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Anticipating Rare Events: Can Acts of Terror, Use of Weapons of Mass Destruction or Other High Profile Acts Be Anticipated?

A Scientific Perspective on Problems, Pitfalls and Prospective Solutions

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Contributing Authors:

Gary Ackerman (U MD START), Renee Agress (Detica), Beth Ahern (MITRE), Fred Ambrose (USG), Victor Asal (SUNY, Albany), Elisa Bienenstock (NSI), Alan Brothers (PNNL), Hriar Cabayan (RRTO), Bradley Clark (TAS), Allison Astorino-Courtois (NSI), Sarah Beebe (PAL), Eric Bonabeau (Icosystem), Sarah Canna (NSI), Jeffrey Cares (Alidade), Alan Christianson (Detica), Frank Connors (DTRA), Lee Cronk (Rutgers), Laurie Fenstermacher (AFRL), Daniel Flynn (ODNI), Nic Grauer (AFRL), Bud Hay (ret), Carl Hunt (DTI), Gary Jackson (SAIC), Kathleen Kiernan (RRTO), Lawrence Kuznar (NSI), Kenneth Long (IPFW), Elizabeth Manak (PAL), Donna Mayo (PA Consulting), Brian Nichols (Detica), Sue Numrich (IDA), Jennifer O'Connor (DHS), John Patterson (Detica), Krishna Pattipati (U Conn), Stacy Lovell Pfautz (NSI), Randolph Pherson (PAL), Terry Pierce (DHS/USAFA), CAPT Brett Pierson (Joint Staff J8), Bob Popp (NSI), David C. Porter (Detica), Karl Rethemeyer (SUNY, Albany), Tom Rieger (Gallup Consulting), Maj Joseph Rupp (Joint Staff J3), David Schum (GMU), Alan Schwartz (PAL), Ritu Sharma (PA Consulting), Steven Shellman (William and Mary, SAE), Sandy Thompson (PNNL), Pam Toman (NSI), David Vona (NSI), Paul Whitney (PNNL), and Katherine Wolf (PNNL)

Coordinated and edited by: Nancy Chesser (DTI) – Nancy.Chesser@js.pentagon.mil

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Preface

By Captain Todd Veazie USN, SOCOM

The body of work before you should be viewed as the commencement of a journey with a somewhat murky destination – an exploration of terra incognita. Indeed the challenge addressed in this white paper, that of anticipating "rare events" is daunting and represents a gathering threat to national security. The threat is supercharged by the increasing lateral connectedness of global societies enabled by the internet, cell phones and other technologies. This "connected collective" as Carl Hunt has termed it, has allowed violent ideologies to metastasize globally often with no hierarchical, command-directed rules to govern their expansion. It is the emergent franchising of violence whose metaphorical "genome" is exposed to constant co-evolutionary pressures and non-linearity that results in continuous adaptation and increasing resiliency making the task of effectively anticipating their courses of action all the more difficult.

So what distinguishes a rare event in the context of national security? The easy response is to describe them as unlikely actions of high consequence and for which there is a sparse historical record from which to develop predictive patterns or indications. I would offer that the "rare events" problem is rooted in the principles of *fourth generation warfare* (4GW) characterized by decentralized, non-state or transnationally-based antagonists applying political, economic, social and militarily networked strategies in complex and protracted engagements directed against populations and cultures. These are often low-intensity conflicts that employ terrorism to achieve the greatest psychological impact.[1] By examining the struggle between a state and a violent ideological network there is an implied *asymmetry* toward which we have developed a consuming preoccupation over the past seven years. In truth, asymmetric warfare is not a new concept but it is the *idiosyncrasy* of the 4GW threat that makes it peculiarly dangerous. Since these are rare events, the study, much less the prediction, of idiosyncratic asymmetric warfare is more an abstraction than an operationally relevant approach. This must change.

We are all familiar with the fine print in the semi-annual financial investment reports that states that "past performance is no guarantee of future results." But it is past performance that gives us our best glimpse of possible futures. Indeed it is the absence of well-understood historical patterns for which there is a rich corpus of supporting data (evidence) and observable indicators that makes this challenge all the more unnerving. So it becomes unmistakable that traditional approaches alone will not be enough.

When addressing the rare events problem among the underlying challenges facing the national security community are the highly distributed nature of these adversary networks and the endemic non-linearity of the idiosyncratic asymmetric event course of action chain. This implies that a massively data intensive, wide search space (global, multi-lingual) must be interrogated to sense inimical perturbations in the mosaic of these networks and overcome what could be an almost indiscernible signal through the noise. We must reform the way that we examine and marshal "evidence" and constantly explore the predictive qualities of discrete variables alone, or in combinations, or in their absence. We will need to overcome biases in hypothesis generation where instinct and intuition may only distract us from the correct path. It points to the necessity for "smart automation" support to the analytical community both on the "front end" data ingestion and "back end" analytical techniques. Also present is the need to "marshal all the elements of national power to shape rather than just react, and anticipate as well as innovate"[2] in order to provide strategic warning of "an existing threat, either in terms of intention or capability, and provide sufficient time for policymakers to assimilate, plan, and provide resources for offsetting responses."[3] To succeed we must employ practitioners from across the government, academia and the private sector brought together in collaborative environments that are as yet, unconceived and "emphasizes the importance of approaching national security challenges as multiple risks – such as the possibility of nuclear or bioterrorism – that may never occur but need to be managed and minimized, rather than as an overriding threat that can be eliminated."[4] The contributors to this white paper were expertly selected from across many specialties. They are perfectly suited to colonize this new domain and to initiate this very necessary conversation.

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1 "Fourth Generation Warfare," Wikipedia, 22 September 2008, http://en.wikipedia.org/wiki/Fourth_generation_warfare (11 November 2008).

2 Project on National Security Reform Cites Need for Restructuring of U.S. National Security System," Project on National Security Reform, 29 July 2008, http://www.pnsr.org/web/module/press/pressID/106/interior.asp (11 November 2008)

3 John W. Bodnar, Warning Analysis for the Information Age: Rethinking Intelligence Process (Washington, DC: Joint Military Intelligence College Center for Strategic Intelligence Research, 2003), ix.

4 Project on National Security Reform

Executive Summary (Hriar Cabayan)

Author: Hriar Cabayan
Organization: OSD DDR&E RRTO
Contact Information: hriar.cabayan@osd.mil

This white paper covers topics related to the field of anticipating/forecasting specific categories of “rare events” such as acts of terror, use of a weapon of mass destruction, or other high profile attacks. It is primarily meant for the operational community in DoD, DHS, and other USG agencies. It addresses three interrelated facets of the problem set:

1. How do various disciplines treat the forecasting of rare events?
2. Based on current research in various disciplines, what are fundamental limitations and common pitfalls in anticipating/forecasting rare events?
3. And lastly, which strategies are the best candidates to provide remedies (examples from various disciplines are presented)?

This is obviously an important topic and before outlining in some detail the overall flow of the various contributions, some top-level observations and common themes are in order:

1. We are NOT dealing here with physical phenomena. Rather these “rare events” that come about are due to human volition. That being the case, one should not expect “point predictions” but rather something more akin to “anticipating/forecasting” a range of possible futures. Furthermore, the difficulties are compounded because these forecasts, to be relevant, have to be done on a global scale and chronologically as far in advance of the rare event occurrence as possible. Therefore, caution is in order when dealing with these phenomena and the reader should approach this topic with a critical disposition and eyes wide open. Hubris is NOT a recommended frame of mind here!
2. The reader will be disappointed if she/he expects a linear menu-driven approach to tackle these problems. Brute force approaches are NOT feasible. Or stated differently, the problem set is NOT amenable to a “blueprint” driven reductionist approach! The approach taken here is heavily tilted towards a dynamic methodological pluralism commensurate with the magnitude and scale of the problem set. Emphasis is placed on judiciously incorporating uncertainties and human foibles and attacking the problem set with approaches from various disciplines. These involve analytical, quantitative, and computational models primarily from the social sciences.
3. On the other hand, the reader who is disposed to eclectic approaches to this very critical problem set will NOT be disappointed. Inductive, deductive, and abductive approaches will be discussed along side themes from gaming theories. Key to all this is a mix of creative intuition and the age-old scientific method. The concepts from the fields of complex adaptive systems, emergence, and co-evolution all contribute to a sustained strategy. The process of objective multi-disciplinary inquiry is at the heart of any success in this challenging domain.
4. The vast majority of the data for such assessments come from open sources. The reader will encounter approaches that take advantage of such data. Equally important

is development of an appreciation of the "cultural other" within their own "context" and "discourse". This is critically important. On the other hand, this massive amount of data (the good, the bad, and the ugly!) brings with it its own share of problems that will need to be dealt with. There is NO free lunch in this business! In all circumstances however, a prudent frame of mind is to let the data speak for itself!

5. The points made so far point to a multi-disciplinary strategy as the only viable game in town. On top of that, we don't expect single agencies to be able, on their own, to field these multi-disciplinary teams. Agile, federated approaches are in order. The reader who approaches this topic with that frame of reference will resonate with the report.

6. Finally, and most importantly, rare events, by their very nature, are almost impossible to predict. At the core of this white paper is the assumption that we can do a better job of anticipating them, however, if we learn more about how our brain works and why it gets us into trouble. Although we may not be able to predict rare events, we can reduce the chances of being surprised if we employ measures to help guard against inevitable cognitive pitfalls.

The reader should also be forewarned that the approaches discussed in this paper are by no means a "be all…end all". All contributors would agree that the approaches presented here are to varying degrees "fragile" and will need further nurturing to reach their full potential.

The reader should not be put off by the size of the report. The articles are intentionally kept short and written to stand alone. You are encouraged to read the whole report. However even a selective reading would offer its own rewards. With that in mind, all the contributors have done their best to make their articles easily readable.

We open up the white paper with an article by Gary Ackerman (1.1). It serves as a scene setter. Gary makes the point about differences between strategic and point predictions; points out general forecasting complexities; and, as the reader will be reminded throughout the rest of report, the limitations of purely inductive approaches (i.e., the happy-go-lucky turkey all year until the unexpected on Turkey Day!). These inductive approaches work best when coupled with other complementary approaches. He makes the point that forecasting must rely on information sharing, extensive collaboration, and automated tools, a point that will be made by other contributors.

From this scene setter, we're ready to assess how various disciplines have been treating this genre of problem set. We start with an anthropological perspective by Larry Kuznar (2.1). The realization that a broader understanding of culture is necessary to meet modern national security challenges is a "no-brainer" and has naturally refocused attention toward anthropology. Historically, the human ability to use past experience and creative imagination to model possible futures provides humans with a powerful and unique ability for prognostication. The article makes the point that when creative imagination departs from empirically verifiable social processes, and when beliefs in predictions become dogmatic and not adjustable in light of new data, the benefits of prediction are lost and whole societies can be destroyed due to a collectively held fantasy.

From an anthropological perspective, we move to philosophical and epistemological considerations (i.e., what we know and how we know it) by Ken Long (2.2). The paper summarizes recent results in the epistemology of the social sciences which indicate that the employment of case-by-case studies in combination with theories of limited scope involving a select intersection of variables can produce results that are far more useful than more traditional research.

In the following paper (2.3), Carl Hunt and Kathleen Kiernan provide a law enforcement (LE) perspective to the challenges criminal investigators and police officers on the street face in anticipating rare events. Similarities and differences with intelligence analyses are highlighted. The authors discuss the three "I's" in LE (i.e., Information, Interrogation and Instrumentation) in the context of our problem set and highlight the role of fusion of intuition, probability and modeling as enhancements to the three "I's".

We next move to the all important evolutionary theory and the insights it can provide.c In his contribution (2.4), Lee Cronk makes the case that although it deals mainly with the common and everyday, evolutionary theory may also help us forecast rare events, including rare human behaviors. Understanding evolutionary theory's contributions to this problem requires an understanding of the theory itself and of how it is applied to human behavior and psychology. He describes concepts such as costly signaling theory; i.e., terrorist organizations actively seeking recognition for their acts, giving them an additional reason to send hard-to-fake signals regarding their collective willingness to do harm to others on behalf of their causes. An appreciation of the signaling value of terrorist acts may increase our ability to forecast them. He also describes the concept of mismatch theory; i.e., the idea that much of the malaise in modern society may be due to the mismatch between it and the kinds of societies in which we grew up. And finally he describes "the smoke detector principle" (i.e., early warning system) from the perspective of evolutionary theory.

We conclude this segment of the white paper with a military perspective provided by Maj Joe Rupp (2.5). He approaches rare events from the perspective of "crisis" level events. As such, understanding the nature of crises facilitates a better understanding of how rare events may be anticipated. He goes on to dissect the anatomy of crises by tapping a body of literature on the topic. Rather than view a crisis as a "situation", the phrase "sequence of interactions" is used. This implies that there are events leading up to a "rare event" that would serve as indicators of that event. Identification and understanding of these precipitants would serve to help one anticipate rare events. From a military perspective, anticipation of a truly unforeseen event may lie solely in maintaining an adaptive system capable of relying on current plans and available resources as a point of departure from which the organization can adjust to meet the challenge of the unforeseen event. In contrast to the Cold War planning construct, he introduces the concept of Adaptive Planning and Execution (APEX) which through technology, uses automatic "flags" networked to near-real-time sources of information to alert leaders and planners to changes in critical conditions and planning assumptions that warrant a reevaluation of a plan. All this calls for "agile and adaptive leaders able to conduct simultaneous, distributed, and continuous operations".

From here we move on to part 3 of this report to examine fundamental limitations and common pitfalls in anticipating/forecasting rare events. The opening article by Sarah Beebe and Randy Pherson (3.1) discusses the cognitive processes that make it so difficult to anticipate rare events; i.e., the things that help us efficiently recognize patterns and quickly perform routine tasks can also lead to inflexible mindsets, distorted perceptions, and flawed memory.

The next article (3.2) by Sue Numrich tackles the set of interrelated empirical challenges we face. The human domain is currently broken down and studied in a variety of disparate disciplines including psychology, political science, sociology, economics, anthropology, history and many others, all of which, taken as a whole, are needed to understand and explain the human terrain. These factors require an ability to share information in new ways. Moreover, the abundance of information sources in our internet-enabled world creates a problem of extracting and managing the information events and requires a balance between the amount of information acquired and the capability to process it into usable data.

No discussion of rare events is complete these days without due consideration to Black Swans! That challenge is taken on by Carl Hunt (3.3). Carl differentiates between true Black Swans (TBS, the truly unpredictable) from anticipatory black swans (ABS, which may be difficult but not impossible to anticipate), which is more in line with the topic of this white paper. He states that it's the questions as much as the answers that will lead to success in anticipating what we call Black Swans, regardless of category. Often these questions are posed in the form of hypotheses or assumptions that bear on the conclusions decision-makers take. We must also be willing to let go of prejudice, bias and pre-conceived notions. Carl reinforces a strong theme in this white paper namely that "Intuition and the Scientific Method" should synergize to help in tackling anticipatory black swans.

Having set the cognitive limitations, we next move to discuss remedies. The reader who has stuck with us so far will find the subsequent papers offering some guarded hope. For methodological purposes, we divide the solution space into two categories: front-end and back-end. These are discussed in turn by Fenstermacher/Grauer and Popp/Canna.

Laurie Fenstermacher and Maj Nic Grauer (4.1) start off by depicting the daunting task ahead not just as a "needle in a haystack" but as a "particular piece of straw in a haystack" (the perennial discouragingly low signal-to-noise problem!). They define "Front end" as the group of capabilities to retrieve or INGEST, label or CHARACTERIZE, apply specific labels, extract information, parameterize or CODE and VISUALIZE data/information. Besides the low "signal-to-noise" ratio challenge, there are other challenges such as languages other than English. In addition, the information is more often than not "unstructured" and multi-dimensional. They state firmly that there are no "silver bullet" solutions…but (and dear reader please don't despair!) there are genuinely a number of solutions. These can do one or more of the above functions and, in doing so, provide a force multiplier for scare human resources by enabling them to use their time for thinking/analysis and not data/information processing. They go on to describe promising capabilities in all front-end categories. Their parting claim is that properly employed as part of an "optimized mixed initiative" (computer/human) system, the solutions can provide a key force multiplier in providing early warning of rare events well to the "left of boom".

The following article (4.2) by Bob Popp and Sarah Canna provides an overview of the back-end solution space. Stated simply, the challenge here is how to make sense of and connect the relatively few and sparse dots embedded within massive amounts of information. They state that the IT tools associated with the back-end are the analytic components that attempt to meet this challenge and provide analysts with the ability for collaboration, analysis and decision support, pattern analysis, and anticipatory modeling. They go on to make the case that IT tools can help invert a trend – sometimes referred to as the "Analyst Bathtub Curve" – thus allowing analysts to spend less time on research and production and more time on analysis. They illustrate how several such tools were integrated in a sample analytic cycle.

Having introduced the broad concepts of front-end and back-end, we go on to discuss various promising remedies. The first article in this category (4.3) by Bob Popp and Stacy Pfautz discusses the landscape of Quantitative/Computational Social Science (Q/CSS) technologies that provide promising new methods, models, and tools to help decision-makers anticipate rare events. They describes the three main Q/CSS modeling categories; namely quantitative, computational, and qualitative techniques.

Kuznar et al (4.4) follow-up with a discussion of statistical modeling approaches. The challenge here is data sparseness. They emphasize a common theme throughout this white paper; namely that there is no guarantee that conditions and causal relations of the past will extend into the future. Furthermore, in the case of rare events, there is often precious little information upon which to base predictions. They do discuss state-of the-art methods to extract and structure data, impute missing values, and produce statistically verifiable forecasting of rare WMD terrorism activities. A key product from this effort is the identification of key factors (i.e., fingerprints, indicators, antecedents, or precursors) that are statistically related to increases in the probability of rare events occurrence.

We shift gears next with an article by Tom Rieger (4.5) on models based on the Gallup World Poll data This provides the ability to spot areas that are currently or could be at risk of becoming unstable, including pockets of radicalism. These can provide very useful avenues for narrowing down search spaces for origin and destination of rare event activities.

Having presented empirically based approaches to forecasting and the evaluation of the environmental factors from which they arise, we turn our attention next to the use of applied behavior-based methodology to support anticipation/forecasting. The author of this article (4.6) is Gary Jackson. Key to his argument is the assumption that if antecedents and consequences associated with repeated occurrences of behavior can be identified, then the occurrence of that behavior in the future may be anticipated when the same or highly similar constellations of antecedents and likely consequences are present. In the absence of adequate history, Jackson has developed a hybrid approach of behavioral data combined with subject matter expert (SME) generated scenarios. A neural network pattern classification engine is trained and used to generate hypotheses given real world injects.

In the following article (4.7), Sandy Thompson, Paul Whitney, Katherine Wolf, and Alan Brothers discuss a data integration framework for quantitatively assessing relative likelihood, consequence and risk for rare event scenarios. Current methodologies are limited as they are qualitative in nature, based on expert assessments, and elicited opinions. The authors advance structural models to organize and clarify rare event scenario assessments, including qualitative as well as quantitative factors. Benefits to intelligence analysts would include increased transparency into the analysis process, facilitation of collaborative and other parallel work activities, and mitigation of analyst bias and anchoring tendencies. They discuss concepts based on Bayesian statistics and the three primary factors that drive the analysis: the motivation and intent of the group directing the event, the capabilities of the group behind the attack, and target characteristics. They conclude their article by pointing out that the methodologies are intended to address and mitigate bias, reduce anchoring, and incorporate uncertainty assessments.

In the following article (4.8), Allison Astorino-Courtois and David Vona make the case that subjective decision analysis – viewing an adversary's choices, costs and benefits from his perspective – can provide invaluable assistance to the rare event analyst. Here "subjective" refers to a decision model designed according to how the decision maker views the world rather than the beliefs of the analyst. Such an analysis helps the analyst gain insight into three critical areas; namely motivation, intent, and indicators. The authors argue that such an approach is valuable because it forces the analyst to look at the issue of rare and dangerous events from the perspective of those deciding to engage in them.

In the next article (4.9), Elisa Bienenstock and Pam Toman provide an overview of Social Network Analysis (SNA) and propose a manner in which potential rare events may be recognized a priori through monitoring social networks of interest. In line with a common theme throughout this white paper, they emphatically state that SNA alone is not a sufficient perspective from which to anticipate the planning or imminence of a rare event. To be useful, SNA must be used as a component of a more comprehensive strategy requiring cultural and domain knowledge. They go on to state that SNA is both an approach to understanding social structure and a set of methods for analysis to define and discover those activities and associations that are indicators of these rare, high impact events. In particular, they focus their discussions on two insights from the field of social network analysis: 1) the innovation necessary to conceive of these rare events originating at the periphery of the terrorist network, and 2) the organization of an event and how it generates activity in new regions of the network.

Ritu Sharma, Donna Mayo, and CAPT Brett Pierson introduce in the next article (4.10) concepts from System Dynamics (SD) and systems thinking to explore some of the ways in which this technique can contribute to the understanding of "rare events". Their focus is on identifying the key dynamics that drive behavior over time and the explicit consideration of feedback loops. Starting with the by now familiar premise that building a model that can accurately predict the future is impossible, they go on to enumerate the benefits attributed to a System Dynamics model to help prepare for, and hopefully mitigate the adverse effects of, rare events such as understanding which rare events generate the most harmful impacts, highlighting the factors and causal logic that would drive a rare event, and lastly identifying the highest leverage areas for focus and mitigation. They conclude by stating that System Dynamics can integrate valuable experience, research, and insight into a coherent framework to help refine and accelerate learning, facilitate discussion, and make the insight actionable by identifying key leverage points and creating a platform to test impacts of various strategies.

The next article (4.11) by Carl Hunt and David Schum advances approaches that harness the science of probabilistic reasoning augmented by complex system theory in support of testing hypotheses for unforeseen events. Key assumptions here go to the heart of the challenge of forecasting rare events: nonlinearity of input and output; the ambiguity of cause and effect; the whole is not quantitatively equal to its parts; and that results may not be assumed to be repeatable. Adaptation and co-evolution are important features in this approach. The article stresses the role of curiosity and discovery in the process of abduction as a formal method of reasoning. We often deal with evidence that is typically incomplete, often inconclusive, usually dissonant, ambiguous, and imperfectly credible. When this occurs, we must apply some sort of probabilistic inference method to assess the effect a particular piece of evidence will have on our decision-making, even when there are no historical event distributions to assess – the authors discuss how this might be accomplished.

Eric Bonabeau in his contribution (4.12) re-states a now-common theme; namely our inability to predict low-frequency, high-impact events in human and manmade systems is due to two fundamental cognitive biases that affect human decision making. These are availability and linearity. Availability heuristics guide us toward choices that are easily available from a cognitive perspective: if it's easy to remember, it must make sense. Linearity heuristics make us seek simple cause-effect relationships in everything. He makes the case that to anticipate rare events we need augmented paranoia. His corrective strategies include tapping the collective intelligence of people in a group and tapping the creative power of evolution

At this juncture in the white paper we change course again and discuss the key role of gaming and its role in anticipating rare events. Although games cannot "predict" the future, they can provide enhanced understanding of the key underlying factors and interdependencies that are likely to drive future outcomes. There are four contributions in this section.

The first contribution (4.13), by Fred Ambrose and Beth Ahern, makes the case for moving beyond traditional Red Teams. They state that the conventional use of Red Teams is not to serve as an anticipatory tool to assess unexpected TTPs. Rather they are configured to test concepts, hypothesis, or tactics and operational plans in a controlled manner. They recommend instead modifying traditional red teams by acknowledging the importance of the professional culture of individuals who make up these teams augmented by consideration given to the knowledge, experience, skills, access, links, and training (KESALT) of people who may be operating against the blue teams. This can help alleviate failures on the part of Blue Teams to fully understand the role of "professional cultural norms" of thought, language, and behavior. They introduce the concept of Social Prosthetic Systems (SPS) and the value of integrating it into Red Team formation. SPS can help analysts to understand the roles that culture, language, intellect, and problem solving play for our adversaries as they form planning or operational groups in a manner similar to "prosthetic extensions". They point out that a red team based on the KESALT of known or suspected groups and their SPSs, can provide much greater insight into the most probable courses of action that such a group might devise, along with the greatest potential to carry out these actions successfully. In addition, such red teams can provide invaluable insights into and bases for new collection opportunities, as well as definable indications and warning. In this sense it can help create the basis for obtaining structured technical support for a blue team or joint task force and lead to unique training opportunities for joint task force officers. Such red team efforts can lead to unique training opportunities for joint task force officers; newly identified metrics and observables that can serve as unique indications and warnings, and even can anticipate both the state of planning and execution and the ultimate nature and target(s) of military or terrorist actions.

In the following article (4.14), Dan Flynn opens his contribution with a theme which is common by now: that standard analytic techniques relying on past observations to make linear projections about the future are often inadequate to fully anticipate emerging interdependencies and factors driving key actors toward certain outcomes. He posits that strategic analytic gaming is a methodology that can be employed to reveal new insights when complexity and uncertainty are the dominant features of an issue. Through strategic analytic games, events that are "rare" but imaginable, such as a WMD terrorist attack, can be explored and their implications assessed. In addition, strategic gaming can reveal emerging issues and relationships that were previously unanticipated but could result in future challenges and surprise if not addressed.

In his contribution to the role of gaming (4.15), Jeff Cares describes an innovative approach to planning for uncertain futures, called "Co-Evolutionary Gaming." His focus is on complex environments in which trajectories to future states cannot all be known in advance because of strong dependencies among states. He discusses problematic characteristics of existing gaming methods. He then goes on to highlight characteristics of a method for proposed scenario-based planning that more creatively explores the potential decision space. He introduces the concept of Co-evolutionary Gaming as a method of planning for uncertain futures with which players can quickly and inexpensively explore an extremely vast landscape of possibilities from many perspectives.

We end this series on gaming with a contribution by Bud Hay (4.16) who approaches gaming from an operational perspective. Instead of focusing on the worst possible case, he advocates addressing more fundamental issues, such as: What is the adversary trying to achieve? What are his overall interests and objectives? What assets are needed to accomplish those objectives? What are the rules of engagement? What alternative paths are possible to achieve success? He advocates an "environment" first and "scenario" second approach to gaming. He goes on to make the case that operational level gaming can be a valuable technique for planners and operators alike to anticipate surprise, evaluate various courses of action, and sharpen understanding of critical factors regarding potential crisis situations. By examining the congruence of capabilities and intent, it helps decision makers better anticipate rare events. All these can provide a contextual framework from which to postulate likely, and not so likely, terrorist attacks and to evaluate readiness and preparedness against them.

We shift gears again with a series of four articles that will round out the discussion of analytic opportunities in our remedy section. In the first contribution (4.17), Sue Numrich tackles the all-important issue of knowledge extraction. Sue's point of departure is that rare events of greatest concern arise in foreign populations among people whose customs and patterns of thoughts are not well understood, largely through lack of familiarity. The expert in such cases is someone who has spent considerable time living with and studying the population in question. The problem with relying on expert opinion is that it is only opinion and all observers, including subject matter experts have perspectives or biases. She tackles the issues of how to elicit expert opinion in a manner that adds understanding and not selecting the wrong experts or interpreting their statements incorrectly. She differentiates between SME elicitation and polling and the all important problem of finding the right experts. She goes on to tackle the issue of how best to structure the interviews and understanding the biases (ours and theirs!).

In the second in this series of articles (4.18), Frank Connors and Brad Clark discuss the important role of open source methods. They state the objective of open source analysis is to provide insights into local and regional events and situations. In this sense, open source analysis provides a tipping and cueing function to support all-source analysis. They go on to describe Project ARGUS, an open source capability to detect biological events on a global scale. A total of 50 ARGUS personnel are fluent in over 30 foreign languages. The scale of open source collection ranges from 250,000 to 1,000,000 articles each day with archiving of relevant articles. Machine and human translation is utilized in conjunction with Bayesian networks developed in each foreign language performing key word searches for event detection. They conclude by stressing that combining the open source data with other classified data sets is key to the overall evaluation.

The next contribution (4.19) by Randy Pherson, Alan Schwartz, and Elizabeth Manak focuses on the role of Analysis of Competing Hypotheses (ACH) and other structured analytical techniques. The authors begin with familiar themes for the reader who has stuck with us so far; namely, engrained mindsets are a major contributor to analytic failures and how difficult it is to overcome the tendency to reach premature closure. The authors go on to describe remedies such as Key

Assumption Check, Analysis of Competing Hypotheses (ACH), Quadrant Crunching, and The Pre-Mortem Assessment amongst others. Key to their argument is that the answer is not to try to predict the future. Instead, the analyst's task is to anticipate multiple futures (i.e., the future in plural) and identify observable indicators that can be used to track the future as it unfolds. Armed with such indicators, the analyst can warn policy makers and decision makers of possible futures and alert them in advance, based on the evidence.

We complete the series of articles on analytical techniques with a contribution by Renee Agress, Alan Christiansen, Brian Nichols, John Patterson, and David Porter (4.20). Their theme is that through the analyses of actors, resources, and processes, and the application of a multi-method approach, more opportunities are uncovered to anticipate a rare event and implement interventions that lead to more desirable outcomes. They stress the need for understanding the motivation of actors (Intent), their required resources (Capability), and the multitude of process steps that the actors have to implement (Access). While each of these items may or may not be alarming in isolation, the capability to identify a nexus of individuals and activities spanning the three areas can facilitate anticipating a rare event. However, anticipation becomes more difficult as time approaches the period of an execution. During and prior to the execution phase, the members of the group become OPSEC conscious and tend not leave a data signature. In line with their multi-method approach, they highlight the need for diverse fields such as econometrics, game theory, and social network analysis, amongst others.

At the beginning of this Executive Summary, it was stated that the challenges caused by rare events points to the need for a multi-disciplinary and multi- agency response built on the notions of transparency, bias mitigation and collaboration. The challenge of course is how to instantiate such concepts. This is taken up by Carl Hunt and Terry Pierce (4.21). They propose the integration of a collaboration concept built on a biologically inspired innovation known as the Flexible Distributed Control (FDC) Mission Fabric which can provide a potential substrate for organizational interaction. These interactions will occur through a setting known as the Nexus Federated Collaboration Environment (NFCE) that is described in detail in an SMA Report of the same name. The NFCE concept is adaptively structured, while empowering collaborative consensus-building. It is built on a multi-layer/multi-disciplinary decision-making platform such as the proposed FDC, while maintaining an orientation towards evolutionary design. The NFCE seeks to highlight and mitigate biases through visibility of objective processes, while accommodating incentives for resolving competing objectives. The authors point out that while these are lofty objectives, the means to integrate and synergize the attributes of the NFCE are coming together in bits and pieces throughout government and industry. The FDC is a proposed concept for creating an instantaneous means to distribute and modulate control of the pervasive flow of command and control information in the digital network. It offers the ability to focus and align social networks and organizations. The FDC weaves the virtues of social networking into a group-action mission fabric that is based on collaboration and self-organization rather than on layered hierarchy and centralized control. The article goes on to discuss the engine for executing FDC; i.e. the *mission fabric* – a new situational awareness architecture enabling collaboration and decision making in a distributed environment. The mission fabric is a network-linked platform, which leverages social networking and immersive decision making. From initial assessments, it appears that the NFCE and FDC may synergize effectively to empower interagency planning and operations.

