), the full sub-team performs the analysis together, first for the attackers, then for the defenders. I advise use of nominal group technique processes during this step. The sub-team leads should decide which brainstormed additions to the various quadrants enjoy consensus support following the round-robin idea submission round and the round-robin discussion round and may be added as elements to the scenario. Those suggestions that have less than unanimous support will require a voting procedure. Sub-team leads should strive to have their team complete the entirety of Step Five within an hour.

Step Six—Apply "Measure-Countermeasure, Move-Countermove" Exercise to the Scenario: Please refer to Step Three of Phase Four for details on how to carry out this exercise. Participants should decide in this step whether defenders benefit from any form of useful intelligence prior to the attack using the Promethean technology, or whether they are taken completely by surprise. The purpose of using this exercise during this phase is to thoroughly brainstorm the prompt/primary, secondary, and tertiary consequences of *both* the catastrophic attack *and* of countermeasures put into place by the defenders, either in anticipation of the attack or in response to the attack having taken place. Once again, I highly encourage participants to brainstorm the *worst* primary, secondary, and tertiary effects they can imagine to incorporate within the scenario (within the bounds of plausibility and while retaining the scenario's internal logical consistency, (i.e.,) do not have two events or consequences occur within the same period that contradict one another).

I advise use of nominal group technique processes during this step. The sub-team leads should decide which brainstormed consequences enjoy consensus support following the round-robin idea submission round and the round-robin discussion round and may be added as elements to the scenario. Those suggestions that have less than unanimous support

will require a voting procedure. Sub-team leads should strive to have their team complete the entirety of Step Six within an hour.

Step Seven—Sub-Teams Present Their Scenarios to the Full Group for Feedback and Critique: The full group reconvenes after each sub-team has completed Steps Two through Six for one of their assigned scenarios. The facilitators randomly assign the order for sub-teams to present their scenarios and respond to questions or comments. The sub-team leads take eight to ten minutes to summarize for the assembled group the results of their team's fleshing out exercises. Then, following nominal group technique procedures, the full group (minus the members of the sub-team) engages in two or three rounds of round-robin questioning/commenting, with each speaker offering a single question or comment per round. Facilitators should instruct participants that they need to keep their questions and comments succinct and to the point. Either sub-team leads, or sub-team members, may speak in response; they should also keep their responses brief and to the point, avoiding extended digressions. Each scenario receives an hour's attention from the full group in this step. Each sub-team lead should take notes regarding comments made about their scenario and the question-and-answer exchanges.

Step Eight—Sub-Teams Reconvene to Decide Whether to Adjust Their Scenario in Response to the Full Group's Feedback: This is the last step of this phase which takes place during the face-to-face portion of Pandora's Spyglass. The sub-team leads reconvene their teams and use nominal group technique procedures to perform a round-robin discussion of the feedback received from the full group, and to then decide whether the sub-team wishes to make any changes to their scenario based this feedback (or in response to any new ideas generated by the feedback). Leads should aim to have this step take between an hour and 90 minutes per scenario. The sub-team members finalize their scenario prior to departing the face-to-face portion of the analysis and sending their science fiction writer team lead back home to polish the scenario and write it up in a compelling, dramatic fashion. Before departing, the sub-teams repeat Steps Two through Eight for their second assigned scenario.

I would like to offer some general suggestions that apply to the entire face-to-face, in-person portion of Pandora's Spyglass. This is a lengthy and arduous process; many

participants will be far from home and families and will likely still need to contend with issues arising from their normal jobs and activities; however, done right and with the proper spirit, this should also be a fun and stimulating process. Participants get to spend several weeks getting to know a cohort of very interesting people, many of whom come from professional backgrounds quite different from their own, and they can develop new critical thinking skills and to think deeply about issues important to the Nation and to their own communities. Many will find themselves stretching their minds in ways new and unfamiliar to them. Facilitators should take every opportunity to foster the growth of team spirit and to remind participants of the goal of Pandora's Spyglass—a safer, more secure America, one less vulnerable to being blindsided by strategic surprise. Ideally, facilitators will encourage team members to share meals and trips to local watering holes after the work days and will suggest shared activities for evenings and weekends, such as nature hikes, bowling, excursions to historical or cultural sites, roasting marshmallows around a campfire, shopping trips, or karaoke (that last activity is sure to help bond a team together). If participants are interested and the authors are willing, perhaps some or all the science fiction writer team members could offer live readings of a selection of their work as after-dinner entertainment.

I would also suggest that facilitators break up the long series of nominal group technique and consensus Delphi procedures with occasional sessions of forecasting calibration exercises, between one and three times a week. Douglas W. Hubbard offers several such exercises in Chapter Six and the Appendix of his book, *The Failure of Risk Management*, and with minimal effort, the facilitators could come up with additional exercises (or find them online). To add an element of fun, facilitators could divide the group up into teams and have them compete to see which team's members can become fully calibrated the quickest (offering some sort of minor prize to the winners, such as sweets or pins featuring the sponsoring agency's logo, would be a nice touch). Apart from breaking up the monotony, these exercises will help participants better understand the nature of probabilities and will help train them to avoid either over- or under-confidence when making forecasts.

Step Nine—Lead Scenario Writers Prepare 15–20 Page Scenario Narratives with One-Page Executive Summaries: This step represents the beginning of the second distance portion of Pandora's Spyglass. The science fiction writers who have served as sub-team leads may take up to a week to write scenario narratives of approximately 15–20 pages in length, complete with a one-page executive summary. The writers should strive to make their narrative vivid, relatable, and emotionally compelling, while keeping within the constraints and plot points collectively established by their team members. They should select memorable names for each scenario. Writers should keep in mind that these narratives will live multiple "lives," serving varying purposes. The narratives will provide the basis for the remaining phases and steps of the Pandora's Spyglass analysis, of course; however, they will also likely be used as "sales tools" that agency administrators can use with members of Congress and appropriations committees to request funding for counter-future-shock R&D projects or to explain the purpose of the counter-future-shock R&D program. If funding is provided, the narratives will likely be included with Request for Proposal packages, or other acquisition solicitation packages, to inform potential offerors (federal research labs, academic labs or consortiums, commercial R&D firms, tech entrepreneurs, etc.) of requirements. In this way, the narratives will also serve as recruiting tools, potentially attracting some of the Nation's best minds to work on some of the Nation's most challenging problems.

I. PHASE SEVEN: RANK THE "DEADLY DOZEN" SCENARIOS

All steps of Phase Seven take place within the second distance portion of Pandora's Spyglass. The purpose of Phase Seven is to rank the "deadly dozen" scenarios in terms of awfulness, sticking with the formula of risk equaling the likelihood of actualization of the malign use multiplied by the dollar value of the worst possible consequences. The reason for ranking individual scenarios within the already prioritized "deadly dozen" group is that in any given funding cycle, it is quite possible that not enough funding will be provided to initiate R&D programs to counter all twelve scenarios. So, the "deadly dozen" must themselves be prioritized, in order that whatever funding is made available gets applied to the "worst of the worst."

Step One—Apply Technology Sequence Analysis to Estimate the Likelihoods of the Promethean Technologies Reaching Market Within a Five to Ten Year Window: I described the process of Technology Sequence Analysis (TSA) earlier, in Section C of Chapter 5. This step can be carried out concurrently with Step Nine of Phase Six, since the team's technical experts are engaged in this step and the team's science fiction writers are engaged Step Nine of Phase Six (two separate groups of team members), and the polished scenario narratives are not necessary for the team's technical experts and their confederates to begin the process of Technology Sequence Analysis on the twelve Promethean technologies or combinations of technologies notionally being put to catastrophic purposes.

Facilitators should be cognizant of the fact that it is likely the technical experts who are already members of the team will not be able to accomplish this step on their own, or at least not in a timely enough fashion. For any complex technology, or system-of-systems, Technology Sequence Analysis is a lengthy, involved process that encompasses hundreds of estimates of the likelihoods of individual components being available within a five- to ten-year period (the time window of interest for a Pandora's Spyglass analysis). Facilitators should have, prior to this point in the process, made arrangements to either temporarily expand the team with an additional cadre of technical experts sufficient to carry out Technology Sequence Analysis on all twelve of the "deadly dozen" technologies, or have a contract prepared with an outside consulting firm that specializes in such analyses (the preferred arrangement in such a case would be to have the consulting firm's expert employees work in conjunction with the team's technical experts in performing the TSAs). The process may be expedited if more than one of the "deadly dozen" scenarios shares the same Promethean technology, or if two or more Promethean technologies share components, or if numbers of the components or sub-systems necessary for a Promethean technology have already been developed. Since the emerging Promethean technologies were identified through an environmental scanning process that focused on patent applications, scientific and technical papers, company reports, and open source journalism regarding tech developments, it is unlikely that most or many of the Promethean

technologies requiring Technology Sequence Analysis will be "clean sheet of paper" efforts for which all enabling components must be developed from scratch.

My rough, back-of-the-envelope estimate of the time to complete Technology Sequence Analyses on the "deadly dozen" Promethean technologies, assuming contracting or partnering arrangements are already in place and that all the analyses will be worked concurrently, is eight to ten weeks. The results of the TSAs for each of the "deadly dozen" scenario technologies will be used by the Pandora's Spyglass facilitators as the independent base probabilities, the likelihood of the Promethean technologies reaching market within the next five to ten years. Team members (aside from the technical experts working the TSAs) will not be asked to estimate these base probabilities in this phase, but they will still be required to assign scores to the six probability-limiting/retarding factors, as well as estimate the dollar values for plausible, worst-case scenario consequences (primary, secondary, and tertiary). Fortunately, the results of the Technology Sequence Analyses will not be needed by facilitators until the scenario narratives have been written and the team members have arrived at consensus estimates for the six probability limiting factors and for dollar value of consequences, so the Technology Sequence Analysis step can be carried out concurrently with Step Nine of the previous phase and Steps Two and Three of this phase.

Step Two—Participants Estimate the Severity of Potential Consequences for Each of the "Deadly Dozen" Scenarios: This step is carried out after participants receiving copies of the polished scenario narratives, but it can be performed concurrently with the Technology Sequence Analysis (Step One). Consensus Delphi procedures should be used for this step. Since participants will not be sharing a space (or even a time zone, in all likelihood), facilitators will need to establish a window of time in which participants may electronically submit their first round estimate, and another, later window in which participants may electronically retrieve the group's median estimate, other summary statistics of the group's inputs, rationales from other (anonymous) group members, and a reminder of what their own estimate was, and then submit their second round estimate, either sticking with their original estimate or adjusting it (either way, providing a justification for their decision). All the stipulations that apply to Phase Five, Step Two

apply to this step, except for the earlier step's more strict time limits. Given that the duration of the second distance period is mainly dependent upon the length of the Technology Sequence Analysis (Step One of Phase Seven), facilitators may be generous with the allowable time windows embodied in this step. I recommend giving participants a half-day's window for their first-round submission and another half-day's window for their second-round submission. Facilitators should make the individual participants' "assumptions dictionaries" electronically available to those participants, so the latter may opt to continue adding to them or to refer to their earlier assumptions, in the interest of keeping assumptions consistent across scenarios being judged.

The main difference for participants in this step from the similar Phase Five, Step Two, apart from different time constraints, is that facilitators ask participants to rank their own level of confidence/self-perceived expertise regarding each individual estimate or ranking submitted. Facilitators should instruct participants to use the following ranking scale (participants may either choose to select an integer value or a decimal value between integers or between 0 and 1 on the low end): 1 = Very Low Confidence/No Sense of Expertise Regarding This Question; 2 = Low Confidence/Minimal Sense of Expertise Regarding This Question; 3 = Moderate Confidence/My Level of Expertise Regarding This Question is Probably About Average; 4 = High Confidence/Higher-Than-Average Expertise Regarding This Question; 5 = Very High Confidence/Very Strong Sense of Expertise Regarding This Question.

At this point in the process, facilitators will also calculate Brier scores for the participants' forecasting skills pre-tests, the pre-tests team members took back in Phase Two, Step Two. (The facilitators should have selected forecasting questions for which answers would be actualized by this point in the procedure, so that individual participants' levels of accuracy in forecasting can be compared.) As a reminder, Brier scores are calculated in the following fashion. Events that occur are coded as 1 and events that do not occur are coded as 0; the Brier score is the sum of squared errors between what actually

occurs and the probability forecast.[349] To provide an example, a participant might have, as part of his or her pre-test, predicted a 70% chance that the Best Actor Award at the Oscars would be won by Sterling Silver (and accordingly, the chance an actor other than Sterling Silver would win the Best Actor Oscar was predicted as 30%); however, in a surprising upset, Thomas Tomas walked away with the golden trophy. This participant's Brier score for this question would be calculated as $(0.7–0)^2 + (0.3–1)^2 = 0.833$. The best possible Brier score is 0, representing perfect forecasting ability, and the worst possible score is 2, representing complete failure at forecasting. Had the participant predicted the reverse set of probabilities, that there was only a 30% chance of Sterling Silver winning the Oscar and a 70% chance that a different actor would win, the Brier score would be calculated as $(0.3–0)^2 + (0.7–1)^2 = .18$. Being much closer to 0 (the best possible score), this latter answer would represent a large improvement in the Brier score for that question.

As part of the process for this step and for the following step, facilitators will calculate a Power Score for each participant for each estimate given. The Power Score is simply calculated using this formula:

Power Score = (Self-Assessed Confidence/Expertise Rating) - ((Mean Brier Score from All Pre-Test Questions) x 2.5)

(The Power Score may be a negative number. The lowest possible Power Score is -5 and the highest possible score is 5. If a participant scores the lowest on Self-Assessed Confidence/Expertise, 0, but the highest on Adjusted Mean Brier Score, 0, their Power Score would be 0. If a participant scores the highest on Self-Assessed Confidence/Expertise, 5, but the lowest on Adjusted Mean Brier Score, 5, their Power Score would be 0.) For each set of estimates submitted in the first round of this step and of the following step, facilitators will disregard the inputs from all participants whose Power Score falls below the median Power Score. This means that, in a team of 30 members, 14 members would have their estimates put aside for a rating or estimating question, and the team's median (or mean, for Step 3) consensus figure for both the first and second rounds

[349] Tetlock et al., "Bringing Probability Judgments in Policy Debates Via Forecasting Tournaments," 481.

would be calculated using only the inputs from the remaining 16 members whose Power Scores equal or exceed the median Power Score. Additionally, when facilitators provide team members' rationales that support those members' estimates to the full team at the beginning of the second round of questioning, they should only include those rationales from members whose Power Score equals or exceeds the median Power Score.

This use of a form of calibration of participants, through a combination of forecasting performance calibration and self-evaluation calibration, allows the Pandora's Spyglass procedure to avoid one of the main criticisms that Douglas W. Hubbard (whose book, *The Failure of Risk Management: Why It's Broken and How to Fix It*, I discuss in Section B of Chapter 2) levels against common practices of risk management and threat assessment: that the participating subject matter experts are rarely, if ever, subjected to a calibration process.[350] The reduction in this phase of the "active" participants, those whose responses will be factored into the group's consensus answers, to only those participants whose forecasting performance and self-assessed expertise are at or above the median meets the recommendations set forth by the authors of "The Wisdom of Select Crowds" (per Mannes, Soll, and Larrick, 2014). Yet this reduction is not so great that it shrinks the "active" crowd below what Satopää, Baron, Foster, Mellers, Tetlock, and Ungar consider the "sweet spot" for the wisdom of crowds, several forecasters between 10 and 20, wherein the addition of more participants to the crowd grants the bulk of marginal improvement in forecasting accuracy (per Satopää et al., 2014). One more advantage of this reduction in "active" participants to only those who meet or exceed the median Power Score is the amelioration of what Juri Pill considers one of the chief shortcomings of Delphi procedures, that they tend to "water down" the inputs of the most expert participants by averaging them with the inputs of less expert participants (per Pill, 1971).

Facilitators should not inform participants that those whose Power Scores fall below the group's median will have their inputs discarded in both the first and second rounds. Rather, participants should be told simply that the results of the forecasting pre-test and of participants' self-evaluations of confidence/expertise will be used as weighting

[350] Hubbard, *The Failure of Risk Management*, 178–179.

factors in this step and the following step. My reasons for this recommendation, which runs partially counter to my earlier recommendation that facilitators continuously inform participants of the Pandora's Spyglass methodology as it evolves throughout the process, are two-fold. For participants' self-evaluations of confidence/expertise to be of any value, they must be honest self-evaluations. I fear that participants might be incentivized to "plus-up" their self-evaluations out of a desire to have their input included, if they feel that being honest significantly raises the chances of their input being discarded. My other concern is that when participants honestly rate themselves low on confidence/expertise regarding a question, they will then lose motivation to apply their best effort to the estimation or rating task at hand, assuming that their input will not matter—yet the possibility exists that their Mean Brier Score from the pre-test will be strong enough to offset their low confidence/expertise self-rating and put them at or above the group's median Power Score.

The facilitators calculate the median dollar value of the "active" team's estimates from the second round (those participants whose Power Scores are at or above the group's median Power Score). This median dollar value is the consensus value for this "deadly dozen" scenario. The facilitators share the consensus value with the participants. Then this step's process is repeated for each of the remaining scenarios in turn. Participants and facilitators should be able to complete this step for one "deadly dozen" scenario per work day.

Step Three—Participants Determine Consensus Values for Each of the Six Probability Factors that Influence the Likelihoods of the Come-to-Market Promethean Technologies Being Used for Malign Purposes: This step is carried out after Phase Seven, Step Two but can be performed concurrently with the Technology Sequence Analysis (Phase Seven, Step One). Consensus Delphi procedures should be used for this step. Since participants will not be sharing a space and will very likely be back at their regular jobs or activities, facilitators will need to establish a window of time in which participants may electronically submit their first round estimate, and another, later window in which participants may electronically retrieve the group's mean estimate, other summary statistics of the group's inputs, rationales from other (anonymous) group members, and a reminder of what their own estimate was, and then submit their second round estimate,

either sticking with their original estimate or adjusting it (either way, providing a justification for their decision). All the stipulations that apply to Phase Five, Step Four apply to this step, except for the earlier step's more strict time limits. I recommend giving participants a two-hour window for their first-round submission per limiting factor per scenario and another two-hour window for their second-round submission. All the Power Score procedures described for Phase Seven, Step Two apply to this step, as well (participants are told to self-evaluate themselves on confidence/expertise for their first-round response only for each limiting factor for each scenario, etc.).

The facilitators calculate the mean rating for the probability limiting factor under review from the "active" team's ratings from the second round (those participants whose Power Scores are at or above the group's median Power Score). This mean rating is the consensus value for this probability limiting factor for this "deadly dozen" scenario. The facilitators share the consensus value with the participants. Then this step's process is repeated for each of the remaining probability limiting factors for that scenario, prior to all six probability limiting factors being estimated for each of the remaining scenarios in turn. Participants and facilitators should be able to complete this sub-step for one "deadly dozen" scenario per 24 hours, or three work days per scenario.

Only after team members have performed consensus Delphi procedures for all six probability limiting factors for each of the "deadly dozen" scenarios stub will they then estimate the probability of that scenario becoming actualized. At this point in the process, facilitators will share with participants the base probabilities for each of the scenarios, which are the results of the Technology Sequence Analyses; these provide the best estimates of the likelihood of the Promethean technologies in question coming to market within a five- to ten-year window. Participants should be instructed to use these results of the Technology Sequence Analyses, rather than trying to estimate base probabilities on their own. All the stipulations described for Phase Five, Step Four regarding participants' creating models (or not) of the relative impacts of the probability limiting/retarding factors apply to this sub-step. Stipulations regarding Power Scores also apply. Facilitators should provide participants with a two-hour response window for the first-round submission and a two-hour response window for the second-round submission. As was done in Phase Five,

Step Four, facilitators should provide participants with examples of ways that the six probability limiting factors may be used in conjunction with the independent base probability to estimate a probability of malign use. Additionally, they should provide participants with the group's consensus, amalgamated mean for each of the six probability limiting factors, the participants' own second round scores for each of the six probability limiting factors, and summary statistics for each of the six calculated figures. Participants and facilitators should be able to complete this sub-step for one "deadly dozen" scenario in four hours, or one-half work day per scenario, for a total of six work days for this sub-step.

Step Four—Facilitators Calculate Estimated Risk Levels for Each "Deadly Dozen" Scenario and Rank Them in Descending Order of Risk: Estimated risk levels are all expressed in dollar terms, to allow for easy ranking and comparisons. The formula for risk is:

Risk = (Consensus Estimated Dollar Value of Scenario's Consequences) x (Consensus Estimated Probability of the Scenario Becoming Actualized)

Facilitators share with participants the list of scenarios ranked in descending order of risk, with the risk formula figures provided for each.

Step Five—Facilitators Prepare a Pandora's Spyglass Analytical Report Including Scenario Narratives, in Ranked Order of Descending Estimated Risk, of the "Deadly Dozen" Scenarios: Fortunately for the facilitators, by this point in the process, much of the material they will need to prepare a report for the sponsors of the Pandora's Spyglass analysis has already been written or tabulated. Far from being a "black box" procedure, Pandora's Spyglass is entirely transparent, and the nature of the procedure leads to its participants and facilitators fully documenting their methods and assumptions as the process is unfolding. Any manager who wishes to question from whence outputs came can trace a trail of artifacts that describe which decisions were made by participants and why; the same applies to researchers who wish to refine the procedure or adapt it or elements of it for other purposes.

Facilitators should share copies of their final report with the participants and welcome their feedback. Collecting participants' feedback regarding participants' level of satisfaction with the process and any suggestions for process improvements should not be neglected, since performing Pandora's Spyglass analyses should be an iterative process, not a "one-and-done" event. Ideally, if the sponsoring agency's confidentiality requirements allow for it, facilitators will keep former participants informed of the progress of various R&D projects initiated by the Pandora's Spyglass analysis, perhaps distributing a periodic newsletter highlighting significant project milestones. This will help "close the circle" for participants and give them a sense of satisfaction that their months of hard thinking and hard work have led to concrete actions to "seal the boxes shut" that hold the very worst of the devil's many gestating toys.

Showing appreciation to the participants and doing what can be done to keep them in the loop regarding the results of their shared analysis should not be an afterthought but, rather, should be baked into the process. Not only because it is the considerate thing to do, but also because, with Pandora's Spyglass being an iterative analysis, the facilitators may need to call upon former participants again a couple of years down the line, and the odds of getting them back on-board will rise if those persons can look back upon their earlier experiences with fondness, pride in their shared service, and a sense of accomplishment.

J. POTENTIAL CRITICISMS OF PANDORA'S SPYGLASS

It Takes Too Long for a Prospectively Annual Process: Pandora's Spyglass, in the example followed in this chapter (30 core team members; environmental scanning surfaces 30 emerging, over-the-horizon Promethean technologies with potential for malign use; core team initially brainstorms 180 scenario stubs), takes approximately six months from end to end. The estimated duration of each phase of the procedure, and of each step within each phase, is tabulated in Table 8. The first distance portion takes eight weeks; the face-to-face portion takes three to four weeks; and the second distance portion takes 14 weeks. Participants and facilitators, working together, are engaged for 17 to 18 weeks, and the facilitators work on their own for an additional eight weeks.