Jennifer O'Connor brings this white paper to a close with an epilogue (4.22). She provides insightful comments on the whole enterprise of forecasting rare events and the role of identifiable pattern of precursors. She warns against confusing historical antecedents with generative causes. She provides a general framework and set of avenues by which one can think about rare-events-in-the-making in contemporary and futuristic terms. She stresses the need for an almost clinical detachment from our own basic information gathering and processing. She concludes by stating that the strategy of inoculating against "rare events" allows us to move off the well-worn path of generalizations based in the past and alarmist projections.

Two appendices to this white paper provide information relevant to the topic at hand. Appendix A describes a Table Top Exercise (TTX) planned and executed by DNI with support from SAIC and MITRE. It was designed to assess analytic methodologies by simulating a terrorist plot to carry out a biological attack. The Appendix goes on to summarize the main insights and implications produced by the exercise. In Appendix B, we reference an article by Harold Ford titled "The Primary Purpose of National Estimating" which addresses the Japanese attack on Pearl Harbor. It is very pertinent to the topic at hand and is alluded to by various contributors to this white paper.

Lastly, Appendix C provides definitions of acronyms used.

1. Introduction

1.1. WMD Terrorism and the Perils of Prediction (Gary Ackerman)

Author: Gary Ackerman
Organization: Center for the Study of Terrorism and the Responses to Terrorism (START), University of Maryland; The Center for Terrorism and Intelligence Studies (CETIS)
Contact Information: gackerman@start.umd.edu

'Prediction is very difficult, especially about the future.' - Niels Bohr (1885-1962)

'For man does not even know his hour: like fish caught in a fatal net, like birds seized in a snare, so are men caught in the moment of disaster when it falls upon them suddenly.'
Ecclesiastes 9:12

1.1.A. Introduction[1]

Who will pose the greatest weapons of mass destruction (WMD)[2] terrorist threat in the next twenty years, and how do we stop them? As responsible actors in the national security domain, we cannot sit on the sidelines with a smug fatalism and provide hollow commentary after a chemical, biological, radiological or nuclear (CBRN) disaster occurs. We place upon ourselves the burden of ameliorating some of the worst possible futures by acting to prevent and prepare for those CBRN attacks with the highest negative consequences for our nation. Thus, no matter how difficult this may prove, we are forced to explore the nebulous region of future environments and events.

Yet, the future is an 'undiscovered country', one that lies forever beyond the horizons of our perception and our present toils. It should be immediately apparent to all but the most solipsistic or fatalistic among us that uncertainties abound as we look further ahead in time, with myriad possibilities presenting themselves at each moment. While this should not be viewed as grounds for quiescence in the matter of trying to anticipate the threat of terrorists acquiring and using WMD, it is only by better understanding the impediments – both conceptual and practical – to accurate prediction of terrorist behavior that we can begin to address them and approach the threat more judiciously. The most important of these impediments are discussed below, separated into three types: 1) general obstacles to accurate forecasting, 2) problems inherent in anticipating human behavior and 3) particular complications in the context of WMD terrorism.

Before turning to these impediments, some preliminary notes are warranted. First, it is important to draw a distinction between two generic types of prediction that occupy opposite ends of a continuum. **Strategic prediction** seeks to describe general trends and the existence and magnitude of future threats, whereas **point prediction** focuses on the precise nature of future events, such as their exact timing and location or the identities of the individuals involved. Generally speaking, while even strategic prediction is often extremely problematic, the closer one moves towards seeking point predictions, the more difficult the enterprise of anticipation becomes.

Second, it is almost axiomatic that as one extends the temporal range of one's forecast, there is a greater level of uncertainty and anticipation becomes more complicated.[3] It is important, therefore, to **select the range of our forecasts with care**, so that we maximize the utility of a forecast by looking as far ahead as practically possible, while at the same time minimizing the attendant uncertainties by not seeking to gaze too far into the future. For example, it is not always necessary to expend a large amount of resources on attaining point predictions, or exploring the long-distant future, when strategic predictions of the medium term will suffice to guide a particular policy decision.

1.1.B. General Forecasting Complexities

1.1.B.1 The fundamental unpredictability of certain classes of events

Most of us are aware of the basic epistemic distinction, highlighted somewhat recently by former US Secretary of Defense Donald Rumsfeld, between 'those things we know that we don't know' and 'those things we don't know that we don't know', and we intuitively recognize that the latter present more of a problem than the former. However, both laypersons and policy makers often fail to realize that, when dealing with certain domains and systems, there are also **things that we absolutely cannot know**. At least since the work of Gödel,[4] philosophers and mathematicians have known that truth in some systems cannot be attained. Such concepts have only recently, however, begun to enter the social sciences and policy community, with notions of formal complexity[5] and "wicked" problems.[6] In this regard, David Snowden and Cynthia Kurtz[7] describe both the complex domain, in which patterns can emerge and be perceived retrospectively but cannot be predicted, and the chaotic domain, which is devoid of cause and effect. If a threat or potential threat is situated in one of these domains, the best strategy is not to attempt to predict the specifics of an outcome, but rather to ameliorate the threat through other means, for example, through a process of probing[8] or actions designed to restructure the environment in which the threat might arise. Terrorism, with its myriad interacting causes, dynamics and effects has many elements of a complex or wicked problem. We must remain open to the possibility, then, that at least parts of the threat we are considering may not even be forecastable in the traditional sense.

1.1.B.2 The past as an imperfect indicator of the future

Most attempts at the anticipation of future threats are based either implicitly or explicitly on extrapolations from past events. There is a variety of opinions on the utility of relying on past observables as indicators of future probabilities, ranging from viewing the past as an indispensable guide to the future, to believing that concentrating on past experiences is, to quote the philosopher Nassim Nicholas Taleb, like "drivers looking through the rear view mirror while convinced they are looking ahead,"[9] so that we are blind to substantial future changes. The objective state of affairs probably lies somewhere in between.

On the one hand, the philosophers Thomas Hobbes and David Hume resolutely demonstrated the inherent perils of induction (deriving general rules from a finite number of observations). In this regard, every innovation in terrorist operations or tactics – for example, the advent of suicide bombers – can be viewed as disrupting a previous trend, thereby frustrating those who had extrapolated from tactics seen prior to the innovation. Then there is the possibility of **large, sudden and unexpected shocks** to the system, what have been described variously as "Black Swans"[10] or "Wild Cards." New information, for example, that South Africa's former nuclear weapons program had produced more intact weapons than previously known and that these weapons had disappeared would represent a radical departure from previous experience and necessitate a complete reevaluation of the dynamics and probability of nuclear terrorism, as would the discovery of a (heretofore undreamt of) cheap and simple method of enriching uranium. A further complicating factor in relying on past experience is that **recorded history is**

an imperfect guide – we often place undue reliance on past *observables*: that is, we impute causation to those factors which we are able to measure and for which we have data. Since many less tangible aspects of past cases of terrorism are not recorded (for instance, a deceased terrorist leader’s true motivation for selecting CBRN over conventional weapons as opposed to what he told his followers), standard empirical analysis can lead to the development of false trend models and erroneous expectations of future events. Taking into account these caveats, it is no wonder that Brian Jenkins has argued that historical analysis provides no reliable basis for forecasting catastrophic terrorism involving WMD.[11]

On the other hand, while one would be foolish to view terrorism as in any way deterministic, it would be equally unwise to dismiss the lessons of our past experience completely. There are **many social and behavioral trends that are both observable and consistent**, and which can serve as a guide to anticipating future threats. Indeed, several behavioral disciplines, ranging from political science to criminology, rely heavily on the notion that the past bears some relevance to the future. While technologies and tactics might change prodigiously, many of the broader strategies, motivations and operational requirements of terrorists remain essentially the same as those of the past. The so-called “new terrorism” should therefore arguably be regarded more in evolutionary as opposed to revolutionary terms, an argument championed by Martha Crenshaw.[12]

The difficulty arises in discerning – prior to employing either quantitative or qualitative inductive techniques – between those aspects of the past record of terrorism or CBRN materials that can be extrapolated and those that are no longer likely to apply. For those areas where the past is unlikely to offer any useful guidance, we need to explore the use of new, non-frequentist and non-deterministic methods of analysis.[13] In sum, past and present events can serve as one (not the only) guide to anticipating future terrorist attacks and paying attention to current trends, while remaining sensitive to outlying possibilities and non-linear dynamics, is thus a prudent strategy.

1.1.B.3 Signal versus noise

The shrinking ratio of relevant signal to irrelevant noise is a more practical, although no less problematic, impediment to anticipating future threats. The maturation of the information revolution has not only meant that more information is available than ever before,[14] but also that that new developments, be they propaganda videos from a remote terrorist hide-out or maps of new genomes, can spread virally, and almost instantaneously, around the globe. The sheer volume of information makes it impractical for any individual to monitor every possible information source to detect early signs of impending disaster, even if we knew what signs to look for. Those seeking to predict future threats therefore **must rely on information sharing, extensive collaboration, and automated tools**. Unfortunately, none of these activities, whether alone or in combination, has thus far been implemented in a manner that would comprise a robust method for finding the needle of true threat in the haystack of superfluous data.

1.1.C. Impediments to Forecasting Human Behavior

The obstacles to anticipating the future mentioned above can apply to all events, whether those are brought about intentionally or are disasters that are “naturally” occurring. There are, however, several aspects of intentional acts by human beings that make behavioral prediction especially difficult and that come into play in any consideration of terrorism. First, **human**

threats are even more dynamic than natural processes (in the sense of being non-stochastic), in that human beings can adapt their behavior instantaneously, can strategize to avoid defenses and can concentrate their efforts on vulnerabilities. Second, human beings display an **exquisite diversity of action** rarely observed in the natural world, with innovation a common occurrence amongst human adversaries. Lastly, while many natural processes are quite well understood and at least relatively well-defined, the **study of human mental processes is in many ways still a rather nascent endeavor**, with few well-defined features and hardly any predictive tools with general application.

1.1.D. <u>The Added Complexity of Predicting Terrorism Using WMD</u>

In addition to the standard impediments to accurate forecasting, the threat of terrorists using WMD can present unique challenges to the predictive endeavor, since this threat lies at the nexus of two subjects – terrorism and advanced weapons – that are both characterized by high levels of dynamism. To begin with, **extreme behavior of any sort serves to exacerbate the baseline difficulties** of predicting human behavior. And fewer actors demonstrate more extreme behavior than the current crop of jihadists who are driven by recondite interpretations of sharia and who must engage in constant organizational reinvention as a matter of survival. Their future intentions and actions are thus likely to prove more difficult to gauge than those of the majority of law-abiding citizens. Another obvious (though no less serious) complication related to terrorists stems from the fact that terrorists and many other dangerous actors, by their very nature, operate clandestinely, thus making proactive identification and data collection more difficult, say, than studying the prospective response of consumers to the addition of a new ingredient in laundry detergent.

Then there are the singular dynamics associated with the technologies underlying weapons of mass destruction. Many of these technologies are growing and maturing[15] at an exponential rate.[16] This is particularly noticeable in the life sciences, but similar breakthroughs are being made almost daily in fields as diverse as metallurgical engineering (including nano-assemblers and rapid-prototyping) and chemical engineering (such as micro-reactors that can combine chemicals on a platform the size of a microchip). If the **rapid rate of technological development** might result in future capabilities that look very different from those of today, we must be careful not to act like the proverbial generals fighting the last war by preparing to confront only past (or indeed present) threats. As noted above, just because no terrorist has ever synthesized a pathogen from scratch, this does not mean that it will not happen sometime in the near future.

Lastly, when looking at the threat of terrorists using WMD, the sample size of previous events is (thankfully) zero, which means that any extrapolations cannot even be based upon the same dependent variable, but must rely on proxy measures, such as past unsuccessful terrorist plots involving WMD or past terrorist use of small-scale CBRN weapons. We must be **especially cautious about using similar events as proxies**, since the non-linearity of the behaviors of interest means that the variance of outcomes presaged by indicators that differ only in seemingly minor aspects can be substantial.

1.1.E. <u>Untangling the threads</u>

It might appear that, with impediments such as undependable proxies that may or may not be indicative of future threats and the possibility of unforeseen factors that we do not or even cannot discern, the entire enterprise of attempting to forecast the behavior of terrorists involving WMD is stillborn. Yet this is hardly so. A diverse array of techniques has emerged in recent years to assist planners and policymakers in assessing the future, several of which will be noted in the following sections of this document. In fact, following Confucius' dictum that "real knowledge is to know the extent of one's ignorance," we are now far better equipped to engage in the forecasting activity, so long as we bear the following in mind:

a) **We should not ignore current trends, but approach them judiciously** by admitting the possibility of outliers and maintaining a healthy index of suspicion regarding rapid changes.

b) **We need to meticulously monitor the dynamics of our adversaries, looking for early indicators of change in patterns of behavior.** For instance, we need to pay more attention to prevailing currents of jihadist ideology for signs of major shifts in the permissibility or appeal of certain tactics.

c) Once we come to terms with the fact that uncertainty is a pervasive element in any predictive effort, we can **manage the uncertainty by incorporating it into our strategies and policies, rather than attempting to minimize or eliminate it.**

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1 This piece is an adapted excerpt from Gary Ackerman, "The Future of Jihadists and WMD: Trends and Emerging Threats" in Gary Ackerman and Jeremy Tamsett (eds.) Jihadists and Weapons of Mass Destruction (CRC Press, forthcoming 2008). It also contains materials drawn from Gary Ackerman "It is Hard to Predict the Future: Evolving Nature of Threats and Vulnerabilities" in Preparedness of Veterinary and Public Health Services in Responding to Accidental and Provoked Biological Disasters, Martin Hugh-Jones (ed), OIE Scientific and Technical Review, Volume 25, Number 1 (April 2006) and Gary Ackerman, "Defining Knowledge Gaps Within CBRN Terrorism Research" in Magnus Ranstorp (ed.), CBRN Terrorism (forthcoming 2009).

2 Although acknowledging definitional debates surrounding the term WMD, we define it here to be chemical, biological, radiological or nuclear weapons that, if used, cause large-scale negative consequences.

3 This is true at least within a human frame of reference, but might not be so over extremely long periods of time. For example, while it might be more difficult to predict events in 2050 than in 2015, we are relatively certain that in approximately 5 billion years time our sun's core will collapse and likely destroy anything unlucky enough to still be living on earth.

4 Gödel's so-called Incompleteness Theorem was one of the first formal representations of this idea. See Kurt Gödel, "Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I." (Over formally undecidable sets of the Principia Mathematica and related systems) Monatshefte für Mathematik und Physik, Volume 38 (1931), pp. 173-198.

5 For a general, non-technical introduction to complexity, see Mitchell M. Waldrop, Complexity: the emerging science at the edge of order and chaos. (New York: Simon and Schuster, 1992) and for a recent application of these concepts to the realm of terrorism, see Nancy K. Hayden, "The Complexity of Terrorism: Social and Behavioral Understanding Trends for the Future" in Magnus Ranstorp (ed.) Mapping Terrorism Research: State of the Art, Gaps and Future Direction (New York: Routledge, 2007).

6 For a definition of wicked problems, see H. Rittel and M. Webber; "Dilemmas in a General Theory of Planning" Policy Sciences, Volume 4 (1973), pp. 155-169.

7 C. F. Kurtz and D. J. Snowden, "The new dynamics of strategy: sense-making in a complex and complicated world" IBM Systems Journal, Volume 42, Number 3 (2003), pp. 462-483.

8 Akin to the echolocation of a bat, "probing" involves taking positive action within a system with the express purpose of observing the reactions of other elements of the system and thus of gaining information which is not otherwise obtainable. An example within the realm of our discussion would be to covertly "leak" or inject a distinctive recipe for creating a nerve agent into jihadist circles. Even

though the recipe might not be genuine, it could be constructed to seem plausible and particularly easy to make and to provide specific signatures (such as a peculiar ingredient or process) that could be observed in the broader system. Counterterrorism authorities could then trace the movement of the recipe through jihadist virtual and physical networks, thus increasing their information about the dissemination of this CBRN knowledge, and also identify any would-be CBRN terrorists who might try to follow the recipe.

9 Nicholas Taleb, The Black Swan: How the improbable rules the world and why we don't know it. (New York, NY: Random House, 2007).

10 Ibid.

11 Brian Jenkins, "The WMD Terrorist Threat – Is There a Consensus View?" in Brad Roberts, ed. Hype or Reality?: The "New Terrorism" and Mass Casualty Attacks (Alexandria, VA: Chemical and Biological Arms Control Institute, 2000), pp. 242, 245.

12 Martha Crenshaw, "Have Motivations for Terrorism Changed?" in Jeffrey I. Victoroff (ed.) Tangled Roots: Social and Psychological Factors in the Genesis of Terrorism (Amsterdam: IOS Press, 2006).

13 For several examples of how to approach such a task, see J. Scott Armstrong (ed.), Principles of Forecasting. (New York: Springer, 2001).

14 For example, the NetCraft Web Server Survey, one of the most widely-cited measures of the size of the Internet, reported in February 2008 the existence of 158,209,426 internet sites – see http://news.netcraft.com/archives/web_server_survey.html, accessed on March 14, 2008. An estimate published in 2003 put the total amount of information on the internet at over half a million terabytes of data. (Peter Lyman and Hal R. Varian, How Much Information?, 2003, retrieved from http://www.sims.berkeley.edu/how-much-info-2003 on March 16, 2008.)

15 Here I am referring to the time it takes a new technology to transition from a laboratory experiment to something that is mass produced and available in COTS (commercial off-the-shelf) applications.

16 Ray Kurzweil, The Singularity Is Near: When Humans Transcend Biology. (New York: Penguin, 2006).

2. Perspectives on Rare Events

2.1. Anthropological Perspectives On Rare Event Prediction (Larry Kuznar)

Author: Lawrence A. Kuznar, Ph.D.
Organization: National Security Innovations, Inc.
Contact Information: lkuznar@natlsec.com

Many national security threats come in the form of rare, unanticipated, “Black Swan” type events (see Article 3.3). In this essay, I review examples of prediction in different cultures, considering why people try to predict, what benefits they gain from prediction, and what pitfalls to avoid, especially when predicting rare events. This essay begins with an examination of the role anthropology has played in making predictions for national security issues. Then, I describe several examples of the prediction of rare events in non-Western cultures, including random process prediction, creative imagination, and the problems with dogmatic prediction. This essay continues with a consideration of the epistemological issues anthropologists have faced when predicting rare events. A final section contains recommendations for policy making based on the ethnographic record and philosophical considerations.

2.1.A. Anthropology and the Policy of Prediction

During World War II many of anthropology’s leading figures were engaged in the war effort. E.E. Evans-Pritchard worked with Sudanese tribes in irregular warfare, Carleton Coon supported resistance in Morocco, Gregory Bateson worked counter-intelligence and psychological operations in the South Pacific, Margaret Mead studied food preferences and their impact on food rationing, and Ruth Benedict produced a classic study of Japanese culture that arguably helped to avoid a costly insurgency in Japan at the end of WWII[1]. Predicting the effects of courses of action on culture was central to many of their efforts. The attention anthropology attracted at this time forced anthropologists to confront the dilemmas of doing applied research for paying customers who demand prediction.

Elsie Clews Parsons summarized these dilemmas in her 1942 Presidential Address to the American Anthropological Association[2]. Parsons began by noting the universal human desire to know the future, and how this is manifest in various forms of divination; “Advance knowledge gives power, or is generally believed to give power – to medicine-men, to statesmen, to a Church, to stockbrokers, and in their own opinions at least, to journalists and scientists[3].” Parsons reduced the newly emergent applied anthropology to “a demand on anthropology for prediction[4].” She envisioned a possible future where, “both those we intend to protect and those we intend to fight, may be surveyed and described in advance by social scientists…. Treaties or declarations of war may be based not on personal bias but on anthropological theories of cultural conduct[5].” A central point of Parson’s argument was that the value of anthropological prediction must be based in its scientific foundation.

In the wake of the September 11, 2001 attacks, anthropologists once again were called upon to contribute understanding and prediction of rare yet tremendously disruptive terrorist attacks[6]. The prospect that terrorists might once again pull off a very low probability but extremely high consequence attack such as employment of WMD, intensified the need for the kind of cultural understanding that could anticipate such a rare event[7]. An examination of how the prediction of rare events takes place in the ethnographic record of non-Western societies may offer some clues to the advantages and pitfalls of rare event prediction.

2.1.B. The Ethnographic Record on Prediction

The anthropological literature is filled with descriptions of divination and prediction from many cultures. As Elsie Clews Parsons noted, the human desire to know the future is nearly universal. In this section, I will review a few examples that illustrate the potential benefits of prediction, methods people have used to predict rare events, as well as pitfalls in having too much faith in one's predictions.

2.1.B.1 Random Predictions for Random Events

Some of the better-described non-Western divination practices concern the use of quasi-random processes to predict random or poorly understood events. Many types of divination are well-known, from ancient Chinese oracle bones to the examination of animal entrails, to the consultation of the ancient Greek oracle at Delphi. In this section I will describe two types of divination based on quasi-random processes, scapulimancy and coca divination, and discuss why they persist and what benefit they may offer to their users. In short, if the events of interest are random, then they cannot really be predicted, so that a quasi-random prediction is as good as any other prediction. Therefore, quasi-random divination practices provide no real predictive power, but they are useful in providing humans with answers upon which they can act, overcoming the paralysis of ignorance.

Scapulimancy is a practice described for the Native American Naskapi in Eastern Canada[8]. It involves heating a scapula from a recently killed caribou on a fire, causing the bone to crack. The Naskapi inspect the pattern of the cracks in the bone, which creates a map of sorts to predict where the next caribou will be found. Practices such as these, which involve an individual invoking metaphysical power to make predictions, challenge scientific explanation; the Naskapi are successful hunters. In fact, the pattern of cracks in the bone is quasi-random, and scapulimancy may serve to randomize hunting behavior, preventing prey from adapting to Naskapi predation[9]. Therefore, scapulimancy does not work because it provides accurate predictions, it works because it supplies a prediction that is no worse than others, and may confuse prey.

Coca divination in the South American Andes is another example of the use of quasi-random processes for predicting highly uncertain events. Coca divination involves tossing coca leaves in the air, picking them up and interpreting the pattern in which the leaves are bundled[10]. Coca divination is used for predicting everything from the location of lost items, to the outcome of a love affair, to the result of a harvest, and in at least one case to the outcome of a criminal investigation[11]. In these cases, the events may not be random, but the decision maker suffers from a high level of uncertainty; the inability to understand the underlying mechanisms of these processes makes them appear random to the decision maker, and therefore the random process of coca divination simulates their outcomes. No real prediction takes place, but psychological assurance occurs for the decision maker so that he or she can decide on a course of action and move ahead.

In summary, much divination does not work as a form of prediction, but instead provides psychological comfort and a basis for action. These qualities may very well explain the ubiquity of divination noted by Parsons. One lesson to be gained from these examples is that, when facing an extremely turbulent situation where causality is obscured, sense-making approaches to decision making (randomly chosen action, followed by adaptive changes as new situations arise) may be the best policy[12].

2.1.B.2 Political Intrigue, Hunting and Creative Imagination

Recent research into the evolution of human intelligence has stressed the ability of the human mind to model the processes people want to predict. The human ability to use past experience and creative imagination to model possible futures provides humans with a powerful and unique ability for prognostication. Increases in the size of the frontal lobe (and therefore reasoning power) throughout human evolution are associated with new technologies, increases in hunting efficiency, and increased sociality[13].

Two complimentary theories exist to explain these jumps in frontal lobe size. One theory posits selection for Machiavellian intelligence; as early human societies became more complex, selection favored individuals who were more adept at manipulating others and predicting the outcomes of complex shifts in alliances[14]. The other theory is that expanded reasoning power enabled hunters to imagine alternative lines of logical operation in a hunt, including "getting into the minds" of their prey, and therefore predict prey behavior and adjust hunting behavior accordingly[15]. Both theories are based on observations of the behavior and reasoning of people in modern hunter-gatherer bands; people in these societies are very political (as are people in any society) and hunters use a great deal of imagination for predicting the location and behavior of prey.

Prediction in these societies is enhanced by taking past experience, and building upon that a series of scenarios that outline possible futures. Each of these futures is unique and therefore rare. While they are based on imagination, they are also grounded in previous experience with the empirical world. Their reasoning process is a form of disciplined structured reasoning. The benefit is the ability to envision things that could be and to plan for them. Ironically, some researchers credit this ability with creating a host of anxiety disorders that only highly intelligent animals appear to suffer[16]!

2.1.B.3 The Perils of Dogmatic Prognostication

Many religious traditions incorporate prophecies of the future. When these prophecies fail to be based on scientifically verified processes, when the prophecies involve overly creative imagination, and when the prophecies are adhered to dogmatically, preventing further creative imagining of alternative futures, the result can be devastating.

The Aztec of central Mexico developed an empire based on conquest and trade during the 1400s. Divination was a highly developed art in the Aztec empire, and its core tenant was that each individual had a predetermined fate[17]. The Aztec also believed in the predictive power of omens, and searched for omens that would give clues to their individual fates. Allegedly, ten years before the arrival of the Spanish, omens, including comets, fires and lightning strikes to important temples, boiling lake waters, and visions of strange people, foretold an impending disaster for the Aztec people.

In 1519, Hernando Cortez arrived with 600 men on the shores of Veracruz in modern day Mexico. Cortez adroitly exploited divisions between indigenous societies, winning allies, defeating enemies, and building a large Spanish and indigenous army to conquer the Aztec. The Aztec ruler, Moctezuma, monitored Cortez's progress and was clearly concerned about this growing threat. Plagued by thoughts of the unavoidable doom of his empire, and further intrigued by the possibility that Cortez may actually be the incarnation of the powerful Aztec god Quetzalcoatl, Moctezuma vacillated between honoring Cortez, sending sorcerers to bewitch the Spaniard, and defending the Aztec empire[18]. In the end, Moctezuma welcomed Cortez into the capital city of Tenochtitlan, and through a series of intrigues and events, wound up losing his own nobles' support and eventually his life. Smallpox ravaged the population and the Aztec empire, indeed, met its doom.

The Aztec case is an exemplar of how human imagination, unfettered by scientific standards of evidence, can create possible futures that become self-fulfilling prophecies. Aztec divination, as with all forms of allegedly supernatural intervention, was free of empirical checks. Coupling this non-scientific prediction with dogmatic adherence to prophecy seemingly crippled the Aztec ruler's ability to envision alternative futures and develop alternative courses of action to meet them; Moctezuma ignored empirical reality, envisioned one possible future and only one, and he paid the price for his lack of imagination.

Each of these cases of rare event prediction from the ethnographic record illustrates key potentials and pitfalls in modern prediction for national security, as Parsons pointed out nearly 70 years ago. Those who wish to predict rare events are perpetually challenged on how to use past and/or common experience to predict the future, and when to abandon the staid, established empirical record for creative imagination. Anthropologists struggling to develop a scientific theory of culture have wrestled with these issues for a century and a half.

2.1.C. The Epistemology of Anthropological Prediction

Anthropologists often argue for the uniqueness of each culture, which logically, 1) defines each culture as a rare event, and 2) challenges attempts to achieve the sort of general understanding of culture that could support prediction. Several epistemological approaches have emerged from this dilemma, including historical particularism, unilineal evolutionism, the multilinear evolution theory of culture change, progressive contextualization, and causal mechanical explanation.

2.1.C.1 Particularism

The particularist tradition dates to late 19th century adoption of the Germanic *Geisteswissen-schaften* academic tradition by American anthropology's titular founder, Franz Boas[19], and has come to be known as historical particularism. This tradition emphasized the integrated, holistic nature of each culture as an entity that, because of its uniqueness, could not be compared to others. In that sense, each culture represents the rarest of events, a singularity of the social geometry, and the aim of a social science is to explain these unique events.

2.1.C.2 Scientific Explanation: Identifying General Forms vs. Processes

In the late 19th century, unilineal evolutionists provided the earliest attempts to produce scientific generalizations in anthropology. They emphasized common phases through which human societies passed in their evolution from small bands of hunter-gatherers, to large, settled agrarian societies, and ultimately to modern, industrialized societies[20]. One problem with this tradition was its failure to explain the existence of modern industrial nation states alongside hunter-gatherer bands, as one can still see in Australia, the Amazon, Africa, or Alaska today; if all human societies are on a trajectory of social evolution, how could there be so many diverse paths?

In the mid-20th century, Julian Steward attempted to reconcile general theory with the prediction of unique events with the multilineal evolution theory of culture change[21]. Steward stressed that differences in environment and chance historical endowments of technology would create initial conditions that would influence a society's unique evolutionary trajectory. Steward provided a more flexible approach to explaining the diversity of cultures, without sacrificing the generation of scientific theories that could explain the commonalities in culture. Refinements in the 1960s introduced systems theory and demographic change into Steward's scheme, and a general shift from explaining cultural forms to explaining cultural processes that would generate those forms[22].

In the late 20th century, another epistemological movement in anthropology similarly stressed the identification of specific causal processes as the sine qua non of explanation. This was the emphasis on causal mechanical (CM) explanation in which an explanation was achieved not by the generality of a theory, which can only provide a statistical correlation of most likely events, but by being able to trace the specific causal linkages that led to particular events. An early proponent of this view was Andrew Vayda, who was wrestling with explaining the diverse causes of tribal warfare in New Guinea[23]. Vayda's prescription was for progressive contextualization in which one traced the cause of a conflict from very specific events proximate to the outbreak of war (for instance, revenge for a homicide), back to that event's precursors (for instance, the homicide victim's trespass on another's territory, and further back to competition over land due to a population increase)[24].

Generalizing approaches in anthropology have been based in the traditional deductive-nomological, or covering law, tradition of the natural sciences[25]. The problem with these approaches is that a covering law, or general statement that predicts an event as a general class of events, is based less on a demonstration of an actual connection between events, and more on their correlation. Furthermore, if that correlation is validated by its statistical regularity, one is engaged in asserting a causal connection between most likely events, which seemingly does little to enable the prediction of rare events. On the other hand, particularistic approaches to causation, like causal mechanical explanation, are hard pressed to validate why two events are causally connected. Usually, two events are considered causally connected if one can infer a general process that one can expect to connect the two processes. In the end, it is difficult to escape some appeal to generality (even if it is to processes) in order to make causal connections[26]. Recent reviews of these dilemmas by leading philosophers have resulted in an impasse – scientific explanations appear locked in a methodologically plural oscillation between casual mechanical explanations and deductive generalization[27].

2.1.D. Conclusions

The realization that a broader understanding of culture is necessary to meet modern national security challenges[28] has naturally refocused attention toward anthropology and its potential for prediction. Prediction, in the form of divination, is nearly universal in human societies, and often appears to provide a degree of psychological assurance used to deal with uncertainty and randomness, rather than provide any scientifically defensible predictions about the empirical world. When causal processes are somewhat understood (as in prey behavior in hunting or the social intrigues of a small social group), creative imagination can provide models of possible futures useful for contingency planning. However, when creative imagination departs from empirically verifiable social processes, and when beliefs in predictions become dogmatic and not adjustable in light of new data, the benefits of prediction are lost and whole societies can be destroyed due to a collectively held fantasy.

In summary, whether diviners are anthropologists in the employ of government, hunters trying to feed their people, or sacred kings protecting their societies, their experiences highlight several requirements for sound prediction of rare events. These requirements include:

- Don’t attribute cause unnecessarily; if one is genuinely grappling with a random event, predict it with random processes, develop a range of courses of action and move on adaptively – one can do no better.
- Traditional generalizing science only characterizes most likely events – the truly unique and novel will be missed.
- Generalizing research can, however, highlight associations that provide clues to mechanisms.
- Empirical science for prediction should be focused on verifying the existence and effect of processes, not of forms.
- Causal mechanical research of particular case studies can establish the causal linkages necessary for an event to occur.
- Creative imagination is necessary to go beyond deductive covering law explanation of the most likely, but only if checked by empirical science.
- Disciplined structured reasoning, based on empirical evidence and what it can entail, is a useful way to harness creative imagination and project possible futures and events.

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2.2. Philosophical and Epistemological Considerations (Ken Long)

Author: Kenneth A. Long
Organization: Department of Philosophy, Indiana University-Purdue University Fort Wayne (IPFW)
Contact Information: long@ipfw.edu

The presuppositions researchers make about the aim or aims of science, about correct scientific methodology, and about the nature of scientific explanations have implications concerning how to improve rare event projection and forecasting, and preemptive or causal interdiction capabilities. These presuppositions need to be critically examined. Some background in issues of scientific epistemology in contemporary philosophy of science is needed in order to do this. This may seem hopelessly abstract at first but the practical payoff is that we can discover better ways to bridge the notorious gap between theory and reality that confronts every policy maker.

What is the aim or aims of science? Several mainstream approaches to this question include scientific realism, empiricism, conventionalism, and instrumentalism. The scientific realist says that the aim is truth, or at least movement towards greater approximations to the truth.[1] Better theories are more like the way the world is in terms of the theoretical and unobserved entities they posit. To explain something is to identify the real entities and real causal mechanisms in the world that produced it. For strict empiricists the only aim is empirical adequacy; better theories account for more phenomena with greater precision and allow greater predictability or retrodictability.[2] Truth need not be a factor. The reality of posited entities or processes need not be a factor. "As-if" theories are good enough if they meet the standards of empirical adequacy. A strict conventionalist perspective views the way theories carve up the world as merely convenient classificatory schemes, the overall aim of science being the production of the most economical ordering of all our experiences.[3] Pragmatic philosophers of science also view theories instrumentally, only for them they are instruments for the achievement of practical goals.

The debate over the aim or aims of science is necessarily entwined with the debate about scientific methodology. Methodological monists (those that argue for a single best approach to science) say there is a single essential methodology, or set of rules for doing science, the so-called "scientific method"[4], which in all areas of research distinguishes genuine science from non-science or from spurious pseudo-science. However, no consensus has yet been reached on what the method is and how it serves to demarcate science from non-science.

It is natural to try to ground scientific methodology formally, in logic. Karl Popper[5] attempted to ground scientific methodology in deductive logic. Scientists are in the business of disproving hypothesis (H) based on the observable evidence it entails (O) using the valid deductive argument form modus tolens: If H then O, not O, therefore not H. But Popper's falsification picture of scientific methodology, while arguably applicable in some areas of the natural sciences, is of little use for testing hypotheses about rare events. For rare events we necessarily lack the statistical evidence needed to form suitable hypothesis for testing and we haven't the luxury of taking the time to test mere conjectures. What we need are reasonable candidate hypothesis and some way of determining which are better and which are worse, not simply a method of determining which are false. While Popper does propose a way of doing this using resistance to falsification over time, the more direct way is to abandon a deductive grounding of methodology in favor of an inductive, probabilistic grounding.

According to this formal approach, scientists employ an *incremental* confirmation procedure. A simplified *Bayesian* confirmation theory runs as follows. We first assign a certain initial probability to a given hypothesis H and to some observable event E.[6] Then, if confronted with new evidence E, we calculate the probability of H given E using one or more versions of *Bayes's Theorem.* A simple version of the theorem is $P(H/E) = [P(E/H) \times P(H)]/P(E)$. This says that the new probability I should rationally assign to H given the new evidence E is equal to the product of the prior conditional probability of the new evidence E given the hypothesis H and the prior probability of H, divided by the prior probability of E. It is easy to see that in cases where E by itself has a low prior probability but E given H has a high probability then E will significantly raise the posterior probability of H. E will constitute significant evidence for H and will be highly confirmatory. It is also easy to see that, in cases where E by itself already has a fairly high initial probability, then, regardless of the probability that E would occur given H, E will not constitute a significant confirmation of H. This is an attractive bootstrapping method of confirmation which, given certain assumptions, will over time lead to a convergence of opinions concerning the probability of any (empirical) H, even if we all start with different prior probabilities (so long as they are not 0 or 1). While the Bayesian approach is limited because of the problem of how to rationally assign prior probabilities, it is undoubtedly an important tool in the arsenal of any scientific researcher. And it is entirely compatible with the approach to social science theorizing we are about to advocate.[7]

But there is a popular view about science that is not compatible with the approach I will be advocating. Under the influence of a variety of iconoclastic thinkers[8], a large number of philosophers, sociologists, anthropologists, feminists and literary critics have adopted the position that the claims of science have no greater epistemic status than competing claims emanating from other social institutions or from various religious, mystical or magical practices. For them no methodological or demarcation criteria are needed. But such a perspective sheds no light at all on just how to approach practical problems such as the prediction or prevention of rare events. Moreover, it dangerously suggests that it is really no better to use best current scientific results and practices to address such problems than not. Thus, this essentially negative position on methodology and demarcation offers no help or enlightenment in our goal of improvement of rare event prediction.

By contrast, a positive view on scientific methodology and demarcation combines a position on methodology with a (hopefully) consistent position on demarcation criteria. While many positive views on methodology and demarcation have been proposed, they all seem woefully inadequate when applied beyond the confines of the natural sciences into the realm of the social sciences, where something akin to "methodological anarchism" seems to be common if not the norm. Because of this, methodological monists grounded in the natural sciences are prone to question the legitimacy of the plurality of practices of the social sciences while methodological monists grounded in the social sciences look for an appropriate model for the social sciences with increasing despair.[9] Methodological pluralists, on the other hand, see the belief in a single scientific method as a reflection of the naiveté of practitioners of the natural sciences.[10] For them methodological pluralism is required in the social sciences given the essential differences between social and nonsocial phenomena. But the problem the pluralist faces is how to prevent science from being infected by epistemological relativism. The concern is that methodological pluralism allows us to rationally justify two or more opposing hypotheses based on different methodological rules. We seem to be in a dilemma. We currently lack a workable broadly applicable single scientific methodology while any pluralist view threatens epistemological relativism in science.

Recent work in the epistemology of the social sciences points to a solution, one that not only casts aside the assumption that science in general and the social sciences in particular are characterized by a single method but also avoids relativism and promises to reduce the gap between theorists and public policy makers. It starts with the recognition that methodological pluralism need not lead to the sort of epistemological relativism or leveling of science advocated by Feyerabend[11] and feared by early proponents of methodological monism. A methodology consists of a set of methodological rules. These rules are normative (justificatory) rules. Taken together they justify certain scientific practices and proscribe others.[12] But what justifies any methodology? Larry Laudan argues that the normative justification of a methodology is empirical; a methodology, whether one or many, is justified if experience shows that adherence to it in any given area advances realizable cognitive aims of science.[13] Since the degree of ends-means instrumentality of proposed methodological rules can be tested by experience, metamethodology, the method of the justification of methodological rules, becomes just another empirical discipline.[14]

Laudan thus shows how methodological pluralism can avoid epistemological relativism, but it is recent work by Howard Sankey[15] that shows how to combine a methodological pluralism grounded in Laudan's empirical metamethodology with scientific realism to give methodological pluralism explanatory power. This is important because methodological pluralism has proven to be a more progressive and fruitful research model in the social sciences than any known version of methodological monism and there is a strong pull towards methodological pluralism based solely on a study of the history of scientific progress[16]. Laudan rejects truth or truth-likeness as cognitive aims of science for the following reason: He sees them as transcendental ideals, unattainable and not knowable, hence worthless for scientific methodology or demarcation.[17] However, Sankey cogently argues that they are realizable ends for a Laudan-style meta-methodological justification. The important position he reaches is that experience can be used to legitimate a plurality of scientific methodologies of limited scope, adjusted to specific areas and problems, changing and evolving over time, yet all linked together by an overriding scientific aim of the pursuit of truth. In the case of the social sciences, and perhaps to a lesser degree of the natural sciences too[18], a progression of theories can be developed over time that, while using different methodological rules, collectively constitute sequentially "truthier" visions of the genuine social entities and causal mechanisms existing in the world outside of our thoughts.

We can summarize Sankey's position as follows:

1. For any field, particularly in the social sciences, there is not one set but many possible sets of normative methodological rules, the rules we should use to determine whether research projects have been conducted in a scientifically proper manner.
2. For each of these possible sets we provide a natural justification using them as normative methodological rules by empirical evidence showing that following them promotes the cognitive aim(s) of science.
3. Since the overriding cognitive aim of science is to advance the truth about the world, a methodological rule conveys epistemic warrant to the extent that fulfillment of it promotes the aim of truth.

4. This is a species of *epistemological reliabalism* in that *reliability as an instrument leading to the truth* is what epistemically warrants methodological rules.

The next step is to combine Sankey's methodological pluralist realism with cutting-edge ideas about scientific explanation. The earliest analysis was the covering-law or deductive-nomological (D-N) model of explanations.[19] The *explanans* (explanation) "subsumed" the *explanandum* (that which is being explained) under an acceptable universal generalization or "law". This makes explanations essentially retroactive predictions or retrodictions. To explain something is to show how, given empirically established *nomic (law-like) generalization*s (e.g., copper expands when heated) and certain *initial conditions* (this is a piece of copper that has been heated), we could have deduced, and thus expected, the event in question (this piece of metal expanded) to occur. But D-N explanations fail to distinguish between causal and noncausal regularities, and genuine covering laws are especially hard to find outside of the natural sciences.[20] For these reasons, it has come to be realized[21] that explanations should ideally be couched in terms of *causal mechanisms*, not in terms of mere nomic ("lawlike") subsumption under a universal or statistical generalization. As Wesley Salmon used to say, the "cause" needs to be put back into the "because". This is especially important in the consideration of forecasting rare events, where we lack the statistical basis for formulating the appropriate covering law generalizations.

This does not mean that D-N explanation is worthless[22], but its inadequacies and those of its *inductive-statistical* and *statistical-relevance* cousins suggest that we should view explanation as a layered concept. Sometimes the best explanation we can give of a phenomena is in terms of its expectability, whether deductively or inductively grounded, but a better sort of explanation is in terms of processes leading from some situation X to another situation Y through various intermediate stages A, B, C, etc. Because this is what causal mechanisms allow us to do, they are explanatorily more fundamental than general covering laws, which merely involve the conditional explanatory form "If X then Y." Explanations via genuine causal mechanisms also fit nicely with the idea (Cartwright, Humphries) that the proper form of an explanation is not simply "X happened because of A" but "X happened because of A, *despite* B", that is, that the occurrence or nonoccurrence of an effect is a function of the non-canceling or canceling interactions between *bundles* of causal mechanisms.[23]

We can then usefully apply this notion of causality to the corresponding notion of *typological theorizing* based on comparative case studies.[24] Typological theories specify independent variables and then delineate them into categories applicable to measuring *specific cases and outcomes*. They employ not just hypotheses about how the variables operate *individually* but also hypotheses about how they behave *conjunctively* and *disjunctively* (where specified conjunctions and disjunctions are the *types*). Typological theorizing allows for the discovery of just the contextual offsettings or complementary interactions between causal mechanisms required by so-called aleatory causal explanations, the causal explanations of chance events.

The final element in the picture of science I am proposing as appropriate for the task of predicting rare events is the concept of *middle-range theories.*[25] If the overriding (not necessarily sole) cognitive aim of science is truth, and not simple empirical adequacy or the realization of pragmatic ends, then the causal mechanisms cited in our explanations should be real, not "as if". This means there is in principle an irreducible appeal to unobservables as described by our current best micro and macro theories (e.g., of atoms and black holes, or cells and species). But such theories are too far removed from the middle-level where we live and operate in the practical world. Even if we could in principle bridge between atoms and rare events, such overarching micro or macro theories are of little practical use in predicting or forecasting rare events. What are useful are so-called *middle range theories*. These are theories of limited scope involving a select intersection of variables that, while ideally linkable to real causal mechanisms at the micro and macro level, employ *non-covering law generalizations* of limited range and applicability. They are used to test *aleatory causal hypotheses* of the form “In this case, X caused Y through a process involving stages A, B, C and variables a, b, c in spite of the presence of variables d, e, f.”

Furthermore, such theories have the advantage of being empirically acquired and tested by a comparative case study approach employing the technique of *process tracing*. Process-tracing is described by George and Bennet as a method which

> …attempts to trace the links between possible causes and observed outcomes. In process-tracing, the researcher examines histories, archival documents, interview transcripts, and other source to see whether the causal process a theory hypothesizes or implies in a case is in face evident in the sequence and values of the intervening variables in that case. Process-tracing might be used to test whether the residual differences between two similar cases were causal or spurious in producing a difference in theses cases’ outcomes. Or the intensive study of one deviant case …may provide significant theoretical insights. Process tracing can perform a heuristic function as well, generating new variables or hypotheses on the basis of sequences of events observed inductively in case studies.[26]

Such an approach does not rule out formal and statistical approaches, which can be employed in congruence with the case-study approach.

In summary, recent results in the epistemology of the social sciences (and indeed in the epistemology of science in general) indicate that the employment of case-by-case studies in combination with middle-level and typographical theorizing centered around the concept of aleatory causality can produce results that are far more useful to policy makers than traditional research centering around covering-law model theorizing and a merely conditional concept of causality.

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[1] There are several varieties. Proponents include Bertrand Russell, G. E. Moore, Roy Wood Sellars, Karl Popper, Grover Maxwell and J. J. C. Smart.

[2] This position is represented most prominently today by Larry Laudan and Bas Van Frassen.

[3] Early conventionalists were Jules Henri Poincare (1854-1912) and Pierre-Maurice Duhem (1861-1916). The most prominent modern one was Willard Van Orman Quine (1908-2000). Darwin was apparently a conventionalist about the concept of a species; a species denotes a classification scheme based on taxonomic and other similarities between individuals, not something out there in the world.

[4] So-called *naïve verificationism* has the basic: collect some data, organize the data, infer a hypothesis from the organized data, test the hypothesis, readjust if needed and collect more data, retest, repeat the last two steps as needed. The most naïve step in the procedure is probably the requirement that the hypothesis be inferred from the organized data, since it is now generally recognized that neither the organization nor the inference can be theory-neutral. And if falsification is indeed the desiderata of science, as Popper thinks, then a conjecture will do, the riskier the better. An argument in favor of this view is that it does seem closer to how hypotheses are actually generated.

[5] As advanced in Popper, Karl, Conjectures and Refutations: *The Growth of Scientific Knowledge* (Routledge, London, 1963).

[6] For example, H might be the hypothesis that the continents have moved and E the observed fit of the coasts of Africa and North America.

[7] A crisp summary of the Bayesian approach can be found in Mellor, D. H., *Probability: A Philosophical Introduction* (Routledge 2005).

[8] See Kuhn, Thomas, *The Structure of Scientific Revolutions, 2nd Ed.* (University of Chicago Press, 1970), Feyerabend, Paul K., *Against Method* (New Left Books, London 1975), Rorty, Richard *Consequences of Pragmatism* (Minneapolis: University of Minnesota Press, 1982), and LaTour, Bruno and Woolgar, Steve, *Laboratory Life: The Construction of Scientific Facts* (Princeton University Press, 1986).

[9] Popper’s attacks on Adler, Marx and Freud (as all positing unfalsifiable theories) exemplify the first point while Hempel’s failed attempts to apply statistical versions of the covering-law model of explanations to social phenomena exemplify the latter.

[10] A classic statement is Taylor, Charles, ‘Interpretation and the Science of Man’, *The review of metaphysics* 25, pp. 3-51, 1971.

[11] “Of course, science will not play any prominent role in the society I envisage. They will be more than balanced by magicians, priests and astrologers.” Feyerabend, Paul K., ‘How to Defend Society against Science’ in *Introductory Readings in the Philosophy of Science*, Klemke, E. D., Hollinger, Robert, Rudge, David Wyss, & Kline, David A. eds. 1998, pp. 54-65.

[12] As we already noted, the methodological monist thinks there is a set of rules or procedures that constitutes a single overriding methodology for all of science and the pluralist thinks there are several different sets and no overriding set.

[13] See Laudan, Larry, ‘A Confutation of Convergent Realism’, *Philosophy of Science* 48, pp. 19-48, 1981 and Laudan, Larry, *Science and Values* (University of California Press, Berkeley, 1984). Laudan takes a nonrealist progressive view of science: science progresses but not via truth or even approximation to truth. Progress towards the truth, he argues, is unmeasurable and hence it is an unrealizable cognitive aim of science.

[14] Such a naturalistic account of the justificatory basis of methodological rules follows the naturalistic approach to epistemology in general made fashionable by the empiricist Quine. See Quine, Willard Van Orman, *Ontological Relativity and Other Essays*, (Columbia University Press 1969)

[15] See Sankey, Howard, ‘Methodological Pluralism’ in Nola, Robert & Sankey, Howard, *After Popper, Kuhn and Feyerabend* (Kluwer Academic Publishers, 2000, pp. 211-229 (especially pp. 216-223.)

[16] See notably Friedman, Michael, *Dynamics of Reason* (CSLI Publications, Stanford, California 2001.

[17] Laudan, Larry, ‘A Confutation of Convergent Realism’, *Philosophy of Science* 48, pp. 19-48, 1981.

[18] Since Einstein, Newtonian mechanics might be said to represents a *middle range* theory that nicely bridges the gap between theory and practice for all practical space-flight purposes.

[19] Due largely to the work of Carl G. Hempel. See Hempel, Carl G, and Oppenheim, Paul, *Studies in the Logic of Explanation* in *Philosophy of Science*, Vol. 15, No. 2 (Apr., 1948), pp. 135-175.

[20] Some philosophers, such as Nancy Cartwright, hold that they are hard to find within the natural sciences, physics included. For her, most, if not all, so-called laws of nature are literally false. They only work to allow predictions if we make a host of assumptions as to the presence or absence of enabling or disabling conditions, an anticipation of the aleatory analysis of explanation below. See Cartwright, Nancy, ‘Capacities and Abstractions’ in *Scientific Explanation* (University of Minnesota Press, 1989), Kitcher, Phillip & Feigl, Herbert, eds.

[21] Largely due to the work of Wesley Salmon. For a very good historical overview see Salmon, Wesley, ‘Four Decades of Scientific Explanation’ in *Scientific Explanation* (University of Minnesota Press, 1989), Kitcher, Phillip & Feigl, Herbert, eds.

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[22] One can still maintain that the search for D-N explanations may need to take precedence over the search for causal mechanisms in young or developing areas of science. See Kuznar, Lawrence A. & Long, Kenneth, ‘Deductive-nomological vs. Causal-mechanical Explanation: Relative Strengths and Weaknesses in Anthropological Explanations’ in *Against the Grain: The Vadya Tradition in Human Ecology and Ecological Anthropology*, Walters, Bradley, McCay, Bonnie J., West, Paige, & Lees, Susan, eds.

[23] This is the so-called aleatory conception of causality that is used in aleatory causal explanations. ‘Aleatory’ means literally ‘a matter of chance.’

[24] See George, Alexander L. & Bennet, Andrew, eds., *Case Studies and Theory Development in the Social Sciences* (MIT Press, 2004) especially chapter 11, ‘Integrating Comparative and Within-Case analysis: Typological Theory’ pp. 233-262.

[25] Ibid pp. 265-269.

[26] Ibid p. 266. This concept is associated with the sociologist Robert K. Merton. Such theories are applicable to limited ranges of data, transcend any mere description of social phenomena and bridge the gaps between the raw empirical data and grand or all-inclusive theory (meta or macro.) Merton’s concept is a development of ideas of Emile Durkheim and Max Weber. See Merton, Robert K., *Social Theory and Social Structure* (Free Press, 1968).

2.3. Law Enforcement (Carl Hunt, Kathleen Kiernan)

Authors/Organizations: Carl W. Hunt (Directed Technologies, Inc) and Kathleen Kiernan (RRTO/SMA Support Team, Joint Staff J39 and DDR&E RRTO).
Contact Information: carl_hunt@directedtechnologies.com, kiernangroup1@comcast.net

2.3.A. Introduction

From the earliest days of the police academy, most law enforcement officers are tutored from the classic work entitled *Fundamentals of Criminal Investigation*.[1] This book, now in its Seventh Edition, shares much with its original edition, first published in 1956, recounting the three fundamental tools of the investigator: Information, Interrogation and Instrumentation. In fact, the entire book, according to the authors, is "an exposition of the nature and use of the three 'I's'." As law enforcement officers mature and leverage their experiences in the field of criminal investigations, they learn to exploit the three "I's" as O'Hara called them, and begin to infer about future events and behaviors: they forecast what a human actor might do.

The three "I's" are at their core information-based, at least as viewed in the light of the Information Age, only beginning to show signs of awakening when this classic text was first written. Even then, however, these three "tools" significantly contributed to the potential for success in overcoming the problem of forecasting unique or rare events or behaviors for which there is little if any tangible or statistical evidence to analyze in the course of anticipating the occurrence of these events. In this paper, we will discuss some of the limitations and common pitfalls that law enforcement officers have encountered and touch on how they have leveraged expertise in the three "I's" in dealing with the challenges of anticipating unique or rare events.[2]

2.3.B. The Challenges of Forecasting Unique and Rare Events in the Law Enforcement World[3]

2.3.B.1 The Challenges of Evidence.

Anyone who has studied the differences between conducting intelligence analyses/investigations and law enforcement investigations will likely cite first the issue of the disposition of evidence obtained in the respective investigations. The intelligence analyst (known collectively as the Intelligence Community or IC) collects and assesses evidence in ways that support the decision-maker (e.g., the President or military commander/agency director) in directing operations in defense of the nation, both at home and abroad. The law enforcement officer must anticipate the use of the evidence collected to ultimately be exposed to an open forum such as before a judge or jury. While many law enforcement agencies also have dedicated intelligence units, the evidence they collect and analyze still supports criminal investigations. Since September 11, 2001, there has been a burgeoning curiosity by the IC about the type and content of law enforcement information and as well with the collection process. In part this has been the result of the gradual shift by the IC to recognize the value of open-source information and in part due to the fact that there were so many shortcomings in the information gathering and sharing process which were illustrated by the 9/11 Commission Report. Clearly, there were ways of knowing information that were underutilized, and even when potential derogatory information was known, it was not shared between agencies to the extent it could have or should have been.[4]

There are clearly parallels between the methods used by criminal investigators and intelligence analysts to collect evidence to support a hypothesis—the principal difference is in the disposition of the final product. The former is transparent, open to rigorous examination and after disposition, is typically available in open public records. The latter is seldom transparent, and while subject to review is often conducted individually, in secret, and not open for later review. These differences also change the way investigators approach the signs or evidence about unexpected events or behaviors, such as those discussed throughout this paper. Law enforcement officers, and criminal investigators in particular, seek their evidence and ask questions with a perspective of eventually bringing it before a public trial, guaranteed by the Constitution of the United States. They know their evidence must withstand the scrutiny of a very public legal system. The questions asked by law enforcement are subjected to legal considerations aiming to convict a criminal rather than substantiating a decision to take military action against a national or non-national entity (e.g., a terrorist group).

The relationship between the actor and the intelligence analyst or criminal investigator is also quite different. An analyst will almost never have any direct contact and "knows" the adversary through an examination of documents and intelligence derived from other human and technical means of collection. A law enforcement officer's knowledge is both more tactical and more visceral; he/she will have direct contact with the individuals under investigation and upon arrest, throughout the judicial process. This proximity also provides the opportunity to assess veracity and to potentially turn an individual against a more serious offender in return for a recommendation of a reduced sentence. The keys however, to both types of investigation are objectivity and the ability to examine an issue/person from multiple perspectives in order to understand the elements of the crime or terrorist activity.

2.3.B.2 The Challenges of Crime Prevention

Apart from the challenges of evidential disposition before a judge or jury, law enforcement officers also have community protection and crime prevention responsibilities. It is in this domain that this conversation about forecasting unique or rare events or behaviors draws the most parallels with the challenges faced by the IC. Crime Prevention is a community-oriented task, and requires an immersion of the law enforcement officer within a community, penetrating the rhythm of the actors within to enable recognition of both overt and subtle behaviors to include anomalies. The absence of an anticipated activity is as relevant an indicator as its routine presence. The key to success is the buildup and sustainment of trust by community members in the law enforcement officer to impact the events which hinder safety and security for the particular neighborhood. As that trust increases, members of the community are more inclined to report suspicious indicators to include the tactical – for example, an escalating illegal drug enterprise – to the more strategic indicators which could include changes in assimilation patterns, which may be early warning of activity by a terrorist element.

2.3.B.3 The Challenges of Connecting the Dots

Perhaps the largest challenge about forecasting unique or rare events, however, is making sense of the connections and interactions between actors and the environment in which they plan and commit crime. These connections and interactions are the "enabling infrastructure" for criminal activity and it is here that any predictions or forecasts must be based. This is where science and instrumentation, as O'Hara called it, lend themselves most handily to anticipation of rare events.

The aim of science is not things themselves, as the dogmatists in their simplicity imagine, but the relations among things; outside these relations there is no reality knowable. - Henri Poincare

Relationships between the objects, as Poincare called them, are the "connections between the dots." Law enforcement (LE) professionals have been connecting the dots since at least the time of Sherlock Holmes and Arthur Conan Doyle, the creator of Holmes. Science and law enforcement have been partners since at least the 19th Century. Although Doyle (and through him, Holmes) was actually inspired by the real Scottish medico, Dr. Joseph Bell, they all understood that forecasting is based on understanding the evidence which has led to the current situation: evidence that has already manifested itself in the past and present. Projecting the future from the past is common to both analysts and investigators and offers the same limitations to both the IC and LE. Another Scotsman, David Hume, is credited with coining what is called the "Inductive Fallacy," the notion behind the admonition that the future has no obligation to follow the past.[5] Forecasting and prediction is a challenge common to both the IC and LE, and it is quite likely that the world's intelligence services have copied and improved upon the art and science of dot connection from the law enforcement community.

There's more to it than connecting dots, though, as Bell, Doyle and Holmes substantiated time and again. There's also the need to find the right dots to connect and to infer the right connections between them. This is called "asking the right questions" as we've pointed out above, and it's also where the exploitation of O'Hara's three "I's" comes into play.

2.3.C. Limitations of Other Traditional Tools and Techniques

Gradually the impediments posed by the lack of information sharing are being eliminated, although the proclivity to do so has neither been natural nor organizationally inspired. In the world of law enforcement the move towards interagency fusion centers populated by multiple agencies with common accesses has helped considerably, while in the IC the change has been harder won. Building common architectures and common virtual IC analytic workspaces has provided the opportunity to break the cycle of individual production, leverage other related and historical work, and reduce the relative isolation of analysts from their peers throughout the community.[6] The extension of security clearances to a wider subset of law enforcement, while not a panacea, has been an accelerator to information sharing and to the broader education of IC analysts at the national level. The exchange of knowledge and experience, the "streetcraft" of law enforcement, has made significant contributions to the tradecraft of intelligence analysis. As these relationships develop, so too does knowledge discovery of common tools and technologies and mechanisms to share these across the communities. Limitations imposed by law and regulation will compel a separation between the IC and law enforcement with respect to direct tasking; however, the sharing of best practices continues to grow to the benefit of both.

2.3.D. The Three "I's": Information, Interrogation and Instrumentation: Necessary but not Sufficient without Synergy – A Problem of Self-Imposed Limitations

O'Hara defined Information in the context of his book as the "knowledge the investigator gathers from other persons," both from willing witnesses and informants and other "cultivated sources." In the military, we tend to think of Information in a broader context, of course, but O'Hara's point is that there are sources of insight that can be gained from dialogue with others. He points out that this tool is most often how one deduces motivation for committing a crime, not unlike the intelligence analyst trying to infer intent of potential adversaries. Information, when marshaled well, points to the right next questions to ask, particularly when trying to forecast rare events and the motivations for those events before they transpire.

Together with O'Hara's second criminal investigative tool, Interrogation, the skilled questioning of both witnesses and suspects, these two capabilities form the essence of Human Intelligence, (HUMINT) that is so critically necessary in the resolution of any criminal investigation or intelligence investigation. In a meaningful admonishment, O'Hara tells us that an unskilled investigator often overlooks the most important question he could ask a suspect: did he or she commit the offense? Sometimes the most simple questions, given they are the right questions, produce the most useful facts for resolving the investigation. After all, "the normal person is possessed by an irresistible desire to talk," a human characteristic that has helped to solve some of the most important investigations in law enforcement history (and even intelligence analyses).[7]

The third "I", Instrumentation, includes "the application of instruments and methods of the physical sciences to the detection of crime."[8] The techniques that fall within this category are especially favored within the US IC in cases where HUMINT is difficult to obtain or where large investments in stand-off collectors seem to require their use to gain a return on the significant resources required to put them in place. Feeling compelled to use expensive instrumentation, even in cases it may not apply, is also a limitation common to the IC and LE. Return on investment often drives the uses of tools that are ill-suited, when just asking the right questions at the right time could be more effective.