Table 8. Approximate Duration of Pandora's Spyglass Analytical Procedure

Phase	Step	Planned Duration	Distance or Face-to-Face Portion?	Sequential or Concurrent?
PHASE ONE: ENVIRONMENTAL SCANNING	One	Two Weeks	1st Distance	Sequential
PHASE TWO: ASSEMBLE THE TEAM	One—Recruit Team Members	Four Weeks	1st Distance	Sequential
	Two—Administer a Forecasting Pre-Test	One Day	1st Distance	Sequential
PHASE THREE: BRAINSTORM SCENARIOS	One—Push Out the Results of Environmental Scanning	One Day	1st Distance	Concurrent with Step Two
	Two—Distribute Questions to Promote Brainstorming	Two Weeks	1st Distance	Concurrent with Steps One and Three
	Three—Train the Science Fiction Writer Members of the Team in Small Group Processes and Optimally Facilitating Small Group Interactions	Half Day	Face-to-Face	Concurrent with Step Two
	Four—Bring the Participants Together for the Face-to-Face Portion of the Analysis and Begin with an Emphasis on Personal Accountability and the Importance of the Mission	Half Day	Face-to-Face	Sequential
	Five—Apply Convergent Thinking to the Scenario Stubs	Half Day	Face-to-Face	Sequential
PHASE FOUR: RED TEAM THE SCENARIO STUBS	One—Introduce the Concept of Red-Teaming to the Full Group and Provide Training on Avoiding Cognitive Biases	Half Day	Face-to-Face	Sequential
	Two—Divide the Full Team into Groups of Four	10 minutes (repeated at the beginning of each work day spent in Phase Four)	Face-to-Face	Sequential (facilitators assist eight teams concurrently)

Phase	Step	Planned Duration	Distance or Face-to-Face Portion?	Sequential or Concurrent?
	Three—Randomly Assign a Scenario Stub to Each Group to Red Team; Assign Each Group a Red Teaming Method to Use	20 minutes (repeated at the beginning of each work day spent in Phase Four)	Face-to-Face	Sequential (facilitators assist eight teams concurrently)
	Four—Red Team Each Scenario Stub, Then Present Results to Entire Team and Allow for Questions	Three to Four Days	Face-to-Face	Sequential
PHASE FIVE: RANK THE SCENARIO STUBS	One—Facilitators Provide Participants with List of Scenario Stubs	Five Minutes	Face-to-Face	Sequential
	Two—Participants Rate Each Scenario Stub Regarding Severity of Potential Consequences	2.5 to 3.75 Days (20–30 hours; 40 minutes per scenario stub; each half-team responsible for 30–45 stubs)	Face-to-Face	Sequential
	Three—Participants Receive Refresher Training in the Laws of Probability and How to Calculate Probabilities	Three Hours	Face-to-Face	Sequential
	Four—Participants Rate Each Scenario Stub Regarding the Likelihood of Its Becoming Actualized	Four to Six Days (rating each stub takes 1.75 hours; each half-team can rate four stubs per work day; each half-team responsible for 30–45 stubs)	Face-to-Face	Sequential
	Five—Facilitators Calculate Estimated Risk Levels for Each Scenario Stub	30 Minutes	Face-to-Face	Sequential
	Six—Finalizing Determination of the "Deadly Dozen" Scenarios	Two Hours	Face-to-Face	Sequential

Phase	Step	Planned Duration	Distance or Face-to-Face Portion?	Sequential or Concurrent?
PHASE SIX: FLESH OUT THE "DEADLY DOZEN" SCENARIOS	One—Divide the Full Team into Scenario Expansion Sub-Teams	10 Minutes	Face-to-Face	Sequential
	Two—Select the Three Key Axes of Driving Environmental Forces Most Significant to Facilitating Malign Uses of the Scenario's Promethean Technology	Two Hours (process takes one hour per scenario; six teams perform this step for two scenarios apiece)	Face-to-Face	Sequential (however, six teams are working concurrently, evaluating two scenarios apiece)
	Three—Apply "Through the Terrorist's Eyes" Exercise to the Scenario	Two Hours (process takes one hour per scenario; six teams perform this step for two scenarios apiece)	Face-to-Face	Sequential (however, six teams are working concurrently, evaluating two scenarios apiece)
	Four—Brainstorm Precursors	Two Hours (process takes one hour per scenario; six teams perform this step for two scenarios apiece)	Face-to-Face	Sequential (however, six teams are working concurrently, evaluating two scenarios apiece)
	Five—Apply Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis to the Scenario	Two Hours (process takes one hour per scenario; six teams perform this step for two scenarios apiece)	Face-to-Face	Sequential (however, six teams are working concurrently, evaluating two scenarios apiece)
	Six—Apply "Measure-Countermeasure, Move-Countermove" Exercise to the Scenario	Two Hours (process takes one hour per scenario; six teams perform this step for two scenarios apiece)	Face-to-Face	Sequential (however, six teams are working concurrently, evaluating two scenarios apiece)
	Seven—Sub-Teams Present Their Scenarios to the Full Group for Feedback and Critique	12 Hours, or 1.5 Days (process takes one hour per scenario)	Face-to-Face	Sequential
	Eight—Sub-Teams Reconvene to Decide Whether to Adjust Their Scenario in Response to the Full Group's Feedback	Two to Three Hours (between an hour and 1.5 hours per scenario, with each sub-team assessing two scenarios)	Face-to-Face	Sequential (however, six teams are working concurrently, evaluating two scenarios apiece)

Phase	Step	Planned Duration	Distance or Face-to-Face Portion?	Sequential or Concurrent?
	Nine—Lead Scenario Writers Prepare 15–20 Page Scenario Narratives with One-Page Executive Summaries	One Week	2nd Distance	Sequential (however, six sub-team leads are working concurrently, writing up two scenarios apiece)
PHASE SEVEN: RANK THE "DEADLY DOZEN" SCENARIOS	One—Apply Technology Sequence Analysis to Estimate the Likelihoods of the Promethean Technologies Reaching Market Within a Five to Ten Year Window	Eight to Ten Weeks	2nd Distance	Concurrent with Phase Six, Step Nine and with Phase Seven, Steps Two and Three
	Two—Participants Estimate the Severity of Potential Consequences for Each of the "Deadly Dozen" Scenarios	12 Days (about 2.5 Weeks)	2nd Distance	Sequential (but concurrent with Phase Seven, Step One)
	Three—Participants Determine Consensus Values for Each of the Six Probability Factors that Influence the Likelihoods of the Come-to-Market Promethean Technologies Being Used for Malign Purposes	42 Days (about 8.5 Weeks)	2nd Distance	Sequential (but concurrent with Phase Seven, Step One)
	Four—Facilitators Calculate Estimated Risk Levels for Each "Deadly Dozen" Scenario and Rank Them in Descending Order of Risk	One Hour	2nd Distance	Sequential

Phase	Step	Planned Duration	Distance or Face-to-Face Portion?	Sequential or Concurrent?
	Five—Facilitators Prepare a Pandora's Spyglass Analytical Report Including Scenario Narratives, in Ranked Order of Descending Risk Estimate, of the "Deadly Dozen" Scenarios	Two Weeks	2nd Distance	Sequential

Duration of 1st Distance Portion			**Eight Weeks, One Day**
		(1st Distance Portion, Facilitators Only)	(Six Weeks)
		(1st Distance Portion, Facilitators and Participants)	(Two Weeks, One Day)
Duration of Face-to-Face Portion			**14.5 to 19 Work Days (Three to Four Weeks)**
Duration of 2nd Distance Portion			**14 Weeks**
		(2nd Distance Portion, Facilitators and Participants)	(12 Weeks)
		(2nd Distance Portion, Facilitators Only)	(2 Weeks)
Duration of Entire Pandora's Spyglass Procedure			**25 Weeks to 26 Weeks**
		(Entire Procedure, Facilitators and Participants)	(17 to 18 Weeks)
		(Entire Procedure, Facilitators Only)	(Eight Weeks)

In defense of the procedure, I must point out that participants' full-time, face-to-face portion of their involvement lasts only three to four weeks, in the middle of the analysis. For the remainder of the 17 to 18 weeks of their involvement, they participate on a part-time basis from their homes or normal work locations, with daily inputs likely to take between 45 minutes and an hour (or less). Not that a four-week commitment of time is inconsequential, for a working professional who presumably already has a full-time job,

but critics of this aspect of Pandora's Spyglass should not look at the entire procedure's six-month timeframe and assume that all the participants will be required to devote all their working hours during this timeframe to the procedure.

One of my assumptions is that the Pandora's Spyglass procedure will be used to support an annual R&D project selection cycle. One possible way to make the procedure's length less onerous for the sponsoring organization would be to schedule Pandora's Spyglass to be performed every two years, rather than every year, with half the "deadly dozen" scenarios having their R&D projects initiated in the first year and the remaining half having their R&D projects initiated in the second year. The length of time required for the second distance portion of the procedure could be squeezed down by a couple of weeks if the time windows for the remote consensus Delphi procedures are halved; however, reducing the time required for the consensus Delphis to less than the time required for the Technology Sequence Analyses would not result in any time savings, so that needs to be kept in mind.

Federal Hiring Processes are Cumbersome and Lengthy, and Agencies Would Face Logistical Difficulties Hiring Short-Term Employees and Consultants: This concern may be assuaged in a couple of different ways. Several different federal agencies, such as the Census Bureau and the Federal Emergency Management Agency (FEMA), have secured authority to hire temporary employees or short-term, emergency surge employees. Or the sponsoring agency could pursue the alternate route of contracting with an outside consulting firm to perform the Pandora's Spyglass analysis, leaving it up to a private firm to acquire temporary facilitators and consultants, with the stipulation that the sponsoring agency have the right to designate some of its internal managers and subject matter experts as participants.

Pandora's Spyglass Lacks Statistical Rigor; Its Variables Have Not Been Validated; No Model is Supplied for the Respective Intensities of How Each of the Probability Limiting Factors Affects the Base Probability in Each Scenario: Observers who would level these criticisms misconstrue the purpose of a Pandora's Spyglass procedure. As described in this chapter, Pandora's Spyglass is not a conventional risk assessment or threat assessment tool, nor is it meant to be used for a cost-benefit analysis

to support a budget request for a R&D project(s). It assumes that a budget has already been allocated for as-yet unselected R&D projects intended to counter future-shock threats in the homeland security arena, and it is intended to guide decision makers in identifying the worst possible plausible threats that emanate from over-the-horizon, emerging Promethean technologies, then guide those decision makers in ranking those plausible threats so that whatever R&D funding that is available can be best allocated. I formulated the Pandora's Spyglass procedure primarily to assist the homeland security R&D enterprise in winnowing down the potentially vast number of scenarios involving emerging Promethean technologies, either used singly or in combination with other emerging or established technologies, to a manageable group of scenarios that represent the worst of the worst, encompassing the direst, severe consequences that may plausibly occur. To abet this goal, I recommend that the Pandora's Spyglass participants stretch their scenarios to the limits of dire plausibility, that in estimating the dollar value of consequences, they disregard the possibilities of attacks being misfires or only partially successful. In terms of the bell-shaped curve of normal distribution of possible outcomes, I ask participants, in estimating consequences, to essentially ignore 95% of the distribution and concentrate upon what might lurk beneath the tapering tail at the right side of the curve, representing the most severe 5% of the distribution.

However, if additional validation steps are taken, the Pandora's Spyglass procedure could be re-purposed to support budget formulations. The first of these validation steps would be for cost estimators to examine each of the consequences listed in each of the "deadly dozen" scenarios—loss of life, costs of medical care, loss of property, loss of productivity, prompt impacts on economic activity, delayed impacts on economic activity, costs of remediation and defensive measures instituted in response to the attack, secondary and tertiary costs stemming from those remediation and defensive measures, etc.—to assign a range of possible values to each cost category, and to then use Monte Carlo simulations to establish a range of potential total costs falling within a 90% confidence level. This differs from the basic Pandora's Spyglass procedure in that the latter directs participants to assume the worst plausible case for all consequences, pushing the total cost

estimate of consequences far out to the right-hand tail of a probability curve of potential costs.

The second essential validation step would be to use back testing to establish a "best fit" model of the relative weightings of the six probability-limiting/retarding factors as they apply to the base probability of the Promethean technology being brought to market within a five- to ten-year window, resulting in the probability of that technology being used for the malign purpose envisioned in a scenario. A reader might ask, "How can somebody use *back testing* to validate a model for a kind of event that has not happened yet?" Douglas W. Hubbard cautions against what he calls the Mount St. Helens Fallacy, the notion that any level of dissimilarity between systems or events makes comparisons between the two systems or events unworkable and without value. He describes the cognitive blind spot of geologists, specialists in the behavior of volcanoes, during the months leading up the catastrophic lateral eruption of Mount St. Helens in May of 1980. These geologists observed the development of a magma bulge on the volcano's north side, a magma bulge that grew increasingly unstable. Such a development had been observed to cause other volcanoes to laterally erupt, or spew a magma stream sideways, rather than out the volcano's top rim. Yet these geologists held to the notion that each volcano was a unique system, subject to local geological conditions, and Mount St. Helens had never been observed to laterally erupt before. Thus, the observing geologists did not consider the possibility of this very dangerous event occurring, even though the increasingly dire evidence that it would occur was staring them in the face.[351]

Thus, even though Pandora's Spyglass is meant to analyze potential future events of an unprecedented nature—catastrophic malign uses of technologies that have not been invented yet—the notional events being imagined and examined are not entirely unprecedented. I venture a suggestion later in this Section that both the 9/11attacks and the Aum Shinrikyo sarin attack on the Tokyo subway system can be considered as rough analogues to a "devil's toy box" attack. If one is willing to venture a bit farther afield and consider more distant analogues, one has a huge number of earlier events with which one

[351] Hubbard, *The Failure of Risk Management*, 180–181.

could back test various models of the Pandora's Spyglass probability limiting factors—successful and unsuccessful terror attacks using conventional technologies and modes of attack. In carrying out a Pandora's Spyglass analysis, participants, in Step Three of Phase Seven, offer their notional models of the relative weightings of the six probability limiting factors. Various databases can be accessed that describe the sequences of events and operational and environmental factors associated with samplings of both successful and unsuccessful terror attacks. A researcher could retroactively apply each of the notional models that emerge from a standard Pandora's Spyglass analysis of the probability limiting factors to a large sample of both successful and unsuccessful terror attacks and in that way determine which of the models best correlates with the success or failure of an attack. Each of the notional models would represent a separate hypothesis, and the researcher would test each hypothesis by applying it, in turn, to actual events and seeing how well the model fits, eventually selecting the model that displays the best fit across the sample of actual events. This would require a great amount of work, but it could be done. Then the validated model of the weightings of the six probability limiting factors could be applied to the base probability of the Promethean technology of interest coming to market within the five- to ten-year window, already calculated through a Technology Sequence Analysis. Finally, the probability of the Promethean technology being used for the malign purpose envisioned in the "deadly dozen" scenario could be multiplied with each of the consequence dollar values estimated through a Monte Carlo procedure to formulate a range of possible risk levels for that scenario. Doing the same for all 12 scenarios would establish a broader possible range of risk levels.

It Spends Money and Resources Seeking to Counter a Bunch of Notional Threats That May Never Materialize: This criticism strikes at the very ground underlying the rationale for any sort of a "devil's toy box" analysis. What is the bang for the buck? In the case of a "devil's toy box" analysis in general or Pandora's Spyglass in specific, the bang for the buck is the *absence of a bang*. How can the absence of something be quantified? It *can*, perhaps not as precisely or with the level of confidence a user would prefer; but more on that in a moment. The fact that this criticism so easily comes to mind indicates why the homeland security enterprise has consistently prioritized its systemic

mission over its counter-future-shock mission, and why the Homeland Security Advanced Research Projects Agency (HSARPA), despite having been founded in 2003 as the Department of Homeland Security's counterpart to the Department of Defense's highly successful DARPA, has devoted most of its resources to low- or moderate-risk, moderate-benefit R&D projects meant to assist in DHS's systemic mission set, not its counter-future-shock mission set (please refer to Appendix A for a thorough discussion of this issue). It is human nature to focus on already actualized issues or pressing problems and threats, to the detriment of expending resources countering longer-term, more distant or uncertain threats, even if the latter are of far higher potential consequence than the former. If a homeowner's roof is leaking and it is raining outside, with more rain projected for the coming week, and the leak is right over the homeowner's bed, that homeowner is going to be a lot more concerned about hiring a contractor to patch the hole in his roof than he is about researching and purchasing a fire insurance policy—even though a leak, by itself, may only cause, at worst, a couple of thousand dollars' worth of damage to the homeowner's property and belongings, whereas a fire could destroy everything he owns, potentially costing him hundreds of thousands of dollars.

Think of Pandora's Spyglass and the R&D projects it facilitates as that fire insurance policy. So how much should the insurance policy cost? How much is the policy worth? One way to estimate its worth is to use analogy, to look at the costs of the primary, secondary, and tertiary impacts and consequences of an attack roughly comparable to one of the envisioned "deadly dozen" scenarios. One such event would be the 9/11terror attacks. These attacks did not make use of any Promethean technologies; rather, the attacker re-purposed existing, tried-and-true technologies and combined them in a new mode of attack, one that linked five-dollar box cutters with fuel-laden jumbo jets to create a new system of highly destructive guided missiles. Setting up this attack cost al Qaeda somewhere less than half a million dollars. The costs to the United States? Primary costs include the loss of about 3,000 lives (valued at about $4 million apiece), the loss of the World Trade Center towers and surrounding properties, the cost of repairs to the Pentagon, the costs of three destroyed jet liners, and the costs of all the fire-fighting and police equipment destroyed when the Twin Towers collapsed. Secondary costs include the health

care costs incurred by all the persons who were injured but not killed in the attacks, including those who suffered delayed health impacts due to inhalation of the toxic dust resulting from the Twin Towers' collapse; the direct costs of the war in Afghanistan; a portion of the direct costs of the war in Iraq (which was justified, in part, by the assertion that, following the 9/11attacks, the United States could no longer tolerate a hostile regime potentially sharing weapons of mass destruction with terror groups); the costs of the large-scale federal government reorganization that created the Department of Homeland Security; the costs of the twelve-year hunt for bin Laden; the costs of armoring cockpit doors on all passenger aircraft; the costs of additional security measures at the Nation's airports; the costs of shutting down all air traffic for several days following the attacks; the costs of the economic recession that followed the attacks; the costs to the travel, tourism, and convention industries of potential customers who opted to avoid air travel following the attacks; and, however, they might be quantified, the psychological and emotional costs of the fear of future terrorism inspired by the attacks. Tertiary costs include the value of the lives of American servicemen and servicewomen lost to the fighting in Afghanistan, along with the value of the lives of Central Intelligence Agency agents, diplomats, and contractors lost; the value of a portion of the lives of Americans lost during the Iraq War and its long aftermath; the decades-long health cost expenditures for those Americans injured in those two conflicts; the reduction, however, quantifiable, in Americans' civil liberties and quality of life (Americans have had to adjust to an overall increase in government surveillance of the population, and the ease and quality of travel by air has been significantly degraded, possibly permanently); the cost of interest payments that have been and will be made for additional government debt incurred because of increased military and homeland security spending attributable to a reaction to the attacks; and the opportunity costs of investments and expenditures not made because they were displaced by increased national spending on homeland security efforts and military campaigns and by increased national debt. (This should not be considered a complete list of costs, by any means.) Add it all up, and the Return on Investment (ROI) al Qaeda saw on its less than half-a-million-dollar investment is staggering—the costs to the United States run into the

trillions of dollars, and if lost opportunity costs are added to the total, perhaps into the tens of trillions of dollars.

A similar tabulation of the costs of the consequences of the Aum Shinrikyo sarin attack on the Tokyo subway system could be performed. That attack, unlike the 9/11attacks, fell far short of its destructive potential, due to the cult's primitive, ineffective delivery system for the sarin, but even so, the attackers managed to kill dozens and sicken or injure thousands, and the secondary and tertiary costs of the attack to the Japanese government and Japanese society far outpaced the primary costs. Yet, due to its partial failure to meet its instigators' goals and its falling well short of its lethal potential, the Aum Shinrikyo attack as it played out, if imagined as one of the Pandora's Spyglass scenario stubs, would be discarded by the participants midway through the process, not surviving the culling to be chosen as one of the "deadly dozen" scenarios.

For the sake of argument, let us say the 9/11attacks and the Aum Shinrikyo subway attack are two rough analogues for the sort of catastrophic attacks using Promethean technologies envisioned by a Pandora's Spyglass analysis. Just two events are not a lot to work with, but the fact that there have been two since the dawn of the modern era of terrorism in the late 1960s allows me to calculate an estimate of an annual chance of occurrence for a "devil's toy box" attack, the sort of attack that falls within the rubric of the homeland security enterprise's counter-future-shock mission. The modern era of terrorism has lasted 50 years thus far. Two "devil's toy box" attacks in a 50–year span equates to a 4% chance of such an occurrence per year. I'll conservatively estimate the cost of such an attack, notionally averaging the consequences of the 9/11attacks and the lower-consequence Aum Shinrikyo attack (Japan did not enter any wars or a recession because of the latter), at $1 trillion. Four percent times $1 trillion equals an annual risk level of $40 billion. Is this the amount that should be spent annually by the homeland security enterprise on counter-future-shock R&D? Or would it be more accurate to narrow the timespan under consideration? Perhaps to the span of time between the present and the earlier of al Qaeda's formation in 1988 and Aum Shinrikyo's turn to terrorism in 1990? Taking this tack would narrow our timespan to 30 years, rather than fifty. In this case, two occurrences of a "devil's toy box" attack in a 30–year span equates to a 6.7% chance of such an occurrence per year.

One trillion dollars times 6.7% equals an annual risk level of $67 billion. Is *this* the amount that should be spent annually by the homeland security enterprise on counter-future-shock R&D efforts? (For point of comparison, as will be seen in Appendix A, the average allocation annually budgeted for the entirety of the DHS Science and Technology Directorate's R&D efforts during the half-decade from FY2010 to FY2014 was $445 million, or about 1.1% of the lower of the two annual risk levels calculated above—and only a small portion of that funding was devoted to what could be characterized as counter-future-shock R&D expenditures.) Alternatively, budget formulators could perform a series of sensitivity analyses, asking themselves how much they would be willing to spend on an annual basis to avert an attack having combined consequences valued at $1 trillion (or $2 trillion, or some other amount, up to the full tabulation of primary, secondary, and tertiary costs associated with the 9/11attacks) with a range of annual likelihoods of occurrence (perhaps ranging from .5% likelihood per year to 10% likelihood per year).

Another method for estimating the value of a "devil's toy box" insurance policy—what should be spent annually to ensure "the absence of the bang"—would be to perform a detailed cost analysis of the consequences set forth in each of the "deadly dozen" scenarios, average the results of the dollar totals for each of the scenarios, and then apply one of the annual likelihood of occurrence figures formulated above, such as 4% or 6.7%. The most rigorous method of estimating the value of our notional insurance policy would be to apply the validation procedures I describe in my response to the third criticism of Pandora's Spyglass listed above, and only then use the Pandora's Spyglass outputs to support budget formulation efforts.

A final response to the criticism that a "devil's toy box" analysis and subsequent R&D efforts waste money and resources in attempting to counter threats that are notional and may never materialize is what I would call the DARPA comeback. The most famous and consequential DARPA project to date, the invention of ARPANet, the ancestor of today's Internet, was initiated, depending on which version of the tale you believe, either to create a resilient communications network that could not be knocked out by a limited nuclear strike or to create a reliable, durable system for the exchange of academic materials between research centers (or both, perhaps). ARPANet and its descendants have, indeed,

been used to reliably transmit academic materials between research centers; however, they have never had to be used to maintain military and government communications in the event of a nuclear strike (and thank the good Lord this notional capability of ARPANet has never been tested under real-world operational conditions). Does this mean DARPA's and the Nation's investment in ARPANet was a waste of money and resources? Well, before you jump to conclusions, kindly recall that little matter of ARPANet's unforeseen positive spinoff effect—the transformation of America's and much of the world's economies, the creation of new industries, many trillions of dollars in economic activity, new modes of working, recreating, and interacting, and an acceleration of technological progress such as humanity had never previously experienced. Not a bad spinoff effect, that.