While all three "I's" must synergize to confirm (or negate) information obtained through the use of other techniques, overreliance on instrumentation and technical capabilities has been criticized when it comes to detecting surprise. Instrumentation is also the most difficult of the three tools for detection of motivation and intent, although it may be very useful in confirming it. As pointed out below, these tools, as O'Hara labeled them, must work together in order to support anticipation and forecasting of unique events and intelligent inquiry is still the driving force behind potential success.

2.3.E. <u>Pointers to Improved Capabilities to Forecast</u>

This paper on Forecasting Unique and Rare Events in the Law Enforcement domain would not be complete without some pointer to overcome the limitations in forecasting faced by the law enforcement community. Some of the techniques are directly related to the challenges above, while some are more general concepts common to any approach to forecasting. In the concluding section of this paper we will consider relevant factors of modern criminal investigations – three more tools for success: intuition, probability and modeling.

Intuition has traditionally played a significant role in the field of law enforcement. It has been a major factor in the success of many criminal investigations. Intuition, by itself, however, can be very weak. The uses of probability and modeling have also been important factors in dealing with complex investigations and trying to make sense of signs of impending crime. While the enumerative methods that statistics typically require may not be useful in forecasting unique or rare events, there are probabilistic and modeling techniques that do apply. Such techniques seek to preserve the intuition, experiences, wisdom and imagination of the police commander and staff as they deal with complex decision-making for which there may be little precedence. The key is to use techniques that augment intuition and capture instead of eliminate complexity, techniques that penetrate and exploit underlying networks that support criminal behavior.[9]

Combinations and connections are the ingredients of using intuition, probability and modeling creatively to forecast what's coming down the pike. These are all part and parcel of the process of discovery and the third inference process to deduction and induction, called abduction. Another French scientist, Jacque Hadamard, understood the importance of combining ideas, declaring this process as key to discovery and invention. This is the essence of abduction as an inferential process.[10] For the present, however, consider the words of Hadamard as applied to invention and discovery, both fundamental to forecasting unique events:

> *Indeed, it is obvious that invention or discovery, be it in mathematics or anywhere else, takes place by combining ideas* – Jacque Hadamard[11]

For many years now, successful law enforcement agencies (particularly larger metropolitan agencies) have used information technologies to improve their capability to analyze trends and specific criminal patterns, as well as project where the next murder, robbery, rape, etc. might occur based on analytical techniques. In addition, these same techniques have informed the very personal police business of crime prevention in schools and communities. Successful deployment of modern law enforcement capabilities rely on "prediction" and forecasting tools, techniques and tactics, the mechanical contrivances of the abductive inferential process.

Advances in instrumentation similar to those used by the IC have also improved the way the law enforcement community anticipates and predicts criminal activity. Some of these techniques greatly improve the way the law enforcement community is able to model patterns of criminal behavior and anticipate where the next criminal episode may happen. These modeling tools also improve the likelihood of catching the tip-off to unanticipated activity, improving the chances that these sorts of events will at least be considered if not expected.[12]

Consistent with the previous discussions on crime analysis and prevention, the sciences of complex systems thinking have brought new insights into how networks of all types function. Networks are the enabling infrastructure of any complex interaction that produces interesting behaviors, including the process of discovery as Poincare and Hadamard have suggested. Failure to understand networks and the dependencies they produce and exploit has long been a significant inhibition to solving crime and penetrating the evidence that actors in both criminal and intelligence investigations leave behind – advanced modeling techniques that are making their way into both law enforcement and intelligence are helping to mitigate some of the shortcomings discussed above. The effective synergy of intuition, probability and modeling will lead investigators to the next plateau of success, particularly in forecasting unique and rare events.[13]

2.3.F. Conclusions

In this paper, we have examined some of the difficulties the law enforcement community has faced through the centuries and in modern times in terms of anticipating and dealing with unique events or events that have never before transpired. It is no easier for a criminal investigator than an intelligence analyst. The law enforcement community has endured many of the same analytical shortcomings their brethren have in the intelligence community, except that the business of "modern" criminal investigations has been around considerably longer than its equivalent in the intelligence business.

Within this paper, we have also discussed the fusion of intuition, probability and modeling as enhancements to O'Hara's three "I's" and as a possible method of dealing with the challenges of anticipating unique or rare events. Information, Interrogation and Instrumentation continue to be the criminal investigator's chief tools to uncover the evidence of pending unanticipated events, but prediction is still a formidable challenge in any business, particularly when trying to anticipate something that has never happened before. It has been difficult to avoid comparing the law enforcement community to the intelligence community as their work is so similar and so critical to success of this nation, both internally and externally.

It remains to be debated whether or not the LE community has better excelled at HUMINT, the primary beneficiary of the use of the Three "I's", than the intelligence world over the years, but cops clearly have a good case to argue. While it has been difficult to compare and contrast the differences before September 11, 2001, we are beginning to see more of what each community has to offer to the other, and it is improving national security as a result.

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[1] O'Hara, C., and O'Hara G., Fundamentals of Criminal Investigation, Thomas Books, Springfield, IL, 2003.

[2] See also the chapter in this document on the subject of "Black Swans."

[3] In this current discussion of forecasting in the field of law enforcement, much of the forecasting discussed also includes criminal and other actor behaviors, as well as the events and unintended consequences derived from these criminal behaviors. Most evidence collected by law enforcement and the Intelligence Community (IC) does reflect on human behaviors, but law enforcement evidence almost exclusively supports the investigation of human behavior as an individual or acting in small groups.

[4] The 9/11 Commission Report, http://www.9-11commission.gov/.

[5] Taleb, N., The Black Swan: The Impact of the Highly Improbable, Random House, NY, 2007.

[6] Note for example the A-Space project, set up by the US IC. A-Space, a social networking-based collaboration virtual space for intelligence analysts was formally implemented on 22 September 2008 on the Joint Worldwide Intelligence Communications System (JWICS). For more information about A-Space, see: http://en.wikipedia.org/wiki/US_intelligence_community_A-Space.

[7] O'Hara, Ibid.

[8] Ibid.

[9] These techniques are discussed in more detail in the papers in Section 4, Remedies and Strategies, particularly Paper 4.10, "Complexity-Based Reasoning," by Hunt and Schum.

[10] Ibid.

[11] Hadamard, J., *The Psychology of Invention in the Mathematical Field*, Princeton University Press, NY, 1945.

[12] See for example, the work on Geographic Profiling at Texas State University. According to the website, "The process analyzes the locations connected to a series of crimes to determine the most probable area of offender residence. It should be regarded as an information management system designed to help focus an investigation, prioritize tips and suspects, and suggest new strategies to complement traditional methods." This is an example of instrumentation augmenting criminal investigations in ways that potentially improve the use of Information and Interrogation techniques O'Hara discusses. See: http://www.txstate.edu/gii/geographicprofiling.html.

[13] See Paper4.11, "Complexity-Based Reasoning," by Hunt and Schum.

2.4. Evolutionary Theory and the Prediction of Rare Events (Lee Cronk)

Author: Lee Cronk
Organization: Center for Human Evolutionary Studies, Rutgers University
Contact Information: lcronk@anthropology.rutgers.edu

2.4.A. Rare events in evolution

The term evolution simply means that organisms change over time. Darwin identified a process he called selection as the main driving force behind evolution. His key insight was that members of a species are not all the same. Instead, members of a species vary from one another, and some of those variations both are heritable and have an impact on the ability of their bearers to leave descendants. The result is differential reproduction: Some varieties leave more descendants than others. Differential reproduction leads both to small changes, as when a species becomes better adapted to its particular environment, and to big ones, as when a new species arises from an existing one. Other processes, such as genetic drift (random changes in gene frequencies), the flow of genes between populations of organisms, and the prevention of gene flow through the isolation of populations (e.g., by physical barriers) are also important causes of evolutionary change, though they lack selection’s directionality and thus its ability to make predictions about the kinds of changes that are most likely to occur.

Some kinds of rare events are very important in evolution. For example, genetic mutations are the starting point of all evolution because they provide the variation upon which selection can act. Because DNA is an extremely high fidelity copying system, mutations in general are rather rare. Rarest of all, however, are the beneficial mutations upon which adaptations are built. Catastrophes are another category of rare event that is important in evolutionary history. The most famous example is the asteroid impact thought to have caused the extinction of the dinosaurs about 65 million years ago. Many other such events, including not only impacts from space but also earthbound events, such as episodes of high volcanic activity, may have had dramatic impacts on many species and thus on the trajectory of evolution more broadly. As important as rare events like mutations and catastrophes may be, evolutionary theory itself has little to say about them. This is because they are, by definition, exogenous to the theory. They affect evolution by changing the basic material on which evolution works.

2.4.B. Evolution and the prediction of rare behaviors

The concern here is with the prediction not of rare evolutionary events generally but of rare human behaviors. On the face of it, evolutionary theory would appear to be poorly suited to the prediction of rare behaviors. The reason is that any rare behavior that is helpful to the organism performing it will be favored by selection (i.e., it will enhance its bearers’ ability to reproduce) and then quickly spread in the population. Particularly if selection in favor of the characteristic is strong, this will usually result in the behavior becoming common before any observers have had a chance to notice and record it. Conversely, any rare behaviors that are harmful to the organisms performing them (i.e., reducing their ability to reproduce) will be quickly selected out and so disappear. Furthermore, evolutionary theorists are usually interested in common behavioral patterns, such as food acquisition, predator avoidance, mating, parenting, and cooperation. However, there are at least a few principles that emerge from evolutionary theory that may help us forecast rare behaviors.

2.4.B.1 Rare behavior may occur at one end of an adaptive continuum

Many behaviors are not simply dichotomous, either present or not present in an organism. Rather, behaviors often exist along a continuum, ranging from strong expression to weak expression. How strongly they are expressed may vary from individual to individual or from one circumstance to another within the same individual. In most circumstances, we expect organisms to respond appropriately and adaptively, but in extreme and unusual circumstances their responses may become unpredictable, and the result may be the occurrence of rare (and often undesirable) behaviors.

A case in point is child neglect, child abuse, and infanticide by adults who are unrelated biologically to their victims. Although cases in which the victims of these crimes are related to the perpetrators receive lots of media attention, in fact they are quite rare. Most biological parents take excellent care of their children. Most non-biological parents also take excellent care of their step, adopted, and foster children, but the rates of child neglect, child abuse, and infanticide by individuals not biologically related to the victims are much higher than for biological parents and their children. This has been documented extensively by Martin Daly and Margo Wilson[1]. In data sets from several different countries, rates of child abuse, child neglect, and infanticide by adults living in the same household as the victim but not biologically related to him or her are many times greater than those for parents and other biological relatives of the victim. This pattern extends to older homicide victims, as well. Controlling for opportunity, you are more likely to be killed by someone you live with who is not biologically related to you than by a co-resident biological relative.

The reason for this pattern becomes clear if we look at the relationships among parenting behaviors along a continuum. Because one's own biological offspring carry one's own genes, selection will favor greater investment in them than in young to which one is more distantly related or unrelated. This differential solicitude is an everyday fact of life that we all accept. Indeed, we expect parents to be primarily responsible for their own children, not for the children of others. However, when differential solicitude shades into neglect, problems arise. A first step in this direction appears in data from the US and South Africa analyzed by Case et al.[2]. They found that in both countries, less money is spent on groceries when at least one of the children in the household is unrelated to the mother. The pattern is the same whether the mother is the child's step-parent, foster parent, or adoptive parent. The data from South Africa, which are more detailed than those from the US, also show that households in which there is at least one non-biological relationship between the mother and a child spend more on liquor and tobacco than households in which all relationships between the mother and resident children are biological. Such a bias is subtle and difficult to detect without fine-grained data. Because Daly and Wilson's studies use crime statistics rather than data on household economics, they move us into more extreme biases in parental investment. Only cases of neglect and abuse extreme enough to have attracted the attention of authorities enter their field of view. But here, too, we see the same pattern: Children are more likely to be victims of neglect and abuse if they live with an unrelated adult. A very common pattern is for that adult to be the mother's boyfriend or new husband.

The rarest event that arises in this situation is the death of a child. When it does occur, it usually appears to be the unintended consequence of extreme child abuse rather than a deliberate act of murder. This becomes clear in Daly and Wilson's comparisons of the methods used when biological and non-biological parents kill their children. On those rare occasions when biological parents do commit such a crime, they typically use methods that are guaranteed to result in the death of the child, such as a gunshot or strangling. Biological parents who kill their children also often then kill themselves, suggesting that the pattern is fundamentally pathological. When non-biological parents kill children, in contrast, it is usually the result of a behavior that might not always result in death, such as beating and kicking, and they only rarely also kill themselves. The rare event of infanticide by unrelated adults thus appears to be one very extreme end of a continuum of parental behaviors, the more mild form of which – greater solicitude towards one's own children than towards children unrelated to you – we both accept and expect.

It should be noted that this pattern in humans is unrelated to a pattern found in infanticide in a wide variety of nonhuman species, such as langurs[3], baboons[4], and lions[5]. In those species and many others, males often kill unrelated offspring. Because most species that display this pattern have little or no male parental investment, this cannot simply be an extreme expression of differential solicitude. Furthermore, the methods used to kill in these cases are usually swift and extreme, leaving no doubt that the intention is to kill. In such non-human species, selection has favored this behavior in males because it frees females from parental responsibilities, making them sexually accessible sooner than if they were to continue nursing their young. Although this is good for neither the females nor their offspring, it is favored in the males because it increases their reproductive success. Nothing like this is being suggested for the human case. In our species, the pattern documented by Daly and Wilson appears to emerge from the continuum of differential solicitude, and there appears to be nothing adaptive about it for anyone involved. This includes the perpetrators, who often end up in prison.

2.4.B.2 Rare behavior may be a costly signal

Normally, selection in favor of a trait will lead to it becoming very common in a population. But this creates a problem for an organism that needs to let others know that it is anything but a common organism. For example, male organisms typically send signals to females regarding their quality as potential mates. Because males have an incentive to send deceptive signals about their quality, females have been selected for skepticism. Males who are of truly high quality must therefore find a way to send a signal that not only displays their quality but that does so in a way that cannot be faked by males of low quality. One way to do this is by making the signal costly to produce in a way that low quality males cannot afford to mimic. These are referred to as costly signals. In biology, costly signaling theory was developed mainly by Zahavi[6] and Grafen[7]. Evolutionary biology's costly signaling theory has parallels in other fields, such as Veblen's[8] notion of conspicuous consumption and the insights of economist A. Michael Spence[9] regarding job market signaling. Employers seeking high quality employees have an incentive to look at hard-to-fake signs of applicant quality, such as degrees from elite institutions. This is true even if the degrees happen to be in fields unrelated to the job at hand. Prospective employees, then, have an incentive to send such signals, leading them to compete for slots at elite universities and for honors and other signs of quality. The rarer and more difficult to achieve the accomplishment, the stronger the signal of quality.

This kind of reasoning has been successfully applied to some rare but very visible behaviors among humans. On the Pacific atoll of Ifaluk, Sosis[10] has documented something called "torch fishing." This involves using torches at night to attract flying fish, which then serve as bait for prized dog-toothed tuna. Although torch fishing is not very productive compared to more common forms of fishing, it is quite a spectacle when seen from shore, and that appears to be why men do it. Torch fishing turns out to be a good signal of male quality as a food producer. Although it is not very productive, fish production from torch fishing by individual men correlates with their fishing productivity overall. A similar pattern has been found on the Australian island of Mer by Smith et al.[11] On Mer, sea turtles are an important food source. The easiest way to obtain turtles is to capture them when they lay their eggs on the islands’ beaches, which is something that virtually anyone can do. However, men on Mer also hunt turtles at sea during the turtles’ mating season. This is a dangerous and relatively unproductive practice, but, like torch-fishing on Ifaluk, it shows off the males’ qualities. Men who hunt turtles in this way end up with more wives and more desirable wives than men who do not do so.

Unless you are a tuna, a turtle, or a low quality male, torch-fishing and turtle hunting are benign sorts of rare behaviors. However, pressures to send hard-to-fake signals have the potential to lead to behaviors that are both rare and undesirable, such as extreme forms of violence. For example, becoming accepted in organized crime often means “making your bones,” i.e., killing someone on behalf of the organization[12]. Unlike crime gangs, terrorist organizations actively seek recognition for their acts, giving them an additional reason to send hard-to-fake signals regarding their collective willingness to do harm to others on behalf of their causes. An appreciation of the signaling value of terrorist acts may increase our ability to forecast them.

2.4.B.3 Rare behaviors may be responses to evolutionarily novel environments

An important thing to remember about selection is that it happens to organisms in specific environments. Each adaptation is associated with a particular environment, which is known as its “environment of evolutionary adaptedness”[13] or “adaptively relevant environment[14]. When we observe organisms in the kinds of environments in which they evolved, we generally expect their behavior to be adaptive. If we fully understand their adaptations, then their behavior should also be quite predictable.

When organisms are removed from the environments in which they evolved, or when those environments change rapidly, their behavior may no longer be adaptive and our ability to predict it may be sharply reduced. Many examples of maladaptive behavior in animals come from situations in which humans have rapidly altered their environments. The large numbers of dead deer and other animals on the sides of our highways are evidence of the fact that they did not evolve in an environment that included large objects moving at high speeds. A more colorful example comes from the Korean War, where bored G.I.s were known to capture toads and then roll shotgun pellets past them. In the environment of toad evolution, small moving objects were typically edible insects, so the toads would eat the pellets, filling up until they resembled beanbags. Although toads do have the ability to learn to avoid bad-tasting prey, shotgun pellets apparently did not trigger that learning mechanism. Bored G.I.s and shotgun pellets were both evolutionarily novel elements of the captured toads’ new environments[15].

When this insight about novel environments is applied to human psychology and behavior, it is called mismatch theory[16]. The idea is that much of the malaise in modern society may be due to the mismatch between it and the kinds of societies in which we grew up. While today’s society is characterized by interactions with large numbers of strangers and small families, our ancestors lived in the opposite situation: frequent interactions with members of their large, extended families and only rare interactions with strangers. The result, some argue, is the lonely-in-a-crowd mindset that creates feelings of depression and alienation in many people. In extreme forms, this may lead to pathological behaviors that are harmful not only to the affected individuals but also to those around them. When such feelings are experienced by large numbers of people, and when those people can identify each other and feel alienated en masse, the potential exists for responses ranging from peaceful movements in favor of what are perceived as more traditional values to violent movements in favor of the overthrow of the system that is seen as responsible for the problem.

2.4.C. Evolution of organisms' reactions to rare events

Evolutionary theory also offers insights into how organisms have been selected for their ability to deal with rare events in their own lives. Although selection pressures that rarely occur will, ceteris paribus, be less important than those that occur frequently, selection pressures that are rare but extreme may shape adaptations in powerful ways. For example, although becoming a predator's meal is, by definition, something that can happen only once in an organism's life, it is so catastrophic for that organism's reproductive success that selection will clearly favor extreme vigilance and other methods for avoiding it. Such vigilance may come with a cost: acting to avoid predators even when none are present. But, given the alternative, that may be a cost worth paying. In evolutionary theory, this is referred to as "the smoke detector principle"[17]. You don't want a smoke detector that goes off only if your house is burning down. It's better (though annoying) to have one that goes off even if you are just making toast. Similarly, responding inappropriately when it is just the wind making the bush next to you move is a small price to pay for responding appropriately when it is not the wind but rather a predator.

The smoke detector principle has certainly been reinvented by everyone ever called upon to create an early warning system for any serious threat, whether it be a household fire, missile launchings by a potential enemy, or terrorist use of WMDs. It may also be worth keeping in mind that one's adversaries are also likely have early warning systems designed on the same principle, making it both more difficult and more important to avoid any inadvertent signals of immediate hostile intent.

2.4.D. Conclusions

Though it deals mainly with the common and everyday, evolutionary theory may also help us forecast rare events, including rare human behaviors. Understanding evolutionary theory's contributions to this problem requires an understanding of the theory itself and of how it is applied to human behavior and psychology. This paper has presented some possible insights from evolutionary theory, but it is by no means exhaustive. Other evolutionary anthropologists, biologists, and psychologists would surely come up with additional insights, and their counsel should be sought.

This paper has offered the following suggestions:

- Some rare behaviors may represent the extreme ends of behavioral continua that are otherwise adaptive.
- Some rare behaviors may arise because of their value as signals to others of some quality in the signaler, such as his or her potential as a mate or his or her commitment to the group.
- Some rare behaviors may arise from mismatches between the environments in which organisms evolved and the circumstances in which they now find themselves.

- If rare events exert sufficient selection pressure, then organisms may have hypersensitive mechanisms for detecting them, which may lead to inappropriate reactions to perceived threats.

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2.5. Military Perspective (Joseph Rupp)

Author: Maj Joseph Rupp
Organization: Joint Staff J3
Contact Information: joseph.rupp@js.pentagon.mil

2.5.A. Introduction

"Our challenge in this new century is a difficult one. It's really to prepare to defend our nation against the unknown, the uncertain and what we have to understand will be the unexpected," SecDef D.H. Rumsfeld.

The 21st century national security environment differs qualitatively from the security environment that nations faced throughout the industrial age. "Militaries now need to respond to a wider range of potential threats, many that are difficult to assess and many that cannot be responded to with conventional military tactics and capabilities."[1] The crises faced in the modern warfighting environment demand a response that is many times more complicated than those to which the current leadership is accustomed. The factors that must be brought to bear today are not necessarily the factors required in times past. US military leadership's current vision calls for "agile and adaptive leaders able to conduct simultaneous, distributed, and continuous operations."[2] This implies that foreseeable challenges will demand greater knowledge, insight, and ability in decisionmakers. As military leaders become increasingly agile and adaptive, their organizations will follow.

Transforming an industrial age, hierarchical organization, such as the Department of Defense (DoD), into an information age, networked organization is a daunting process. As military leaders adapt to meet the challenges in today's security environment, the military organizational culture as a whole changes with them. Organizational structure changes follow the changes in cultural. Communication increases. Transparency increases. Hierarchical organizations become more collaborative. As this is occurring, the military organization is increasing in adaptive capacity. In order to fully leverage the increased capacity within military organizations and leadership, changes are required in planning and operational processes used throughout DoD. These processes must meet and exceed the adaptive capacity of the organization in order to maximize organizational agility and adaptive capacity.

Threats to national security continue to expand the spectrum of challenges that the military will face in the next century. In addition to maintaining traditional military capabilities, emphasis is needed to manage or prevent crisis events that have an irregular, catastrophic, or disruptive precipitant.

By conducting an analysis of crisis level rare events, how they have and may effectively be managed, or altogether eliminated; leadership, staff, and action officers throughout DoD can develop and implement an Adaptive Planning and Execution System (APEX) that will better prepare today's military to anticipate and address the complex, multidimensional, rare events and unforeseen threats to our national security.

2.5.B. Rare Events and the Nature of Crises

When assessing the underpinnings for rare events such as acts of terror, the use of weapons of mass destruction, or other rare events of significant negative consequence, they bear the characteristics of "crisis" level events. As such, understanding the nature of crises will facilitate a better understanding of how rare events may be anticipated.

This discussion will not focus on rare events of lesser consequence, as they do not pose a threat to national security and therefore, do not drive changes to the status quo. The old adage, "if it's not broke, don't fix it" would apply.

According to Thomas Schelling, "The essence of the crisis is its unpredictability."[3] Most students of crisis agree that it is an acute rather than chronic phenomenon. Most definitions of crisis include a number of common elements. These include: "the perception of threat, heightened anxieties on the part of decision-makers, the expectation of possible violence, the belief that important or far-reaching decisions are required and must be made on the basis of incomplete information in a stressful environment."[4] Similar to incomplete information is the element of uncertainty, or unpredictability.

Snyder-Diesing take a slightly more in-depth assessment on the impetus behind a crisis. Rather than view a crisis as a "situation", the phrase "sequence of interactions" is used. *Sequence of interactions* is described as more meaningful, first because it is the kind of interaction going on between the actors, that gives their relations the character of "crisis". *Sequence* also clearly denotes a span of time and certain relatedness between the specific instances of interaction.[5]

Pfaltzgraff emphasizes the creation of a *fait accompli* in the development of crisis.[6] This "accomplished act" serves, not as a cause, but rather as a precipitant to which an organization must respond. The *fait accompli* is many times the defining event that results in a conflict situation crossing the threshold into crisis.

The concept of a *sequence of interactions* implies that there are events leading up to a "rare event" that would serve as indicators of that event. Even in the Pfaltzgraff model, there are pre-crisis, escalatory events that culminate in the creation of a *fait accompli.* Both models serve to point out that there are one or more precipitants to a crisis. Identification and understanding of these precipitants would serve to help one anticipate rare events.

As this discussion will focus on military organizations, one must include US military doctrine and the joint definition of crisis. Joint publications define crisis as:

> An INCIDENT or SITUATION involving a threat to the United States, its territories, citizens, military forces, and possessions or vital interests that develops rapidly and creates a condition of such diplomatic, economic, political, or military importance that commitment of US military forces and resources is contemplated to achieve national objectives. An adequate and feasible military response to a crisis demands a flexible adaptation of the basic planning process that emphasizes the time available, rapid and effective communications, and the use of previously accomplished joint operation planning whenever possible.[7]

Following consideration of the various approaches to the definition of crisis, and in the context for which the definition of crisis will be used throughout this paper, the following definition will be applied. *Crisis results from an acute, unforeseen sequence of interaction leading to a fait accompli, where vital interests, values or system stability are threatened, and to which an organization must respond to uncertainty within a finite time period in order to achieve success*.[8] The genre of "rare events" that are the subject of this paper fall within the context of this definition.

Further discussion regarding frequency, magnitude, duration, previous occurrence, recentness and the degree to which an event is actually foreseeable could address aspects of what makes an event "rare?" An event could be rare due to infrequent occurrence. It could be an event that takes place regularly, but not to such a magnitude or duration as to exceed organizational capacity or serve as a threat to vital interests. A "rare event" could be an occurrence of something that has not previously occurred or was perhaps historically commonplace but has not occurred "recently."

Anticipation of rare events is varied dependent on what category it falls into. Some examples of varied anticipation could include the following: For events that are known to occur, but do so infrequently, plans can be developed, worked through, and then put on a shelf to be pulled out when the event occurs. Since it is something that has previously occurred, perhaps indicators could be identified prior to the *fait accompli* and measures could be taken to prevent its occurrence. For an event that is rare due to its magnitude, perhaps a plan is already in execution and requires use of a branch, sequel, or reallocation of resources to the effort. Anticipation of a truly unforeseen event may lie solely in maintaining an adaptive system capable of relying on current plans and available resources as a point of departure from which the organization can adjust to meet the challenge of the unforeseen event.

2.5.C. The Adaptive Planning and Execution System (APEX), How the Military Anticipates Rare Events

“Today’s environment demands a system that quickly produces high-quality plans that are adaptive to changing circumstances.”[9]

In the process of deciding how best to engage Iraq in 2003, Secretary of Defense Donald Rumsfeld evaluated the plan that United States Central Command (USCENTCOM) had developed for the invasion of Iraq. Upon review, civilian leaders wanted multiple options. They wanted risk assessments for each option. They were not happy with the large amount of resources that the existing plan called for. They also felt that some of the assumptions and assessments used in the development of the plan were wrong, outdated, or not applicable.[10] The existing planning process was considered cumbersome and utilized outdated planning technology. It was difficult to modify plans quickly and put them into execution. The bottom line is that extraordinary effort was required to adapt plans to rapidly changing strategic circumstances.

The existing Cold War planning construct that was still in effect included the following elements: assumed forces would be ready and available, static conventional threats, forces postured to mitigate time-distance challenges and convey resolve, assumed little strategic change occurred during a 2-3 year planning cycle.

The demands of homeland and global operations warranted revisions to the existing planning and execution paradigm. Rapidly changing circumstances and uncertainty define the security environment. The accelerated pace and complexity of military operations requires the President of the United States (POTUS), Secretary of Defense (SecDef), Chairman of the Joint Chiefs of Staff (CJCS) and combatant commanders (CCDR) have the ability to respond quickly to dynamic threats and challenges. The fluid and uncertain international situation requires a transformed planning and execution capability, which quickly generates and/or updates detailed plans containing multiple options that can be readily adapted to the given circumstances and then rapidly transitioned to execution.[11]

At the direction of the SecDef, the Principal Deputy Under Secretary of Defense for Policy tasked the Deputy Assistant Secretary of Defense for Plans and Policy (DASD(P&P)) in August 2003 to work with the Joint Staff (JS) to create a successor to the deliberate (now termed "contingency") and crisis action planning systems and processes. Specifically, he sought an approach that would considerably shorten the time required to produce plans and ensure they could be readily adapted to a constantly changing strategic landscape.[12]

The Adaptive Planning and Execution (APEX) is the Joint capability to create and revise plans rapidly and systematically, as circumstances require. The APEX construct allows for plans to be rapidly developed and continually adapted. It supports real-time collaboration and iterative planning. Parallel planning across multiple echelons exist to the maximum extent possible. APEX involves frequent harmonization of planning considerations (e.g., approaches, courses of action) at all levels throughout the process, even after the plan is "completed." This further supports plans with more options, adaptable to a variety of changing circumstances. Plans, planners, planning tools and relevant data bases will be networked. Automatic triggers will alert planners for possible modifications, adjustments, or revisions. Integrated tool suites will exist for faster analytical feedback and broader collaboration.

Figure 1. Transformation of Operational Planning[13]

2.5.D. The Way Ahead

The Adaptive Planning (AP) initiative has made great strides merging contingency and crisis planning into a single end-to-end planning and execution, "living plans" construct. AP will provide the foundation for a constellation of joint and combined operations, and living plans designed and resourced to achieve national defense, and military strategy objectives in a manner that is both militarily and politically acceptable. Therefore, it is important that we embrace the new processes, systems, and technologies that further enhance our ability to rapidly develop, assess, adapt, and execute plans in a dynamic environment.[14]

The *Implementation Stage* for the APEX commenced with the approval of Adaptive Planning Roadmap II in March 2008. This stage will, through spiral development, focus on achieving an improved transition from planning (contingency and crisis) to execution via a refined APEX process.[15]

AP-transformed processes, procedures, products, training, and technology will enhance the ability of combatant command, Service, component command and Joint Staff planners to conduct parallel, collaborative planning with subordinate elements and with other members of the Joint Planning and Execution Community (JPEC). It will align and synchronize a wide group of functional activities (e.g., situational awareness, intelligence, force employment, force projection, force management, readiness, communications, logistics and security cooperation functions) that require rapid integration and support operational net assessment (ONA). The APEX system will provide a methodology that allows plans to support resourcing decisions. Consequently, the APEX system will extend from the national-strategic level within and across the multiple echelons of operational and tactical command and further across the JPEC as needed.[16]

Many of the AP initiative principles have been incorporated into the current Joint Publications. They consist of a multi-volume set of Chairman of the Joint Chiefs of Staff Manuals (CJCSM 3122 series) that specifies policies, procedures, and reporting structures supported by communications and computer systems for planning mobilization, deployment, employment, sustainment, redeployment and demobilization of joint forces and supporting technology. These CJCSMs will be retitled APEX volumes at their next update and rewritten to complete the transition from the legacy system to the Adaptive Planning and Execution system.