Ah, you might say, but the impact of ARPANet was an incredibly lucky fluke, a one-in-a-million freak occurrence; it is delusional to expect any pie-in-the-sky R&D project with roots in a Pandora's Spyglass analysis to have anywhere even a minute fraction of the unintended positive impact that ARPANet has garnered. To this I would have to say, do not be so quick to completely dismiss this possibility. Nicholas Dew, working for the DARPA Adaptive Execution Office, performed research in 2011 to analyze the outcomes of 113 DARPA-sponsored R&D projects. Twelve of these resulted in systems or products that were deployed to components of the U.S. military. Another 20 succeeded in transitioning major elements into Programs of Record, (i.e.,) the originally envisioned system or product was not deployed to warfighters, but significant elements or components found their way into systems or products that did end up in service members' hands. Of the remaining projects, 47 resulted in no further development, deployments, or integration with other systems. These proved to be dead ends, essentially; high-risk, high-benefit projects that resulted in no benefits (that's why they're high-risk); however, 34 of the no-direct-benefit-to-the-military projects resulted in productive transitions to civilian technology initiatives.[352] In other words, just over 30% of the DARPA projects considered

[352] Nicholas Dew, "Technology transfer metrics at DARPA" (classroom lecture, Strategic Planning and Budgeting for Homeland Security, Center for Homeland Defense and Security, Monterey, CA, June 14, 2017).

in this study did *not* benefit the military by providing useful fresh capabilities (their intended purpose), but still enjoyed positive spinoff effects in the civilian realm. Considering the high-risk, highly speculative and cutting-edge nature of DARPA's sponsored projects, this must be considered a pretty darned good batting average for unintended positive spinoff effects.

(Given the not-insignificant likelihood that the R&D projects initiated by Pandora's Spyglass will have unforeseen, positive spinoff effects in the civilian economy, our notional fire insurance policy can be seen to have one attractive feature of a whole life insurance policy. The policy's owner gets to "have his cake and eat it, too"—he gets the risk protection benefit of the policy, which he hopes he will never need to use, along with some investment income, as well.)

The issue of DARPA projects resulting in unintended positive spinoff effects for the civilian economy aside, the highest goal of the U.S. military is that it never need use its impressive arsenal of weaponry for war-fighting purposes, because the existence of that arsenal has deterred the aggressive actions of would-be assailants. In my view, the goal of the homeland security enterprise regarding its notional arsenal of shields designed to counter future-shock attacks should be the same.

K. CONCLUSION—BUY THAT FIRE INSURANCE POLICY!

The pace of technological development and change is accelerating. Current and near-term developments in nanotechnology, materials science, and machine learning and artificial intelligence promise to bring the impact of Moore's Law to realms of technology far beyond computer chip manufacturing, paving the way for exponential growth in humanity's abilities to create—and destroy. Emerging Promethean technologies promise to deliver to average persons, of average financial means and average skills, capabilities which until the present time have been relegated only to national governments, well-funded military establishments, and research laboratories employing hundreds of highly skilled scientists and technicians. Prometheus's most significant gift to humanity, the gift of fire, has always offered both life-enhancing capabilities—providing recipients with the ability to cook food, heat homes in wintertime, shape bronze, iron, and other metals, and catalyze

chemical reactions that enable the creation of life-saving medicines—and life-extinguishing capabilities… such as the potential to lay waste to entire cities in a single afternoon.

The history of technology reflects this dual nature of Prometheus's gift. The requirements of warfare have always driven technological development, from the time of the earliest bronze swords and shields and the invention of the chariot to the present day. Yet until very recently, the keys to the devil's toy box have been exclusively in the hands of governments. Governments have interests, territory, wealth, and assets to protect. Competing governments have always had the ability to hold each other's interests, territories, wealth, and assets hostage to destruction or confiscation through use of force, and thus often deter one another from acts of aggression, although miscalculations result in wars. The big change we are faced with at present is the emerging ability of individuals or small groups to wield destructive powers equivalent to those formerly exercised only by governments. These individuals and small groups are not bound by concerns for territory or assets, as governments are. They typically have no distinctive territory that can be surveilled by electronic or human means, to detect the development of new capabilities of destruction. They are not the size of war elephants, crowned with gaudy armor and platforms for archers; they are the size of microbes, and like virulent bacteria or viruses, they can hide virtually anywhere, while still preparing to strike.

Pandora's Spyglass is a tool to assist the homeland security enterprise in "thinking about the unthinkable" (to name-check the title of futurist Herman Kahn's somewhat infamous 1962 book that applied game theory to the notion of fighting and winning a nuclear war). It seeks to effectively harness and consolidate expert opinion for the task of identifying and ranking the worst-case plausible malign uses of emerging Promethean technologies, so that the homeland security enterprise can prepare itself and the Nation for the worst notional threats that may actualize five to ten years down the road. It does so by adapting best practices from the full range of forecasting techniques that have been developed since the end of World War II. It is not meant to justify budget formulation, not in its basic form. But if key elements and variables of the procedure are validated through

processes I have described, Pandora's Spyglass can be adapted to the purpose of justifying budget requests, if desired.

The devil is hard at work on his marvelous, terrifying toys. The shield-makers must work just as hard, if not harder, and certainly *smarter*. The devil holds the initiative; the shield-makers cannot forge shields to protect against the nearly infinite variety of terrible toys that could potentially spring forth from the devil's toy box. Yet by making use of Pandora's Spyglass, the shield-makers can peer inside the devil's toy box and through the walls of the multitude of smaller boxes sitting within, to catch glimpses—foggy, unclear, flickering glimpses, to be sure—of the toys gestating inside those interior boxes. Then the shield-makers can apply their powers of judgment and discernment to deciding which of those interior boxes most need to be sealed shut, which ones contain the most awful, most destructive toys, the worst of the worst. Or, if those most baneful boxes cannot be sealed shut in time, the shield-makers at least will not be cripplingly surprised by the terrible toys that emerge, for they will have had time to forge the appropriate shields with which to protect the innocent.

APPENDIX A. IS HSARPA THE MOST APPROPRIATE FEDERAL AGENCY TO SPEARHEAD THE COUNTER-FUTURE SHOCK MISSION?

A. BUREAUCRACY AS A HINDRANCE TO THE COUNTER-FUTURE SHOCK MISSION

Rodrigo Nieto-Gómez, in analyzing the differences between the homeland security enterprise's systemic mission and its counter-future-shock mission, states that the enterprise handles the former with aplomb. The nature of the bureaucratic form of organizational design, he asserts, partially accounts for this. Bureaucracy is a system evolved to apply standardized policies and procedures to deal with known, incremental threats; "(b)ureaucracies are good organizations for managing iterative processes that are subject to continuous improvement loops and must be executed every time in the same way … (t)hey are the best solution to the problem of maintaining the same level of quality in a repetitive process."[353] However, these very qualities of homeland security bureaucracies tend to make them *ineffective* in meeting their future-shock mission. Nieto-Gómez explains that "disruptive and unpredictable threats posed by the recombining nature of new technologies cannot be confronted by incremental methodologies. They are outside of the feedback loop … the bureaucracy might get as good as it can possibly be and still miss the next threat precisely because it has learned to be very efficient in its normal operation, thus resisting any change outside its sustaining processes."[354]

Other observers have also focused on the ways in which traditional bureaucratic organization structures and allegiance to powerful constituencies hinder the homeland security apparatus's achievement of its future-shock mission. Christopher Bellavita notes that in the U.S., the homeland security enterprise's most politically powerful internal constituency is the Nation's first responders' community, which lobbies for funding for response equipment essential for the systemic mission. Contrarily, the role of prevention lacks a similarly influential political and economic constituency. He then identifies three

[353] Nieto-Gómez, "'Power of 'the Few,'" 11.

[354] Ibid., 13.

additional factors that hamper homeland security institutions' provision of effective threat prevention services. The first of these is the fear of new behavior. He contrasts public safety leadership's familiarity and comfort with response behaviors and with their lack of familiarity and lack of confidence regarding prevention activities, prevention activities focused on terrorism, which he states is a new role for public safety agencies, thrust upon them in the wake of the 9/11 attacks. The second factor is the fear of imagination. He suggests as an example the creation of the Department of Homeland Security, an amalgamation of 22 existing agencies with little or no redefinition or coordination of their traditional mission sets. A further example is the political establishment's ill-conceived rejection of the Defense Advanced Research Project Agency's Policy Analysis Market initiative, an effort to utilize a prediction market to forecast political developments in the Middle East that could have strategic implications for the defense and homeland security of the United States. The third factor he cites is the fear of emergence, which Bellavita defines as reluctance on the part of centralized federal homeland security authorities to let go of total control of policy and procedures and allow fresh thinking to emerge from the bottom up, from law enforcement partners at the state, local and tribal levels.[355]

Coming from a non-homeland security-centric perspective, Helle Vibeke Carstensen and Christian Bason, in their review of the history of Denmark's MindLab, a government-sponsored innovation incubator, identify factors that make the task of innovation difficult for traditional governmental bureaucracies. They point out that much research has determined that public sector agencies tend to be more focused on improvements to their internal policies and procedures than they are on supplying innovative new services and improved outcomes to the public. The regulation of processes and standard operating procedures that are characteristic of governmental bureaucracies tend to lessen the potential for innovation and creativity. They point to the prevalence of organizational siloes within public bureaucracies, which lead to a reluctance to share information and expertise between different organizational units. Other limiting factors include a lack of formal procedures within governmental bodies for conducting the process

[355] Bellavita, "What is Preventing Homeland Security?"

of innovation, a heavy reliance upon linear project processes, and a lack of effective performance evaluation procedures, most of which focus upon the faults found within past performance and few of which focus on how improvements can be made for future endeavors. Finally, the authors point out that governmental bureaucracies' improvement procedures are almost entirely focused upon verification efforts (are we doing things right?) rather than validation efforts (are we doing the right things?).[356]

To summarize, observers have noted that public bureaucracies are often ill-suited to either engage in innovation or to counter malign innovations because (1) bureaucracies are designed to control and standardize processes, a mindset and mission set that works against the exercise of creativity; (2) to optimize their functioning, bureaucracies engage in incremental, linear continuous improvement processes that are not conducive to innovation; (3) bureaucracies tend to focus on "doing things right" at the expense of "doing the right things;" and (4) political environments within public bureaucracies tend to disincentivize sharing of information and innovative processes between siloed operational units. Additional factors that apply to public bureaucracies within the homeland security enterprise include: (5) a political and economic environment that favors the provision of equipment and services to the first responders community, rather than equipment and services intended to support prevention efforts; (6) homeland security leadership is more familiar and comfortable with response activities rather than prevention activities; and (7) federal homeland security agencies are reluctant to relinquish control and incorporate innovative ideas from law enforcement and security partners at the state, local, and tribal levels.

The following observations regarding the origin, development, internal processes, and political criticisms of the Homeland Security Advanced Research Projects Agency, HSARPA, should be viewed with these observations regarding the strengths and limitations of traditional bureaucracy in mind. It seems to me that many of the difficulties, certainly the internal difficulties, that HSARPA has encountered in its attempts to accommodate the homeland security enterprise's counter-future-shock mission are likely

[356] Vibeke Carstensen and Bason, "Powering Collaborative Policy Innovation," 3–5.

attributable to the agency's inability to break out of the traditional government bureaucracy mold, in contrast to the Defense Advanced Research Projects Agency's (DARPA's) marked success, due to deliberate design, in escaping the tentacles of traditional bureaucratic structures.

B. INTRODUCTION TO HSARPA

On the surface, HSARPA is ideally positioned to address the homeland security counter-future-shock mission. Its founding rationale, set forth in the months following the 9/11 surprise attacks, was to foster high-risk, high-benefit projects of potential revolutionary impact in meeting rapidly evolving threats to homeland security. It was placed within the Science and Technology (S&T) Directorate, which itself was a freshly-created, key element of the newly organized Department of Homeland Security, organizationally close to the Secretary. HSARPA was deliberately modeled after DARPA, the Federal Government's most illustrious and successful technology incubator, origin of such transformative technologies as the Internet and military stealth applications, and it was allotted many of the same acquisition and organizational partnership freedoms and flexibilities that have benefited DARPA's efforts.

Yet, to date, HSARPA has seemingly fallen short of the vision its Congressional parents had for it. The following sections explore the likely reasons for this. They include frequently shifting organizational roles within the S&T Directorate, as well as uncodified and inconsistent procedures for identifying, selecting, and prioritizing R&D projects. A history of Congressional criticism, micromanagement, and budget cuts has certainly been a factor in HSARPA's flailings; these Congressional interventions, rather than getting HSARPA back on course, have likely contributed to a counterproductive internal culture of risk avoidance and quick, easily identifiable payoffs (the exact opposite of the culture required by an agency whose founding rationale was revolutionary change). Finally, the S&T Directorate, rather than emphasizing that HSARPA's crucial mission is to facilitate DHS's counter-future-shock efforts, has assigned to HSARPA over the years a portfolio of R&D projects predominately consisting of incremental improvements to existing technologies that address current, rather than future, homeland security needs. In other

words (per Nieto-Gómez's "The Power of 'the Few'"), HSARPA has been directed to support the systemic mission, rather than the counter-future-shock mission.

C. HSPARPA'S HISTORY OF CHANGING PROCEDURES FOR IDENTIFYING, SELECTING, AND PRIORITIZING R&D PROJECTS

HSARPA was one of the brand-new organizational units created by the 2003 Homeland Security Act (many of the constituent elements of the new Department of Homeland Security were pre-existing agencies amalgamated from other parts of the federal government). As originally constituted, HSARPA's primary role was to manage the Acceleration Fund for Research and Development of Homeland Security Technologies. The George W. Bush administration requested $350 million for the Acceleration fund for FY2004; this represented nearly half the $803 million requested in FY2004 for the entire S&T Directorate. HSARPA's concept of operations, that of awarding merit-reviewed grants, contracts, or cooperative agreements with outside R&D organizations (to include private companies, university research centers, and federally funded laboratories), was modeled after that of the illustrious DARPA.[357] Daniel Morgan, performing an analysis for the Congressional Research Service (CRS) in June 2003, noted that the Homeland Security Act assigned the Director of HSARPA responsibilities for DHS's basic and applied research, test and evaluation (T&E), and both accelerated prototyping and field deployment, yet did not provide guidance regarding the proper balance between these functions. Morgan expressed concern that the Department's immediate operational needs would drive HSARPA's R&D efforts at the expense of necessary, but less immediately relevant basic research.[358] As subsequent events have borne out, Morgan's trepidations were more prescient than not.

Shortly after the establishment of the S&T Directorate, HSARPA's first Deputy Director, Jane Alexander, prepared a PowerPoint presentation for public release entitled

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[357] Daniel Morgan, *Research and Development in the Department of Homeland Security*, CRS Report No. RL31941 (Washington, DC: Congressional Research Service, June 20, 2003), 2-10, http://research.policyarchive.org/1741.pdf.

[358] Ibid., 17.

"HSARPA—How We Intend to Do Business." It described for the commercial and university-based R&D community the new agency's solicitations and proposals process. At a high level, it described the work flow of the agency's program managers as "Planning => Solicitation => Contract => Execution." Alexander listed the following among her anticipated drivers for identification of projects for solicitation and for subsequent selection of proposals for funding. These drivers included fundability; overall risk; the maturity of the proposed technology; the anticipated time before fielding; the technology's concept of operations (CONOPS); whether the technology was proprietary in nature; and how the proposed technology related to similar technologies either deployed by or under development by the Departments of Defense and Energy. Alexander listed several flexible acquisition instruments that HSARPA could choose to utilize, including standard government contracts, cooperative agreements, grants, and Other Transaction Authority (OTA). Contracts could be solely sourced, limited, or fully competitive. Engagement with the vendor community could take the form of pre-solicitation discussions, unsolicited white papers, Statements of Work for Comment, Requests for Proposals, or Broad Agency Announcements (BAAs).[359] Interestingly, this early outreach document makes no mention of any intentions on HSARPA's part to align their technology acquisition and development work with the operational needs of the Department of Homeland Security, or to help the department to meet future threats and challenges. Project selection criteria appear to have been based more upon project feasibility than alignment with the DHS mission. This either may be explained by the presentation's focus on purely acquisition-related issues, or it may reflect HSARPA's possible initial emphasis, which was more "blue sky," "let's throw it against the wall and see what sticks," and less focused on a mission-support role than the agency's later emphasis.

A DHS Inspector General's report on the S&T Directorate, published in August 2008, described the Directorate's processes for selecting and prioritizing its R&D projects. Prior to Admiral Jay Cohen's appointment as the Directorate's Under Secretary in 2006, the Directorate's Plans, Programs, and Budgets office was solely responsible for

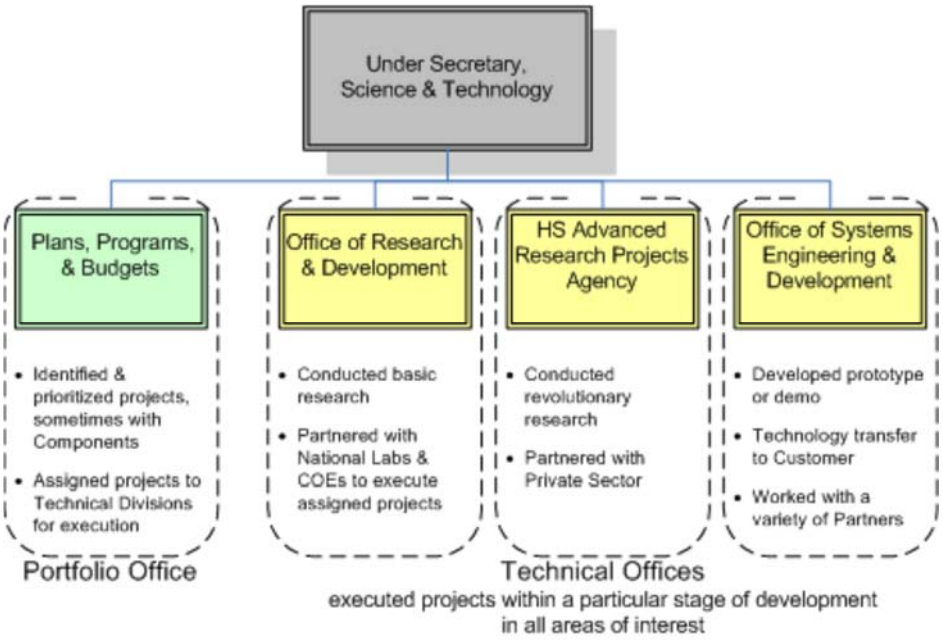
[359] Jane Alexander, *HSARPA – How We Intend to Do Business* (Washington, DC: DHS Science and Technology Directorate, November 17, 2003), accessed on the DHS Intranet.

identifying, selecting, and assigning funding for R&D projects. That office then assigned projects to one of three executing organizational elements, among them HSARPA. The office's decisions regarding which of the three organizational elements to assign various projects were determined, not by the nature of the projects themselves, but rather by the type of partner organization that would conduct the R&D activities. These were either university Centers of Excellence, private companies, national laboratories, or federally funded research and development centers (FFRDCs). Since the Homeland Security Act had tasked HSARPA with initiating and managing R&D projects that were revolutionary in scope and potential, and had also stipulated that HSARPA pursue contracting arrangements with both public and private entities, the Plans, Programs, and Budgets office assigned the management of *all* projects intended for private firms to HSARPA, whether or not the projects could be considered "revolutionary" in scope and potential impact.[360] This rather confused state of affairs may represent the point of origin of what I would term HSARPA's on-going "identity crisis," as an agency with *Advanced Research* in its name, but which oversees projects that are oftentimes merely incremental in scope, representing valuable but limited advances in existing homeland security-related technology. This mission-altering decision was made with bureaucratic needs in mind, not out of consideration for what should have been HSARPA's unique mission within DHS.

The Inspector General's report included the following diagram that represents the S&T Directorate's structure prior to its reworking by Under Secretary Cohen in 2006:

[360] Department of Homeland Security, *The Science and Technology Directorate's Processes*, 3.

Figure 2. Original Structure of the DHS Science and Technology Directorate[361]



The PP&B office utilized an Integrated Product Team (IPT) to generate ideas for R&D projects, which the leadership of the PP&B office then prioritized. Membership in this Integrated Product Team was limited to PP&B staff and the heads of the three technical offices, with no representation from any of DHS's operational components, a fact singled out for criticism by the Inspector General's report. Following the PP&B office's prioritization of projects, an S&T Directorate Internal Review Board then selected which projects would be green-lighted and would receive funding.[362]

Under Secretary Cohen attempted to better align the S&T Directorate's R&D portfolio with DHS's operational priorities by creating six technical divisions in his 2006 reorganization of the Directorate, with each division focusing on a different priority of the homeland security enterprise. These technical divisions included Borders and Maritime Security; Chemical/Biological; Command, Control, and Interoperability; Explosives;

361 Ibid., 5.

362 Ibid., 13-14.

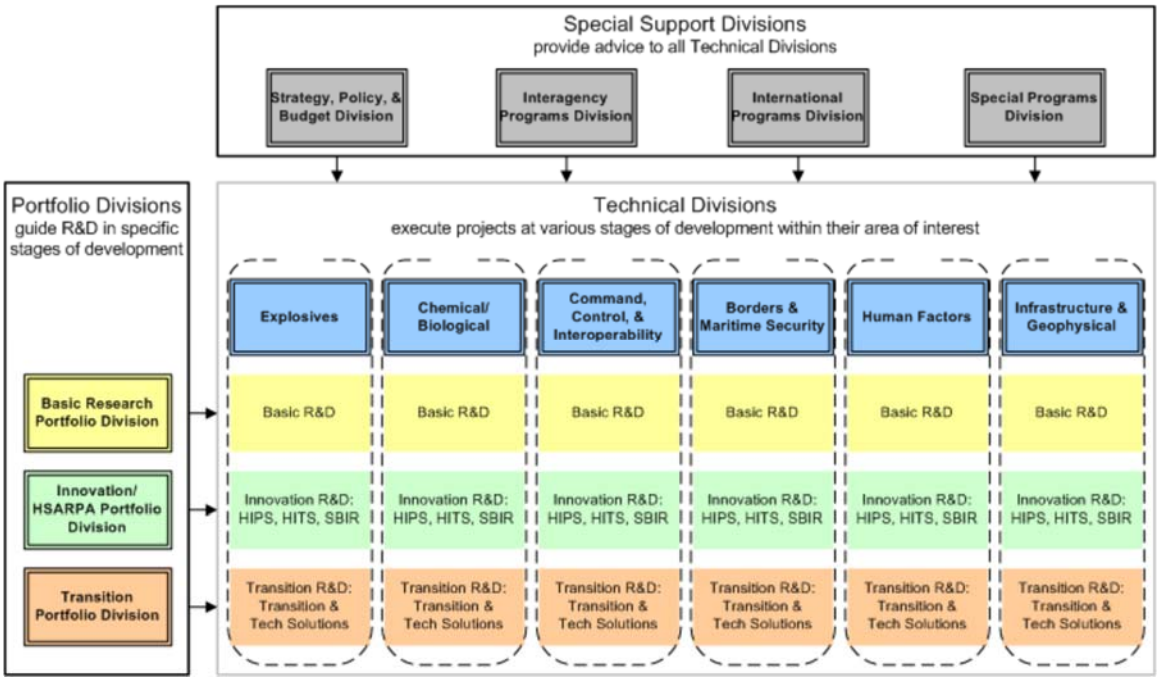
Human Factors; and Infrastructure and Geophysical.[363] Under the new structure, HSARPA became one of three portfolio divisions that provided programmatic direction to R&D projects being executed by the various technical divisions. HSARPA was assigned programmatic responsibility for what was called the innovation portfolio. This portfolio encompassed Homeland Innovative Prototypical Solutions (HIPS), these being projects with a moderate to high risk of failure that were expected to deliver significant new capabilities in prototype form within two to five years; High Impact Technology Solutions (HITS), defined as projects with a high risk of failure but very significant potential benefit that were planned to deliver a proof of concept demonstration within a one to three year envelope; and the Small Business Technology Transfer (STTR) and Small Business Innovative Research (SBIR) programs.[364] Once more, HSARPA's counter-future-shock mission was being diluted by R&D projects devoted to the systemic mission. Only the High Impact Technology Solutions projects could be described as counter-future-shock in nature; the Homeland Innovative Prototypical Solutions projects were intended to deliver incremental technological improvements for systemic mission tasks, and the Small Business projects were defined by the nature of the contractor and associated socio-economic acquisition goals, not the nature of the project.

These various categories of HSARPA projects could fall within any of the six technical divisions, as can be seen in the following chart representing the revised S&T Directorate organizational structure:

[363] Ibid., 7.

[364] Ibid., 8.

Figure 3. Revised DHS Science and Technology Directorate Structure[365]



Although the Inspector General's report tended to regard the revised organizational structure as an improvement to what had preceded it, it did not exempt the S&T Directorate and HSARPA from criticism, some of which was specific to the Directorate's and HSARPA's processes (or lack thereof) for selecting and prioritizing projects. The report singled out projects falling within the basic research portfolio, as well as Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects, for suffering from a lack of standardized, consistent procedures for identifying and prioritizing their R&D efforts. The Integrated Project Teams that suggested projects failed to consistently solicit input from DHS's operational components, and this failure to include potential future field users in the selection process often resulted in a lack of buy-in from the field when the S&T Directorate eventually attempted to transition their products to end users. Of interest, some interviewed staffers expressed the opinion that numerous projects had been selected and funded due to their being of interest to one of the National research

365 Ibid., 7.

laboratories, rather than their potential usefulness to DHS and the overall homeland security enterprise.[366] The IG report noted the deluge of unsolicited project proposals the S&T Directorate received from the private sector, which had prompted the establishment of an Office of Concepts and Ideas, under the purview of the Transition portfolio. The report offered praise for the Transition portfolio's procedures for selecting and prioritizing projects, which it noted were clear, objective, and consistent; however, the report criticized this aspect of the Innovation portfolio's management, stating that its project selection was the sole responsibility of the Under Secretary, who had failed to establish a consistent, repeatable procedure.[367]

As of FY2007, the selection of Basic Research projects was based upon the following set of steps. First, R&D ideas were generated by the university Centers of Excellence, the National research laboratories, private sector companies, the technical divisions' Integrated Project Teams, DHS components, and interagency working groups. The resulting ideas were then prioritized and assigned funding by the Technical Division's Section Chief and Division Director. For Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects, R&D ideas were generated by academia, private companies, DHS senior leadership, the heads of DHS component agencies, the Innovation Division Director, and the Under Secretary for S&T. The latter was then solely responsible for prioritizing and assigning funding to projects.[368]

The selection process for Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects was altered because of the recommendations of the 2008 Inspector General's report. In his response to the report, Under Secretary Cohen noted that in the months following the Inspector General's staff's interviews with S&T Directorate staff, he had established a formal process for identification and prioritization of Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects. Under the new, formal process, the Director of Innovation/HSARPA would solicit

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[366] Ibid., 13-14.

[367] Ibid., 18-19.

[368] Ibid., 27-28.

suggestions from the academic, homeland security, and private industry communities, then make a report to the S&T Corporate Board on proposals received. The Board would have an opportunity to make additions to the list of proposed projects, after which the Director of Innovation would brief the Under Secretary and Deputy Under Secretary for S&T, and the former would propose projects to the DHS Technology Oversight Group (TOG). This Oversight Group's voting members included the DHS Deputy Secretary, the Under Secretary for Management, and the Under Secretary of the DHS National Protection and Programs Directorate (NPPD); its advisory, non-voting members included the S&T Under Secretary, the DHS Chief Financial Officer, and the heads of the DHS operational components.[369]

In his March 26, 2009 testimony before the House Committee on Appropriations, Subcommittee on Homeland Security, Acting S&T Under Secretary Bradley Buswell reported that the Homeland Innovative Prototypical Solutions/High Impact Technology Solutions project identification and selection process outlined above had continued, with a significant addition, the advisory involvement of thirteen Capstone Integrated Project Teams. These teams' duties included soliciting information and project suggestions from DHS operational components, homeland security end users/practitioners, and private industry partners. The thirteen Capstone Integrated Project Teams were divided by homeland security functional areas. These included Biological/Agricultural Defense, Border Security, Cargo Security, Chemical Defense, Counter Improvised Explosive Devices (IED), Cyber Security, First Responder Support, Incident Management, Infrastructure Protection, Maritime Security, People Screening, and Transportation Security.[370]

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[369] Ibid., 41-42.

[370] Department of Homeland Security, DHS: Testimony of Acting Under Secretary Bradley I. Buswell, Science and Technology Directorate, before the House Committee on Appropriations, Subcommittee on Homeland Security, "Science and Technology Research and Transitioning Products" (Washington, DC: Department of Homeland Security Documents, Federal Information & News Dispatch, Inc., March 26, 2009).

Reorganizations continued at the S&T Directorate and HSARPA. A 2010 reorganization sorted the S&T components into four divisions: the Homeland Security Advanced Research Projects Agency (HSARPA), encompassing six technical divisions, along with the Special Projects Office for classified R&D projects; the Support to the Homeland Security Enterprise and First Responders Group, having responsibility for transfers of technologies to first responders and ensuring compatibility and interoperability; the Acquisition Support and Operational Analysis Division, responsible for oversight of the requirements generation process, as well as establishing test and evaluation policy; and the Research and Development Partnerships Division, which interfaced with the S&T Directorate's external partners in the federal government and academia.[371] As of FY2014, HSARPA's six technical divisions had been reduced to five: the Borders and Maritime Security Division (BMD), the Chemical and Biological Defense Division (CBD), and the Explosives Division (EXD), which were all carry-overs from the FY2007 organization chart; the Resilient Systems Division (RSD), which appears to have replaced the old Infrastructure and Geophysical technical division; and the new Cyber Security Division.[372]

This division of the entirety of the S&T Directorate's portfolio between HSARPA and the Support to the Homeland Security Enterprise and First Responders Group represented a significant change for HSARPA—an expansion of the latter's scope of responsibilities and a dilution of its founding mandate. Under the FY2007 reorganization instituted by then Under Secretary Cohen, although HSARPA's management and advisory responsibilities extended throughout all six of the technical divisions, those responsibilities were limited only to those sorts of projects that could be construed as meeting HSARPA's "revolutionary, game-changing" mandate from Congress—the Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects (along with projects associated with the two small business technology and research programs). Even this

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[371] Shea, *The DHS S&T Directorate: Selected Issues for Congress*, 3.

[372] Department of Homeland Security, *Science and Technology Directorate Review 2014* (Washington, DC: U.S. Department of Homeland Security Science and Technology Directorate, 2014), 89, accessed on the DHS Intranet.

connection to the "revolutionary, game-changing" mandate was somewhat tenuous, given the inclusion of the systemic mission-supporting Homeland Innovative Prototypical Solutions projects. All other projects were overseen by either the Basic Research Portfolio Division or the Transition Portfolio Division; however, within the more recent organizational structure, any project that does not directly benefit the first responders' community lands within HSARPA's wheel house. In an upcoming section, I will show that only a small minority (26%) of the 92 projects falling under HSARPA's umbrella as of FY2014 could be characterized as supporting a homeland security counter-future-shock mission, and only four projects were both novel in conception and technically challenging, the sort of projects that would be expected to make up the majority of an "Advanced Research" R&D organization. If anything, it appears that between FY2007 and FY2014, HSARPA moved farther away from its Congressionally mandated mission of fostering innovative, revolutionary technology to meet and deter rapidly evolving threats to homeland security.

As of FY2014, the S&T Directorate organized a process to identify its Visionary Goals that would drive its 2015–2019 Strategic Plan. This process consisted of (a) internal brainstorming sessions involving S&T staff; (b) an online crowdsourcing portal to solicit and ingest ideas from outside the Directorate; and (c) a cross-referencing of the identified ideas against DHS's policy doctrines and mission priorities.[373] The online crowdsourcing portal was used by 1,298 respondents from the homeland security operational community, the homeland security industrial base, academia, and the public, who collectively posted a total of 138 ideas and 308 comments.[374] The resulting Visionary Goals included:

- Screening at Speed: Security that Matches the Pace of Life
- A Trusted Cyber Future: Protecting Privacy, Commerce, and Community

[373] Science and Technology Directorate, *Strategic Plan 2015–2019* (Washington, DC: Department of Homeland Security, April 2015), 12, accessed on the DHS Intranet.

[374] Ibid., 15.

- Enable the Decision Maker: Actionable Information at the Speed of Thought
- Responder of the Future: Protected, Connected, and Fully Aware
- Resilient Communities: Disaster-proofing Society[375]

How truly "visionary" these goals are may be judged by the reader, but to this observer, they seem to all focus heavily upon the homeland security systemic mission—its response to known threats or habitual risks—rather than upon the counter-future-shock mission. This may be explained by the "visioneering" process itself, which relied heavily upon the homeland security enterprise's insiders: governmental and industry professionals who are primarily incentivized to respond to current or near-term operational needs. Also, it appears that DHS has attempted to combine under a single umbrella two different types of R&D organizations, those focused on the systemic mission and those focused on the "blue sky," counter-future-shock mission, in contrast with the Department of Defense, which separates them. Under the Department of Defense structure, each service has its own dedicated R&D component to service the needs of that component's systemic mission, but DARPA, which serves the counter-future-shock mission, stands apart from all these. DHS may have opted to pursue a contrary path due to budgetary restrictions; the total R&D budgetary pie Congress has chosen to grant to DHS is a tiny fraction of that assigned to the Department of Defense, and DHS may have decided to put all its R&D "eggs" into one basket to avoid slicing a small pie into pieces too thin to be viable on their own. It may have done so due to bureaucratic self-interest and the tendency toward "empire building;" perhaps the S&T Directorate leadership has successfully lobbied DHS to retain all the agency's R&D functions under their purview. Alternatively, the decision may have been due to the internal logic of traditional bureaucratic processes (an overriding focus on "doing things right" at the expense of "doing the right things"), or due to bureaucratic drift and a failure of DHS leadership to remember HSARPA's founding mandate to be DHS's DARPA. Whatever the case may be, HSARPA can no longer be said to be focusing on the

[375] Ibid., 16–17.

pursuit of "revolutionary, game-changing" technological developments—if ever that was the case.

The Department of Homeland Security appears to have recognized, at least to an extent, that HSARPA has strayed from this original mission and has recently attempted to rectify this. The S&T Directorate utilized new authority granted under the America COMPETES Act to establish in March 2015 the InnoPrize Program to administer prize competitions intended to foster innovative solutions to homeland security challenges.[376] The InnoPrize Program provides HSARPA with an additional acquisition arrow in its quiver, a method of open-ended solicitation and challenge-based financial remuneration (far different from typically burdensome and slow forms of governmental contracting, which can be intimidating and off-putting to small businesses with no prior federal contracting experience), which may prove especially appealing to America's technology entrepreneurs. As of FY2017, the Directorate intended to make use of the following R&D solicitation and acquisition vehicles: Applied Research/Technology Development Solicitations, Small Business Innovation Research, and Long-Range Broad Agency Announcements.[377] The Directorate's 2015–2019 Strategic Plan describes a new initiative, the Targeted Innovative Technology Acceleration Network (TITAN), which aims to utilize a suite of collaborative tools to actively engage the wide community of technology innovators and coordinate the efforts of a host of homeland security technology innovation actors into a more cohesive set of projects.[378] At first blush, this appears to be a promising development; however, a glance at the list of players shows "all the usual suspects" (national laboratories, academia, private industry, the old Small Business Innovative

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[376] "Frequently Asked Questions: The America COMPETES Act and DHS Prize Authority," U.S. Department of Homeland Security website, accessed March 12, 2017, https://www.dhs.gov/frequently-asked-questions; "How will this prize authority be implemented in the Department?" U.S. Department of Homeland Security website, accessed March 12, 2017, https://www.dhs.gov/frequently-asked-questions ; "Department of Homeland Security," Challenge.gov website, "More Information" section, accessed March 12, 2017, https://www.challenge.gov/agency/department-of-homeland-security/.

[377] Calvin J. Bowman, "A DHS Skunkworks Project: Defining and Addressing Homeland Security Grand Challenges" (master's thesis, Naval Postgraduate School, 2016), 50.

[378] Science and Technology Directorate, *Strategic Plan 2015-2019*, 24.

Research program, etc.), with prize authority being TITAN's only innovation to preexisting S&T solicitation and award processes. Disappointingly, TITAN appears to be little more than a "rebranding" or reshuffling of teaming arrangements and linkages that have long existed within the S&T Directorate, yet another example (in the tradition of the S&T Directorate's frequent reorganizations) of government bureaucracy's focus on "doing things right" at the expense of "doing the right thing."

Perhaps of more promise than TITAN in meeting the challenges of the homeland security counter-future-shock mission, in January 2015, the S&T Directorate launched what it calls its DHS National Conversation on Homeland Security Technology. This is intended to foster "a dialogue between the public as well the Nation's first responders, industry representatives, academia, and government officials to shape the future of homeland security technology;" the initiative means to accomplish this through "dialogues to address different areas of need in the research and development community: responder of the future; enabling the decision maker; screening at speed; a trusted cyber future; and resilient communities. Members of the public are encouraged to join the discussion online via the S&T Collaboration Community or by attending virtual or in-person events."[379] Additional research will be required to learn how frequently this public access portal has been used, and what uses the S&T Directorate has made of the feedback it has received. The predecessor to the National Conversation, S&T's crowdsourcing portal, resulted in five Visionary Goals that were much more focused on the homeland security systemic mission than its counter-future-shock mission. Only time will tell whether the National Conversation produces the same "mold-sustaining" rather than "mold-breaking" results.

As the preceding overview makes apparent, HSARPA has experienced (and presumably suffered from) a lack of stability during its less than a decade and a half of existence. The prime culprits have been the agency's shifting roles and authorities within the larger S&T Directorate structure and HSARPA's oftentimes uncodified, non-

[379] "DHS S&T Launches National Conversation on Homeland Security Technology," U.S. Department of Homeland Security website, January 13, 2015, accessed February 16, 2017, https://www.dhs.gov/science-and-technology/news/2015/01/13/dhs-st-launches-national-conversation-homeland-security.

repeatable, and continually evolving processes for identifying, selecting, and prioritizing its projects. Frequent changes in the S&T Directorate's top management and organizational structure have, likely, focused a great deal of HSARPA's program managers' and staffers' attention on responding to internal organizational changes and pressures, rather than deciding what sorts of projects could best benefit the homeland security enterprise and then shepherding the products of those projects to their ultimate transitioning to the field. A series of internal and external reviews of the S&T Directorate and HSARPA, containing these critiques and others, has resulted in a history of consistent criticism and micromanagement from Congress. This, in turn, has quite possibly resulted in a negative feedback loop for HSARPA—Congressional criticism (codified in negative reports and budget cuts) led to management and organizational structure changes, perhaps hastily implemented, which led to anxiety, distraction, and lessened morale on the part of HSARPA's staff, which led to decreased focus on the agency's core mission, which led to fewer products being transitioned to the field, or to the projects that are transitioned being less than what the field (or Congress) had hoped for, which led to more Congressional criticism… and so on. The next Section provides an overview of this cycle.

D. CRITICISM OF THE DHS S&T DIRECTORATE AND HSARPA

Following the implementation of the Homeland Security Act in 2003, Congress's initial high hopes for the S&T Directorate were apparently frustrated quickly. A June 2006 Senate report included this lament: "the [c]ommittee is extremely disappointed with the way S&T is being managed. … This component is a rudderless ship without a clear way to get back on course."[380] Two months later, Admiral Jay Cohen took over as the new Under Secretary for the S&T Directorate. That same month, Rep. Tom Davis, serving as Chairman of the House Committee on Government Reform, requested that the DHS Office of the Inspector General conduct a review of HSARPA's processes for identifying, selecting, and prioritizing its R&D projects.[381] Many the Inspector General's criticisms of

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[380] *S. Rept. 109-273 – Department of Homeland Security Appropriations Bill, 2007*, 109th Cong. 2 (2006), https://www.congress.gov/109/crpt/srpt273/CRPT-109srpt273.pdf.

[381] Department of Homeland Security, *The Science and Technology Directorate's Processes*, 3.

the Directorate were discussed in the previous section. A significant criticism focused on the lack of clear, consistent, repeatable selection, prioritization, and funding procedures for Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects, which had led to at least the appearance of possible impropriety. Under Secretary Cohen, solely responsible for the selection and funding of these projects, had accepted R&D project ideas from contacts at his former employer, the Office of Naval Research. Although the Inspector General did not find evidence of wrongdoing, his report labeled this lack of defined procedures a significant management shortcoming and advised the Under Secretary to both relinquish selection authority of Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects to the Director of Innovation/HSARPA and to ensure that formal procedures would be established.[382]

As of 2007, the S&T Directorate included an Office of Innovation, which sponsored HomeWorks, a relatively low-funded homeland security skunk works that pursued projects such as Cell-All, an effort to develop sensors for commercial cell phones that could detect dangerous biological, chemical, or radiation hazards. HSARPA's Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects fell within the purview of the Office of Innovation; the former aimed to product prototypes of innovative homeland security technology solutions within two to five years, whereas the latter pursued longer-term, more speculative technology plays, of which perhaps only half would ultimately lead to products that could be fielded within the homeland security. These more speculative High Impact Technology Solutions projects were only funded for $8 million in FY2008, or approximately one percent of the S&T Directorate's budget. Even this early in the S&T Directorate's existence, it was suffering from the heat of Congressional criticism; between FY2007 and FY2008, the overall DHS budget increased by 8.4 percent, whereas the S&T Directorate's budget *decreased* by 18 percent, which followed a decrease of 35 percent the previous fiscal year. This indicates that, whereas Congress remained generally supportive of homeland security efforts, the legislature wanted to invest in projects and activities with immediate benefits, rather than those with a more uncertain, longer-term

[382] Ibid., 30-31.

horizon. The chairman of the Emerging Threats, Cyber Security and Science and Technology Subcommittee of the House Homeland Security Committee, Rep. Kim Langevin (D-R.I.), was quoted as saying that he preferred funding immediate cybersecurity needs over the longer-term R&D efforts pursued by HomeWorks and HSARPA's Homeland Innovative Prototypical Solutions and High Impact Technology Solutions portfolios.[383]

On March 8, 2007, Jay M. Cohen, the Under Secretary of the S&T Directorate, appeared before Rep. Langevin's committee to address the committee's concerns with the Directorate. Cohen promised to focus his Directorate's efforts on what he termed the "four Bs—bombs, borders, bugs and business." In other words, in response to political pressure, he would focus S&T's R&D efforts on the systemic mission, at the expense of the counter-future-shock mission. He touted a new organizational structure for the Directorate, which had been put in place in September of 2006 and that had reduced business expenses by 50 percent, and a Capstone Integrated Product Team Process to better identify DHS's most pressing needs and more swiftly transition technology products to the field. He stated that his Capstone Integrated Project Teams' structure was based upon twelve mission priorities: "Information Sharing/Management; Cyber Security; People Screening; Border Security; Chemical/Biological Defense; Maritime Security; Explosive Prevention; Cargo Security; Infrastructure Protection; and Incident Management (includes first responder interoperability)."[384]

Dr. Tara O'Toole succeeded Jay Cohen as the Under Secretary of S&T in November 2009. A November 2011 Congressional hearing, "Science and Technology on a Budget: Finding Smarter Approaches to Spur Innovation, Impose Discipline, Drive Job Creation, and Strengthen Homeland Security," featured members of the Subcommittee on

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[383] Alan Joch, "Homeland Security's High-Tech Gamble," *Federal Computer Week*, November 12, 2007, 17–23.

[384] Hon. Jay M. Cohen, Under Secretary, Science and Technology Directorate, U.S. Department of Homeland Security, Before the U.S. House of Representatives, Appropriations Committee, Subcommittee on Homeland Security, House, 110th Cong. 2 (2007), https://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/30807_cohen.pdf.

Cybersecurity, Infrastructure Protection, and Security Technologies of the Committee on Homeland Security expressing measured approval of Dr. O'Toole's changes; however, they also expressed dissatisfaction with the Directorate's lack of internal controls over its projects, lack of defined procedures for prioritizing its projects, and DHS's lack of strategic planning for its full portfolio of R&D efforts across all its components (although they noted that the S&T Directorate was approaching the end of its first five-year strategic plan and was about to begin work on its second).[385] It seems worth noting that the committee's focus was on "doing things right" (and less expensively than before), rather than "doing the right things."

The S&T Directorate suffered a 56% reduction in budgetary allocation for research and development activities between FY2010 and FY2012.[386] This most likely reflected Congress's lack of confidence in the Directorate, its processes, products, and leadership. The Directorate's number of R&D projects shrank from more than 250 in FY2010 to 75 in FY2012, and the cuts forced S&T leadership to funnel resources away from lower priority areas such as borders, resilience, and maritime security in favor of projects meant to aid efforts in the areas of aviation security, first responders' needs, cybersecurity, and biodefense; however, as of FY2014, the Directorate had recovered financially; its R&D funding had reached approximate parity with its FY2011 allocation, and the number of projects grew once more to over 100.[387] See Table 9.

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[385] *Science and Technology on a Budget: Finding Smarter Approaches to Spur Innovation, Impose Discipline, Drive Job Creation, and Strengthen Homeland Security* – Hearing Before the Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies of the Committee on Homeland Security, House, 112th Cong. 1 (2011), https://archive.org/details/gov.gpo.fdsys.CHRG-112hhrg74533.

[386] Department of Homeland Security, *Science and Technology Directorate Review* 2014, 13.

[387] Ibid.