At full implementation, the APEX system will provide a single planning process encompassing both contingency and crisis action planning through execution (called the APEX process) and will establish and facilitate a constellation of joint operations, military activities, and living plans integrated with living databases designed and resourced to achieve the objectives of the National Security, Defense and Military Strategies in a manner that is both militarily and politically acceptable.[17]

The APEX has a significant affect on the anticipation of rare events. Through technology, automatic "flags" networked to near-real-time sources of information will alert leaders and planners to changes in critical conditions and planning assumptions that warrant a reevaluation of a plan.[18] Execution of a plan does not end the planning process. Planning continues for future operations in the plan using the planning functions. Using information and data continuously acquired through situational awareness and monitoring the level of success of the plan's tasks and requirements, the planning cycle may be reentered at any point to receive new guidance, provide an in-progress review, execute branches or sequels, modify the plan or terminate the execution.[19] A key measure of success will be the ability to rapidly transition an entire plan from contingency planning to crisis action planning for refinement, implementation and execution.[20]

2.5.E. Conclusion

"The major institutions of American national security were designed in a different era to meet different challenges."[21] Continued development of AP processes is vital to the anticipation of crisis level rare events and providing the President and senior leadership with viable options that will successfully support national objectives and allow the DoD to address the challenges of the twenty-first century.

The strategic landscape is no longer dominated by traditional threats such as regional powers with conventional and (some) nuclear capability as well as the continued instability created by interstate conflicts. Non-traditional, irregular threats that involve a global radical Islamist insurgency; asymmetric warfare fought by decentralized groups of terrorists; and exploitation of failed and failing states with intrastate conflicts now pose a great challenge for today's security establishments.

Threats to national security are expanding the spectrum of challenges that the military expects to face in the next century. A greater emphasis is needed to manage or prevent crisis events that have an irregular, catastrophic, or disruptive precipitant, in addition to maintaining traditional military capabilities. In order to meet the demands of this environment, the military must continue to increase the adaptive capacity in the areas of culture, organizational structure and processes.

A basic measure of the adaptive capacity of an organization is the speed of command within the organization, or in other words, "the time it takes to recognize and understand a situation (or change in the situation), identify and assess options, select an appropriate course of action, and translate it into actionable orders."[22] In many respects, the speed of command we are accustomed to in "industrial age" hierarchical organizations is insufficient to respond to more agile adversaries, crises, complex emergencies, and rare and unforeseen events. The military must continue to develop a cognizance of challenges they know or believe they will face. Then, to the extent of the resources they have available, implement changes that can be applied in the event the organization is called to react or respond to such rare events as are addressed in this article. These measures must extend beyond the foreseeable challenge, to include any branches, sequels, or contingencies as may threaten the nation.

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3. Limitations and Common Pitfalls

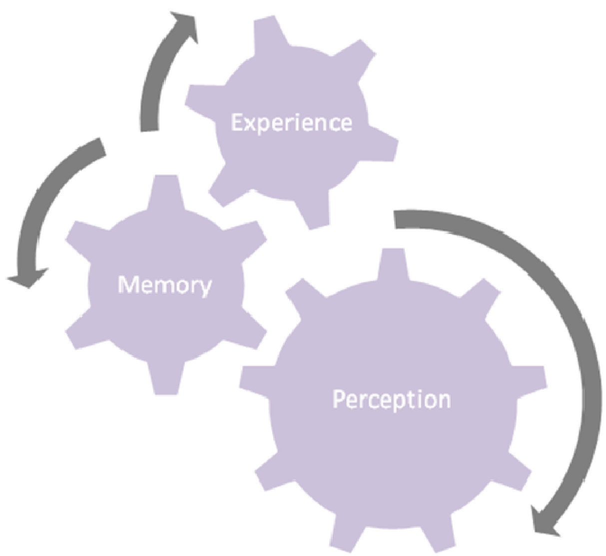
3.1. Cognitive Pitfalls (Sarah Beebe, Randy Pherson)

Authors: Sarah Miller Beebe and Randolph H. Pherson
Organization: Pherson Associates, LLC
Contact Information: SMiller@pherson.org and rpherson@pherson.org

What is it in our cognitive process that makes it so difficult to anticipate rare events? Rare events by definition are uncommon, but the cognitive processes that seem to limit our ability to anticipate them are not. Neuroscience, psychology, biology, and simple experience have taught us much about how the brain works and the factors that can help—and hurt—our ability to anticipate rare events. Rare events, by their very nature, are almost impossible to predict. We can do a better job of anticipating them, however, if we learn more about how our brain works and why it gets us into trouble. Although we may not be able to anticipate rare events, we can reduce the chances of being surprised if we employ measures to help guard against inevitable cognitive pitfalls.

An understanding of the human cognitive process begins with acknowledging the vast capacity of the human brain, with its roughly 100 billion neurons. Such immense cognitive capacity facilitates fast thinking and effective cognition, but there is a hitch: the things that help us efficiently recognize patterns and quickly perform routine tasks can also lead to inflexible **mindsets**, distorted **perceptions**, and flawed **memory** (See Figure 1). These cognitive realities prove most often to be at the heart of faulty thinking and failures of analytic imagination.

Figure 1 Mindsets: Unavoidable But Surmountable



Mindsets are an unavoidable result of the method by which our brains process experiences and store information as memories based upon our perception of what we experience, rather than an exact copy of what occurred. Over time and with the right practice, we can overcome these cognitive pitfalls in order to help ourselves think creatively about the future and improve our ability to anticipate the precursors of rare events.

The ramifications of these seemingly minor hitches can be devastating. For example, they can produce upsets in athletic competitions when coaching staffs fail to anticipate innovative game plans used by rival teams. They can prevent businesses from anticipating the competitive threats of new technologies and business practices, resulting in lost market share or corporate failures. And for war fighters, they can lead to tragic loss of life, as happened in the case of the attack on the USS Cole.

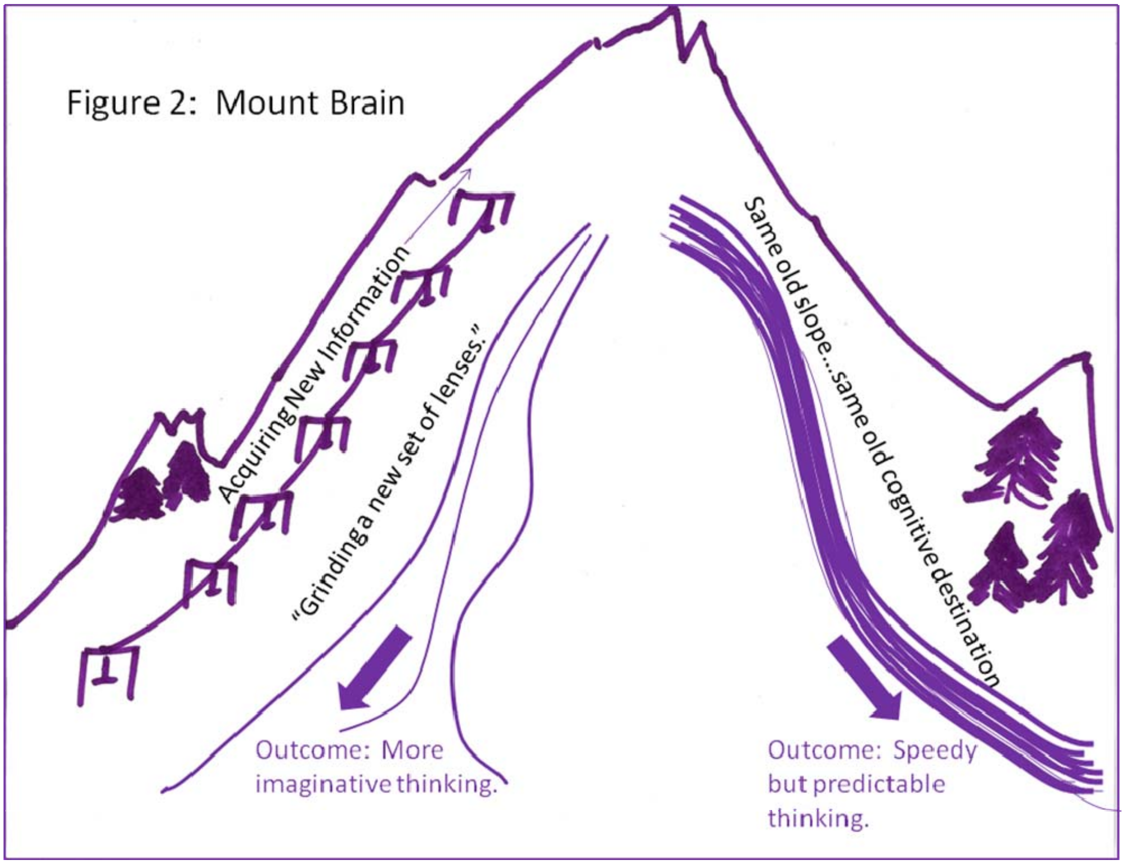
Postmortems of virtually every major intelligence failure over the past two decades have identified ingrained analytic mindsets as a key contributing cause. Mindsets, as bad as they may sound, are neither good nor bad, they are simply unavoidable.[1] Take, for instance, a recent Stanford study in which 48 students, half of whom said they favored capital punishment and half of whom said they opposed it, were presented with two pieces of evidence, one supporting and one contradicting the claim that capital punishment deters crime. Both groups were more convinced by the evidence that supported their initial position.[2]

The Stanford students were, in a sense, tricked by their over-efficient brains. Neuroscience tells us that whenever two of our neurons are activated, the connections or "synapses" between them are strengthened. Much like muscles, the more frequently those same neurons are activated, the stronger the path between them.[3] The pitfall for the Stanford students—or for anyone who is asked to consider new information or think creatively about the future—is that once you have started thinking about a problem a certain way, the same mental circuits or pathways are activated and strengthened each time you think about it. On the positive side, this process facilitates efficient retrieval of information. On the downside, these pathways become the mental ruts that make it difficult to reorganize, reconsider, or in a more general sense, think creatively about the information. This is what makes mindsets so easy to form and so extraordinarily difficult to overcome.

Just as these cognitive ruts can distort the ways we process new information, they can also interfere with the ways we recall old information—our memory. Memory—both short and long-term—plays a critical role in our ability to deal with time pressure, large volumes of information, and multiple competing priorities. To process large amounts of new information quickly, our brains compare each new bit of data to old information that we have stored in memory—but as the volume of information mounts, we become increasingly inclined to recall evidence that supports our favored hypothesis and to ignore or reject information that is inconsistent with it. This phenomenon is readily apparent in another recent study with a group of Stanford students in which the subjects were exposed repeatedly to an unsubstantiated website claim that Coke is an effective paint thinner. Students who read the statement five times were nearly one-third more likely than those who read it only twice to attribute it to the reputable Consumer Reports rather than the less reputable National Enquirer. In essence, their memories, when retrieving the information, gave the claim a degree of credibility even though the statement was false.[4]

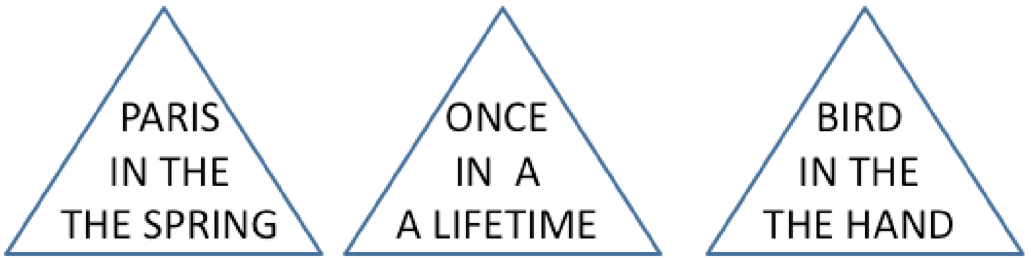
3.1.A. Mental Ruts: Why We Like to Follow the Same Tracks in the Snow

One prominent neuroscientist calls this process the "plastic brain."[5] In contrast to elastic, which always returns to its original shape, Boston neuroscientist Alvaro Pascual-Leone explains that the plastic brain is changed with every experience. Much like a snowy mountain in winter, if we ski down it—or think about a particular problem—we will make a path in the snow. What is fascinating is that each time we think about the same problem or ski down the mountain, we will be more likely than not to take the same general path. The more we use these ruts in the snow, or mental tracks, the speedier, but more predictable, the path becomes. For "Mount Brain," this predictability can lead to either good or bad habits (See Figure 2). Pascual-Leone notes that over time our "ability to take a different path becomes increasingly difficult. A roadblock of some kind is necessary to help us change direction."[6] More or even better information is not sufficient to bump our thinking out of these tracks and into new ones. Indeed, as John Seely Brown has noted, "instead of pouring knowledge into people's heads, you need to help them grind a new set of eyeglasses so they can see the world in a new way."[7]



The lesson we can take from Pascual-Leone's work and the Stanford study is that while the brain's efficiency allows it to reach a judgment or decision quickly by utilizing the same synapses and well-worn pathways through the brain, these pathways will exclude other more imaginative routes that might lead to a different and more accurate answer. We assume that the homogeneous answer produced by this process is right not because it is, but because we arrive at this same answer each time we think about it. A further complication is that this result—or how we perceive the result—is often more a product of our expectation than what is actually occurring (See Figure 3).[8]

Figure 3: The Role of Perception



In *Psychology of Intelligence Analysis*, Richards Heuer uses this graphic to illustrate the role that perception plays in analysis, noting that we tend to see what we expect to see. Look at the three figures above and say out loud what is printed in each triangle. Did you notice that the article “the” appears twice in the first triangle? What articles are repeated in the other two triangles? Our expectations make it highly difficult for us to notice that one article is repeated in each triangle. This is the result of perception, mindset, and our over-efficient brains at work.

3.1.B. <u>Insufficient Mental “Bins”</u>

Another cognitive obstacle to perceiving rare events is the tendency of human beings to categorize and simplify what they perceive. It is easier to understand a complex world if you can organize it. The fewer bins or labels you employ, the easier the task. This tendency to categorize and oversimplify makes it much easier—and quicker—to process data, but it also desensitizes the individual to anomalies or behaviors that do not fit into traditional patterns and may be a precursor to significant, major new developments.

An example of this phenomenon occurred when some of the 9/11 terrorists took pilot training. While this behavior was observed and reported, it did not send up a sufficient warning flag because government officials did not have an appropriate "bin" in which to put and think creatively about the information. They were accustomed to terrorists who hijacked airplanes but then landed and made demands while threatening the lives of their hostages; they did not have a sufficiently developed "bin" for terrorists who were planning to crash the airplane, killing the passengers and themselves. The 9/11 Commission Report notes that "since al Qaeda and other groups had already used suicide vehicles, namely truck bombs, the leap to the use of other vehicles such as boats (the Cole attack) or planes is not far-fetched." And while "at least some government agencies were concerned about the hijacking danger and speculated about various scenarios" they had failed to meet "the challenge...to flesh out and test those scenarios, then figure a way to turn a scenario into constructive action." As a result, they did not create a new bin that would have allowed them to consider the use of a large, fully-fueled passenger airplane as a weapon. The full effect of the failure to develop a new bin was not felt until the 9/11 attacks themselves.

3.1.C. We Can Challenge Our Mindsets

The first failure of mindset and memory traps is a failure to recognize that they are an inherent part of being human. Knowing that our natural tendency is to put things into existing "bins" rather than ask if new "bins" should be created is a key first step. Knowing that we should lay down new tracks in the snow because it could lead to a different, more imaginative result is also essential. The second failure is our failure to take steps to challenge them. We first must recognize our analytic assumptions, our beliefs, and our insecurity in knowing that we do not have all the information. Then we can challenge our mindsets in order to be open to new information and new ways of thinking about it.

Rare events present tough cognitive challenges that are difficult, but not impossible, to overcome. It is exceedingly difficult to overcome the challenges of mindset, perception, and memory unless we actively challenge our ingrained cognitive processes. If the impetus for doing so is not obvious at first, we will naturally want to continue to find patterns and connect the dots, and will continue to do so until we recognize that the potential cost of doing so is failure. This is true even if most of the time we are lucky enough to choose the correct mental mindset and experience a speedy and accurate outcome.

Simply sensitizing ourselves to these cognitive glitches, however, is not enough. Thankfully, the human brain can change itself; it just needs encouragement to do so. Past experience shows that we can overcome the challenges of cognitive and memory pitfalls, but it takes practice—with the proper exercises—over time. Like any fitness program, cognitive improvements come gradually, with daily exercise, and the full extent of our improvement is often hard to recognize until the day of the competition.

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[1] Richards J. Heuer, Jr., *The Psychology of Intelligence Analysis*. (Washington: Pherson Associates, 2007) p. 10.

[2] Sam Wang and Sandra Aamondt, "Your Brain Lies to You," *New York Times*, 27 June 2008, www.nytimes.com.

[3] Richards J. Heuer Jr., "New Approaches to Challenge Analysis," *Unpublished Paper*, 2008.

[4] Sam Wang and Sandra Aamondt, "Your Brain Lies to You," *New York Times*, 27 June 2008, www.nytimes.com.

[5] Norman Doidge, The Brain that Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science (New York: Penguin, 2007) 209.

[6] Ibid. 210.

[7] John Seely Brown and William Ellet, *Seeing Differently: Insights on Innovation* (Boston: Harvard Business Press, 1997) 216.

[8] Richards J. Heuer Jr., "New Approaches to Challenge Analysis," *Unpublished Paper*, 2008.

3.2. Data Sharing: Lessons Learned from Two Previous Studies (Sue Numrich)

Author: S. K. Numrich
Organization: Institute for Defense Analyses
Contact Information: snumrich@ida.org

There is a tendency to mistake data for wisdom, just as there has always been a tendency to confuse logic with values, intelligence with insight. Unobstructed access to facts can produce unlimited good only if it is matched by the desire and ability to find out what they mean and where they lead. Facts are terrible things if left sprawling and unattended. They are too easily regarded as evaluated certainties rather than as the rawest of raw materials crying to be processed into the texture of logic. Norman Cousins[1]

Datum (pl. data) Any fact assumed to be a matter of direct observation.
The American College Dictionary [2]

3.2.A. Introduction and Statement of the Problem

How do we begin to anticipate rare events? In the physical sciences (for example, anticipating geological events) we explore all the theories and begin to collect and monitor on a regular basis all the parameters that theory declares important. The rare events that concern us are outside the physical domain. They involve the complexity of human activity. Human activity is explored and explained (to the extent that it can be explained) by examining different facets of human activity: psychology, sociology, political science and economics, history and anthropology. Information is collected by government, industry and academia. Each of these disparate disciplines offers clues to they type of human activity that contributes to rare events, but it is only in sharing theory and information across these different perspectives that we can hope to see the threads that converge into the rare event. Therefore, the ability to communicate across disciplinary and organizational lines, sharing both theory and data, is fundamental to being able to forecast rare events.

Human understanding is plagued both by an unquenchable appetite for data and by our ever-increasing capability for acquiring data. The simple, four-letter word "data" is a stumbling block. It is not knowledge, but the acquisition of knowledge starts with data. It does not produce solutions or insight, but the scientific processes that help us develop understanding depend upon being fed by good, clean data – whatever that means. This chapter will concern itself with the nature and meaning of data: how we acquire it; how we understand and misunderstand it; and the problems inherent in sharing it across disciplinary as well as organizational barriers.

The dictionary's definition of data contains two very important words: assumed and direct. We make many assumptions about data. An expert who develops statistical models thinks of data as quantitative information, perhaps even an integer, but certainly a numerical value that can be manipulated by his mathematics. However, not all observations lend themselves to being reduced to numbers. Yet as observations, they may still contribute to knowledge – just not through the use of a mathematical equation. The manner in which an expert employs observations forms the way he or she uses the term "data".

Data are assumed to be "direct" observations; however, even in the world of empirical science, data are not exactly direct observations. All observations are mediated. Voltage is measured by means of a voltmeter whose sensitivity and accuracy determine the quality of the measured data.

Our observations are limited by the capability of the sensor. This is as true for human observations as it is for instrumented scientific data. All observers have sensitivity, by that we mean the nature and extent of detail that can be sensed by the observer. In addition, all observations are subject to bias. Reliance on "trusted sources" is a tacit acknowledgement of the presence of bias and the inherent limitation of sources – human and otherwise. Even the best of data gathered from the most sensitive instruments are subject to interpretation, and rightly so. Observations are not reality; they are simply observations. Thus, observations are not certainties, but are very properly "the rawest of raw materials crying to be processed into the texture of logic".

3.2.B. Access – Not Just Classification

In a complex world, the deepest understanding of people and events is drawn by experts from different fields of study applying their tradecraft to the problem. The need for multiple experts creates the first tension with the Department of Defense (DoD) requirement for security. The more people, institutions, or communication nodes exposed to an issue, the less likely it is to remain secret. There are numerous reasons for restricting access to information – protecting sensitive sources, preventing disclosure of commander's intent, and preserving the element of surprise, to name a few. Security argues for limited disclosure while understanding requires exposure of information to a wide range of experts. When the bulk of expertise lies outside the government, particularly in academia where clearances are rare and secure facilities are almost uniformly absent, the tension is stressed to the breaking point. Yet, for the issues critical to waging "the long war" and for gaining insight to project trends and explore rare events, the expertise exists in academia. Therefore, security issues and the handling of data and information must be addressed with both caution and creativity.

Security classification, or limitation of distribution, is applied because of the nature of the data or its source. Individual sets of information that are unclassified in themselves often become sensitive in the aggregate. Open source, unclassified information can be treated as sensitive because of the organization that has acquired that information and redistributes open source media articles as "for official use only". While these restrictions are understandable in many cases, the classification is often habitual rather than intentional. With the understanding that the participation of academia is desirable, habitual classification should be examined, including the habitual classification of military data gathered in operating areas. This should be done with the clear understanding that even cleared experts in the private sector may not have storage or processing facilities for classified information. Providing ready access to secured sites for these cleared experts is a matter of practical necessity if they are to work with data and information at levels for which they are cleared.

Classification issues discussed above apply to sharing information between the DoD and experts in the private sector. Sharing of data and information across agency boundaries is similarly hampered by classification. In many cases, the clearances used in other agencies of the government do not match precisely with the clearances in DoD and it requires considerable effort to share information. This is true not only for organizations within the intelligence community, but for departments of Commerce, Justice, Treasury, and Energy. Yet, the insight that might be gained by examining all of the data from various sources should outweigh the issues involved in sharing that data.

When agencies do share information with one another, they often share the "finished products" of their analysis rather than the data and information used in that analysis. Sharing products is far better than not sharing, but it prevents the fullest extent of exploration by the widest range of experts. A piece of information discarded by one analyst because it has no meaning based on that analyst's background and tradecraft may provide insight to someone whose career has been spent on graph theory, statistical analysis, organizational anthropology or other expertise absent in the development of the finished product. The ability to exchange information and processed or cleaned data with experts who use different analytical methodologies increases the possibility of unearthing that latent evidence of a rare, but dangerous event.

Finally, providing a site for sharing data is yet another problem. Unclassified data ports that required common access card (CAC) access strictly limits access to information, even to experts with clearance, but without CAC cards. In a recent exercise, access to Intelink was offered to participants in a large effort, but access required sponsorship and citizenship and the ability to work through firewalls at both user and Intelink sites. The "unclassified" part of Intelink is for all practical purposes "for official use only". Understanding how to use collaboration tools more effectively to permit data and information sharing is critically important if we hope to acquire the insight needed to help anticipate rare events.

3.2.C. Understanding Data – Analyst vs Modeler

Different communities interpret the term "data" very differently. For many academics and intelligence analysts, data means a set of documents containing information about subjects of interest. A highly recognized database of socio-cultural information is the Yale University Human Relations Area Files (HRAF)[3]. The collection, the work of a consortium of over 300 educational and research institutions from 30 countries, consists of over a million pages of information about nearly 400 cultures and is organized according to the *Outline of cultural Materials (OCM)*. The OCM contains a list of more than 700 subject codes or searchable descriptors. Collection such as HRAF are composed of "unformatted text" or "unformatted data".

In contrast, the Global Terrorism Database (GTD)[4] developed by the National Consortium for the Study of Terrorism and Responses to Terrorism (START) at the University of Maryland is a structured database with information on nearly 80,000 incidents of international and domestic terror reduced into over 120 variables suitable for use in computational models. The GTD stores quantitative data extracted by a well-structured, human-intensive, analytical process from thousands of pages of open source reports. To a modeler, HRAF is not data, but rather a daunting amount of material that has to be systematically converted into data.

Two problems provide barriers to sharing and interpreting data: organization and interpretation. Organization of data into commonly understood categories is essential for acquiring, storing and sharing that data. This framework for information sharing is normally provided by a taxonomy or ontology. There is no commonly accepted taxonomy for socio-cultural information and yet this information is perhaps the most critical for anticipating rare events of military consequence.

The interpretation of data is a widely recognized problem. Problems in interpretation begin with a failure to document the precise meaning of the data elements. Consider reports of improvised explosive device incidents. Does the lethality refer to all deaths at the scene, or all deaths and fatal injuries, or all military deaths, or all deaths both military and civilian? Is the time of the incident the time when the device went off or the time a report was received of the incident? Was the location that of the device or that of a GPS signal from the device used to report the incident? Accurate analysis is hampered by this type of uncertainty.

Incident data is one type of data used in understanding events and developing trend analysis. Other important sources of information are the national and international statistical tables[5] that provide birth and death rates, provision of health and education, trade and economic status, and numerous other types of data important for understanding the status of the government and its ability to provide essential services for its population. Projections from such information gathered over many years can point to areas where insurgency is likely to arise. Unfortunately, standards for collecting and reporting critical statistical information have not been agreed upon and applied universally, particularly in areas where prevalent conditions could lead to insurgency and the presence of terrorist activity. In addition, the lack of data at local and provincial levels prevents the desired level of analysis. While the World Bank and the United Nations with the collaboration of numerous countries including the US are working to improve this situation,[6] the problem of incomplete and inaccurate data will persist for many years.

Various groups and agencies also amass data on topic of interest to them – topics that may also be of interest in examining insurgencies and problems of military interest. While exchange of reports and media articles can be useful, development of trend analysis requires that the information in those thousands of pages be distilled into structured date such as that found in the GTD. The distillation is accomplished by determining the type of information to be extracted from the sources and a code book that contains the criteria for interpreting and extracting that data. These are human-intensive efforts and require great time and attention to accomplish. However, the process of distilling large amounts of data into a structured format is vital if models are to be used for analysis and projections.

3.2.D. Managing the Acquisition and Processing of Open Source Data

The penetration of the internet and electronic publishing has dramatically increased the amount of information available for analysis. In addition to the routinely published news media and recorded radio and television programs, websites, blogs and portals are rich sources of information. Mining all of these sources and making sense of the information contained in the hundreds of thousands of pages of data available is a major challenge.

Just as a successful search using Google requires a strategy and some knowledge of the topic, mining open source media requires carefully crafted search strategies. All searches start with at least a thesaurus of words or phrases descriptive of the information sought. More refined searches require a more structured input. Case studies may be used to develop a set of indicators for specific types of events sought.[7] Use of a taxonomy for search provides the additional advantage of having a structure for cataloging and storing the collected information. Of critical importance is the collection of foreign language information. Often only the local, vernacular sources report on the information needed to interpret current events or forecast rare events.

Our ability to extract huge quantities of information creates an equally large issue of managing, sharing and extracting data from this information. The more widely we cast our nets, the more likely we are to capture the critical piece of information needed to forecast a particular rare event. However, that wide net also results in a massive amount of data to be processed. Unless the data acquisition capacity is matched with an equal capacity to extract data from the flood of information, and to process that data to build understanding and knowledge, the user might as well not collect the information.

On the other hand, if we rely on only English language sources or narrow our searches prematurely, we are likely to miss critical indicators of unrest, insurgency or other important events. Extracting information in native languages, interpreting that data and all other types of data and distilling structured data from all such sources is currently a human-intensive process for which the manpower is not available. In many cases, the best source of such manpower is in universities where both graduate students and subject matter experts have the talent to apply to the problem. Once again, this creates a problem of sharing information across traditional boundaries. In the long run, technology may provide the solution to managing and interpreting the vast amount of open source information, but in the foreseeable future, the process will require human intervention.

3.2.E. Summary of the Challenge

The ability to forecast rare events presents a significant set of interrelated challenges. Most rare events of significance to the military involve the complexity inherent in the human domain. That domain is currently broken down and studied in a variety of disparate disciplines including psychology, political science, sociology, economics, anthropology, history and many others, all of which, taken as a whole, are needed to understand and explain the human terrain in which the military must operate – strategically as well as operationally.

Most of the expertise needed to understand the human dimension exists outside of the military and often the means for shaping the complex environment reside in agencies of the government other than the military. These factors require an ability to share information in new ways.

The abundance of information sources in our internet-enabled world creates a problem of extracting and managing the information. Frameworks for storing and sharing information require careful attention and solutions that involve both policy and technology. The quantity of information points to the need for computational methods that can aid the human in making sense of disparate data and draw inference from it. Models require structured data and the process of creating that data from unstructured sources remains a human-intensive process.

Finally, detecting and forecasting rare events requires a balance between the amount of information acquired and the capability to process it into usable data. Narrowing search strategies prematurely is as apt to result in missing rare events as is the inability to process all the information retrieved.

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[1] Norman Cousins, "Freedom as Teacher", Human Options: An Autobiographical Notebook, Norton (1981)

[2] The American College Dictionary, ed. C. L. Barnhart, Random House, New York, 1970

[3] The Human Relations Area Files are found online at http://www.yale,edu/hraf/ and represents a subset of the entire collection for which the older files are being gradually converted from microfiche format.