Table 9. S&T Directorate Research and Development Funding, FYs 2010 - 2014388

Fiscal Year	Funding (in Thousands)
FY2010	$598,473
FY2011	$459,689
FY2012	$265,783
FY2013	$431,846
FY2014	$467,000

An April 2014 report by the Congressional Research Service identified a range of issues of concern with the S&T Directorate and made some pointed observations regarding HSARPA. It stated that, despite HSARPA's originating mandate (mirroring DARPA's mission in the Department of Defense realm) to foster revolutionary technologies in the homeland security sphere, much of HSARPA's efforts have been conventional, incremental R&D work of only moderate risk. Secretary Cohen's reforms, resulting in the Homeland Innovative Prototypical Solutions and High Impact Technology Solutions projects, had steered HSARPA somewhat back toward its original rationale, yet the relatively minute funding available for these projects never allowed for results approaching those of DARPA's famed successes. The 2010 reorganization once more pushed HSARPA towards a portfolio of moderate-risk, conventional R&D, and in subsequent fiscal years, HSARPA had taken on an increasing number of closely related projects, which has served to narrow its focus to a handful of threat vectors.[389] The report also addressed the deleterious impact of uncertain and programmatically restricted funding through Continuing Resolutions on the R&D process. Additionally, it subtly pointed out the mismatch between Congress's desire for DARPA-like results and its aversion to risk. High-risk, high-reward R&D of the type practiced by DARPA "requires an increased and

388 Ibid., 12.

389 Shea, *The DHS S&T Directorate*: Selected Issues for Congress, 17.

sustained financial commitment… [i]n the current fiscal environment, congressional policy makers may find it difficult to provide such an increased and sustained financial commitment."[390]

Congressional impatience and dissatisfaction with the S&T Directorate were reflected in the language and intent of H.R.3578, the DHS Science and Technology Reform and Improvement Act of 2015. The proposed bill directed DHS, among other stipulations, to "establish a process to define, identify, prioritize, fund, and task its basic and applied homeland security research and development activities," to establish procedures for regular portfolio reviews and Integrated Project Teams (IPTs) to ensure that Departmental objectives are being supported by the R&D portfolio, and to ensure that the Directorate formulate and regularly update a five-year plan for its activities. The bill passed the House but died in Senate committee.[391] An observer might express surprise to learn that, a dozen years after the S&T Directorate's founding, its Congressional overseers would find it necessary to stipulate such basic managerial best practices as a defined, standardized process to select and prioritize projects, utilize Integrated Project Teams, and conduct periodic portfolio reviews. The recommendation regarding the use of Integrated Project Teams is surprising, due to the S&T Directorate's proud reporting to Congress as recently as March 2009 of the benefits of its Capstone Integrated Project Teams process.[392] The language of the proposed reform bill indicates that this process had been abandoned at some point.

In her 2015 master's thesis, "Solving Homeland Security's Wicked Problems: A Design Thinking Approach," Kristin Wyckoff contrasted the project management approaches of DARPA, Denmark's MindLab, and the S&T Directorate. She laid out the following criticisms of the latter. The S&T Directorate predominately relied upon use of traditional federal government contracting approaches, which resulted in lengthy periods

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390 Ibid., 20.

391 "H.R.3578 - DHS Science and Technology Reform and Improvement Act of 2015," Congress.gov, accessed on February 2, 2017, https://www.congress.gov/bill/114th-congress/house-bill/3578.

392 Department of Homeland Security, Testimony of Acting Under Secretary Bradley I. Buswell.

needed for project requirements definition, acquisition of R&D services, and transitioning efforts.[393] The Directorate placed heavy reliance on a linear systems engineering R&D approach, appropriate for incremental improvements to existing technologies, but not well suited for truly innovative work.[394] It focused on individual performance incentives rather than team or unit performance incentives, and it failed to incentivize collaboration.[395] Perhaps most detrimental to HSARPA's Congressionally mandated mission of producing revolutionary, game-changing innovations, Wyckoff identified a pervasive culture of risk avoidance and seeking "quick wins," which she asserted had taken root in the S&T Directorate due to its history of repeated, severe Congressional criticism and resultant budget cuts.[396]

The following Section fleshes out these criticisms by examining more closely the composition of HSARPA's R&D portfolio (as of FY2014) and judging how much of that portfolio can be ascertained as being high-reward, high-risk, versus incremental and moderate risk. In other words, how truly does the Homeland Defense Advance Research Programs Agency reflect its own name, and how well is it balancing the roles of supporting both the systemic mission and the counter-future-shock mission?

E. HSARPA R&D PROJECTS: SUPPORTING THE COUNTER-FUTURE-SHOCK MISSION OR THE SYSTEMIC MISSION?

The *Science and Technology Directorate Review 2014* provides the following overview of HSARPA's mission, methods, and partnerships:

> HSARPA is evolving to focus on applied technology development and integration into component operations. Its divisions strive to understand and to define operational context by conducting systems analyses of current missions, systems, and processes, and ultimately to identify operational gaps where S&T can have the greatest impact on operating efficiency and increasing capability. HSARPA then employs the concept of technology foraging ("tech foraging"), working with its partners and In-Q-Tel (IQT)—

[393] Wyckoff, "Solving Homeland Security's Wicked Problems," 13.

[394] Ibid., 38.

[395] Ibid., 64.

[396] Ibid., 38-39.

> an independent, strategic investment firm—to identify potential solutions already being researched or developed by external partners. HSARPA's end goal is to transition products to the field for operational use.[397]

Prior to the initiation of fresh R&D projects, S&T Directorate program managers were required to engage in technology foraging, an institutionalized market research process intended to eliminate redundancies by identifying new technological advancements undertaken by the Directorate's existing network of technology partners or by potential future partners.[398] Technology foraging efforts were ongoing in the areas of

> automated pollen recognition, biometrics, cargo conveyance security devices, chemical sampling, climate change adaptation, eGovernment portals, Federal Emergency Management Agency projects, flood mitigation for substations, fuel cells, geocoding, infrastructure protection projects, insider threats, metric insights, missile deflection, mobile device management, NoSQL databases, ozone widget framework, photo ballistics, Platfora/Datameer competitors, portable Sensitive Compartmented Information Facility (SCIF), robotic systems and camera integration, sensors for small unmanned aerial systems, social media analytics, social media tools for federal communication, Tensator information and competitors, text analytics, undergrounding cables, (and) video recovery.[399]

As was noted in an earlier section, as of FY 2014, HSARPA's R&D projects were divided among five mission-based divisions:

- **Borders and Maritime Security Division (BMD)—**Prevent contraband, criminals, and terrorists from entering the United States, while permitting the lawful flow of commerce and visitors.

- **Chemical and Biological Defense Division (CBD)—**Detect, protect against, respond to, and recover from potential biological or chemical events.

- **Cyber Security Division (CSD)—**Create a safe, secure, and resilient cyber environment.

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397 Department of Homeland Security, *Science and Technology Directorate Review* 2014, 25.

398 Ibid., 62.

399 Ibid., 89.

- **Explosives Division (EXD)—**Detect, prevent, and mitigate explosives attacks against people and infrastructure.

- **Resilient Systems Division (RSD)—**Enhance resilience to prevent and protect against threats, mitigate hazards, respond to disasters, and expedite recovery.[400]

Additional HSARPA R&D efforts were categorized as **Apex projects**, described as "high-priority, high-value, rapid delivery project(s) focused on a DHS component's unique mission and capability needs."[401] This category of projects was initiated in 2011 to allow for the promulgation of R&D projects requested by the head of a DHS operational agency. The S&T Directorate would then commit, not only to fostering the R&D process, but also to working collaboratively with field operatives within the sponsoring DHS component to ensure a successful transition of the newly developed technologies.[402]

The 2014 Review provides lists of the R&D projects assigned to each of these five divisions, and I have made use of these lists to compose Table 10.[403] I use the list of FY2014 projects for analysis because this list is the most recent list of projects available to me for which S&T Directorate employees have assigned scored analytical variables such as Novel Approach Score, Technical Feasibility Score, and Innovation Level. My goal is to ascertain whether the projects support homeland security's systemic mission (preventing or responding to known threats) or whether they might serve the counter-future-shock mission (aiding prevention and response efforts against threats from cutting-edge or repurposed technologies, used maliciously, and previously unencountered by the homeland security enterprise). I have assigned projects to one mission or the other depending on my judgments of the project descriptions. Evaluations of individual projects' level of Novel Approach, Technical Feasibility, and Innovation Level, where available, have been taken

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[400] Ibid.

[401] Ibid., 26.

[402] Shea, The DHS S&T Directorate: Selected Issues for Congress, 12.

[403] Lists of HSARPA projects, broken out by division, are found in Department of Homeland Security, *Science and Technology Directorate Review 2014*, 26-37. A handful of projects in each division were highlighted with descriptions, which assisted me in making determinations on whether those projects are intended to support the system mission, the counter-future-shock mission, or possibly both.

from the *2014 DHS S&T Portfolio Review Final Analysis: Briefing Document for S&T Leadership* and reflect the judgment of the authors of that document. See Tables 10 through 16.

Table 10. FY 2014 HSARPA Apex Division Projects, by Project Name, Type of Mission Supported, Novel Approach Score, Technical Feasibility Score, and Innovation Level

Division	Project Name	Systemic/ Future Shock	Novel Approach[404] (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility[405] (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
Apex	Air Entry and Exit Re-Engineering Project (AEER)	Systemic	N/A[406]	N/A	N/A
	Border Enforcement Analytics Program (BEAP)	Systemic	N/A	N/A	N/A

404 Novel Approach scoring definitions are taken from Department of Homeland Security, *2014 DHS S&T Portfolio Review Final Analysis: Briefing Document for S&T Leadership* (Washington, DC: U.S. Department of Homeland Security Science and Technology Directorate, May 2015), 27, accessed on the DHS Intranet (do not release without prior approval from the Department of Homeland Security). Project scores are taken from pages 43-53.

405 Technical Feasibility scoring definition is taken from Department of Homeland Security, *2014 DHS S&T Portfolio Review Final Analysis*, 22. Project scores are taken from pages 43-53.

406 "N/A" means Not Available; this project was not analyzed as part of the portfolio review included in the *2014 DHS S&T Portfolio Review Final Analysis*.

Table 11. FY 2014 HSARPA Borders and Maritime Security Division Projects, by Project Name, Type of Mission Supported, Novel Approach Score, Technical Feasibility Score, and Innovation Level

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
Borders and Maritime Security	Cargo Container Security -Central Examination Stations (CES)/In-Bond	Systemic	5	9	Incremental / Tech Feasible
	Cargo Container Security -Maritime Cargo Security Pilot	Systemic	5	9	Incremental / Tech Feasible
	Cargo Container Security -Secure Hybrid Composite Container	Systemic	5	9	Incremental / Tech Feasible
	Cargo Validation - Currency Detection	Systemic	7	8	Novel / Tech Feasible
	Cargo Validation - Pollen Forensics	Systemic	7	8	Novel / Tech Feasible
	Land/Sea Cargo Screening - Mid-Level Energy Scanning System Upgrade	Systemic	4	9	Incremental / Tech Feasible
	Air Based Technologies - Airborne Sensors for Wide Area Surveillance	Systemic / Future Shock	4	7	Incremental / Tech Feasible
	Air Based Technologies - Robotic Aircraft for Public Safety	Systemic / Future Shock	4	7	Incremental / Tech Feasible
	Ground Based Technologies - Buried Tripwire	Systemic	4	5	Incremental / Tech Feasible
	Ground Based Technologies - Canada-US Sensor Sharing Pilot	Systemic	4	5	Incremental / Tech Feasible

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
	Ground Based Technologies - Mobile Surveillance System Upgrade (MSS-U)	Systemic	4	5	Incremental / Tech Feasible
	Ground Based Technologies - Slash CameraPole	Systemic	4	5	Incremental / Tech Feasible
	Ground Based Technologies - Unattended Ground Sensors	Systemic	4	5	Incremental / Tech Feasible
	Rapid Response Prototyping	Systemic	N/A	N/A	N/A
	Small Dark Aircraft	Systemic	N/A	N/A	N/A
	Tunnel Detection and Surveillance - Tunnel Activity Monitoring	Systemic	7	5	Novel / Tech Feasible
	Tunnel Detection and Surveillance - Tunnel Detection	Systemic	7	5	Novel / Tech Feasible
	Coastal Surveillance System (CSS)	Systemic	4	9	Incremental / Tech Feasible
	Detection of People in Water	Systemic	4	9	Incremental / Tech Feasible

Table 12. FY 2014 HSARPA Chemical and Biological Defense Division Projects, by Project Name, Type of Mission Supported, Novel Approach Score, Technical Feasibility Score, and Innovation Level

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
Chemical and Biological Defense	Adaptive Facility Protection (Bio and Chem)	Systemic	N/A	N/A	N/A
	Agricultural Screening Tools	Systemic	N/A	N/A	N/A
	Bioassays	Systemic	5	6	Incremental / Tech Feasible
	Bio-Defense Knowledge Center (BKC)	Systemic	N/A	N/A	N/A
	Bio-Forensics Operations (NBFAC)	Systemic	N/A	N/A	N/A
	Bio-Forensics Research and Development	Systemic	4	4	Incremental / Tech Difficult
	Bio Terrorism Risk Assessment	Systemic	4	4	Incremental / Tech Difficult
	Bio-Threat Characterization (BTC)	Systemic	3	4	Incremental / Tech Difficult
	Chem-Bio Event Characterization	Systemic	N/A	N/A	N/A
	Chemical Forensics and Attribution (FAP)	Systemic	5	4	Incremental / Tech Difficult
	Chemical Forensics Project	Systemic	N/A	N/A	N/A
	Chemical Security Analysis Center (CSAC)	Systemic	N/A	N/A	N/A
	Detect-to-Protect Bio-Aerosol Detection Systems	Systemic	N/A	N/A	N/A
	Enhanced Passive Surveillance	Systemic	N/A	N/A	N/A
	Foreign Animal Disease Modeling	Systemic	N/A	N/A	N/A
	Foreign Animal Disease Vaccines and Diagnostics	Systemic	5	4	Incremental / Tech Difficult

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
	Integrated Consortium of Laboratory Networks	Systemic	N/A	N/A	N/A
	Integrated Terrorism Risk Assessment	Systemic	4	3	Incremental / Tech Difficult
	Livestock Decontamination, Disposal, and Depopulation (3D)	Systemic	4	10	Incremental / Tech Feasible
	Multi-Application Multiplex Technology Platform	Systemic	N/A	N/A	N/A
	National Bio and Agro-Defense Facility (NBAF) Agro Defense and Research Assessment	Systemic	N/A	N/A	N/A
	Next Gen Bio Detection	Systemic	N/A	N/A	N/A
	Operational Tools for Response and Restoration	Systemic	N/A	N/A	N/A
	Rapid Diagnostic Capability	Systemic	N/A	N/A	N/A
	Underground Transport Restoration	Systemic	N/A	N/A	N/A
	Viable Bioparticle Capture	Systemic	N/A	N/A	N/A

Table 13. FY 2014 HSARPA Cyber Security Division Projects, by Project Name, Type of Mission Supported, Novel Approach Score, Technical Feasibility Score, and Innovation Level

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
Cyber Security	Comprehensive National Cybersecurity Initiative (CNCI) Cyber Economic Incentives	Future Shock	5	4	Incremental / Tech Difficult
	CNCI Leap Ahead Technologies	Future Shock	N/A	N/A	N/A
	CNCI Moving Target Defense	Future Shock	8	4	Novel / Tech Difficult
	CNCI Tailored Trustworthy Spaces	Future Shock	N/A	N/A	N/A
	CNCI Transition to Practice (TTP)	Future Shock	5	7	Incremental / Tech Feasible
	Cybersecurity Assessment and Evaluation	Systemic / Future Shock	N/A	N/A	N/A
	Cybersecurity Competitions	Systemic / Future Shock	8	10	Novel / Tech Feasible
	Cybersecurity Forensics	Systemic / Future Shock	3	4	Incremental / Tech Difficult
	Data Privacy Technologies	Systemic / Future Shock	N/A	N/A	N/A
	Enterprise-Level Security Metrics and Usability	Systemic / Future Shock	N/A	N/A	N/A
	Experimental Research Testbed	Future Shock	N/A	N/A	N/A
	Experiments and Pilots	Future Shock	N/A	N/A	N/A
	Homeland Open Security Technologies (HOST)	Systemic / Future Shock	4	7	Incremental / Tech Feasible

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
	Identity Management	Systemic / Future Shock	4	6	Incremental / Tech Feasible
	Internet Measurement and Attack Modeling	Systemic / Future Shock	5	7	Incremental / Tech Feasible
	Process Control Systems (PCS) Security	Systemic / Future Shock	N/A	N/A	N/A
	Research Data Repository	Systemic / Future Shock	N/A	N/A	N/A
	Secure Protocols	Systemic / Future Shock	5	8	Incremental / Tech Feasible
	Security for Cloud-Based Systems	Systemic / Future Shock	6	6	Incremental / Tech Feasible
	Software Assurance Marketplace (SWAMP)	Systemic / Future Shock	4	4	Incremental / Tech Difficult
	Software Quality Assurance	Systemic / Future Shock	N/A	N/A	N/A

Table 14. FY 2014 HSARPA Explosives Divisions Projects, by Project Name, Type of Mission Supported, Novel Approach Score, Technical Feasibility Score, and Innovation Level

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
Explosives	Air Cargo	Systemic	5	6	Incremental / Tech Feasible
	Aircraft Vulnerability Tests	Systemic	4	9	Incremental / Tech Feasible
	Algorithm and Analysis of Raw Images	Systemic	N/A	N/A	N/A
	Canine Explosives Detection	Systemic	6	6	Incremental / Tech Feasible
	Checked Baggage	Systemic	6	7	Incremental / Tech Feasible
	Eye Safe Trace Detection	Systemic	N/A	N/A	N/A
	Homemade Explosives Characterization	Systemic	5	4	Incremental / Tech Difficult
	Integrated Passenger Screening System	Systemic	7	4	Novel / Tech Difficult
	Mass Transit	Systemic	7	2	Novel / Tech Difficult
	Next Generation Passenger Checkpoint	Systemic	7	3	Novel / Tech Difficult

Table 15. FY 2014 HSARPA Resilient Systems Divisions Projects, by Project Name, Type of Mission Supported, Novel Approach Score, Technical Feasibility Score, and Innovation Level

Division	Project Name	Systemic/ Future Shock	Novel Approach (7-8=Fresh Perspective; 9–10=Revolutionary)	Technical Feasibility (1-2=Very Difficult; 3-4=Difficult)	Innovation Level (Novel/Tech Difficult; Incremental/Tech Feasible)
Resilient Systems	Actionable Indicators and Countermeasures	Systemic / Future Shock	1	10	Incremental / Tech Feasible
	Advanced Incident Management Enterprise System	Systemic	N/A	N/A	N/A
	Blast Analysis of Complex Structures	Systemic	N/A	N/A	N/A
	Drinking Water Resilience	Systemic	N/A	N/A	N/A
	Geospatial Location Accountability and Navigation System for Emergency Responders (GLANSER)	Systemic	N/A	N/A	N/A
	Human Systems Research and Engineering (HSRE)	Systemic	N/A	N/A	N/A
	Non-Cooperative Biometrics	Systemic	5	8	Incremental / Tech Feasible
	Overhead Imagery Data	Systemic	4	8	Incremental / Tech Feasible
	Passive Methods for Precision Behavioral Screening	Systemic	N/A	N/A	N/A
	Rapid DNA	Systemic	6	8	Incremental / Tech Feasible
	Resilient Electric Grid	Systemic	4	5	Incremental / Tech Feasible
	Resilient Tunnel Project	Systemic	4	5	Incremental / Tech Feasible
	Risk-Based Resource Deployment Decision Aid Prediction Project	Systemic	6	7	Incremental / Tech Feasible
	Standard Unified Modeling Mapping Integrated Toolkit (SUMMIT)	Systemic	4	9	Incremental / Tech Feasible

Table 16. FY 2014 HSARPA Projects, by Type of Mission Supported and Innovation Level

Mission Type Supported	Number of Projects	Incremental / Tech Feasible	Incremental / Tech Difficult	Novel / Tech Feasible	Novel / Tech Difficult
Systemic	68 (74%)	24	7	4	3
Counter-Future Shock	7 (8%)	1	1	--	1
Systemic / Counter-Future Shock	17(18%)	8	2	1	--
Totals	**92 (100%)**	**33**	**10**	**5**	**4**

This FY 2014 snapshot of the HSARPA R&D project portfolio presents a far more conservative cast than one might expect for an innovation incubator with "Advanced Research" as part of its name, whose founding Congressional mandate is centered on the development and implementation of revolutionary technology. Of the 92 projects listed, only 24 (26%) can be said (in my estimation) to support counter-future-shock mission. Of the 52 HSARPA projects assessed during the FY 2014 portfolio review within the *2014 DHS S&T Portfolio Review Final Analysis: Briefing Document for S&T Leadership*, only 4 (8% of these 52) were of the type—novel in conception and technically challenging—which might be expected to make up the majority of a "revolutionary" "Advanced Research" organization. Contrary-wise, 33 (63% of these 52) of the projects were incremental in their conception and technically feasible; and of these 33, 24 supported the systemic mission. One might ask whether these latter projects and their like belong under the umbrella of HSARPA, or whether they would more realistically belong in one of the S&T Directorate's other portfolios.

An earlier Section described the process initiated by the S&T Directorate to identify its five Visionary Goals that would drive much of its R&D effort from FY2015 to FY2019. The Directorate's Apex programs are those R&D efforts that most closely adhere to the five Visionary Goals. As of FY2015, eight Apex programs were underway: Screening at Speed; Real-Time Biological Threat Awareness; Next Generation First Responder; Relational Adaptive Process of Information and Display; Cybersecurity in Critical

Infrastructure; Border Situational Awareness; Border Enforcement Analytics; and Air Entry and Exit Reengineering.[407] Virtually all these Apex programs are intended as responses to known, existing threats and risks. These include air travel security (Screening at Speed; Air Entry and Exit Reengineering), border control and security (Border Situational Awareness; Border Enforcement Analytics), biohazards and terror attacks using biological agents (Real-Time Biological Threat Awareness), cyber attacks (Cybersecurity in Critical Infrastructure), community determination of flood hazards and risks from other potential natural disasters (Relational Adaptive Process of Information and Display, or RAPID[408]), and the needs of first responders who engage with natural or man-made disasters (Next Generation First Responder). This seems to represent, once again, the S&T Directorate's and HSARPA's ongoing focus on the systemic mission at the expense of preparing for the counter-future-shock mission.

To sum up, all the criticisms leveled at HSARPA by Congress, Inspector General's reports, and outside observers appear to be valid. Both HSARPA and its parent organization, the S&T Directorate, have been negatively impacted by factors both internal and external. These have included poor internal controls of R&D projects, a history of a lack of clear, repeatable processes for identifying, selecting, and prioritizing projects, frequent changes in leadership, wildly vacillating funding levels, and funding by Continuing Resolutions, which limits the initiation of new projects and places severe limits on how appropriated funds can be spent. HSARPA has made gradual progress over the years in formulating and adhering to repeatable procedures for identifying, selecting, and prioritizing projects, and the organization appears to have made progress in gathering and incorporating feedback, inputs, and collaboration from DHS operational components and R&D partners in industry, academia, and federal laboratories. Yet the adoption of these procedures, as part of a series of S&T Directorate reorganizations, has served to focus HSARPA's program managers almost entirely on supporting the homeland security systemic mission, with very little effort being expended on the equally vital counter-future-

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[407] Science and Technology Directorate, *Strategic Plan 2015-2019*, 19.

[408] Ibid., 48.

shock mission. This is not to say that HSARPA's sponsored projects are not carrying out vital, important work—they are. Saying the counter-future-shock mission is suffering in comparison with the systemic mission in no way denigrates the importance of the latter. What I have been emphasizing, though, is that the homeland security enterprise currently has no other element other than HSARPA to focus on the counter-future-shock mission. So, if HSARPA is not doing that, then no organization in homeland security is; and, given the magnitude of potential threats lurking over the horizon, that is a frightening thought.

As the federal government's designated "tip of the spear" for counter-future-shock technology incubation in the homeland security realm, HSARPA appears to have abdicated its unique role. Can this agency be made to realign with its founding mandate? HSARPA's Congressional "parents" anticipated that their "baby" would grow up to become the homeland security equivalent of DARPA. Can elements of the DARPA model be effectively applied to HSARPA to shift the latter's focus to more high-reward, high-risk R&D efforts meant to protect against evolving, future threats? Or is the homeland security sphere of responsibilities too fundamentally different from that of the Department of Defense for the DARPA model to be transposed to HSARPA? Pursuing answers to these expansive questions is outside the scope of this thesis; however, in the next Section I will set forth those questions I feel must be answered to determine the best home for a "devil's toy box" analytical effort and the R&D projects such an analytical effort would support.

F. WHAT IS THE MOST APPROPRIATE HOME FOR A "DEVIL'S TOY BOX" ANALYTICAL EFFORT AND SUBSEQUENT R&D PROJECTS?

In my estimation, six potential "homes" for a "devil's toy box" analytical effort may be considered as alternatives. These alternatives are:

- ***HSARPA as-is***: No changes are made to HSARPA's organizational structure to accommodate a "devil's toy box" analytical effort and subsequent R&D efforts to support the counter-future-shock mission. A "devil's toy box" analysis is assigned to existing or newly hired staff as a new effort.

- ***"Refocused" HSARPA***: The S&T Directorate removes R&D efforts that support the systemic mission from HSARPA and reassigns them to another organizational unit, freeing the existing HSARPA to concentrate on fostering R&D that supports the counter-future-shock mission.

- ***"Mini-ARPA"***: The S&T Directorate leaves all R&D projects currently assigned to HSARPA in place but creates a "mini-ARPA" (mini Advanced Research Projects Activity) inside the existing HSARPA and gives its managers autonomy from existing lines of bureaucratic control, freeing them to concentrate entirely on the counter-future-shock mission.

- ***"New" HSARPA***: The existing HSARPA, "old" HSARPA, officially (de jure) becomes what it has essentially evolved into over the past decade (de facto)—DHS's R&D wing to support its systemic mission efforts, its counterpart to the Army's, Navy's, Air Force's, and Marines' dedicated R&D units. In parallel, DHS establishes a "new" HSARPA, not under the same S&T Directorate umbrella as "old" HSARPA, as its counterpart to the Defense Advanced Research Projects Agency (DARPA). "New" HSARPA is a mostly autonomous agency that will focus exclusively on high-risk, high-benefit programs to support the counter-future-shock mission in the homeland defense realm. Its placement in the DHS organizational structure parallels the placement of DARPA in the Department of Defense organizational structure.

- ***Subcontract with DARPA***: The S&T Directorate, recognizing DARPA's history of success with the types of high-risk, high-benefit projects likely to emerge from a "devil's toy box" analytical effort, subcontracts with DARPA to have the latter organization perform the analytical effort and to manage subsequent R&D projects.

- ***Subcontract with the Intelligence Advanced Research Projects Agency (IARPA)***: The S&T Directorate, recognizing IARPA's successful history

of fostering projects focused on technological forecasting, such as FUSE and the Aggregative Contingent Estimation (ACE) program/Good Judgment Project, subcontracts with IARPA to have the latter organization perform an ongoing "devil's toy box" analytical effort and to manage subsequent R&D projects.

I will consider each of these alternatives, their advantages and disadvantages, in ascending order, beginning with the alternative I feel is least promising (#6) to that which I feel is most promising (#1) for achieving the goals of a "devil's toy box" analysis. I offer these rankings with the following caveats. One, I have never worked within HSARPA, the S&T Directorate, IARPA, or DARPA; my knowledge of their organizational cultures is that of an outsider, based upon Congressional hearings, Inspector General's reports, and scholarly articles. Two, I based my analysis of HSARPA's set of projects on those which were active during FY2014, the most recent fiscal year for which I was able to obtain relatively complete data regarding project descriptions and internal rankings of those projects regarding novel approach and technical feasibility, and I recognize the possibility that, in the three fiscal years that have elapsed since FY2014, the mix of HSARPA-managed projects may have changed.

#6: HSARPA as-is. This, in my view, is the least promising of all the alternative homes for a "devil's toy box" analysis. The history of HSARPA, thoroughly covered in previous sections of Appendix A, illustrates the powerful pull of the systemic mission set's needs over the counter-future-shock mission set's needs within the S&T Directorate. Existing organizational imperatives, the drag of bureaucratic habits and existing mindsets, and prevailing political interests within the Department of Homeland Security and the larger homeland security enterprise, all which favor more immediate, pressing needs of the first responders community, would likely mean that inserting a "devil's toy box" analytical project into "HSARPA as-is" would result in low buy-in of the analytical effort by top HSARPA and S&T Directorate management, or low prioritization of the resulting R&D projects, or perhaps even co-optation of the analytical effort by top management so that the analysis leans towards support of the systemic mission set rather than the counter-future-shock mission set. Another factor that must be considered is the history of a low level of

Congressional confidence in the work of the S&T Directorate and HSARPA, reflected in funding reductions or unpredictable funding levels, as well as in the results of Congressional hearings and resulting bills intended to reform HSARPA and the S&T Directorate. While a "devil's toy box" analytical effort would be relatively low-cost on its own, the resulting R&D projects would require appreciable new funding or reallocations/reprogramming of existing appropriations. It is an open question whether Congress would allocate additional funds for a new R&D initiative to an agency for which they have expressed low confidence, absent significant reforms. I believe the funding spigot would remain squeezed shut in such an instance.

#5: "Mini-ARPA." The main strike against this option (creating a mini Advanced Research Projects Activity inside the existing HSARPA) is that it has already been tried within HSARPA and has failed, or at least only served to temporarily refocus a portion of HSARPA's R&D efforts on high-risk, high-benefit projects for a few fiscal years, before the agency returned to its overwhelming emphasis on projects that benefit the systemic mission. As described earlier in Appendix A, in FY2007, S&T Directorate Under Secretary Jay Cohen rebalanced HSARPA's R&D portfolio, seeking a more even mix between low- or moderate-risk, moderate-benefit projects (the Homeland Innovative Prototypical Solutions) and high-risk, high-benefit projects (the High Impact Technology Solutions), favoring the latter with his establishment of the Office of Innovation and its HomeWorks portfolio. Yet in FY2010, Cohen's successor, Dr. Tara O'Toole, undid all this rebalancing with another HSARPA reorganization, which placed virtually all the S&T Directorate's low- or moderate-risk, moderate-benefit projects to support the systemic mission under HSARPA' s management. Even before O'Toole's arrival on the scene, Cohen was already backing away from his own reforms due to criticism and pressure from Congress, to whom he reported that he would refocus the S&T Directorate's efforts on what he called the four 'Bs'—borders, bombs, bugs, and business. These developments illustrate the pervasive influence of supporters of the systemic mission set over the counter-future-shock mission set within the Department of Homeland Security. They also show how Congress is apt to be of two or more minds (sometimes contradictory) regarding an issue—in this case, having created HSARPA to focus on the counter-future-shock mission for DHS, yet also

severely criticizing that organization and its parent for not adequately supporting the systemic mission. Although history is not destiny, absent a significant culture change in the S&T Directorate or a major, enduring political push from Congress and the administration, trying what has been tried in the past will likely result in a similar outcome to that already seen.

#4: Subcontract with the Intelligence Advanced Research Projects Agency (IARPA). As noted earlier, IARPA has sponsored several major R&D projects related to technological emergence and improving forecasting efforts, which would appear to make it a hospitable organizational setting for a "devil's toy box" analytical effort; however, the goals and mission sets of the intelligence community and the homeland defense community may be too divergent to allow for a successful "hand-off" of the management of homeland security's counter-future-shock mission's R&D effort to a branch of the intelligence community. The primary divergences involve timeframes of interest and goals/outcomes of R&D efforts. The intelligence community is primarily concerned with discovering situations and events that are occurring in the present or within an actionable timeframe, this being the very near-term future to a year. This was reflected in IARPA's Aggregative Contingent Estimation (ACE) program's focus on forecasting events and developments that would actualize within a six-month to one-year timeframe. Contrarily, as I have suggested in earlier chapters, homeland security's counter-future-shock efforts should focus on potential malign events that would occur five years in the future or farther out. This mismatch in timeframes of focus need not be disqualifying, but it needs to be taken into consideration as a contributing factor in divergence of organizational cultures between the two potential partners. Equally important, a divergence of goals exists between the intelligence community's R&D efforts and those of the homeland security community. The former primarily seeks improvements in the collection of information; intelligence components seek to improve their capabilities to provide timely and accurate information to law enforcement or national defense components, which will use the information to better counter adversaries' aggressions. In contrast, while the homeland security enterprise's R&D efforts may sometimes focus on improvements in collection of information, they have historically focused far more upon facilitating efforts to more

effectively prevent, respond to, or mitigate malign events, whether caused by nature or by human adversaries. This focus better aligns with the R&D focus of the Department of Defense, which also tends toward a longer timeframe, trying to anticipate and counter (or, better still, surpass) whatever new capabilities potential adversaries may develop in the next five to twenty years.

#3: "Refocused" HSARPA. This option envisions a "back-to-basics" HSARPA, one refocused on its founding mission of facilitating high-risk, high-reward R&D projects. HSARPA would remain under the S&T Directorate umbrella, but all its current low- to moderate-risk, medium-reward projects, those that support the systemic mission, would be removed from HSARPA and assigned to a new S&T Directorate subcomponent, which would act as DHS's version of the Army's, Navy's, Marine Corps', and Air Force's "in-house" R&D establishments. The potential pitfall with this option lies with Nieto-Gómez's, Bellavita's, and Carstensen's and Bason's critiques of traditional bureaucracies that are assigned the tasks of innovation, cited in the first Section of Appendix A. Traditional bureaucracies do not do innovation well. HSARPA's current managers have presumably grown accustomed to primarily supporting the homeland security enterprise's systemic mission. In this role, they have presumably developed a different mindset and array of bureaucratic procedures than the mindset and practices best suited for facilitating the blue-sky, innovative work that would proceed from a "devil's toy box" analytical effort. This is not to say that "old dogs" cannot learn "new tricks," nor that a refocused HSARPA could not recruit managers with more of a blue-sky mindset (perhaps veterans of some of DARPA's projects). Also, decisively refocusing HSARPA on its originating mission would help "inoculate" the agency from pressures, organizational and political, to fall back into its past habit of primarily supporting the systemic mission set. A decisive "re-branding" of HSARPA, one portrayed as a major executive branch initiative, could help overcome Congressional reluctance to assign the agency increased appropriations, by addressing past criticisms; however, Congressional wariness of the S&T Directorate could still be a factor in resource allocation, although presumably less than with options #6 (HSARPA as-is) and #5 ("mini-ARPA").

#2: "New" HSARPA. Of all the alternative options for housing a "devil's toy box" analytical effort and its subsequent R&D projects within the Department of Homeland Security, I feel the option that holds the most promise of success is that of a "new" HSARPA, a newly-formed organizational unit with DHS that is no longer under the S&T Directorate's umbrella, but that reports directly to the Secretary of DHS. This would parallel the organizational placement of DARPA within the Department of Defense. A "fresh sheet of paper" HSARPA would address many, perhaps most, of the criticisms that can be lodged against options #6 (HSARPA as-is), #5 ("mini-ARPA"), and #3 ("refocused" HSARPA). The creators of this new agency could recruit program and project managers with experience in other innovation incubator organizations and could roll out the agency with a fresh organizational culture not bound by traditional bureaucratic constraints and incentives. The S&T Directorate would retain its "old" HSARPA, presumably to be renamed with a title better suited to its mission of supporting the homeland security enterprise's systemic mission set. The creation of a "new" HSARPA would require passage of legislation by Congress, and the political effort involved in this legislative push should translate into parallel support for adequate appropriations to support the new Congressional initiative. On the downside, any solution that relies upon the passage of Congressional legislation comes with increased risk and uncertainty inherent in the political process.

#1: Subcontract with DARPA. As noted earlier, HSARPA was deliberately modeled after the Defense Advanced Research Projects Agency (DARPA), the federal government's most illustrious and successful technology incubator, origin of such transformative technologies as the Internet and military stealth applications, and was initially allotted many of the same acquisition and organizational partnership freedoms and flexibilities that have benefited DARPA's efforts.[409] DARPA enjoys tremendous prestige in Congress and is widely viewed as one of the federal government's most effective investment instruments, having been the source of multiple innovations that have not merely elevated the capabilities of the U.S. armed forces above those of potential adversaries in the decades since the 1980s, but that have also served to transform the U.S.

[409] Morgan, *Research and Development in the Department of Homeland Security*, 2-10.

civilian economy and infuse it with fresh dynamism. An adage states, "if you want something to get done, give it to a busy person," i.e.: someone who is in the habit of working hard and getting things done. DARPA has a long and successful track record of facilitating the types of blue-sky, high-risk, high-reward R&D projects that would result from a "devil's toy box" analysis. Moreover, a "devil's toy box" analytical effort, staffed by a mix of scientists, technologists, terrorism analysts, and science fiction writers, would not be an "alien element" within DARPA's organizational culture. Better still, the budgetary resources that have traditionally been granted to DHS for R&D could be considered a rounding error when compared with the resources assigned to the Department of Defense in general and to DARPA in specific. (A direct comparison cannot be made, due to DARPA's involvement in classified, "black box" projects whose budgets are not accessible to the public; however, DARPA's budget for its roughly 200 R&D programs is estimated to be about $3 billion annually.[410] As shown above, in FY2014, the budget for the entire S&T Directorate, of which HSARPA is only a part, was less than half a billion dollars.) Since many of the R&D projects that would be initiated by a "devil's toy box" analytical effort would likely be dual-use in nature, having applicability to the needs of both DHS and the Department of Defense, it is possible that DHS's financial contribution to a shared R&D effort could be viewed as "seed money," dollars that would be matched several times over by Department of Defense R&D funds. If so, this would result in a far larger pot of money for "devil's toy box" R&D than would be available if this effort were to be entirely contained with DHS.

What are the downsides of this otherwise promising alternative? Although HSARPA's mission aligns with DARPA's better than it does with IARPA's, the homeland security counter-future-shock R&D effort does not align precisely with the Department of Defense blue-sky R&D effort. DARPA's mission is to counter strategic surprise by creating strategic surprise; its activities focus on incubating new offensive and defensive capabilities for the U.S. military that force potential opponents to expend time, money, and

[410] Regina E. Dugan and Kaigham J. Gabriel, "'Special Forces' Innovation: How DARPA Attacks Problems," *Harvard Business Review* (HBR Reprint R1310C), October 2013, 76.

resources on countering American innovations.[411] This means that DARPA project managers have the initiative in selecting their R&D projects; they are "playing offense" and can set the rules of the competition, following the advice of the old adage, "the best defense is a good offense." However, the mission of the homeland security enterprise is essentially protective, defensive, and reactive. In most confrontations with homeland security, the enemy holds the initiative—the devil gets to choose which toy he will select from his toy box next and where and when he will play with it. The "devil's toy box" analytical effort described in this thesis is quite different, as a mechanism for identifying, selecting, and prioritizing R&D projects, than the procedure used by DARPA, which has generally been to encourage potential partner vendors (government and private sector research labs, universities, large technology companies, start-up tech firms) to pitch blue-sky ideas to DARPA managers, as though they are entrepreneurs pitching investment in a high-tech start up to a venture capital firm. Regina E. Dugan and Kaigham J. Gabriel, at one point the director and deputy director, respectively, of DARPA, define DARPA's two modes of identifying and selecting projects as follows: "One is to recognize that a scientific field has emerged or reached an inflection point, and that it can solve, often in a new way, a practical problem of importance. … The second way to identify projects is to uncover an emerging user need the existing technologies cannot address. … A (DARPA) project portfolio should include a healthy balance of both kinds of initiatives—projects that are focused on new possibilities created by scientific advances and projects that are focused on solving long-standing problems through new scientific development."[412] If it were to be described along the same lines, a notional HSARPA's counter-future-shock mission, focused on pursuing priorities identified by a "devil's toy box" analysis, would be projects that are focused on new possibilities *for adversaries' malign actions* created by scientific advances. On the other hand, "projects that are focused on solving *long-standing problems* through new scientific development" (emphasis added) are projects that, by definition, support the systemic mission and thus are outside the scope of a "devil's toy box" analysis.

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411 Ibid., 77.

412 Ibid., 78–79.

However, this is not to say that considerable overlap does not exist between the notional HSARPA counter-future-shock mission set and the DARPA mission set; the latter is simply broader and more inclusive. Prior to the creation of the Department of Homeland Security and the S&T Directorate in 2003, many projects that might well be imagined to fall within HSARPA's basket were shepherded by DARPA. Despite DARPA's oft-stated mission to avoid strategic surprise by creating strategic surprise—a mission devoted to the offense—the agency's most significant legacy thus far, ARPANet, which evolved into the Internet, was essentially a *defensive* initiative, equally as useful in conception for homeland defense organizations as it was for the armed forces. A resilient communications network, stocked with redundant capabilities, is certainly essential to preserving the military's offensive capabilities in the aftermath of a nuclear strike, but it is just as essential to preserving both the military's command and control functions needed for force preservation and the emergency response and mitigation capabilities of the homeland security enterprise. ARPANet was very much a dual-use technology, of equal value to the military and to the homeland security enterprise. That its originally unforeseen role in fostering commerce has perhaps eclipsed its original mission set has been a happy accident of history.

I have offered my judgments regarding the best-fit placement for an ongoing "devil's toy box" analytical effort. Ultimately, however, the decision that will guide that placement, indeed, whether such a placement will occur at all, will hinge upon political factors, and perhaps upon the level of personal commitment that can be mustered by key individuals in government agencies. With enough push and commitment by key individuals, organizational culture can be changed, and initiatives foreign to an organization's traditional culture can be made to take root. I have judged that the path of least resistance for fostering a productive "devil's toy box" analytical effort would be for DHS to subcontract out the work to DARPA. "Easiest" path does not imply "only" path, however. My judgment should not be taken to imply that leaders with a fresh overarching concept for HSARPA and the determination to thoroughly evangelize that concept could not be successful in their efforts to dedicate that agency to intensive, routine use of

Pandora's Spy Glass, to focusing the agency's vision upon seeing through the multiple walls of the devil's toy box to the innovative deviltries incubating within.

APPENDIX B. DRAWING PARALLELS BETWEEN TWO AUDIENCES—THE SCIENCE FICTION READERSHIP AND POTENTIAL MEMBERSHIPS OF TERROR GROUPS

A. SOCIOLOGICAL AND DEMOGRAPHIC DATA ON THE SCIENCE FICTION READERSHIP

Types of teenage boys and young men are especially drawn to science fiction as a source of recreation, whether that be reading science fiction stories and novels, watching science fiction films, role-playing science fiction board games, reading superhero comics or graphic novels (superheroes and super-powers are a subset of science fiction), playing science fiction-themed video games, or dressing up as science fiction characters at conventions. The stereotypical science fiction fan (short for "fanatic") is a teenage boy, or young man in his twenties, who is socially awkward, timid about approaching the opposite sex, of above-average intelligence, un-athletic, and often bullied or denigrated by his peers. An anthropological excursion to a science fiction or comic book convention would bear out that this sometimes mocking, sometimes affectionate stereotype is often reflected in reality (I spent my adolescence and young adulthood fitting the stereotype to a tee), although conventions that focus primarily on written science fiction tend to skew a good bit older in their attendees nowadays than conventions that focus more heavily on films, television, video gaming, comics, or cos-play (these latter still attract many attendees in their teens and twenties).

Linda Fleming notes in her 1977 consideration of the American science fiction subculture that, since the origins of commercial science fiction in the cheap, widely distributed pulp magazines of the 1920s and 1930s and newspaper comic strips of the 1930s, the general population has tended to look down upon science fiction material as "That Buck Rogers Stuff," and that this derisive dismissal of science fiction produced a strong sense of in-group/out-group thinking among its fans, a sense that science fiction readers and fans are a distinct subculture, a group apart, residents of a literary "ghetto." This socio-psychological reaction to various types of shunning resulted in the creation,

over decades, of a genuine science fiction fan culture, with its own in-group lingo, social behaviors, traditions, and history passed down from one generation of fans to the next.[413]

One unique aspect of science fiction as a commercial genre of literature is that many, if not most, of its writers entered the field through the portal of science fiction fandom and retain contacts with fans and readers after the writers have become professionals. A perusal of the published memoirs or online reminiscences of prominent writers will uncover many accounts of youthful involvement in science fiction fan clubs, writing or editing fanzines (amateur publications), attending conventions, and other social activities centered around science fiction. Linda Fleming notes that ever since the beginnings of organized science fiction fandom in the late 1920s, "the fans of one generation have provided authors and editors for the next," and the most intensively active fans, those who publish fanzines and organize or regularly attend conventions, tend to fill the ranks of the field's professionals, becoming authors, editors, publishers, academic scholars of the field, memorabilia collectors and sellers, or illustrators.[414] Award-winning science fiction writer Roger Zelazny pointed out in 1975 that "science fiction is unique in possessing a fandom and a convention system that make for personal contacts between authors and readers, a situation that may be of peculiar significance. … The psychological process involved in this should be given some consideration as an influence on the field."[415] Writers do not merely write for those whom they perceive to be their paying audiences (or their editors); they also write to entertain and satisfy themselves, writing the sorts of books they themselves enjoy reading. Thus, a bit of demographic background on the science fiction readership would cast light on both the writers of science fiction and the audience they seek to serve.

Albert Berger conducted a survey of the 3,400 attendees of the World Science Fiction convention, held in September 1973. He distributed 3,000 questionnaires, of which

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[413] Linda Fleming, "The American SF Subculture," *Science-Fiction Studies* 4, no. 3 (November 1977): 264–265.

[414] Ibid., 264–268.

[415] Roger Zelazny, "Forum: Some Science Fiction Parameters: A Biased View," *Galaxy* 36 (July 1975): 11.

282, or about 8%, were returned. He found that 78% (rounded) of his respondents reported that they had begun intensive reading of science fiction between the ages of 9 and 15, with another 5% having begun before the age of 9. Males made up 65% of his respondents and females 35%. This gender balance skewed less heavily male than earlier surveys, conducted between 1949 and 1975 by science fiction magazines of their readerships, which Berger cites for comparison; these surveys ranged from a low of 71% male to a high of 95% male. Berger notes that the age breakdown of his respondents most likely skewed older than the overall science fiction readership, due to the costs of convention membership, lodging, and travel to Toronto (as with most large science fiction conventions held in North America, many of the attendees reside in the United States). Even so, the bulk of his respondents fell into the lower age categories, with 36% being between 18 and 25 and 41% being between 25 and 35 (8% were between 13 and 17). Seventy-one percent reported being single (either never married, divorced, widowed, or co-habitating) and 29% reported being married. The respondents were a highly-educated group; 53% percent reported either a bachelors or a graduate degree, and another 24% reported having completed at least some college education. Nearly half of those who reported a college degree or attendance at college stated their major field of study to be the physical or biological sciences.[416] In the early 1980s, *Locus* Magazine, a monthly "semi-prozine" that serves as the unofficial newspaper of the science fiction and fantasy community, did an in-depth survey of nearly a thousand of their readers (who tend to be the most committed of science fiction fans, or science fiction professionals—writers, editors, illustrators, acquiring librarians, publishers—seeking to keep current with news and developments in their field). The survey results indicated that most respondents made their initial deep commitment to science fiction reading between the ages of 10 and 14, following an initial "gateway" exposure to science fiction concepts, in less sophisticated forms, in comic books, movies, or television shows. Many respondents reported that, around the age of 12, they entered into a period of intensive reading of science fiction that lasted anywhere from several months to years, in the latter case typically ending upon graduation from high

[416] Albert I. Berger, "Science-Fiction Fans in Socio-Economic Perspective: Factors in the Social Consciousness of a Genre," *Science Fiction Studies* 4, no. 3 (November 1977): 232–238.

school. Thereafter, intensive reading of science fiction (up to several books per week) declined to more occasional, recreational reading of the material.[417] (As anecdotal backing for the results of this survey, my own pattern of science fiction readership followed this template nearly exactly. My earliest exposure to science fiction was to Japanese monster movies and *Planet of the Apes* films as a young child, which was followed by voracious reading of science fiction from the ages of 12 to 17. This period also included my earliest attempts to write and sell science fiction stories, my publication with friends of a fanzine, and my attendance at conventions, including BosCon II, the 1980 World Science Fiction Convention. My reading of science fiction declined by at least two-thirds when I entered college and was required to read a far broader range of materials, including non-science fiction literature, but I never abandoned science fiction as recreational reading and have continued reading it, in various forms, into my fifties.)