[4] The Global Terrorism Database is described online at http://www.start.umd.edu/data/gtd/

[5] The World Bank provides a list of national and international organizations that collect statistical information Bank (http://www.worldbank.org) where the permanent website for the page is listed as http://go.worldbank.org/URKXL1MJ90

[6] The list of international efforts to improve statistical data is published by the World Bank (http://www.worldbank.org), permanent website for this list is http://go.worldbank.org/O0U6SATNQ0

[7] The Argus program for forecasting epidemiological events is built upon case studies from which a taxonomy of secondary and tertiary indicators is developed. The methodology is documented in an article by the developers. Wilson, J. M., Polyak, M. G., Blake, J. W. and Collmann, J., "A Heuristic Indication and Warning Staging Model for Detection and Assessment of Biological Events", J Am Med Inform Assoc, 15:158-171, Jan. 2008,

3.3. Black Swans (Carl Hunt)

Author: Carl Hunt
Organization: Directed Technologies, Inc.
Contact Information: Carl_Hunt@DirectedTechnologes.com

3.3.A. Introduction

This paper examines the problem of forecasting unique or rare events known as *Black Swans*. To be faithful to the concept of Black Swans as defined by author Nassim Nicholas Taleb in his recent book of the same name, we must first distinguish between what are "real" Black Swans[1] and the type of "Black Swans" we will discuss in this paper.[2] His book, while also a critique on the human reasoning process, goes to great length to help us understand that there are events that are so improbable that we can't even conceive of their existence, much less their occurrence in our lives, until after the fact, when they seem to have been predictable. In spite of the failure of our imagination to foresee these events before they occur, our hindsight allows us to see how they happened and assemble the pieces leading up to the event – an important part of Taleb's definition. We are surprised but convince ourselves that we should not have been – we chastise ourselves for our failures to predict the event: this is a true black swan in Taleb's parlance. These distinctions are important for they affect how we reason about these sorts of events.

According to Taleb, a Black Swan is 1), an *outlier*, as the event considered lies outside the realm of regular expectations; nothing in the past can convincingly point to its possibility; 2) the Black Swan event carries an *extreme impact*, creating turmoil and even chaos; and 3) regardless of the event being an outlier, human nature *encourages us to concoct explanations for its occurrence after the fact*, making it appear to us to be explainable and therefore predictable.[3] Taleb goes on to say that "the applications of the sciences of uncertainty to real-world problems has had ridiculous effects."[4] By this, he means that we continue to operate under the false pretext that our scientific tools can help us predict the unpredictable. His bottom line is that any logic we could fashion of Black Swans makes what we don't know even more relevant than what we do know. His suggestion offers a clue to how we might cope: only objective inquiry will help.

If all black swans were of the same ilk, it would be fruitless to discuss them as events about which we should be interested in a paper such as this. By definition, Taleb's true Black Swan (TBS) cannot be predicted or anticipated. In recognition of the type of event that is merely hard to anticipate (vice impossible), Taleb concedes that there is a class of events that share some TBS characteristics that can be anticipated. To be sure, our failure in the use of probability and statistics based on trends from past events applies to both categories of "swans" but we must quit deluding ourselves into thinking that we can anticipate or predict everything. This paper is about what might be anticipated, *while drawing conclusions on our attempts to anticipate what we cannot*. In contrast to the TBS, we will label the events we discuss in this paper the anticipatory black swan (ABS).[5] This perhaps would chafe Taleb a wee bit, but we must clearly distinguish between what can be known beforehand and what is truly a surprise.[6]

Interestingly, the "strategy" for both dilemmas is roughly the same: ask the right question at the right time (and be wise enough to understand the response or appreciate the signs we receive). Intelligent query, a holy grail of intelligence analysis and criminal investigation, could lead to success in the matter of anticipating what can be anticipated, and at least understanding sooner the impact of what cannot be anticipated, *while it is happening or in a timely manner after it has* *happened*. Understanding the emergence of a TBS during or immediately after its occurrence is probably our best defense and offers the greatest potential to mitigate the effects of unpredictable events, but we must be looking, or at least be aware of the possibility of surprise.

It's the questions as much as the answers that will lead to success in anticipating what we call Black Swans, regardless of category. Often these questions are posed in the form of hypotheses or assumptions that bear on the conclusions decision-makers take, but again, the nature of unknown or incomplete information, even when fashioned into hypotheses, demands that good questions be asked, and meaningful sources of evidence be considered. We must also be willing to let go of prejudice, bias and pre-conceived notions.

3.3.B. <u>ABS, Intuition and the Scientific Method</u>

As stated above, this paper considers events, however unlikely, that can be anticipated. A significant weapon in the anticipation of ABS, or anticipatory black swans, is an inquisitive intuition. Intuition has traditionally played a significant role in the field of law enforcement and intelligence analysis. It has been a major factor in the success of many criminal investigations; it is not always reliable, but can at least provide a starting point for reasoning about the world, if (and it's a big if) the investigator or analyst is willing to have his intuition tested by objectivity. The objective use of what Popper called the Scientific Method has been an important factor in dealing with complex analyses and investigations and trying to make sense of signs of impending attacks or other types of crime.

Focusing on what we don't know can help. "Black Swans being unpredictable, we need to adjust to their existence (rather than naively try to predict them). There are so many things we can do if we focus on anti knowledge, or what we do not know."[7] It also seems that we are better at learning the precise than the general, according to Taleb; Richards Heuer, in his work on intelligence analysis, concludes the same. Informed intuition, kept objective by understanding general principles, appears sometimes to be a bridge too far. But, since we need for this paper to do more than tell us what we can't do, and borrowing from Taleb, let's think about how to tackle an anticipatory black swan. Intuition and the Scientific Method should help.

The best place to start in understanding the role of intuition is to understand its boundaries. Both Taleb and Richards Heuer comment frequently in their works about the poor state of affairs of human brains and the thinking processes that apparently reside within. Not only do we often not know what we don't know, we often don't know why we don't know and how badly we are off the mark. "It is very difficult, at best, to be self-conscious about the workings of one's own mind," notes Heuer.[8] Heuer's claim is that we can train ourselves to think better: that seems to be our best hope! Otherwise, our expectations will likely attune us to what we are most sensitive to at the time, subject to the phenomenon that "mindsets seem quick to form, but resistant to change." This is most likely due to the problem in human reasoning that "new information is assimilated to existing images," according to Heuer.[9] Having failed to thus far discover the "intuition gene," it seems likely that induction, with perhaps a smattering of deduction, is the reasoning process that most closely resembles intuition.

If we start with an untrained or unsophisticated intuition, we have to be very lucky to avoid the pitfalls of flawed thinking that Taleb and Heuer caution against. Citing "Hume's problem" of inductive fallacy, and recalling that the future is under no obligation to follow the past, we do seem to come equipped with "mental machinery that causes us to selectively generalize from experiences," relying on biology and evolution from our ancestors' ways of thinking and learning.[10] It appears then that the untrained intuition may suffer more from a lack of inquisitiveness than anything else – this shortcoming contributes significantly to our responses to both TBS and ABS. Meaningful, science-based inquiry remains perhaps the most important way to learn, overcome bias and mitigate the "lessons" of experience.

Reasoning by analogy is another specific pitfall that Heuer uses as an example: "US policy-makers tend to be one generation behind, determined to avoid the mistakes of the previous generation. They pursue the policies that would have been most appropriate in the historical situation but are not necessarily well adapted to the current one" Heuer notes, citing the work of Ernst May.[11] Hume, Karl Popper and others proposed we resolve the problem of inductive fallacy (by extension, reasoning by analogy) through the use of the Scientific Method. This way we rely on testable hypotheses and the quest for evidence to disprove hypotheses rather than simply proving hypotheses to the satisfaction of the investigator before generalizing even further (and probably incorrectly). The proposition, articulation and growth of the scientific method greatly furthers the cause of avoiding reasoning by analogy and "Hume's Problem."[12]

This wise precaution, in spite of perhaps centuries of failure to apply it in the intelligence and law enforcement communities, bears repeating again. Statistics and probability still rely on an analysis of the past to make future projections (anticipation in the vernacular of this paper), but if used consistent with Popper's thinking about the Scientific Method, statistics form the basis for more consistent methods of testing hypotheses and questions about the linkages of past, present and future. Fortunately, new techniques in multidisciplinary thinking and supporting computational tools (modeling, simulation and visualization) offer some assistance to analysts and investigators who need occasional prodding to better and more consistently apply the Scientific Method to their work.

3.3.C. Understanding the Power of Co-Evolution and Emergence, and asking The "Right" Questions about Black Swans and Countering High Profile Terorist Attacks

Inquiry today more than ever is a collaborative tool, but it is still slow in developing and gaining acceptance in our culture. Consistent and collaborative inquiry about the environment is one of the best tools we have to identify ABS and mitigate TBS after the fact. In a paper entitled "The Primary Purposes of National Estimating," by Harold T. Ford, we learn more about the roots of interagency competition and failure to collaborate. "Responsibilities for intelligence were divided at the time (before Pearl Harbor). No one looked at the total situation: the Army watched the Imperial Japanese Army; the Navy watched the Imperial Navy." Joint operations were almost unknown and certainly not practiced, and thus the US Army and Navy forces at Pearl Harbor were operating in their respective voids.[13] Fortunately, the US intelligence community and the Department of Defense have made significant progress in overcoming these biases and prejudices, but we have a ways to go as we seek to operationalize concepts such as the Joint Intelligence Preparation of the Operational Environment.

The sciences of complex systems thinking (also called complex adaptive systems, CAS) have brought new insights into how networks and organizations of all types function.[14] Complexity science is actually a collection of sciences within an interdisciplinary forum (formal and informal) that encourages decision-makers to consider their actions from a variety of perspectives. In order to sustain energy, most living systems evolve slowly and incrementally (e.g., note the discussion on the evolution of reasoning discussed above), leveraging the amplifying and dampening effects of networks as efficiently as possible. Evolution occurs in reaction to something else, hence the concept of co-evolution as a more descriptive term for what really happens in living systems. Even those who seek to harm the United States through the use of weapons of mass destruction are likely co-evolving their intents and behaviors in response to some perceived grievance against us, or to attain power or status. Killing only for the sake of killing, while it does happen on rare occasions, is a poor use of energy and resources.

The concept of emergence has become a slightly more technical description of co-evolution to describe one layer deeper how interactions of evolving entities produce outcomes that are greater than the sum of the entities' constituent parts. An example of this is seen in the collaborative decision-making environment, particularly as described by Ernst May as quoted in the Ford article on intelligence analysis failings before Pearl Harbor. "The psychological theory points out that the Japanese, even more than the Germans, are a people of combination. 'Nothing is much stupider than one Japanese, and nothing much brighter than two,'" wrote Fletcher Pratt, a leading expert on naval warfare in 1939.[15] We should not take this almost 70-year old claim as an indictment of a race of people since it could have applied to all races and cultures, and Pratt was commenting on the ability of Japanese aviators. Pratt's words are more of an observation on the power of synergy of thought and action – combinations, co-evolving, produce outcomes greater than the sum of the parts (think of the tactical success of the attack on Pearl Harbor). These combinations produce better lines of inquiry to anticipate ABS and rare events such as acts of terror, use of a weapon of mass destruction, or other high profile attacks.

CAS approaches to problem-solving and decision-making integrate very well with the Scientific Method. As the decision-maker and her staff consider problems through the synergized lenses of economics, social science, physical and biological sciences, using the power of computer science, she is forced to test single discipline-derived ideas in a multi-disciplinary way. Hypotheses are fashioned and tested considering multiple perspectives and the co-evolutionary fashion in which the world (and people) actually operate are considered. Computational technologies such as modeling and simulation, as well as advanced visualization also assist the decision-maker who can view things from a CAS perspective.[16] In fact, modeling and simulation may be one of the best ways to avoid "mirror imaging" and to explore the world of the possible in which the outlying True Black Swans may be lurking. Who knows, perhaps as we get better at using these tools, we may even be able to anticipate (and even "predict") TBS!

3.3.D. <u>Conclusions</u>

According to Taleb, the "sources of Black Swans today have multiplied beyond measurability."[17] CAS approaches to thinking and multi-disciplinary hypotheses generation and testing offer great promise in anticipating and mitigating an ever-increasing source of Black Swans. Recognizing and dealing with TBS as soon as possible is critical to achieving whatever success we can with these unpredictable events. Our operating strategy with black swans of any sort must be to ask the right questions, hear and appreciate the right responses, anticipate and act upon what we can, and recognize and deal in a timely manner with the consequences of what we cannot.

The most important element of this strategy is to recognize that Black Swans do exist and that we cannot predict or anticipate everything: that recognition in itself may be the one best way to counter Taleb's Black Swans. The process of effective (read objective) multi-disciplinary inquiry is at the heart of any success in this challenging domain.

[1] This paper does not discuss swans of the feathered variety, but rather the kind of event that Taleb identifies as truly unpredictable, the substance of his book (see below endnote). As Taleb intentionally capitalizes the spelling of Black Swan in his writings, this paper also capitalizes the spelling when considering the "true" Black Swan.

[2] Taleb, N., The Black Swan: The Impact of the Highly Improbable, Random House, NY, 2007.

[3] Taleb, N., "The Black Swan: The Impact of the Highly Improbable," The New York Times Online, April 22, 2007, http://www.nytimes.com/2007/04/22/books/chapters/0422-1st-tale.html?pagewanted=1&ei=5070&en=bdae1078f2b4a98c&ex=1178769600, accessed September 9, 2008.

[4] Ibid

[5] Note this class of event, ABS, is a black swan in lower case in order to differentiate from Taleb's TBS.

[6] Taleb spends much of his book trying to tell us the difference, describing concepts such as "grey" swans for example, but in the end, it is about events that could be anticipated and prepared for, and events that cannot even be foreseen (ABS and TBS). Work that tries to tell us that TBS can be anticipated misinterpret Taleb's main thesis. For this reason, this paper deals only with ABS.

[7] Taleb, NY Times article.

[8] Heuer, Jr., R., *Psychology of Intelligence Analysis*, Central Intelligence Agency Center for Study of Intelligence, Washington, DC, 1999, p. 6.

[9] Ibid., page 10.

[10] Taeleb, page 61. Taleb also discusses the Fallacy (or Problem) of Induction and the Narrative Fallacy as ways of trying to explain to others causal relations that cannot be known based on what is currently known. An example is a newspaper writer making a blanket statement that the "stock market fell today based on investor concerns about inflation," a statement in the press that we hear frequently. Such a generalization is misleading and in fact irresponsible as the writer could not possibly have any special, generalized insight from which to draw such conclusions (and, which statement from the author of this paper is over-generalizing, as well, given the author does not have any special causal insights about financial reporters!). Carveth Read defined the "Formal Fallacies of Induction" as follows: "Formal Fallacies of Induction consist in supposing or inferring Causation without attempting to prove it, or in pretending to prove it without satisfying the Canons of observation and experiment." See Read, C., *Logic: Deduction and Induction*, Grant-Richards, London 1898, accessed via Google Books: http://books.google.com/books, accessed 9 September 2008. Note Read's use of "Observation and experiment:" sounds a lot like the Scientific Method!

[11] Heuer, p. 39.

[12] A corollary to Hume's problem could be "the adversary is under no obligation to follow our 'mirror-imaging' of his reasoning processes." For example, the adversary does not have to do what we think he will do, as clearly pointed out in Harold Ford's article about Pearl Harbor intelligence failures described elsewhere in this paper.

[13] Harold Ford, The Primary Purpose of National Estimating, Defense Intelligence College, 1989 – available at http://www.dni.gov/nic/PDF_GIF_anal_meth/tradecraft/purpose_of_estimating.pdf (p. 72).

[14] The effects of all types of black swans will propagate through networks, as do all disruptions and innovations.

[15] Ford, p. 76, and annotated endnote (20) on page 79.

[16] This Strategic Multilayer Assessment on WMD-T JIPOE has held recent workshops on these techniques and as such there is no further mention of them in this paper. Please refer to the reports on these workshops.

[17] Taleb, *The Black Swan*, p. 61.

4. Remedies and Strategies

4.1. Overview of Front End and Visualization Solution Space (Laurie Fenstermacher, Nic Grauer)

Authors: Laurie Fenstermacher, Major Nic Grauer
Organization: Air Force Research Laboratory
Contact Information: laurie.fenstermacher@wpafb.af.mil, nicolaus.grauer@wpafb.af.mil

4.1.A. Front End Introduction.

Not a needle in a haystack, but a particular piece of straw in a haystack. That is the challenge facing analysts attempting to find, fix and finish rare events such as WMD-terrorism and other high-profile attacks. And at the front end of the analysis process is this mountain of data. The internet alone has billions of web pages and trillions of information bits. No number of trained analysts can efficiently hunt through this source for relevance, let alone the hundreds of other intelligence sources analysts use. It comes as no surprise that the most efficient handling of the "front end" data is paramount to the discovery and elimination of high-profile terrorist threats. "Front end" is used to refer to the group of capabilities to retrieve or INGEST, label or CHARACTERIZE, apply specific labels, extract information, parameterize or CODE and VISUALIZE data/information. We use data and information interchangeably to try to compensate for the fact that "data" to some is a group of documents and to others it is numbers needed to feed a model.

4.1.B. Rare Events and Low Signal-to-Noise.

Within the data sources, there is a discouragingly low signal-to-noise ratio, insomuch that for every one million bits of data, only a handful give us information pertinent to high-profile-terrorism. This is, in fact, a characteristic of rare events. They are hard to detect and forecast because they are rare and their "signals" (or indicators) are masked by or buried in the proverbial haystack of background information. This was the case back prior to World War II, even when most of the information used was from intelligence sources. Harold Ford, in his "hindsight is 20/20" Special National Intelligence Estimate (SNIE) on Pearl Harbor, states that "the full Key Judgments and the full text of the SNIE would have given its readers a fairly good sense of the "noise" and "chaff" present: i.e., the existence of a fairly large body of reporting information, but with the nuggets of intelligence indistinct amid the mass of somewhat ambiguous indicators."[1] In fact, much of the "chaff" or "noise" may be generated by an adversary who deliberately seeks to make it difficult to detect an event, for example where the Japanese were increasing the "noise" level of radio traffic by inserting "previously issued and deliberately garbled messages". However, this problem is exacerbated by the sheer volume of information available in unclassified, open sources. The ability to process this data (the "front end" capabilities about which we write) is both a blessing and a curse. However, the ability to forecast rare events fostered, planned and executed by people (or groups of people) well "left of boom" compels us to search in this haystack for early signals/indicators of increasing radicalization.

4.1.C. Understanding the Adversary is a "Hard Data" Problem.

Understanding a state adversary in preparation of a traditional force-on-force conflict entailed understanding their capacity to wage war (industrial capacity, military capabilities). Many of the key factors were quantitative (numbers of weapons, numbers of troops, numbers of factories).

Even so, there is always the tendency to "mirror" (that is, to interpret and forecast based on your own filters/values rather than the adversary's). For example, Harold Ford recounted how many decision makers thought Japan would not attack the United States because they felt such an attack on an adversary with superior military and industrial strength would be irrational[2]. Furthermore, it is not sufficient to focus on capability alone, but it is also important to understand the adversary's perception of our capabilities as well as their perception of the potential effectiveness of our candidate strategies/tactics. Understanding a non-state actor for whom "sacred values" and moral imperatives trump utility and rational choice[3] is more difficult. They tend to be opportunistic, adaptive, and less predictable. Much of the related information for a particular group may be qualitative (e.g., their discourse pertaining to how they perceive themselves and others). While some "front end" capabilities can infer or disambiguate, there are definite limits to how well they can do this and thus the focus for the near-term is on enabling analysts to improve the detection/identification of rare events.

4.1.D. <u>Front End Challenges.</u>

While the total amount of pertinent data may be statistically insignificant, the information contained within the data has massive real-world significance. This low "signal to noise" ratio is one of the many challenges facing the front end. Often the information is in languages other than English (and many of the "front end" technologies were developed for English), although there is a big push currently to develop multi-lingual capabilities especially for "high demand, high density" languages (e.g., Chinese, Arabic, Spanish). The information is more often than not "unstructured" (not in the form needed for analysis and/or modeling), making it difficult to extract the salient information much less to determine meaning (e.g., intent). The information is multi-dimensional, meaning there are actors, locations, capabilities, intentions, human networks, sentiments, timeframes, etc. This makes it difficult for analysts to find and track individuals/ groups, behavior patterns or trends in the information. The complexity and multi-dimensional nature of the information presents a challenge to the developers of intuitive, novel visualization capabilities to enable information/pattern discovery and understanding. Most importantly, experienced linguists/analysts are scarce and very valuable resources, so it is imperative that any "front end" capabilities enable/optimize these resources and not encumber them.

4.1.E. <u>The Front End "Good News and Bad News".</u>

It would be ideal if there were a "silver bullet" solution, a piece of software that magically pulls in the information a person/analyst/planner or model needs, sorts the relevant pieces from the irrelevant pieces and changes it into the type of information you need (the proper format, parameterized, labeled appropriately, etc). Alas, there isn't any such magic, but there are genuinely a number of solutions that can do one or more of the above functions and, in doing so, provide a force multiplier for scare human resources by enabling them to use their time for thinking/analysis and not data/information processing.

For the purposes of this paper, we will label or categorize the major "front end" capabilities needed as: [data/information] INGEST, [data/information] CHARACTERIZATION, [data/information] CODING and [data/information] VISUALIZATION. The labels are not as important as what they connote, so if the reader prefers others, so be it. For each category/label a brief description of the capability will be given, followed by several representative solutions. Not all solutions are listed due to the impossibility of being able to highlight all potential capabilities due to space limitations. Mention of a representative solution is not an endorsement of a specific solution, but rather of a class of solutions.

4.1.E.1 Data/Information Ingest.

INGEST connotes the capability to find the information and import it for further processing by people and/or computers. This information can be structured or unstructured, multi-lingual and in many forms and/or formats. The ability to forecast rare events is important across the globe for all types of events, all types of instigators and perpetrators. The ability to forecast rare events in enough time to have sufficient degrees of freedom to shape/halt or accelerate the events requires detection of key indicators well in advance (or "to the left"). To do that requires a focus on the individuals and groups (and state actors) that are behind rare events and their motivations, intent and capabilities. Some examples of information to INGEST: speeches, contents of weblogs, threads or chat, text documents downloaded from websites (e.g., manuals on how to make chemical weapons). The catch? Simplistic search/ingest schemes that rely on precise recognition of one or more search terms will NOT suffice. These methods are brittle and error-prone, reliant on the user's spelling ability and knowledge of the "right" terms in the right language; that is terms that are discriminating and don't have multiple meanings/contexts. In addition, the INGEST/information retrieval method must be flexible and not reliant on the information being in a single format (e.g., HTML). Representative solutions include "spiders" (that retrieve information based on relevance to search terms as well as links to relevant information) as well as INGEST capabilities that use either latent semantic indexing (which analyzes relationships between documents and their terms and captures the latent meaning of the words present in the documents) or concept indexing (in which a collection of documents are clustered and labeled by "concept" and then the new concept clusters are used to characterize subsequent documents). Ideally, one should use both semantic and concept indexing since they err in different ways and combining the two results in better INGEST performance.[4] Additionally, solutions exist that function like the brain's associative memory, learning associations between data and using them to make predictions based on analogy or experience. Several of these concepts are being explored for potential implementation in the Large Scale Internet Exploitation (LSIE) project at the Open Source Center. Solutions to the multi-lingual challenge include IBM's Translingual Automatic Language Exploitation System (TALES) and BBN's Broadcast and Web Monitoring Systems enable analysts to collect, index and access information in foreign language broadcasts and websites.

4.1.E.2 Data/Information Characterization.

CHARACTERIZATION connotes the capability to apply a coarse-grain label for the entire (or large portion of the) body of information. The label or category could be based on sentiment (e.g., hostile, friendly, neutral), the main idea(s) and/or concept(s) contained (e.g., documents about "Mercury" could be about bands, planets, temperature, etc.), the style of the writer, or the "frame" (mechanisms employed to influence target audiences, e.g., framing a conflict as a "jihad") of the information. These labels are helpful for sorting/filtering the information for processing by humans and/or models. In the case of processing by humans, CHARACTERIZATION is a key enabler, essentially performing "triage" (sorting by priority) such that the person(s) can spend their time looking at information that is likely to be relevant to the problem/

analytical question at hand. Performance can be incrementally improved by employing "supervised learning" (addition of manual labeled data/information). Representative solutions are Bible-based "Rosetta Stone" approaches to document clustering and characterization of multi-lingual documents based on ideology, sentiment analysis of jihadi websites, author profiling (based on analysis of their documents), and rule-based characterization for profiling and media analysis. Additional solutions to the multi-lingual challenge include IBM's Translingual Automatic Language Exploitation System (TALES) and BBN's Broadcast and Web Monitoring Systems, both of which enable analysts to collect, index and access information in foreign language broadcasts and websites.

4.1.E.3 Data/Information Coding.

CODING connotes either the capability to apply a more fine-grain label on a part of the information, the capability to extract specific "entities" from the information (e.g., people, places, things) or the capability to parameterize a factor or factors based on the information. The specific labels are necessary to transform the information into the form needed for an analytical method or model. The label can be generic (e.g., types of events, numbers of casualties, numbers killed, actors) or very specific. The parameterization is, likewise, necessary for an analytical method or model. For quantitative computational social science models, numbers are needed for input (e.g., Gross National Product, Infant Mortality, etc.). CODING solutions are typically either statistical (more generalizable, adaptable/flexible, but less precise) or rule-based (more precise, but more brittle, adaptable/flexible). Performance can be incrementally improved by employing "supervised learning" (addition of manual labeled data/information).

Representative solutions include TABARI/PERICLES (event coders for media reports), Automated Text Exploitation Assistant, ATEA, ("entity" extraction from text of people, organizations, facilities, locations, etc. utilizing BBN's statistical "Serif" coder), Profiler Plus (rule-based tailorable coding of text) and Linguistic Pattern Recognizer (searching variations of characteristic linguistic patterns related to indicators used by computational social science models). All of these approaches have been applied to information in at least one language other than English (typically Arabic, but in one case Bohasa).

4.1.E.4 Beyond Coding to Hypothesis Generation.

In addition to processing information for an analytical method/fingerprinting model or a person, "front end" capabilities can constitute a pseudo-model; that is, they can automatically highlight important patterns in information and provide a cue to the analyst to look further and verify a hypothesis. For example, the processing could highlight a pattern in discourse that is indicative of a change in a group's attitude toward a behavior; hence, hypothesizing or forecasting an event with that behavior. The analyst can then accrue evidence for that hypothesis which can then be confirmed or not. In addition, self-organizing information "agents" can automatically deduce relationships between concepts, as well as improved document clustering/labeling (or CHARACTERIZATION) by using semantic understanding. Representative solutions include statistical or rule-based information extraction and analysis as well as agent-based evidence marshaling.

4.1.E.5 Data/Information Visualization.

VISUALIZATION is a critical capability that enables analysts to develop a better understanding of (often) very large sets of data/information by helping them sort through the data and discover patterns and trends that were otherwise not obvious to them. Visualization also enables the analyst to evaluate the data/information; that is to identify whether there is missing or anomalous/outlier data/information and to be able to filter the data/information or gather more. A typical view is that the primary purpose of visualization is to present results to a decision maker or as the final step in the creation of a social science model, but it is best utilized throughout information processing. It is a form of analytic output that adds depth, value, and utility to an effort.[5] Effective visualization minimizes user rigor to extract meaning from data and information.

Representative solutions such as visual analytics provide the user with "layers", multiple ways to look at the data to draw conclusions, infer relationships and make observations. Visualizations can be coupled with data/information processing capabilities and/or models to enable visual analysis (e.g., visualization of the impact of changing a factor such as the quality of government services on a segment of the population). Other representative visualization solutions are theme-based visualization tools (e.g., INSPIRE), knowledge glyphs (in which the various contexts for a piece of data can be flexibly visualized by rotating the glyph), and "magic book" technology.[6] In addition virtual worlds can be used to visualize and explore real-world rare event scenarios (e.g., responses during an epidemic).

4.1.F. Summary.

Detection and identification of rare events is inherently a "digging through a haystack for a needle" problem with lots of misleading and irrelevant information obscuring the weak "signals" or indicators that an individual or group has both the motivation (and intent) and capability to employ WMD or another high-profile threat. "Front end" capabilities are critical to success, but must be employed wisely as key enablers of the analyst. Solutions exist to INGEST, CHARACTERIZE, CODE and VISUALIZE data/information, even unstructured multi-lingual information. Integrated systems exist that incorporate multiple multi-lingual data/information processing capabilities. Properly employed as part of an "optimized mixed initiative" (computer/human) system, the solutions can provide a key force multiplier in providing early warning of rare events well to the "left of boom".

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[5] Canna, S. ed. Modeling and Visualization Workshop Report, January 2008, p.42

[6] Billinghurst, M. et al. The MagicBook—Moving Seamlessly between Reality and Virtuality. *IEEE Xplore*. May/June 2001. pp. 6-8

4.2. Overview of Back End Solution Space (Bob Popp, Sarah Canna)

Authors: Bob Popp, Sarah Canna
Organization: National Security Innovations
Contact Information: rpopp@natlsec.com; scanna@natlsec.com

4.2.A. Introduction

The intelligence and defense communities are working to take advantage of the revolution in information technology (IT) to address rare event threats such as terrorism and the use of weapons of mass destruction (WMDs) facing the nation today. The investment in large-scale weapons systems following the end of the Cold War proved insufficient to deal with the amorphous, unpredictable threat of terrorism. The solution for improving the analysis cycle to anticipate and forecast rare events relies on harnessing the power of advanced IT tools. These tools are particularly important to help analysts locate and piece together critical nuggets of information among the burgeoning sources of data flooding analysts daily. Ensuring that critical data are caught and processed well in advance of an event requires a federated government investment in emerging and mature back end IT tools. This chapter addresses the back end, analytic IT tools that comprise the core of the intelligence cycle.

Terrorism and the use of WMDs are rare events that challenge the ability of analysts to anticipate and shape future occurrences. To meet this challenge, analysts must overcome information overload by employing advanced IT tools. There are many technology challenges, but perhaps few more important than how to make sense of and connect the relatively few and sparse dots embedded within massive amounts of information flowing into the government's intelligence and counterterrorism apparatus. IT plays a crucial role in overcoming this challenge and is a major tenet of the US national and homeland security strategies.[1] The US government's intelligence and counterterrorism agencies are responsible for absorbing this massive amount of information, processing and analyzing it, converting it to actionable intelligence, and disseminating it, as appropriate, in a timely manner. It is vital that the US enhance its intelligence capabilities by exploiting its superiority in IT to create vastly improved tools to find, translate, link, evaluate, share, analyze and act on the relevant information faster than ever.