Publishers Weekly solicited the Gallup organization to survey the buyers of science fiction books in 1987. The resulting survey found that the gender breakdown of science fiction book consumers was 60% male and 40% female, and that 65% of these consumers were under the age of 35, with 67% having attended college (compared with only 60% of the overall book-buying market).[418] The survey did not break out science fiction books from fantasy, media tie-in, or sword-and-sorcery books.

Locus Magazine, mentioned earlier, conducts an annual survey of its readers. Although not representative of the science fiction readership (readers of *Locus* skew towards professionals involved in the field, aspiring writers looking for market information, and heavily involved fans seeking news about writers, new books and magazines, and upcoming or recent conventions), the long-term annual nature of the *Locus* polls allows for a view of the evolving nature of the readership over a period of decades. Over the eight-year period from 1971 to 1979, an average of 81% of respondents to the poll were male, versus an average of 19% female. Over the eleven-year period from 2006

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[417] Peter Graham, "The Golden Age of Science Fiction is Twelve," in *Age of Wonders: Exploring the World of Science Fiction*, ed. David G. Hartwell (New York: Tom Doherty Associates, 1996), 18–20.

[418] Leonard Wood, "Who Buys Science Fiction?" *Publishers Weekly*, November 4, 1988, 41.

to 2016, an average of 62% of respondents were male and 38% were female, showing clear growth in the female percentage of *Locus* readership, reflecting the concurrent growth in the numbers of women writers and editors in the field. Even so, the gender breakdown is not much different from that of the 1987 *Publishers Weekly* survey and still indicates a predominately male audience. The median age of the *Locus* readership has climbed steadily over past decades. In 1971, it was 24 years; in 1979, 28; in 2006, 42; and as of 2016, the median age had reached 46; however, this change comes with a caveat—in 1971, *Locus* Magazine was one of very few regular sources of information on the science fiction field (the other sources being book reviews and an occasional page on upcoming or past conventions in one of the "big three" science fiction magazines, *Astounding/Analog*, *The Magazine of Fantasy and Science Fiction*, and *Galaxy*, whose status as one of the "big three" was lost to *Isaac Asimov's Science Fiction Magazine* in the mid-1970s), so even young fans would have been motivated to subscribe; whereas in 2016, media sources, especially no-cost Internet sources, for information on the science fiction field are both numerous and widely available, and only a more specialized audience, those seeking timely information on market conditions and opportunities,(i.e.,) working or aspiring professionals, needs to pay for *Locus*'s coverage. In 1979, 77% of respondents were college graduates, 30% with advanced degrees. In 2016, these figures had climbed even higher, with 86% being college graduates and 44% having advanced degrees. In 1979, 36% of respondents reported being married; in 2016, reflecting the older average age of respondents, 58% reported being married. In 1979, 51% of respondents reported buying six or more hardcover science fiction books per year, and 29% reported buying six or more paperback science fiction books per *month*. As of 2016, the corresponding figures had risen to 58% for hardbacks (five or more purchased per year) and fallen to only 7% for paperbacks (five or more per month), with the fall-off in paperback purchases being recouped by purchases of eBooks (which had not been available, of course, in 1979). In 1979, 68% of respondents reported having attended at least one science fiction convention, with 40% reporting having attended a World Science Fiction Convention. As of 2016, the corresponding figures had risen to 75% (at least one SF convention) and 44% (a World Science Fiction Convention), most likely reflecting both the larger number of conventions

held in the U.S. in 2016 as opposed to 1979 and the increased household incomes, on average (and thus more money available for optional, leisure spending), of respondents.[419]

Taken altogether, these various surveys and observations point to a science fiction readership that is predominately male, highly educated, frequent book purchasers, and whose members enter their fascination with science fiction in early adolescence, experience intense interest in the field (characterized by voracious reading habits) for periods ranging from a few months to half a dozen years or more, and who then retain a less intense yet loyal interest in the field into adulthood. Involvement in fandom inculcates an in-group/out-group dynamic, and fannish traditions are passed down from one generation to the next, with the current generation's fans providing a "feeder team" population from that emerges the next generation's science fiction professionals. Earlier cohorts of this readership may have skewed younger and less likely to be married than current cohorts, although this shift may be overstated by the demographics of the *Locus* Magazine readership. Science fiction writers, unique among popular fiction writers, benefit from a high familiarity and close association with their audience, due both to the fact that, likely, those writers were somewhat recently fans themselves and that most working writers frequently attend science fiction conventions and interact directly with fans and/or correspond with readers.

In responding to the perceived (and remembered) psychological needs of this audience, science fiction writers have often focused on power fantasies. These plots center around variously deprived or socially disadvantaged (but intrinsically superior) protagonists who manage, primarily through their own intelligence, cunning, and grit, to achieve the prominence that their intrinsic (but previously unrecognized or ignored) superiority merits. Alternatively, or concurrently, the protagonist manages to win the heart of the previously dismissive girl/scientist's daughter/beautiful alien princess. Or our hero achieves a satisfying revenge on his tormentors (some plots manage to incorporate all three power fantasies—a trifecta!). An especially popular subtype of the science fiction power

[419] *Locus*, "1979 Locus Survey," *Locus* 12, no. 10 (November 1979): 8–9; *Locus*, "2016 Locus Survey Results," *Locus* 77, no. 3 (September 2016): 66–68.

fantasy involves the protagonist(s) discovering special powers or abilities, hitherto unsuspected, which emerge suddenly at the onset of adolescence. These newly emerged powers or abilities allow the downtrodden protagonist(s) to achieve the types of success he (usually a he, although recent decades have seen more science fiction writers focusing on heroines as protagonists) has always wanted most, whether that be the establishment of a new, improved social order (with the previously despised/denigrated protagonist on top), successful escape from persecution or imprisonment/slavery, a life of heroism and public admiration, or even ascension to the status of messiah who redeems/perfects the world. Early exemplars of this type of power fantasy plot in science fiction, featuring hidden supermen or genetic mutants, include A. E. van Vogt's *Slan* (a series of magazine stories published in novel form in 1946), Henry Kuttner's and C. L. Moore's *Mutant* (a series of magazine stories published in novel form in 1953 under the pseudonym Lewis Padgett), and Wilmar H. Shiras's *Children of the Atom* (also 1953). Later classics of this sub-genre include Alfred Bester's *The Stars My Destination* (1957, previously published as *Tiger! Tiger!* in 1956), whose protagonist is cruelly abandoned to die in space, but who discovers that this trauma elicits the emergence of world-changing teleportation abilities that allow him to achieve revenge on his enemies, and Robert Heinlein's best-selling *Stranger in a Strange Land* (1961), whose protagonist is raised on Mars, develops incredible mental and physical powers, is brought to Earth as a curiosity, and gathers a mass following before being persecuted and killed, but is then regarded by his followers as a messiah.[420]

This sub-genre of science fiction has achieved mass cultural penetration and popularity through the vehicle of Marvel Comics' *X-Men* franchise, in both its comic book and movie manifestations (not to mention the video games and the proliferation of merchandise, in collectible "action figures"—dolls for boys). The X-Men are all genetic mutants, whose special, "X-tra" powers manifest during adolescence; they are heroes who serve as the protectors for and advocates of Earth's persecuted mutant minority. Creators Stan Lee and Jack Kirby, as well as subsequent writers, artists, and screenwriters, have used the X-Men's experiences as a metaphor for racial, ethnic, and religious persecution

[420] Brian Stableford, "Mutants," in *The Encyclopedia of Science Fiction*, 847; Brian Stableford, "Superman," in *The Encyclopedia of Science Fiction*, 1180–1183.

and social and political discrimination.[421] Many plots revolve around the struggle between the X-Men, who seek benign co-existence between mutants and homo sapiens, and the Brotherhood of Evil Mutants, founded by mutant villain/antihero Magneto (who, nearly twenty years after his introduction in 1963, was revealed to be a survivor of the Nazi Holocaust), which seeks to overthrow the dominion of ordinary humans and achieve world mastery. The Brotherhood is often described as a mutant terrorist group, the mutant equivalent of Stokely Carmichael's Black Panthers, versus the X-Men's more moderate Martin Luther King acolytes.

B. SOCIOLOGICAL AND DEMOGRAPHIC DATA ON TERROR GROUP LEADERS AND FOLLOWERS

As the prior Section indicates, many science fiction writers cater primarily to an audience of socially maladjusted, sexually frustrated, often resentful young men, offering them power fantasies as balms for psychological wounds resulting from rejection, bullying, shyness, social ostracism, and general inability to achieve the success they feel is their due. Who caters to a somewhat similar audience of young men? *The founders and organizers of terror groups*.

An impressionist view of familiar terror groups tends to back up this observation. Politically-oriented, national liberation-focused terror groups (such as the Palestine Liberation Organization prior to the Oslo Accords, or the Tamil Tigers) offer opportunities to achieve honor and heroism, as well as redress from perceived persecution, humiliation, and lack of political agency, for young men belonging to ethnic, racial, or cultural groups that lack a state of their own. Islamicist terror groups (such as al Qaeda, Islamic State, or Hamas) offer their followers redress from what they perceive as centuries of unjust humiliation of Muslims by unbelievers, opportunities to achieve holy martyrdom climaxing in ascension to Heaven and the welcoming arms of 72 beautiful virgins, and the satisfactions of adventure, danger, revenge, and domination. Apocalyptic religious terror cults such as Aum Shrinrikyo offer their followers the emotional satisfaction of believing themselves members of a blessed elect, superior to all non-select, non-believers and

[421] Rob Hansen, "X-Men," in *The Encyclopedia of Science Fiction*, 1355.

entitled to enact violence upon them to hasten the End of Days. Violent Christian Identity groups provide their followers the emotional enticement of being welcomed into a realm of secret, esoteric knowledge, the knowledge that the world is, Manichean-style, divided between the forces of Good and the forces of Evil, the former being the White Race, who are the true Tribes of Israel, and the latter being the false, usurping, present-day Jews and their minions, the Mud Peoples, whose vile influence must be combatted if the White Race is to survive annihilation. In the view of the members of these groups, *they are the heroes of their stories*, not the villains they are considered by most outsiders. Their stories, with a few changes in settings and technology, could conceivably be published as conventional science fiction adventure novels. The *behaviors* of terror acolytes certainly differ enormously in degree from those of science fiction fans, but how different in kind are their *preferred fantasies*, emotionally and motivationally, from those of diehard fans (again, short for "fanatics") of the X-Men and their ilk?

Do the available demographic data on terror group organizers and their followers bear out these impressionistic observations of similarities between this population and the most intense sector of the science fiction readership, those readers for whom science fiction authors target their stories and novels? To an extent, yes, it does. Since the 1970s and the rise of terrorism as a contemporary phenomenon of pressing urgency, academics and researchers of various stripes (political scientists, psychologists, sociologists, and conflict specialists) have attempted to assemble descriptive typologies of terror groups and terrorists. They have attempted to apply explanatory theories from their various disciplines to terrorists' behavior, in hopes of formulating instruments that might allow for predictions of involvement in terror activities by individuals or communities, and, as an underpinning to these more ambitious efforts, to simply collect demographic data on those involved in terror. A report prepared by the Federal Research Division of the Library of Congress in 1999, *The Sociology and Psychology of Terrorism: Who Becomes a Terrorist and Why?*, cautions that most efforts by scholars to create a profile of the "typical" terrorist have achieved mixed success, at best, due to the wide variations in motivations that may lead to politically- or religiously-inspired violence or threats of violence against non-military targets, and variations in the sociocultural environments from which such motivations

arise. The authors of the report, which summarizes prior work on the categorization of terror and terrorists and theories regarding the drivers of terrorism, state that there may be as many differences between members of the broad fraternity of terrorism as there are similarities. Yet this cautionary note has not stemmed the efforts of researchers to ferret out those similarities.[422] The Library of Congress study details a pioneering profile compiled in 1977 by Charles A. Russell and Bowman H. Miller, which was based upon the socioeconomic backgrounds of 350 terror group leaders and followers who were active between 1966 and 1976. The individuals studied included terrorists from eighteen terror groups in Argentina, Brazil, Germany, Iran, Northern Ireland, Italy, Japan, the Palestinian Territories, Spain, Turkey, and Uruguay, a comprehensive sampling of terror groups active during that decade. Russell's and Bowman's profile showed the terror operative to most typically be a single male (males made up 80% of those sampled) between the ages of 20 and 25 (with followers of Palestinian, Japanese, and German terror groups tending toward the younger end of this overall age cohort), predominately middle or upper-middle class, with either a university degree or some college education. Leaders and older members often came from highly prestigious professions, such as university professors, doctors, lawyers, bankers, journalists, engineers, and even mid-ranking government bureaucrats.[423]

Several researchers have attempted to facilitate the task of creating terrorist profiles by focusing on subsets, national, ideological, religious, or temporal, of the terrorist population and describing one subset at a time, then, in some instances, comparing various subsets. In 1990, Jeffrey S. Handler used socioeconomic data provided by the Federal Bureau of Investigation (FBI) regarding 280 persons known to have been involved in terror activities or terror groups in the 1960s or 1970s to develop profiles of leftwing and rightwing American terrorists from those decades (for the purposes of his analysis, Handler decided to not include members of nationalist/separatist groups, such as terrorists focused

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[422] Rex A. Hudson, *The Sociology and Psychology of Terrorism: Who Becomes a Terrorist and Why?* (Washington, DC: Federal Research Division, Library of Congress, September 1999): 43.

[423] Ibid., 46–52.

on Puerto Rican independence).[424] Handler found that the gender balance differed significantly between rightwing and leftwing groups. Although the FBI survey indicated that the majority of all surveyed terrorists were male, the rightwing groups skewed far more heavily male (88.8%) than the leftwing groups (53.8% male), which Handler hypothesizes was due to feminism being a leftwing ideology, making leftwing causes more attractive to Western women, versus rightwing ideology that emphasizes traditional gender roles, with females subordinate.[425] Regarding educational achievement, within leftwing groups, both leaders and followers tended to be highly educated, with about three-quarters of both cohorts having attended undergraduate or graduate school, whereas within rightwing groups, slightly more than half of the leadership cadre had attended undergraduate or graduate school, as opposed to less than six percent of the followership.[426] Regarding socioeconomic status, Handler found that most rightwing terrorists tended to come from middle- or lower-class backgrounds, whereas leftwing terrorists tended to emerge from middle- or upper-class backgrounds.[427] Thomas Strentz, a Special Agent assigned to the Behavioral Science Instruction and Research Unit of the FBI Academy, performed a similar profiling analysis in 1988, although he broadened his field of 1960s and 1970s terrorists to include Europeans and Asians, not just Americans, and he also included Middle Eastern terrorists of the 1980s. He found that the leftwing terrorists of the 1960s and 1970s tended to be highly educated members of the middle or upper-middle class, many of them having been recruited into a terror group during their college attendance, with leadership and membership split between males and females, and leaders tending to be 25–40 years of age and followers 20–25 years of age.[428] Strentz's profiles of the leaderships and followers of rightwing terrorist groups closely track Handler's. Leaders were males, middle

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[424] Jeffrey S. Handler, "Socioeconomic Profile of an American Terrorist: 1960s and 1970s," *Terrorism* 13, no. 3 (1990): 200–203.

[425] Ibid., 203–204.

[426] Ibid., 205.

[427] Ibid., 211.

[428] Thomas Strentz, "A Terrorist Psychosocial Profile: Past and Present," *57 FBI Law Enforcement Bulletin* 13 (Quantico, VA: FBI Academy Behavioral Science Instruction and Research Unit, April 1988), 15.

class, aged 35 to 50, with some college education, and followers were males, lower or lower-middle class, aged 20–50, with limited formal education. Both cadres belonged to their communities' predominant ethnic and religious groupings, and both tended toward a subjective experience of social or economic failure/setback.[429] Strentz's profile of Middle Eastern terror groups focused on leftwing or nationalist groups, predating (apart from Hezbollah in Lebanon) the emergence of Islamicism as a motivating factor and suicide terrorism as a primary tactic. Within these groups, leaders were male, middle class, aged 30–45, with a college education, while followers were male, lower class and from a large family of 9–15 children, aged 17–25, and poorly educated or illiterate.[430]

Jeff Victoroff, writing in 2005, offers a useful summary of demographic characteristics of various terrorist groups that have been gathered in studies carried out since the work of Russell and Miller, Handler, and Strentz. N. Hassan's 2001 study of approximately 250 members of Hamas or Islamic Jihad, covering the 1996–1999 period, found these members' ages to be between 18 and 38 and that many were middle class in origin. A 2003 study by A. Pedahzur, A. Perliger, and L. Weinberg of 80 Palestinian suicide bombers found the terrorists' mean age to be 24.5 years and their mean socioeconomic status (on a 10-point scale, with 10 being highest) to be 5.97, or in the upper half. M. Sageman's 2004 study of 102 Salafi terrorists hailing from either Indonesia, Morocco, Algeria, France, Egypt, or Saudi Arabia found their median age at their entrance to their terror group to be 25.69 years, with 55% of them coming from middle class backgrounds and 18% from upper class backgrounds; also, 71% had at least some college education, and 43% were professionals (this study is biased towards the leaders of these groups, rather than the followers).[431]

Various psychological, sociological, and political science theories have been advanced in attempts to explain why certain individuals resort to terrorism at certain times

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[429] Ibid., 18–19.

[430] Ibid., 18.

[431] Jeff Victoroff, "The Mind of the Terrorist: A Review and Critique of Psychological Approaches," *Journal of Conflict Resolution* 49, no. 1 (February 2005): 8–9.

and under certain conditions. Some of these theories have suggestive overlaps with the socio-psychological portrait of the typical science fiction reader/fan that I have pieced together from personal knowledge, surveys, and the observations of other writers and analysts. Narcissism theory suggests that terrorism may be a psychological reaction to narcissistic ego injuries, primarily experiences of humiliation, rejection, or abandonment, that result in episodes of narcissistic rage. Several observers of terrorist group followers suggest that many are "timid, emotionally damaged adolescents," rather than aggressive, dominating psychopaths.[432] The formulators of Humiliation-Revenge theory offer a similar explanation, focusing, in , on repeated cycles of oppression, humiliation, and reaction in the Arab world.[433] Novelty-seeking theory suggests that terrorism especially appeals to those individuals with powerful needs for stimulation and attendant risk-seeking behaviors, since it embeds the individual in a web of dangerous, often thrilling activities far outside the mainstream of normal social interactions. Researchers in this area suggest that the high percentage of terror group followers whose ages fall within adolescence or young adulthood is due to developmental phenomena of those ages, during which novelty-seeking, sexual frustrations, and attraction to risk-taking are typically at their height.[434] Jeff Victoroff, in his review of these and other theories of terroristic behavior, offers the following critique of the Rational Choice theory of terrorism, or that terrorism is a rational, logical mechanism chosen by actors to accomplish various political, social, or religious goals. He states that emotional peculiarities and strong passions often overcome rational choice, that

> the lure of bravado and romance of risk, the self-destructive urge for "success" in likely failure with or without the utility of martyrdom, the Svengali-like influence of charismatic leaders on either side whose followers march in maladaptive columns, the power of rage to better reason, the blindness of ambition, the illogic of spite, or the frenzy of revenge all may contribute to the stochastic occurrence of surprising scenarios. … (R)ational choice theories cannot predict idiosyncratic responses. Policy recommendations that predict deterrence of terrorist acts are only as

[432] Ibid., 23–24.

[433] Ibid., 29.

[434] Ibid., 28.

> valuable as their capacity to anticipate the extraordinary variability and adaptability of humans.[435]

James Dingley, in his 1997 essay "The Terrorist—Developing a Profile," refers extensively to historian L. O'Boyle's postulation of "The Problem of an Excess of Educated Men in Western Europe, 1800–1850," which O'Boyle formulated to try to explain the sociopolitical unrest and revolutions that characterized parts of the first half of the nineteenth century in Europe. O'Boyle points out that the transition from an agrarian to an industrial society required ambitious young men to seek more formal education to prosper and enter the newly expanded middle class, yet various European economies and societies did not always offer adequate opportunities for this new mass of educated young men to achieve gainful employment in their fields, which led to widespread dissatisfaction and frustration with existing social orders.[436] Dingley builds upon O'Boyle's work to put forth his "overeducated and underemployed" theory of terrorism causation. He points out that, just as O'Boyle's nineteenth century revolutionaries were predominately highly-educated professionals in non-technical, non-scientific fields (those trained professionals with scientific or technical skills were more highly in demand in nineteenth century industrial economies than those with backgrounds in the liberal arts), so do demographic surveys of twentieth century terrorists (those of Russell and Miller) show that college-educated terrorists are predominately those with degrees in the social sciences or humanities. What Dingley terms anarcho-ideological terrorists (akin to Handler's and Strentz's leftwing terrorists) are overeducated, underemployed would-be cosmopolitans who want to change their societies to replace a frustrating, unfulfilling social order with a new order that will properly reward and recognize the talents of persons like themselves. Those whom Dingley terms nationalist terrorists, or modern-day Luddites (having much overlap with Handler's and Strentz's rightwing terrorists), are social conservatives who are overeducated in skills and trades that are being made obsolete by the march of modernity, and thus rendered under- or unemployed by the modernizing of their society's economy.

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[435] Ibid., 16–17.

[436] James Dingley, "The Terrorist – Developing a Profile," *International Journal of Risk, Security and Crime Prevention* 2, no. 1 (January 1997): 29.

They wish to restore traditional economic arrangements (often agrarian-based) and traditional social, cultural, and religious mores, or set up barriers to further changes they feel are threatening their familiar home environments.[437] Dingley's "overeducated and underemployed" theory dovetails with Narcissism theory and Humiliation-Revenge theory by bringing sociological factors to bear on psychological states. Frustrated hopes and aspirations (in leftwing, anarcho-ideological instances, expectations that one's years of higher education will lead to fulfilling careers and lives in an increasingly cosmopolitan society; in rightwing, nationalist instances, expectations that one's training and education in traditional occupations and/or in a traditional language/religion/culture will result in a satisfying life akin to that lived by one's parents or grandparents) lead to frustration with the existing social structure, or to fear of and anger towards undesired social/cultural/economic changes. This frustration/humiliation/narcissistic wound leads, in turn, to acts of violence meant to either achieve or restore the desired social/economic equilibrium.

C. COMPARING DEMOGRAPHIC DATA ON THE SCIENCE FICTION READERSHIP/FANDOM WITH THAT OF COHORTS OF TERROR GROUP LEADERS AND FOLLOWERS

Based upon the studies just synopsized, I have assembled a rough comparison of the demographic and psycho-social profiles of the science fiction readership and various categories of terrorist group leaderships and followers (see Table 17):

[437] Ibid., 32–34.