4.2.B. Background

Some of the core IT areas crucial for counterterrorism include: collaboration, analysis and decision support tools, pattern analysis tools, and anticipatory modeling tools. These tools allow users to: search, query, and exploit vastly more speech and text than would otherwise be possible by humans alone; automatically extract entities and relationships from massive amounts of unstructured data and discover terrorist-related relationships and patterns of activities among those entities; and collaborate, reason, and share information, so analysts can hypothesize, test, and propose theories and mitigating strategies about possible futures.

When doing traditional analysis, an analyst spends the most time on the major processes broadly defined as research, analysis, and production. Historically, analytic methods require analysts to spend too much time doing research (searching, harvesting, reading, and preprocessing data for analysis), too much time doing production (turning analytical results into reports and briefings for the decision maker), and too little time doing analysis (thinking about the problem). IT tools can help invert this trend – sometimes referred to as the "Analyst Bathtub Curve" – allowing analysts to spend less time on research and production and more time on analysis – see Figure 1.[2]

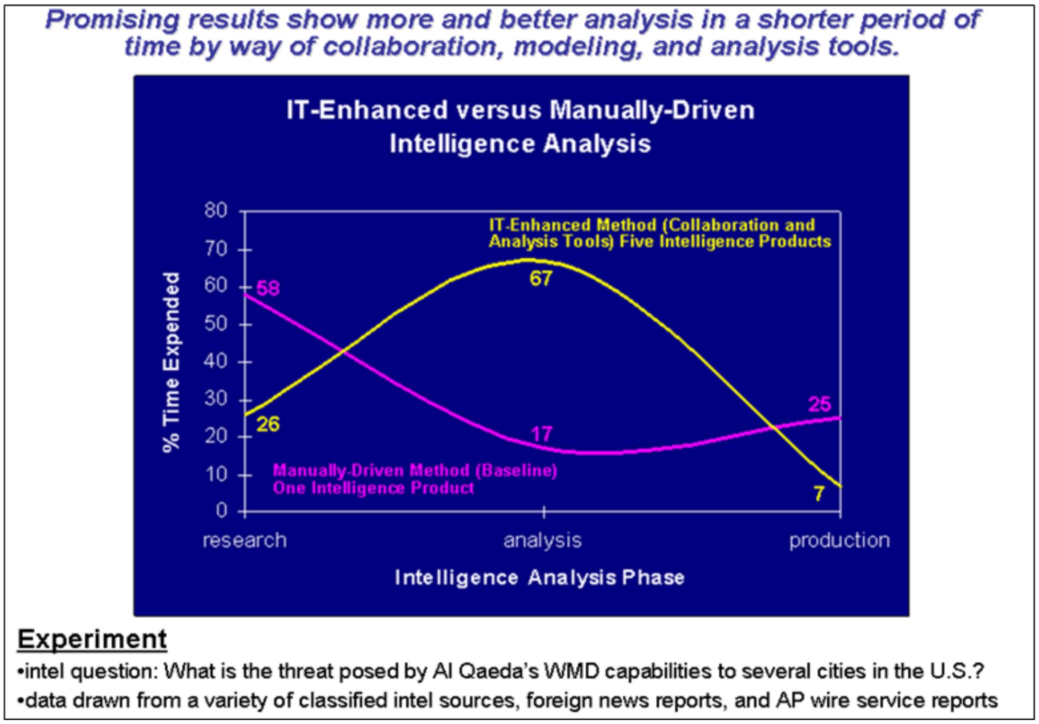

Figure 1. Inverting the Analyst Bathtub Curve.

4.2.C. Example Back-End Analytic Approach – SMA JIPOE

The technologies described in this and the other white papers illustrate how analysts can (i) search, query, and exploit vastly more foreign (multi-lingual) speech and text than would otherwise be possible by human transcribers and translators alone, (ii) automatically extract entities and entity relationships from massive amounts of unstructured data, (iii) create models (and discover instances) of terrorist-related relationships and patterns of activities among those entities, and (iv) collaborate, reason, and share information and analyses so that analysts can hypothesize, test, and propose theories and mitigating strategies about plausible futures so that decision- and policy-makers can effectively evaluate the impact of current or future policies and prospective courses of action. These are examples of what we refer to as "back-end" analytical technologies. Figure 2 illustrates the SMA JIPOE analysis process as one example.

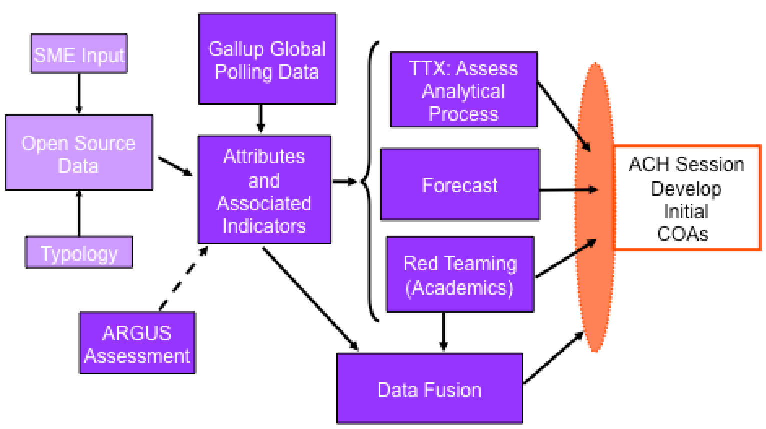

Figure 2. SMA JIPOE Sample Analytic Cycle

As Figure 2 illustrates, the overall approach to the SMA JIPOE analytic cycle contains a number of "moving parts" that collectively feed inputs to the end product: the analysis of competing hypotheses (ACH) process used to develop adversarial courses of action (COAs). To begin, the creation of a baseline data set was accomplished through subject matter expert (SME) input, open sources, and the use of a socio-cultural typology to identify potential indicators of adversarial COAs. Outside sources, such as the Gallup World Poll data and the ARGUS early biological warning system were used to examine global environmental and biological data for state stability, radicalism and early biological warning. The baseline data are used to find correlated attributed and associated indicators of adversarial COAs. The data are then fused to provide full set of attributes and indicators. The data are used to produce forecasts of potential acts of terrorism and other rare events. The red team element allows experts to explore the realm of the possible, the low probability/high consequence events that might happen – adding depth to the analytic cycle. In addition, table top exercises assessed the utility of social network analysis (SNA) for rare events.

The IT tools associated with the back-end are the analytic components that provide analysts with the ability for collaboration, analysis and decision support, pattern analysis, and anticipatory modeling. While there are many notable examples of technologies within these categories, this chapter will only outline the characteristics of these tools. Other efforts have been undertaken to list, describe, and evaluate the specific technologies,[3] which will not be addressed here.

4.2.D. <u>Collaboration</u>

Collaboration tools allow humans and machines to analyze and solve complicated and complex problems together more efficiently and effectively. Combating the terrorist threat requires all elements of the government to share information and coordinate operations. No one organization now has nor will ever have all the needed data. Collaboration tools allow for the breaking down of organizational barriers, sharing data, sharing information, sharing of thinking, and sharing of analyses. This entails sharing multiple perspectives and conflictive argument, and embracing paradox—all of which enable humans to "think outside of the box" to find the right perspective lenses through which to properly understand the contextual complexity where correct meaning is conveyed to data. Collaboration tools permit the formation of high-performance agile teams from a wide spectrum of organizations which is vital for the virtual federated nexus.

Collaboration tools support both top-down, hierarchically-organized and directed, center-based teams, as well as bottom-up, self organized, directed ad-hocracies—edge-based collaboration. An emergent capability is for these two modes of collaboration to seamlessly co-exist and interoperate—"center-edge" hybrid collaboration—overcoming difficult semantic challenges in data consistency and understanding, and the personal preferences, intellectual capital, multi-dimensional knowledge and tacit understanding of a problem by numerous analysts.

Supporting process. Teams, especially in a federated environment, need support in designing and executing strategies embodied in procedures to accomplish their goals. Tools are needed to allow them to develop and execute appropriate processes and procedures throughout their life cycles and to ensure these processes and procedures are consistent with applicable policy. Collaboration technologies may also be used for storytelling, publishing and notification, privacy, process and policy enforcement for virtual organizations and workflow management.

4.2.E. Analysis and Decision Support

Decision-makers must not be simply passive consumers of intelligence. Instead, decision-makers must “engage analysts, question their assumptions and methods, seek from them what they know, what they don’t know, and ask them their opinions.”[4] Because the current interface model between decision makers and analysts was developed in the Cold War era during a time of information scarcity (unlike today’s information-abundant environment), some of the basic assumptions that underlie it are no longer optimal. Novel technology is needed to reinvent the interface between the worlds of policy and intelligence, allowing for intelligence that is, for example: aggressive, not necessarily cautious; intuitive, not simply fact based; metaphor-rich, as opposed to concrete; collaborative, in addition to hierarchical; precedent-shattering, not precedent-based; and opportunistic, as well as warning-based.

A fundamental purpose for these tools is to amplify the human intellect. To deal effectively with the rare event threat, it is not sufficient for well-informed analysts to simply communicate and share data. Anticipating rare events is an intrinsically difficult task that is only compounded by an unaided human intellect. Analysts and analytical teams are beset by cognitive biases – limitations that have been partially responsible for some serious intelligence failures.[5] Analysts must be given assistance in the form of structured argumentation tools and methodologies to amplify their cognitive abilities and allow them to think better.[6]

Another purpose for these tools is to understand the present, imagine the future and generate plausible scenarios and corresponding actionable options for the decision-maker. It is not enough to simply “connect the dots.” The fact that the dots are indeed connected must be persuasively explained and communicated to decision-makers. Traditional methods—briefings and reports—lack on both counts, and they demand a significant amount of analysts’ time to produce. Explanation-generation and storytelling technology is critical to producing traditional products as well as making possible newer forms of intelligence products.

Again, motivated by the virtual federated nexus, these tools must operate virtually within a team framework and concomitant “virtual” policies automatically generated, enforced and managed. Tools are needed to allow virtual policy and process management to be unambiguously defined and understood at all levels, to permit virtual organizations and teams—especially ad-hoc peer teams—to reconcile their differing policies and processes into a single coherent regime, to consistently and reliably apply that regime to its operations, and to identify any deviations from policy and process to prevent abuses. Policy/process management technology to support analysts include: workflow management, policy/process markup language, policy/process enforcement tools, semantic consistency, and alias resolution. IT tools also aid analysts and decision-makers by laying the foundation for strong analytic reasoning using the following tools: knowledge management, scenario/explanation generation, structured argumentation, evidentiary reasoning, consequence projection, and geospatial-temporal-relational analysis.

4.2.F. Pattern Analysis

Many terrorist activities consist of illegitimate combinations of otherwise legitimate activities. For example, acquisition of explosives, selection of a location, and financing of the acquisition by external parties are all legitimate activities in some contexts. However, if combined together or performed by individuals known to be associated with terrorist groups, further investigation may be warranted. While examples of terrorist activities are rare, examples of the component activities are not. Pattern analysis tools, therefore, must be able to detect instances of the component activities involving suspicious people, places, or things and then determine if the other components are present or not in order to separate those situations warranting further investigation from the far larger number that do not. Comprehensive overviews of some of the key technologies are available.[7]

One key pattern analysis concept is representing both data and patterns as graphs. Evidence and (rare event) pattern graphs can be specified as nodes representing entities such as people, places, things, and events; edges representing meaningful relationships between entities; and attribute labels amplifying the entities and their connecting links. These highly-connected evidence and pattern graphs also play a crucial role in constraining the combinatorics and thereby overcoming the computational explosion challenges associated with iterative graph-processing algorithms such as directed search, matching, and hypothesis evaluation.

Pattern analysis techniques are needed to efficiently and accurately discover, extract, and link sparse evidence contained in large amounts of unclassified and classified data sources. These techniques allow for entity-relationship discovery, extraction, linking and creation of initial evidence graphs, which are often sparse and comprised of entities and relationships extracted from textual narratives about suspicious activities, materials, organizations or people. Statistical, knowledge-based, and graph-theoretic pattern analysis approaches are typically used to infer implicit links and to evaluate their significance. By expanding and evaluating partial matches from known starting points, rather than the alternative of considering all possible combinations, efficiency is realized. The high probability that linked entities will have similar class labels (called autocorrelation or homophily) can increase classification accuracy.

4.2.G. Anticipatory Modeling

There is a wealth of literature on anticipatory modeling as related to rare events for anticipating future terrorist group behaviors and terrorist plots, WMD proliferation, failed states and conflict analysis, and so on. Much of this work is based on exploiting a variety of promising approaches in statistics, neural networks, market-based techniques, artificial intelligence, Bayesian and Hidden Markov Model (HMM) approaches, system dynamics, multi-agent systems, behavioral sciences, red teams, and so on. These approaches are addressed more closely in section 4.3 on Quantitative/Computational Social Science. Anticipatory modeling relies on social science modeling technology including the following: models (social network analysis, agent-based models, system dynamics models, game- and decision-theoretic models, statistical models, etc), human/group behavior and intent recognition models, leadership and pathway/process models, model auto-population techniques, and trajectory analysis.

4.2.H. Conclusion

Because the current policy/intelligence interface model was developed in the Cold War era during a time of information scarcity (unlike today's information abundant environment), some of the basic assumptions that underlie it are no longer valid. Novel technology is needed to reinvent the interface, allowing for intelligence that is aggressive vice cautious, intuitive vice simply fact-based, metaphor-rich vice concrete, peer-to-peer vice hierarchical, precedent-shattering vice precedent-based, and opportunistic vice warning-based.

The categories of tools discussed in this paper represent the tip of the iceberg. Many other information technologies are important for successfully conducting the global war on terror and dealing with rare events. Ultimately, IT tools will create a seamless environment where analysts and decision- and policymakers can come together to collaborate, translate, find, link, evaluate, share, analyze, and act on the right information faster than ever before to detect and prevent rare events directed against the US.

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4.3. Quantitative Social Science Models (Bob Popp, Stacy Lovell-Pfautz)

Author: Bob Popp and Stacy Lovell Pfautz
Organization: National Security Innovations
Contact Information: rpopp@natlsec.com, spfautz@natlsec.com

4.3.A. Introduction

Today, we are faced with a rapidly changing world of asymmetrical adversaries that pose a very different challenge from traditional warfare. Modern-day adversaries seek to paralyze the US by employing asymmetrical methods against us to neutralize our military superiority including using catastrophic terrorism and weapons of mass destruction (WMD). The uses of these types of asymmetrical methods by modern-day adversaries are examples of catastrophic rare events.

Modern-day adversaries are often indistinguishable from, as well as intermingled among, the local civilian population and include transnational terrorists, insurgents, criminals, warlords, smugglers, drug syndicates and rogue WMD proliferators. They are not part of an organized conventional military force, but instead are collections of loosely organized people who have formed highly adaptive (and difficult to identify) webs based on tribal, cultural or religious affinities. These new adversaries move freely throughout the world, hide when necessary, and conduct quasi-military operations using instruments of legitimate activity found in any open or modern society. They make extensive use of the Internet, cell phones, the press, schools, mosques, hospitals, commercial vehicles, and financial systems. These adversaries do not respect the Geneva Conventions or the time-honored rules of war and they see WMD not as a weapon of last resort, but instead as an equalizer and a weapon of choice[1]. These new adversaries perpetuate religious radicalism, violence, hatred, and chaos. They find unpunished and oftentimes unidentifiable sponsorship and support, operate in small independent cells, strike infrequently, and utilize weapons of mass effect and the media's response to influence governments. And finally, they seek safe haven and harbor in weak, failing, and failed states[2].

Rare events such as terrorist attacks and WMD proliferation represent low-intensity/low-density forms of warfare; however, terrorist plots and WMD proliferation will leave an information signature, albeit not one that is easily detected. As it has been widely reported about the 9/11 plot and the misdeeds of the Pakistani WMD scientist A.Q. Khan, detectable clues have been left in the information space—the significance of which, however, is generally not understood until after the fact[3]. A challenge is to detect these clues a priori by empowering intelligence analysts with information technologies and tools to detect and understand these clues long before the fact so that appropriate measures can be taken by decision- and policy-makers to preempt them.

The nature of catastrophic rare events makes prediction and deterrence of their actions a formidable challenge. The answer, in our judgment, is not more Cold War oriented intelligence, surveillance, and reconnaissance (ISR) assets or new high-profile weapons systems, but rather a strategy that leads to a greater socio-cultural awareness and thorough social understanding of the threats as well as the surrounding environment in which they reside.

Quantitative/Computational Social Science (Q/CSS) modeling is a key socio-cultural technology that can help advance this cause. Q/CSS models can systematically, transparently, and objectively unravel the socio-cultural complexity, uncertainty and ambiguity inherent in rare event problems. There is a wide range of Q/CSS models that can help with anticipating rare events – reviewing and providing a framework for Q/CSS models is the focus of this chapter.

4.3.B. Quantitative/Computational Social Science (Q/CSS) Overview

Social science modeling has three main components: (1) theory, or the theoretical underpinnings that drive analysis with regards to data requirements; (2) data, typically at multiple levels and multidimensional in nature; and (3) models, which can be observational, analytic, or based on any number of computational methods and techniques. The main social science disciplines are anthropology, economics, political science, sociology, and psychology[1]. Other social science specialties include communication, linguistics, international relations, social geography, management and organization, ethnography, environmental studies, public policy, and some parts of operations research. Social science investigates patterns of human phenomena that range—according to increasing scale or levels of analysis—from cognitive systems to groups, organizations, societies, nations, civilizations, and world systems[1]. Besides this range in "patterns of human phenomena"— microsocial to the macrosocial, or what some have called "consilience"[1] —social science also employs multiple time scales ranging from milliseconds (brain activity) to many hundreds of thousands of years (human origins).

Quantitative/computational social science (Q/CSS) is the branch of science that investigates human/social phenomena (cognition, conflict, decision-making, cooperation, etc.), at all levels of data aggregation (cognitive, individual, group, societal, global, etc.), and is based on direct and intensive application of socio-cultural theories, models, and data. Methodologically, Q/CSS refers to the investigation of social phenomena using the tools of modern computing for advancing the knowledge about the social universe. As illustrated in Figure 1, Q/CSS modeling for the purpose of forecasting includes a landscape of modeling methods spanning the quantitative, computational or qualitative techniques. The remaining chapters in this paper will address various aspects of this landscape of Q/CSS modeling.

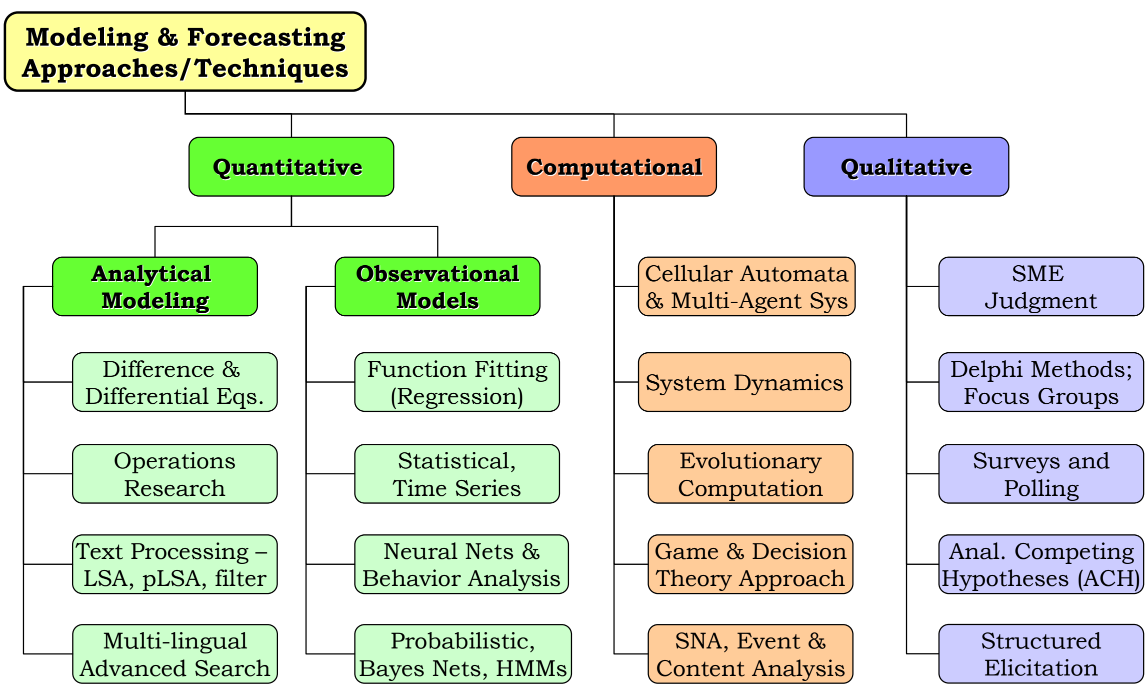

Figure 1. The landscape of Q/CSS modeling

4.3.C. Q/CSS Background

Historically and substantively, Q/CSS refers to the rigorous and systematic analysis of information processing, data structures, control mechanisms, coordination strategies, optimization, energy budgets, behavioral variety, internal architecture, scheduling, implementation, adaptation and other computationally significant processes in human and social systems viewed as artificial systems on various scales[4]. Some recent Q/CSS modeling applications include: (i) a national system of government as a complex adaptive societal system for dealing with emerging issues through policy and other measures; (ii) an extremist belief system as a cognitive structure that uses radical notions arrayed as concepts and associations to interpret information and assign meaning; (iii) an election, on any scale, as a computation of political preferences among a group of voters; and (iv) a counter-terrorism system as a set of computational information processes, capabilities and activities organized for the purpose of preventing terrorism or dampening its effects when not preventable. From a Q/CSS perspective, what these examples share in common is a flow of information that is processed so as to execute some form of purposeful behavior or result[1].

Together, these two dimensions of Q/CSS—pure versus applied, and substantive versus methodological—readily suggest four areas or clusters of computational social science investigations. One dimension contains instances of Q/CSS that are primarily focused on the role of information and computation in human societies—for example, how a system of government functions (and fails) based on information processing, human choices, and resource flows. Another dimension contains Q/CSS that offer a computational perspective on human and social phenomena highlighting certain entities, properties, and dynamics of the social universe—namely, information processing and adaptation in complex environments—while minimizing others[1].

4.3.D. Q/CSS Models and Rare Events

The preconditions, root causes and symptoms that give rise to "rare events" (in particular, catastrophic rare events such as the use of WMD by terrorists) are inherently dynamic, non-linear, and non-deterministic; understanding and modeling rare event problems is not easily reduced or amenable to classical analytical methods. Q/CSS provides promising new methods, models, and tools for such problems in the context of informing decision-making. Such tools provide the systematic transparency and objectivity that is required for analyzing complex, uncertain, and ambiguous rare events. The goal of these models and methods is to help decision-makers evaluate the potential landscape of futures where rare events may take place. Examples of Q/CSS modeling contributions to rare event problems during the past fifty years include the following[1] (many of these examples will be discussed in more detail in subsequent chapters):

- *Early-warning* (EW) *indicators* of warfare and potential conflict, based on quantitative information found in open source statistical datasets[5]
- Low-dimensionality *dynamical systems* of competing adversaries based on differential or difference equations[6]
- *Markov models* to understand the structure, relative stability and long-term social dynamics of conflict processes[7]
- *Events data analysis,* based on abstracting and coding high-frequency streams of short-term interaction occurrences exchanged among adversaries[8]

- *Semantic components analysis,* based on decomposition by evaluation, potency and activity in semantic EPA-space, by itself as content analysis, or paired with event data analysis[9]
- *Large-scale econometric and system dynamics models* of states and regions in the international systems[10]
- *Probabilistic models* of conflict processes, such as escalation, crises, onset, diffusion and termination of warfare and forms of violence[11]
- *Game-theoretic models,* based on the application of 2-person and n-person games to social situations with strategic interdependence[12]
- *Expected utility models* based on Bayesian decision theory[13]
- *Control-theoretic models,* applying models from optimal control in dynamical systems[14]
- *Survival models* and *event history analysis,* based on modeling the hazard rate or intensity function of a social process, which are capable of integrating stochastic and causal variables into unified models of social dynamics[15]
- *Boolean models* based on often complex systems of necessary and sufficient triggers of conflict[16]

Alone, these social science theories and models are rarely sufficient to explain the environment surrounding rare events. An ensemble of models—which contain more information than any single model—must be integrated within a single decision support framework to achieve maximum value. Together the Q/CSS models can generate non-intuitive insights that counter conventional wisdom that helps question analysts' and decision-makers' assumptions that are often the "masks" to rare events. Within the right theoretical framework these models and decision support tools will provide strategic early warning capability and actionable options for the decision-maker[1].

4.3.E. Conclusions

In this section, we discussed how Q/CSS models provide promising new methods, models, and tools to help decision-makers analyze rare events. Forecasting rare events using empirical data from the past is challenging. There is no guarantee that conditions and causal relations of the past will extend into the future, and in the case of rare events, there is often precious little information upon which to base predictions anyway. However, Q/CSS models can provide new insights into anticipating rare events, including:

- Q/CSS models systematically, transparently, and objectively can process large amounts of social science data to help unravel the significant complexity, uncertainty and ambiguity in rare event problems;
- Q/CSS models can provide results that are not biased by analyst views;
- Q/CSS models can supplement early warning analysts who have domain knowledge and expertise to anticipate possible rare events; and
- Q/CSS models can generate non-intuitive insights that counter conventional wisdom and questions decision-makers' assumptions which can be "masks" to rare events.

Ultimately, Q/CSS models can help analysts, planners, and decision-makers to come together to collaborate, translate, find, link, evaluate, share, model, analyze, and ultimately "anticipate" using the right socio-cultural data faster to detect and prevent rare event attacks against the US, as well as mitigate the deleterious effects that such events can have on US national security interests.

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4.4. An Integrated Statistical Modeling Approach for Predicting Rare Events: Statistical Analysis of WMD Terrorism (Larry Kuznar, Victor Asal, Karl Rethemeyer, Krishna Pattipati, Robert Popp, Steven Shellman)

Authors/Organizations: Lawrence A. Kuznar (National Security Innovations, Inc.); Victor Asal (State University of New York, Albany); Karl Rethemeyer (State University of New York, Albany); Krishna Pattipati (University of Connecticut); Robert Popp (National Security Innovations, Inc.); Steven Shellman (College of William and Mary, Security Analysis Enterprises)
Contact Information: lkuznar@natlsec.com

WMD terrorism is, fortunately, extremely rare. Its rarity presents challenges for understanding why it occurs and what its leading indicators might be. These challenges arise from the fact that, by definition, rare events produce much less data than commonly repeated events, which leads to data sparseness; the empirical data on rare events will be spotty and its few cases are likely to have many missing values. In this article, we present a method for integrating various data sources, structured and unstructured, imputing missing data, and performing analyses to identify statistically significant leading indicators of WMD terrorism. The two types of WMD terrorism we focus upon are nuclear smuggling and the possession of and plot to use biological agents.

The literature on WMD terrorism is voluminous, but there is actually little research based on the statistical analysis of empirical data. However, the few statistical studies that exist do point toward several key variables that have a causal connection to WMD terrorism. Interestingly, state sponsorship and specific religious motives are not statistically related to WMD terrorism[1]. The factors that are most related to terrorist WMD activity include the number of connections a group has with other violent groups and a group's previous level of lethality[2]. Globalization appears to create more opportunities to pursue WMD[3] and democracy may provide greater freedom for WMD terrorists to operate[4].

These preliminary findings guided the research team's selection of independent variables, focusing team efforts on measures of governance, freedom, group violence and connectivity, and globalization, as well as economic conditions that may foster an environment conducive to illegal and disruptive activity (crime, corruption, civil unrest, ethnic and religious factionalism). The research team's efforts were global in scope, analyzing environmental conditions that influenced WMD terrorism in all countries and all violent non-state actor (VNSA) groups for which open source data were available. In addition, a specialized effort in event extraction focused on analyzing environmental conditions in Russia at the province level.

A wide variety of dependent variables were chosen, but for the purposes of illustrating our methodology and for presenting some of our sounder findings, we will focus on studies of nuclear smuggling (smuggling fissile nuclear materials) and possessing and plotting to use biological agents.

4.4.A. Data

A variety of databases were used for this study, including standard political science structured databases and unstructured news reports that required processing to create structured databases amenable to analysis.

4.4.A.1 Structured databases

Structured databases focused on two units of analysis: regions where WMD terrorism takes place, and terrorist groups themselves. For regions, the characteristics of countries were analyzed in order to identify environmental conditions that were associated with WMD terrorism. General data on countries were gleaned from publicly available data sets, which included International Atomic Energy Agency data, Heritage US Troops stationed abroad data, 2007 World Bank Development Indicators, DSTO, CIA World Factbook, KOF Globalization Scores data, 1970-2007, and especially the Quality of Government (QoG) dataset.

Monterey WMD Terrorism Database, Monterey Institute for International Studies http://montrep.miis.edu/databases.html, and the Tactical Terrorism Dataset, compiled by the Institute for the Study of Violent Groups (ISVG) at Sam Huston State University. Dr. Asal and Dr. Rethemeyer compiled these data into the Big, Allied and Deadly (BAAD) terror group data set at SUNY Albany. The researchers compiled data on 395 terrorist organizations, and coded organizational variables for the period 1998-2005 as one time period (no yearly data at present).

4.4.A.2 Missing Data and the Imputation of Values

Nuclear smuggling and bio-terrorism data sources are characterized by sparseness and missing data due to the rarity of the events and the unevenness of data coverage. In our datasets the probability of events ranged from 0.03 to 0.1 for nuclear smuggling data, and from 0.0027 to 0.013 for bioterrorism. Typically, our variables had 3-79% missing values.

We estimate missing data via support vector machine regression (SVMR) and auto-regression. As a good data pre-processing practice, we also normalize the data so that each variable has zero mean and unit variance. Scaling of data avoids undue influence of variables having large values on conflict assessment. We also perform data reduction via partial least squares (PLS) prior to classification. Data reduction reduces noise in the data, improves classification/forecasting accuracy and computational efficiency, and reduces memory requirements[5].

If a few data points are missing for a variable, a three-step auto-regressive model is used to fill the missing values. This method is also used to forecast each dependent variable. If a country has missing values for all the years, SVMR is used to fill the missing values. In this process, the given data is divided into training, validation and test sets. Then, complete patterns (with no missing values) from the training set are selected. For each variable, we develop a nonlinear regression model using support vector machine regression (SVMR). After training SVM regression on complete training patterns, missing values in the training set are filled in sequentially by setting each variable (with missing values) as a dependent variable. This process is repeated until all the missing values in the training data set are filled. After the process for the training data is completed, the same procedure is repeated on the validation and testing patterns with missing values.