Table 17. The Science Fiction Readership/Fan Group Demographically Compared With Various Categories of Terrorist Group Leaderships and Followers

Social Category	Gender	Typical Age Range	Social Class	Highest Educational Level Achieved	Motivations For Belonging
Science Fiction Readership/Fans	Majority male	Most fervent involvement between 12 and 17 years; readership usually declines during college years but may pick up during adulthood	Middle or upper-middle class	Very highly educated; virtually all achieve undergraduate degree, many also achieving advanced degrees	Social ostracism by "mainstream" peers resulting in seeking alternative social circle; strong sense of in-group/out-group dynamic; desire for entertainment, novelty-seeking; balm for narcissistic wounds to be found in power fantasies on offer in many SF stories and novels; intellectual stimulation; freedom to engage in unusual behaviors in social settings (costuming, discussions of far-out concepts, fanzine publications, being a nerd/geek in the open); aspiration to become a science fiction professional (writer, editor, artist, collector, screenwriter)
Terrorists, General, 1966–76 (Russell and Miller)	Mostly male	20–25 years	Middle or upper-middle class	College educated, with many leaders having a professional background	Desire to replace repressive government with Marxist-Leninist state; desire for political independence, autonomy, or the establishment of a new ethno-national entity; desire to achieve revenge on Israel or to expel Jews from the Holy Land

Social Category	Gender	Typical Age Range	Social Class	Highest Educational Level Achieved	Motivations For Belonging
Leftwing Terrorist Leaders, 1960s & 1970s (Handler / Strentz)	Male & female	25–40 years (Strentz)	Middle or upper-middle class	College educated, many with advanced degrees	Desire to create Marxist-Leninist "utopia;" desire to overturn existing social order that does not adequately recognize and reward them, and replace with a new social order which will; feminists' desire for a more gender-equitable society
Leftwing Terrorist Followers, 1960s & 1970s (Handler / Strentz)	Male & female	20–25 years (Strentz)	Middle or upper-middle class	College educated	Desire to create Marxist-Leninist "utopia;" desire to overturn existing social order which does not adequately recognize and reward them, and replace with a new social order which will; thrill-seeking; feminists' desire for a more gender-equitable society
Rightwing Terrorist Leaders, 1960s & 1970s (Handler / Strentz)	Male	35–50 years (Strentz)	Middle class (Handler); middle or lower-middle class (Strentz)	Just over fifty percent with some college education	Desire to preserve or restore traditional racial/ethnic/gender privileges and to counter perceived threats from racial/ethnic/religious minorities; desire to avenge perceived social or economic setback or failure; desire to return to a perceived "better" past
Rightwing Terrorist Followers, 1960s & 1970s (Handler / Strentz)	Male	20–50+ years (Strentz)	Middle, lower-middle, or working class	Virtually none with college education; most grade school only	Desire to preserve or restore traditional racial/ethnic/gender privileges and to counter perceived threats from racial/ethnic/religious minorities; desire to avenge perceived social or economic setback or failure; desire to return to a perceived "better" past; fetishization of weapons and violence

Social Category	Gender	Typical Age Range	Social Class	Highest Educational Level Achieved	Motivations For Belonging
Leftist/Nationalist Middle Eastern Terrorist Leaders, 1980s (Strentz)	Male	30–45 years	Middle class	College educated	Desire to achieve own nation-state; desire to replace repressive government with Marxist-Leninist state; desire to achieve revenge on Israel or to expel Jews from the Holy Land
Leftist/Nationalist Middle Eastern Terrorist Followers, 1980s (Strentz)	Male	17–25 years	Lower class	Poorly educated, illiterate	Desire to achieve own nation-state; desire to achieve revenge on Israel or to expel Jews from the Holy Land
Islamist Terrorists, 1990s & 2000s (Hassan / Pedahzur, Perliger, and Weinberg)	Mostly male	18–38 years (Hassan); mean 24.5 years (others)	Mostly middle class (Hassan); mean SES of 5.97 on 10 pt scale (10 being highest)	Not stated; presumably at least some with college degrees	Desire to restore traditionally Islamic societies; desire to achieve revenge on Israel or to expel Jews from the Holy Land; desire to avenge perceived humiliations from the West
Islamist Terrorist Leaders, 1990s & 2000s (Sageman)	Male	Mean 25.69 years	Mostly middle or upper class	Anecdotally, many with college educations (al Qaeda 9/11plotters, for example)	Desire to restore traditionally Islamic societies or the historic Caliphate; desire to avenge perceived humiliations from the West

The cohort of science fiction readers/fans may thus be said to be demographically congruent with the majority of terror cohorts studied in terms of male gender, age of initiation into the group, age of highest intensity of involvement, or age when surveyed (for science fiction readers/fans, adolescence to young adulthood; for most terror cohorts, late adolescence to young adulthood, with leaders tending to be 5–10 years older than followers), social class (middle or upper-middle class), and educational attainment (science fiction readers/fans and leftwing terrorist leaders of the 1960s and 1970s achieving the highest levels of formal education, many members of these two cohorts completing advanced degrees, but the majority of the other cohorts, with a few exceptions, having at least some college education). The cohort of science fiction readers/fans bears the greatest similarity in demographic traits to leftwing terrorist leaders and followers of the 1960s and

1970s and leftist/nationalist Middle Eastern terrorist leaders of the 1980s, with a somewhat reduced similarity to rightwing terrorist leaders of the 1960s and 1970s. This cohort bears less similarity to Islamist terrorists of the 1990s and 2000s, and the least similarity to the leftist/nationalist Middle Eastern terrorist followers of the 1980s. Theoretical psychological motivations of narcissistic injury and response, a Humiliation-Revenge cycle, and novelty-seeking appear to have salience for both the science fiction readership/fan cohort and the majority of the terrorist cohorts, with the key difference being how each cohort or set of cohorts acts upon those motivations. Nearly all science fiction readers/fans, if they act upon those motivations at all, do so in the realm of fiction and the imagination, making use of the products of science fiction (stories, novels, films, TV shows, comic books, video games, role-playing games, and cosplay/costuming activities) to fantasize that they, or a fictional character with whom they identify, are avenging a humiliation; addressing a narcissistic wound caused by rejection, abandonment, or lack of deserved recognition; proving to the world that they are special, talented, and worthy of leadership, wealth, fame, and sexual gratification; or are capable of changing the world to make it more fair, equitable, just, righteous, or pure (or perhaps just less boring). Members of terrorist cohorts may also engage in these fantasizing activities, but they go beyond fantasizing to what was once called "propaganda of the deed," actual acts of violence or threats of violence against non-combatants, meant to spread fear and intimidation and to influence public opinion or political events.

This difference may possibly be due to psychological traits that members of terrorist cohorts do not share with science fiction readers/fans, perhaps a propensity towards violence, a lack of an ability to empathize with the suffering of their victims, heightened impulsiveness and aggression, reduced impulse control, or traumatic developmental events (such as an early loss of a parent or estrangement from a parent). Alternatively, it may be that members of terrorist cohorts are more likely than science fiction readers/fans to be among the ranks of Dingley's "overeducated and underemployed," and that once science fiction readers/fans join the ranks of the "overeducated and underemployed," they become more likely to become involved in radical politics and/or terrorism. Of course, the differences between how science fiction

readers/fans and the varying terrorist cohorts respond to shared motivations may be due to "all the above." Jeff Victoroff believes "(t)errorist behavior is probably *always* determined by a combination of innate factors, biological factors, early developmental factors, cognitive factors, temperament, environmental influences, and group dynamics… The degree to which each of these factors contributes to a given event probably varies between individual terrorists, between individual groups, and between types of groups."[438]

Presumably, not all terrorist cohorts will be equally likely to select the products of future-shock, Promethean technologies for their terroristic assaults. The various terrorist cohorts previously described may be roughly divided into those that are *future-oriented* (leftwing groups; those nationalist/separatist groups that are not trying to recreate an idealized past; Dingley's anarcho-ideological terrorists) and those that are *past-oriented* (rightwing groups; Islamists; Dingley's nationalist-Luddites). Future-oriented terrorists share their temporal orientation with science fiction readers/fans, and the latter are more demographically like the future-oriented terrorist cohorts than they are to past-oriented cohorts. Future-oriented terrorists are more likely than others to be intrigued by emerging, over-the-horizon technologies and how those technologies could be used to serve their ends. Past-oriented terrorists, due to their conservative nature and outlook, are less likely to seek out innovative, emerging technologies for their use and more likely to resort to tried-and-true implements of destruction. Thus, when engaging in a "devil's toy box" analysis, the analytical team would be wise to focus primarily on the threats, capabilities, and emergence of cohorts of future-oriented terrorists.

One cohort of future-oriented terrorists that has not yet been discussed is millenarian terrorists, those terror groups and individual terrorists who look ahead to a coming religious End-of-Days event (a messianic arrival, reckoning with the wicked, and deliverance of the just), or a future socio-political catastrophe that only the elect will survive. One such millenarian cult/terror group with especial relevance to the psycho-motivational overlap between the science fiction readership/fandom and future-oriented terrorist cohorts is Japan's Aum Shinrikyo.

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[438] Victoroff, "The Mind of the Terrorist," 34.

D. CASE STUDY: AUM SHINRIKYO—A SCIENCE FICTION-BASED TERROR CULT THAT SOUGHT TO HASTEN THE APOCALYPSE THROUGH THE MALIGN USE OF ADVANCED TECHNOLOGIES

On March 20, 1995, Japan was shocked by a coordinated sarin gas attack carried out on the crowded Tokyo subway system. Had the formulation of sarin used been more potent, or the delivery system more effective, thousands of deaths could have resulted, rather than the 11 fatalities, dozens of serious injuries, and several thousand more minor injuries and illnesses that did ensue from the attacks on the densely-packed subway cars. The perpetrators were five members of the Aum Shinrikyo cult, whose charismatic leader, Shoko Asahara (real name: Chizuo Matsumoto), had predicted a coming apocalypse that would destroy much of Japan, an apocalypse that the increasingly paranoid and psychopathic cult leader, bitterly disappointed by the failure of his organization to achieve legitimate election to Japan's government, had decided to precipitate himself. His acolytes, eager to see Asahara's prophecies come true, worked to actualize those dire predictions.[439]

Asahara's background reads as though it were a novel written by a twentieth century Charles Dickens. Victim of infantile glaucoma, he lost the use of one eye and had only partial vision in the other. His poor parents sent him to a government-run school for the blind, where, due to his limited but invaluable remaining sight, he came to exercise great informal authority over the totally blind students. Using both his physical advantage over his fellow students and his bullying, authoritarian personality, he convinced them to pay him for guiding them and for providing other services, earning several thousand dollars that way prior to his graduation from high school. Upon opening an acupuncture clinic, he quickly became a successful businessman, albeit one known for his megalomaniac ambitions of becoming Japan's prime minister (or even the supreme overlord of a kingdom entirely populated by robots); however, this business, like another that followed, was derailed by Asahara's proclivities for fighting and for becoming involved in scams and crime. He took the National college entrance exams and failed. Around that time, he taught himself Chinese and immersed himself in study of Eastern religions and the political philosophy of Mao Zedong. In 1984 he founded a yoga center, Aum, Inc., and within a few

[439] Hudson, *The Sociology and Psychology of Terrorism*, 133–139.

years the center had attracted three thousand followers. This success encouraged Asahara to begin portraying himself as a holy man. He embarked on a spiritual odyssey through the Himalayas and returned to his followers, now claiming to have achieved spiritual bliss and to have developed extraordinary mystical abilities. In 1987, he renamed his network of yoga centers, which had previously been secular in their orientation, Aum Supreme Truth, or Aum Shinri Kyo, and reoriented them to focus on him as the center of a personality cult. The newly developed organization, Aum Shinrikyo, adopted trappings and conceptual underpinnings from several sources that would be familiar to science fiction fans—Japanese anime (animated films and television shows), computer games, cyberpunk and fiction, Isaac Asimov's classic series of science fiction novels from the 1940s, the *Foundation* trilogy. Asimov's series, highly influential on subsequent science fiction that dealt with interplanetary empires, focuses on Hari Seldon, a mathematician who discovers the new science of psychohistory, which allows for accurate forecasts of future events. Seldon foresees a coming apocalypse that will result in the fall humanity. To preserve civilization from this disaster, he forms a secret society, the Foundation, which combines scientific and religious precepts, and recruits the greatest minds of his time to become its founding cadre of scientist-priests. He intends for the Foundation to go underground during the ravages of the civilizational disaster and to then rise from the ruins and lead mankind in rebuilding and perfecting its societies. Asahara saw himself as a real-life Hari Seldon. Like Seldon, he claimed the ability to see the future, and his Aum Shinrikyo mirrored the Foundation in that it sought to recruit Japan's (and later Russia's) finest scientific minds, acquire advanced technological resources and capabilities, and prepare for a coming apocalypse, from whose ashes it would arise as a world-dominating authority.[440]

A person with no knowledge of the history of Aum Shinrikyo might well scoff at Asahara's ambition to attract large numbers of scientists and technologists to a cult of personality based on an esoteric mishmash of Buddhism, Hinduism, Taoism, tantric yoga, science fiction, and Maoism. Are not scientists highly intelligent persons dedicated to rationality, the study of observable phenomena, and the scientific method? Yet the

[440] Ibid., 134–136.

backgrounds of Asahara's most prominent disciples, those who killed for him or who developed his weapons of mass destruction programs, are studded with impressive educational achievements in science and technology fields. Seiichi Endo, who served as Aum's minister of health and welfare, had carried out genetic engineering experiments in his biology graduate course of study at Kyoto University. Given control of Aum's biolab, he researched biowar uses of botulism and Ebola virus, and Asahara assigned him the task of creating the sarin nerve gas that was used in the March 20, 1995 Tokyo subway attack. Kiyohide Hayakawa, Aum's second in command, held a MS degree in environmental planning; he sought assistance in Russia for the sect's development of seismological and nuclear weaponry. Dr. Ikuo Hayashi, a respected physician before joining Aum, had graduated from one of Japan's top medical schools; as Asahara's minister of healing, he twisted medical science to extract funds from recruits or to punish members suspected of disloyalty, using drugs and electroshock treatments to erase memories or to torture and kill. Fumihiro Joyu, Aum's foreign affairs minister, had acquired a graduate degree in telecommunications and studied artificial intelligence, but quit his position at the Japanese Space Development Agency to become more involved in Asahara's sect; he was the man primarily responsible for recruiting Aum's Russian followers. Hideo Murai, Asahara's science and technology minister, studied astrophysics and computer programming at Osaka University's Physics Department before performing R&D work at Kobe Steel. He was attracted to Aum Shinrikyo after reading one of Asahara's books. He developed several pseudoscience inventions that sold widely to sect followers and netted Asahara millions of dollars, including an Astral Teleporter and an electroshock cap called the Perfect Salvation Initiation hat. His unsuccessful attempts at militarizing advanced technology for the cult included his effort to create a botulinus toxin, along with microwave-, laser-, and nuclear-based weaponry. He was the mastermind behind the Tokyo subway attack. Masami Tsuchiya, who served as the leader of Asahara's chem-warfare team, had been enrolled in Tsukuba University's doctoral program in chemistry and organic physics, one of the most prestigious STEM programs in the country, where his professors described him as brilliant and he researched methods for altering molecular structure through applications of light. Tsuchiya traveled to Russia to study Russian biowarfare techniques and created Aum's

stockpile of sarin gas based on a Russian formula. He also developed a supply of VX chemical warfare agent for the sect.[441]

The chemical and biological weapons these men developed for Aum Shinrikyo were not used only for the Tokyo subway attack. In April 1990, following the sect's humiliating repudiation in Japan's parliamentary elections, Asahara directed his bio-chem-warfare team to spray poisonous botulin on the grounds of the U.S. naval base located in Yokosuka, home of the Navy's Seventh Fleet. The botulin turned out to have been defectively produced; only this happenstance prevented massive deaths among U.S. military personnel.[442] On June 27, 1994, Hideo Murai spearheaded a sarin gas attack on the home and neighborhood of a judge who had ruled against Aum Shinrikyo. This resulted in seven fatalities and more than 150 non-fatal poisonings. It was a "practice run" for the Tokyo subway attack.[443]

Researchers who have studied the Aum Shinrikyo cult have suggested that Japan's rigid cultural expectations of its young people, that they will excel academically and then devote their lives to the furtherance of the economic prospects of the corporation that hires them, leads to a desire on the part of some young people to rebel against the dictates of their parents, peer group, and society at large. They also suggest that Japanese culture's focus on the well-being of the community and of economic collectives such as corporations, as opposed to the self-actualization and spiritual growth of individual Japanese, may have made the counter-cultural aspects of Asahara's cult—its fusion of many different world religious traditions, its elevation of "low culture" products such as anime and science fiction, the claims of its founder and leader to vast supernatural powers, and its promise to its followers that they would be members of a select group that would survive an upcoming apocalypse—especially attractive to young, educated, alienated Japanese wanting to rebel against social conformity.[444]

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[441] Ibid., 141–151.

[442] Ibid., 136–137.

[443] Ibid., 138.

[444] Ibid., 133–135.

Yet I feel it would be a mistake to intellectually cordon off Aum Shinrikyo and its like as a peculiarly Japanese phenomenon, which can only arise within the context of the culture, constraints, and pressures of life in Japan. Prior to the Tokyo subway attack, Aum Shinrikyo's leadership claimed to have 30,000 followers in Russia, as opposed to 10,000 acolytes in Japan itself.[445] Russian society differs enormously from that of Japan. One explanation for the involvement of so many Russians in the exotic, foreign cult of Aum Shinrikyo in the early 1990s could be Dingley's "overeducated and underemployed" thesis. Russia, prior to the dissolution of the Soviet Union in 1991, was a highly educated society, boasting many talented, well-trained scientists and engineers, many of whom had worked in the defense and space sectors. Upon the abolition of communism and a tumultuous transition to an at least partially market-based economic system (marked by much cronyism), the Russian economy greatly contracted, and funding for national defense, the space program, and all associated R&D efforts was slashed. This economic contraction put many Russian scientists and engineers out of work, cut their salaries, or rendered their continued employment tenuous, as well as dashed the career hopes of tens of thousands of Russian students then in the STEM higher education pipeline. Dingley's theory suggests that being "overeducated and underemployed" raised the propensity of Russians to find a malignly countercultural group such as Aum Shinrikyo perversely attractive, both for the opportunities it provided for them to "strike back" at a society that had hurt and disappointed them and for the ego-soothing balm it provided by telling them they were members of an elect.

Critics of the notion that an Aum Shinrikyo-like organization might take root in the United States can point to the fact that the cult's effort to recruit American acolytes in the early 1990s failed miserably, succeeding only in winning a few dozen followers in the area of New York City.[446] They may also point to the FBI's enviable record of success in infiltrating and dismantling or minimizing various groups of violent extremists, including leftwing and Marxist terror groups in the 1960s and 1970s and rightwing, racist terror

[445] Ibid., 133.

[446] Ibid., 137.

groups during those and subsequent decades. Yet a powerful, wealthy, and influential American analog to Aum Shinrikyo has existed since the 1950s: The Church of Scientology, founded by science fiction writer L. Ron Hubbard. Had Hubbard, an Asahara-like figure in many ways, been more interested in forcing an apocalypse than in amassing wealth and infiltrating the motion picture industry, his Scientologists might now be better known for use of weapons of mass destruction than for the action films and romantic misadventures of famed acolyte Tom Cruise. Also, current trends in the U.S. economy and society may give increasing salience to Dingley's "overeducated and underemployed" thesis in the American context. A 2014 study conducted by Jaison R. Abel and Richard Deitz, economists employed by the Federal Reserve Bank of New York, found that rates of underemployment for both college graduates as a whole (those aged 22–65 and possessing at least a bachelor's degree) and for recent college graduates (those aged 22–27 and possessing at least a bachelor's degree) rose steadily from 2003 to 2014, with the rate for graduates as a whole being 34% in 2014 and the rate for recent graduates in that year being 46%. Abel and Dietz define "underemployment" for college graduates as working in a job/occupation for which fewer than half the occupants hold at least a bachelor's degree.[447] Advances in machine learning, artificial intelligence, and robotics stand to make unemployment and underemployment worse for college graduates. In March 2017, global advisory firm PwC, as part of its *UK Economic Outlook* report, estimated the shares of employment in various sectors in Great Britain that will be at risk of being replaced by automation by the early 2030s. For administrative and support services, they pegged that figure at 37.4%; for professional, scientific, and technical jobs, 25.6%; for public administration and defense jobs, 32.1%; for information and communications jobs, 27.3%; and for financial and insurance jobs, 32.2%. The report's overall figure for jobs at risk from automation, including blue collar and manufacturing jobs, was estimated to be 30%, and the report's author estimated that a somewhat larger overall percentage of jobs in the

[447] Jaison R. Abel and Richard Deitz, "Are the Job Prospects of Recent College Graduates Improving?" *Liberty Street Economics* blog of the Federal Reserve Bank of New York, September 4, 2014, http://libertystreeteconomics.newyorkfed.org/2014/09/are-the-job-prospects-of-recent-college-graduates-improving.html#.Vko9H6SYVgo.

United States was at risk of abolishment due to automation than in the U.K.[448] Fred Destin, a former general partner at Accel and currently organizing his own venture capital fund, goes more dire in his June 2017 prediction, estimating that advances in machine intelligence and automation will eventually obliterate up to 70% of white-collar jobs, with employees of law and insurance firms being most harshly impacted.[449]

American college graduates aspiring for white collar careers stand to be increasingly squeezed from several directions. Not only will advances in automation likely mean they will be increasingly under- or unemployed, but they are and will likely continue to be burdened by sizable college loans, which are non-dischargeable under U.S. bankruptcy laws. As of 2017, approximately 70% of college graduates exited school carrying student debt. More than $1.4 trillion in student loans is owed by approximately 44 million Americans, 60% of whom do not expect to be able to finish paying off their loans until sometime in their forties. A study of graduates of Wisconsin colleges and universities indicated that graduates take 19.7 years to finish paying off loans undertaken for a bachelor's degree and 23 years to finish paying for loans undertaken for a graduate degree.[450]

Taken together, these trends suggest that the "overeducated and underemployed" phenomenon stands to grow worse, not better. Japanese police were relatively fortunate in the early 1990s in that Aum Shinrikyo operated under the twentieth century paradigm for developing advanced weaponry: the cult needed to operate its own bio-lab and acquire components from a network of legitimate suppliers, sometimes through illegal and clandestine means, such as inserting followers into key companies or recruiting insiders,

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[448] "Up to 30% of Existing UK Jobs Could be Impacted by Automation by Early 2030s, But This Should be Offset by Job Gains Elsewhere in Economy," *PwC* website and blog, March 24, 2017, http://pwc.blogs.com/press_room/2017/03/up-to-30-of-existing-uk-jobs-could-be-impacted-by-automation-by-early-2030s-but-this-should-be-offse.html.

[449] Shona Ghosh, "One of Europe's Most Influential Investors Gave a Brutal Example of How AI Could Wipe Out White-Collar Jobs," *Business Insider* website, June 13, 2017, http://www.businessinsider.com/fred-destin-artificial-intelligence-will-wipe-out-white-collar-jobs-2017-6.

[450] Abigail Hess, "This is the Age Most Americans Pay Off Their Student Loans," *CNBC.com* website, July 3, 2017, https://www.cnbc.com/2017/07/03/this-is-the-age-most-americans-pay-off-their-student-loans.html.

or by setting up front corporations to buy sensitive materials; and sometimes through legal means, such as purchasing companies outright.[451] All these activities required the cult to engage with the outside physical world and created paper trails, potential leads for investigators to follow; however, future Aum Shinrikyos will likely be more virtual than physical in nature, more likely to gather in cyberspace than in a yoga ashram. Imagine thousands of outraged, frustrated, "overeducated and underemployed" acolytes of a future apocalyptic cult using Promethean technologies to download schematics for weapons of mass destruction and to manufacture those implements of death in the shelter of their own homes, freed from the necessities of working in a lab, acquiring components from outside firms and organizations, or traveling to foreign lands to gain expertise. Contemplating this, you may begin to recognize the scope of the challenges to be faced by homeland security and law enforcement institutions in coming years.

[451] Hudson, *The Sociology and Psychology of Terrorism*, 137.

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