4.4.A.3 Event Extraction from Unstructured Data

A specialized examination of nuclear smuggling in Russia was conducted to evaluate the environmental conditions that influenced nuclear smuggling within the Russian provinces. The data were obtained from Project Civil Strife using automated methods to extract events of interest from text reports. The source of the text came from 1 million BBC monitor stories (i.e., 4.7 million lines/sentences of text) from 1995-2005. BBC Monitor includes over 500 English & foreign language sources. Dr. Shellman then added the Moscow Times and the Moscow News as data sources.

Dr. Shellman created actor and verb dictionaries for the Russian case and regions and used Text Analysis By Augmented Replacement Instructions (TABARI) to extract the events of interest from text. From the texts the researchers coded over 751,000 political events. Events range from positive and negative statements to political negotiations and armed conflict. Special events of interest included nuclear smuggling activities. The repression, protest, and cooperation variables are coded using the CAMEO scheme (see the following web page for more detail: http://web.ku.edu/keds/data.dir/cameo.html). Russian socioeconomic data were obtained from the Russia & CIS Statistics Online Database compiled by Planet Inform (http://www.planetinform.com/Analytic/default.aspx).

4.4.B. Methods

4.4.B.1 Information Gain Algorithm

Which independent variables have the most relevant information for each nuclear smuggling and bioterrorism dependent variable? We address this question via an Information Gain (IG) algorithm. Information gain is related to the concept of mutual information: how much information does one random variable (an independent variable in our case) reveal about another one (a dependent variable)? To formalize this concept, we need to understand the information-theoretic concept of entropy.

Entropy is a measure of how “disorganized” a set of data related to random variable is; it is a measure of uncertainty. Independent variables provide information on a dependent variable, thereby reducing uncertainty in our knowledge of the dependent variable. If x is an independent variable and y is a dependent variable, their probabilities are $p(x)$ and $p(y)$ respectively, and the probability that they occur together is $p(x,y)$.

The mutual information (information gain) is the relative entropy or Kullback-Leibler distance between the joint distribution $p(x,y)$ and the product distribution $p(x)p(y)$.

$$D_{KL} = \sum_{x \in X} \sum_{y \in Y} p(x,y) \log_2 \left[\frac{p(x,y)}{p(x)p(y)} \right]$$

Mutual information provides a quantitative measure to rank order factors in a decreasing order of mutual information (information gain). If the costs of acquiring data related to factors vary widely, one can rank order factors in decreasing order of information gain per unit cost of acquiring factor data.

4.4.B.2 Hidden Markov Modeling (HMM)

HMMs provide a systematic way to make inferences about the evolution of probabilistic events. The premise behind HMM is that the true underlying sequence (represented as a series of Markov chain states) is not directly observable (hidden), but it can be probabilistically inferred through another set of stochastic processes (or sequences). In our problem, the “hidden” sequence refers to the true dependent variable sequence that describes the behavior of a particular event over time. HMMs are perhaps a natural choice for this problem, because we can evaluate the probability of a sequence of events given a specific model, determine the most likely state transition path, and estimate parameters that produce the best representation of the most likely path. An excellent tutorial on HMMs can be found in Baum[6].

4.4.B.3 Integration of HMM and IG for Forecasting

Fig. 1 shows how country-specific HMMs for each dependent variable are fused together with normalized (observed or forecasted) independent variables to produce dependent variable classifications/ forecasts. The predicted probabilities from the dependent variable HMM model are additional input factors to the statistical classifier, SVM.

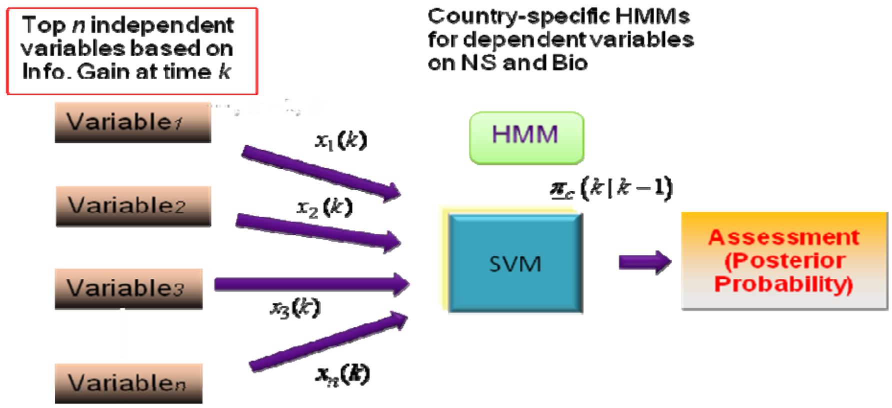

Fig. 1: Fusion of HMM probability predictions and additional input indicators using SVM

Support vector machines (SVM) transform the data to a higher dimensional feature space, and find an optimal hyperplane that maximizes the margin between the classes (conflict levels in our case) via quadratic programming[7]. An advantage of SVMs is that they require only a small amount of training data. Data from 1998 to 2001 were used to train the model, and the model was then tested on data from 2002 to 2007.

A nice feature of our modeling process is that it extends naturally to forecasting rare events. The forecasting steps are as follows:

1. Forecast Factors: If the independent variable is modeled as time series, forecast it using an auto-regressive or nonlinear time series forecasting methods (e.g., SVMR) models.
2. Forecast dependent variables
   a. Compute predicted dependent variable probabilities from the HMM dynamics.
   b. Combine independent variable forecasts with the predicted dependent variable probabilities.
3. Display dependent variable forecast.

4.4.B.4 Logistic Regression

In addition to SVM, HMM, and IG forecasting analysis, more traditional statistical analyses were performed on the structured databases. Logistic regression methods were used since the dependent variables were discrete events, and we were interested in predicting the probabilities of these events.

4.4.C. Findings

Space does not permit an exhaustive presentation of the research findings and their specific coefficients, goodness of fit values, etc. However, a brief review of the project's major findings illustrate that this innovative teaming of researchers, disciplines and methods can extend our understanding of WMD terrorism. Findings were very similar across all studies, regardless of scale (country or Russian province), methodology or dependent variable. The characteristics of locations and groups prone to WMD terrorism activities have characteristics that will not surprise experienced analysts. However, in our analyses, these characteristics are often measured on a continuous scale, meaning that it is not the presence of a factor, but its strength that matters. For instance, every society has a degree of corruption and black market activities, unemployment, connectedness, etc., but some locations have very much more of these factors. The locations and groups that most strongly express the identified factors are those our studies hotspot.

The following factors were statistically related to increases in the probability that nuclear smuggling or bioterrorism will take place in a region.

- A strong black market
- High unemployment
- A globalized economy
- A degree of industrial development
- Sources of Chemical, Biological, Radiological, and Nuclear (CBRN) material
- Ethnic/religious factionalism

Regions with a high likelihood of involvement in nuclear smuggling or bioterrorism tend to be somewhat Westernized and economically developed, but also have high crime rates, worsening economies, and lack security. The countries where these conditions occurred most strongly included, Russia, Caucasus countries, Eastern Europe, Central Asia, Turkey, and India. Additionally, the United States, Israel, Japan and the United Kingdom are at risk of bioterrorism; the presence of religious cults in the US, UK and Japan is a risk factor

The attributes of terrorist groups that were statistically related to their pursuit of nuclear smuggling or bioterrorism included:

- A history of highly lethal attacks
- A high level of connectedness to other violent non-state actor groups
- Experience with violent terrorist activities

Additionally, religious cults are strongly associated with bioterrorism.

Specific groups predicted on the basis of historical data to be involved with nuclear smuggling and/or bioterrorism include:

- Al-Qaeda
- Abu Sayyaf Group (ASG)
- Jemaah Islamiya (JI)
- Riyad us-Saliheyn Martyrs' Brigade (Chechen Militants)
- Hamas
- Jamatul Mujahedin Bangladesh
- Revolutionary Armed Forces of Colombia (FARC)
- Self-Defense Forces of Colombia (AUC)

- National Liberation Army (Colombia) (ELN)
- Irish Republican Army (IRA)
- PKK
- Armed Islamic Group
- Al Aqsa Martyrs Brigade

4.4.D. Summary

Forecasting rare events using empirical data from the past is challenging. There is no guarantee that conditions and causal relations of the past will extend into the future, and in the case of rare events, there is often precious little information upon which to base predictions anyway.

The researchers in this set of exercises employed state-of the-art methods to extract and structure data, impute missing values, and produce statistically verifiable predictions of rare WMD terrorism activities. Data acquisition methods included the fusion of pre-existing data bases, the mining of unstructured new reports and the construction of structured databases with automated tools, and the use of support vector machines (SVM) and hidden Markov models (HMM) to impute missing data, identify leading indicators and provide provisional probability estimates of nuclear smuggling and bioterrorism activities.

Analyses of likely locations (at the country level and Russian province level) indicate that regions where some level of economic globalization and industrial development is occurring, but that have high unemployment, a strong black market and some degree of social instability are most likely to have nuclear smuggling and bioterrorism activities occurring in them. The countries where these conditions occurred most strongly included, Russia, Caucasus countries, Eastern Europe, Central Asia, Turkey, and India. The VNSA groups most likely to be attracted to nuclear smuggling or bioterrorism have a high number of connections with other terrorist groups, a history of lethal attacks, and experience with terrorist operations. Additionally, religious cults seem particularly likely to pursue bioterrorism. The presence of religious cults in the United States makes the US a leading location for bioterrorism activities.

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4.5. Stability and Different Types of Radicalism (Tom Rieger)

Author: Tom Rieger
Organization: Gallup Consulting
Contact Information: tom_rieger@gallup.com

Rare events such as acts of terror, use of a weapon of mass destruction, or other high profile attacks involve two things: someone with the desire to commit such an act, and a means to acquire the materials and equipment to carry it out.

Many parts of the world where these materials are stored are, unfortunately, not terribly stable.[1] It is reasonable to assume therefore that if someone desired to acquire such material, they would have an easier time doing so from somewhere that is less stable overall, where protection may be less effective, or the temptation for bribery or smuggling may be greatest. Knowing stability for specific areas, as well as having the ability to predict future declines in stability, could be very valuable in preempting acquisition of WMD materials.

While stability can help answer "where", it does not help to address "who". Those seeking to acquire materials to carry out a high profile or WMD attack through theft or smuggling may or may not be from the same country or area where the materials are stored, but are presumably highly motivated and accepting of extreme violence to achieve their aims and objectives. Therefore, being able to locate areas where there are relatively high concentrations of people with extreme radical views may help to identify the "swamps" from which radical groups seeking these capabilities may originate, receive active or passive support, or find safe haven.

In short, having the ability to spot areas that are currently or at risk of becoming unstable, as well as pockets of radicalism, can provide a very useful first step in narrowing down potential locations for origin and destination of rare event activities.

4.5.A. Stability

One of the most critical steps in understanding the likelihood of a rare event is to identify unstable locations that may be prone to theft, smuggling, or illegal sale of dangerous material. Unstable areas will be more prone to lawlessness, desperation, corruption, and violence. Outbreaks of violence are an indicator of a regime that is not performing well.[2]

There is certainly no shortage of stability models available. However, most current models share some very serious drawbacks. First, many rely on official or government statistics… even though these statistics may be published by unstable governments. Even when these statistics can be considered to be reliable, they may not be published in a timely manner, and will not typically share the same methodology across countries, making comparison very risky.

Other models rely on content analysis of news reports. In many of these countries, the press is highly controlled, or subject to a particular point of view or bias from the source that is publishing. Bias or incomplete inputs will result in biased or incomplete outputs.

Finally, and of most concern, is that nearly all models of stability provide estimates at a national level only. However, looking at the historical record, stability tends to originate not from some homogenous factor that is exactly the same in every corner of a nation, but rather from a particular province, region, city, ethnic group, religious group, or in some cases, workers in a particular industry.

In short, current models of stability lack the ability to pinpoint a particular subgroup of interest, and then provide an accurate measure of the level of stability, as well as the major contributing factors, in a way that is directly comparable across different points in time, different places, and different countries.

To address these concerns, Gallup Consulting, using data from the Gallup World Poll, developed GLASS – the Gallup Leading Assessment of State Stability.[3] GLASS was developed based on approximately 100,000 interviews across 69 countries. Each country's data set included a representative sample of the citizenry, including both urban and rural areas.

The model identified five primary factors that describe how individuals view the conditions within their country:

- Basic needs, such as access to food, water, etc.
- Living conditions that describe quality of life regarding housing, healthcare, etc.
- Government confidence, including both local and national government, spanning issues such as corruption, confidence in leadership, confidence in the military, faith in the judicial system, etc.
- Economics, both at a local and national level
- Safety and security

Each of these conditions is weighted based on statistical analysis into a composite score of stability. Ranges were determined for unstable, moderate, and stable environments.

Since the model uses survey data as its sole input, stability estimates can be calculated for virtually any population or sub-population of interest. Analysis of conditions across different countries (Afghanistan, Russia, Pakistan, India, and others) has shown not only dramatically different levels of stability within countries, but also identifies very different factors that are to blame, even within the same country. For example, one part of the country may be unstable because of lack of access to water or a sustainable food supply chain, while another area may be unstable because of ineffective governance and a declining economy.

GLASS has been applied to over 100 countries, and has predicted instability as much as a year ahead of time for countries such as Kenya, Zimbabwe, Georgia, Mauritania, and others.

GLASS provides the decision maker with an opportunity to determine areas that are at risk of becoming unstable, with enough lead notice to potentially zero in on very specific cities, provinces, groups, or other sub-samples of the population.

Knowing levels of stability, as well as the underlying cause, can not only help identify areas where additional security may be required, but can also help provide direction for aid and support in a way that would maximize effectiveness in increasing stability overall, and thereby reduce the likelihood of a group acquiring dangerous materials through theft, bribery, smuggling, or in otherwise taking advantage of an unstable environment.

4.5.B. Radicalism

Knowing the origin of dangerous materials is not enough. In order to most effectively prevent and interdict high profile rare-event activities, one must also be aware of the group seeking to acquire such capability, or at least what are some areas or regions in which radical groups may operate, recruit, or find safe haven and support. In order words, there must be some means to easily identify pockets of radicalism within any given geography and where attacks are likely to occur. Research has shown that "in almost 90% of cases, … the origin of the perpetrators and the place where the attack occurred are the same."[4]

Radicalism is at its heart a situation where someone feels compelled and justified in doing things and making decisions that furthers his own agenda regardless of the harm created for others. On a smaller scale, these same types of behaviors occur in organizations every day.

For several years, Gallup has studied what it calls "Barriers", or factors leading to practices that encourage individuals to further their own ability to succeed even though others in the organization, or even the organization as a whole, may suffer as a result. Gallup's barrier framework was developed with guidance from Dr. Daniel Kahneman, 2002 Nobel Prize winner, and is based on a variety of behavioral economic phenomena regarding how people make decisions under risk.[5]

Through this framework, five underlying root causes of barriers have been identified, including fear (primarily fear of loss), misalignment, money/resources, information flow and sorting, and decisions that bring short term gain at the expense of longer term damage.[6]

By applying this same framework to broader societies, Gallup was able to predict incidence of radical views with a high degree of accuracy. Specifically, using data from the 2005/2006 World Poll, Gallup identified 666 individuals across 29 predominantly Muslim countries who held politically radical views… a belief that attacks on civilians are completely justified in pursuit of one's goals, and that acts such as the attacks of 9/11 were completely justified. Using the barrier framework, a series of classification functions were derived that correctly identified this group from the larger population with a high degree of accuracy (POLRAD model).

However, there was a substantial group that the model missed classifying correctly. Further analysis of this residual group identified a second type of radical, with very different attitudes, characteristics and motivations than the first type that was identified.

The Type One radicals tended to be demographically similar to the rest of the population, but were highly intolerant and elitist. They also shared a lack of confidence in local and national government, and believed that little to no improvement in conditions have occurred. This group also tended to thrive in areas where there was currently, or at some time in the past, limited resources or other hardship, and tended to believe their environment was unsafe.

The Type Two radicals were quite different. While the Type Ones were not demographically distinct, the Type Twos were more downscale. In addition, while the Type One radicals were elitist, the Type Twos tended to feel more victimized by others. Type Two radicals also were very accepting of violent or strong acts to achieve progress, and were strongly leader-seeking.

Using data from the 2007 World Poll, the model was replicated and validated. Through discussions with various members of the defense and intelligence communities, the model has been further refined. Initial comparison to actual violent acts of terrorism in one country showed a strong predictive relationship, where spikes in POLRAD levels were accompanied by spikes in violent acts in the following month.[7]

As with GLASS, an advantage of POLRAD is that is can be easily applied to literally any population of interest in a very quick and efficient manner. Like GLASS, it is also based on survey data. So long as sufficient sample exists, estimates of radicalism can be calculated.

Knowing the different types of radicalism is of critical importance in finding likely destinations for dangerous material. The Type One radicals are presumably more ideologically based, while the Type Two radicals seek these types of ideological leaders. Areas with high concentrations of Type Ones, or areas with high concentrations of both types, may be more prone to providing support and safe haven for such activities.

It is important to note that POLRAD does not identify violent non-state actors (VNSAs). It does, however, provide estimates of where a "swamp" may exist where VNSAs may find willing recruits, active or passive support, or the ability to operate more freely.

Estimates from these two models are by no means the final answer in determining the location and responsible group behind rare events. But, knowing stability and radicalism levels can help narrow the playing field considerably. In addition, having the ability to objectively and consistently monitor rises and falls in both sets of metrics can help in development of policy and actions that prevent potential future trouble spots from erupting, and in turn decrease the likelihood that a planned rare event will be successful.

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4.6. The Accurate Anticipation of Rare Human-Driven Events: An ABA/SME Hybrid (Gary Jackson)

Author: Gary M. Jackson
Organization: Systems and Technology Division, Reconnaissance and Surveillance Operation; Science Applications International Corporation
Contact Information: gary.m.jackson@saic.com

Rare events as a topic has received increased attention in recent years. Undoubtedly the rarity of the type of Al-Qaeda attack directed against the United States on September 11, 2001 has increased this focus and has resulted in heightened concern. Often it is assumed that rare events are nearly impossible to anticipate or forecast accurately if the event is exhibited as human behavior and not purely a physical event. However, a deeper treatment of the topic indicates that predictive analysis is complex with successes and failures across both the physical and behavioral sciences. The purpose of this paper is to provide a context for both the complexities inherent in predictive analysis and to illustrate a methodology that can result in accurate anticipation of human behavior, particularly if defined as a rare event.

4.6.A. Physical Events Versus Human Behavior

The visibility of Halley's comet in our planet's night skies is certainly a rare event, yet we can predict its appearance accurately with a lead time of 75-76 years. A total lunar or solar eclipse visible in any location on the globe can be predicted with extreme accuracy over as many years or decades ahead as one may wish to calculate. Yet, it is clear that we may not be able to predict accurately the next Al-Qaeda terrorist attack against US interests, the actual nature of the attack, and the exact target. On the surface, it may appear that human behavior is just not as amenable to predictive analysis as events within the physical sciences. However, one need only point to the lack of capability within the physical sciences to predict the next earthquake, tsunami, volcano eruption, exact path or strength of a hurricane, or specific weather beyond one week to realize that the ability to predict or not predict is not a function of physical science versus behavioral science – it is much more complicated than that.

Human behavior and many physical phenomena are dynamic systems. As pointed out by Monahan and Steadman[1] the accurate anticipation of human behavior is similar to weather forecasting. As dynamic phenomena, both are difficult to predict accurately, especially if the prediction is to occur with a lead time of weeks or months and not just hours or days. As dynamic systems with ever-changing variables that interact to result in event variation, such variation complicates accurate foretelling of future events. Static or scheduled behavioral events such as predicting behavior on New Year's Eve and static physical events such as phases of the moon are easily calculated with high accuracy. It is clear that if the phenomenon is more dynamic than static, prediction will be difficult, whether the event is behavioral or physical in nature.

4.6.B. Forecasting as a Focus on Indicators

No event occurs in a vacuum as spontaneous generation. To predict the return of Halley's comet to our visible skies depends on empirical knowledge based on the juxtaposition of stellar bodies as precursor conditions that exist when the famous comet is visible as opposed to stellar conditions when the comet is not present. When these identified pre-existing conditions are imminent, then the appearance may be predicted accurately. Likewise, the association of unique precursor events such as the alignment of the earth in relation to the moon is so uniquely associated with the occurrence of an eclipse that prediction can occur with a 100% certainty many years in advance. In both examples of physical phenomena, accurate prediction is based on establishing the presence of indicators that precede the physical event with certainty. Prediction in these examples is not the result of a focus on the events themselves; it is a result of the identification of preceding factors that when occurring together are associated with the event of interest and when indicators are present in different combinations the event does not occur.

Extending this view to behavior has been useful. Behavior that may be anticipated accurately appears to be a function of identified precursor conditions that are associated with the subsequent occurrence of behavior. Given historical examples of behavior, indicators associated with those behaviors may be established. Then when indicators associated with the occurrence of a specific behavior in the past are imminent, we can assume that there is an increased probability that the behavior will reoccur. The fact that some events simply cannot be anticipated may simply mean that we have not identified the constellation and complex interplay of precursors that foretell when a new event may occur. However, there is a significant difference when comparing physical events and the occurrence of human behavior even if both phenomena are dynamic in nature. In the case of the latter, the individual or group intercepts precursor events and processes such events perceptually and cognitively prior to exhibiting the behavior. Purely physical phenomena, like weather, are missing this interjected layer between pre-existing conditions and the subsequent event.

Figure 1 depicts prediction of physical events with no human behavior. For example, typical physical events within such fields as chemistry, physics, astronomy, ballistics, or any physical phenomenon not requiring the individual as an intervening variable, have preexisting conditions. If we identify the preexisting conditions, we are likely to be able to predict the future occurrence with high confidence, and perhaps its consequences as well.

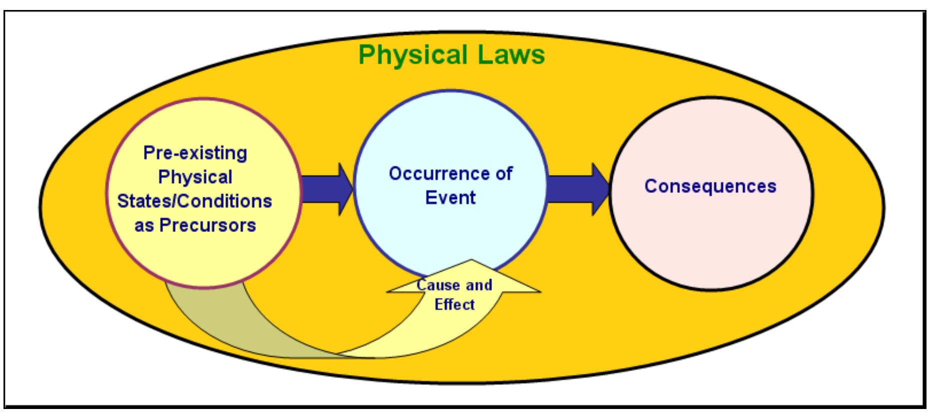

Figure 1. Prediction of purely physical events in nature with no intervening human interaction. Prediction is based on establishing the cause and effect associations among the preexisting conditions and subsequent events. Consequences follow the occurrence of any event.

Contrary to physical event prediction, the accurate anticipation of human behavior interjects the individual between pre-existing conditions and the following human behavior as a response. Because environmental stimuli are processed by the individual, person variables such as history, culture, decision-making style and other variables intervene and create a variety of types of responses that may be affected by such non physical factors as choice. This intervening stage creates a situation that complicates prediction significantly. Figure 2 depicts anticipation of human behavior. The individual or group as an event generator complicates anticipation to the point that we speak of probabilities of future behavior instead of cause and effect. The individual or group as part of the anticipation process adds uncertainty.

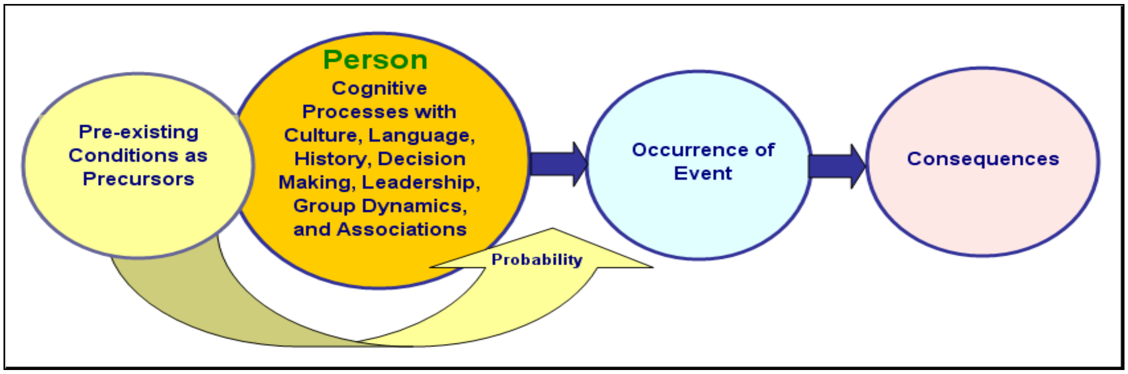

Figure 2. Anticipation of human behavior is complicated by the intervening process of human perception and cognition that interjects numerous intervening variables between pre-existing conditions and the actual occurrence of the behavior.

4.6.C. <u>Additional Complication: Rare Events</u>

Although anticipation of human behavior is complicated by the variability of behavior introduced by the individual processing stimuli in the environment, historical data is useful in identifying patterns of behavior in the presence of antecedent conditions. For example, the field of Applied Behavior Analysis is based on identifying indicators (antecedents) of specific behavior with repeated observations or in historical examples of behavior. The presence or absence of such antecedents may then be used to anticipate the same or highly similar individual or group behavior in the near future with an acceptable degree of confidence.

The study of terrorist events is necessarily a study of human behavior. This is true whether events are frequent or rare. Terrorist events are the product of adversary behavior guided by decision-making, targeting, grievances, location, temporal variables, motivation, opportunity, and planning. Terrorist events are not simply statistically based reoccurrences. Although there are history and patterns to be discovered and analyzed, we must realize first and foremost that we are studying human behavior and not physical event phenomena. Humans may exhibit patterns of behavior, but unlike a law of gravity that dictates the rate of any object falling, individuals are capable of not behaving in an ordered, repeated manner. The future is not a faithful reproduction of the past. Yet, predictive analysis of human behavior has relied on repeated observations and history as a primary approach to anticipating behavior.

Given the complexities involved in predicting human behavior from a study of historical examples, if examples of behavior are limited or missing, prediction becomes even more challenging. When robbed of history or when examples of behavior to predict are restricted to only a few examples, prediction of human behavior often becomes speculation, at best. How does one establish patterns that form predictive analysis without observations or history? Yet, we are faced with serious threat of a first time attack of biological agents or nuclear weapons with devastating loss of life at the hands of terrorist elements. We cannot simply ignore prediction because history is not available.

4.6.D. Toward a Behavior-Based Methodology to Support Prediction of Rare Events

The field of Applied Behavior Analysis stresses that behavior does not occur in a vacuum. Rather, behavior is only one component of a three-part sequence. This sequence is in the form of antecedents (A), behavior (B), and consequences (C) with components defined in the following manner:

- **Antecedent:** Any event or situation occurring before the occurrence of the behavior that is logically related to the behavior;
- **Behavior:** The actual definable and observable occurrence of the behavior of interest; and
- **Consequence:** Any event or situation immediately following the occurrence of the behavior that is logically related to the behavior.

Because of the emphasis on pre-existing conditions external to the individual or group (antecedents) and subsequent behavior as described in Figure 2, the approach is particularly relevant for predicting adversary behavior.

The premise of the applied behavior analysis model is that if antecedents (A) and consequences (C) associated with repeated occurrences of behavior (B) can be identified, then the occurrence of that behavior in the future may be anticipated when the same or highly similar constellations of antecedents and likely consequences are present. This methodological approach has been redesigned as Automated Behavior Analysis (ABA) with automation to the degree that predictive models based on historical examples of behavior may be developed, validated, and prepared for real-time use in a fraction of the time required for previous manual model construction. To be predictive, ABA has typically required multiple examples of behavior and associated contexts to provide the antecedent-behavior-consequence sequences necessary for advanced pattern classification and prediction. However, as stated, sufficient examples of some forms of behavior simply are not available.

When data are sparse as in the prediction of rare events, a hybrid ABA subject matter expert (SME) application has been developed and applied successfully. This ABA/SME methodology may be used if historical examples are missing or if only a few examples of the behavioral phenomenon are available for study. The ABA/SME methodology is a hybrid application. It combines the predictive elements of ABA with combined SME-generated scenarios of behavior and projected indicators as a replacement for historical examples of behavior. If these repeated scenarios are used as a replacement for historical examples of behavior, then ABA methodology and tools may be used to obtain predictive analysis in the absence of adequate history.

Typical artificial intelligence (AI) knowledge capture applications are variants of an approach that begins with extensive interviews of experts and ends with the reduction of such knowledge to basic "if-then" rules. Although proven to be useful in a variety of applications, typical rule-based applications may be brittle. That is, they can faithfully exhibit fairly straightforward decisions based on multiple if-then conditions, but are not capable of providing accurate decisions or outcomes when presented with unique combinations of input variables. ABA/SME was designed to replace typical rule-based engines with the well tested ABA neural network pattern classification methodology. The advantage of this approach has been that the ABA/SME applications developed for specific domains are capable of providing specific decisions and projections when presented with clear input variables like any typical knowledge based application but can also provide "educated guesses" when presented with unique combinations of input variables not present during training of the pattern classifiers

The application described here was based on the methodology used to develop the predictive engine underlying the commercial off the shelf (COTS) Checkmate Intrusion Protection System.[2,3] This application has been independently validated to identify first time network attacks and was based on the development of knowledge using subject matter expertise, as opposed to past attack data. Although the domain of biological agent attack is different than computer network intrusion, the basic principles are identical. That is, there are few examples of new or unique attacks, little useful data supporting the analysis of new signatures, and subject matter expertise is necessary to fill the significant "holes" in available data. More recent work with the ABA/SME methodology has resulted in the automated determination of intent extracted from movement patterns at the Pacific Missile Range Facility for the Office of Naval Research.[4]

4.6.E. ABA/SME Methodology for Biological Threat[5]

Figure 3 depicts the ABA/SME process used recently within the Joint Intelligence Preparation of the Operational Environment (JIPOE) weapons of mass destruction effort to construct the Software Enhanced WMD-T COA Hypothesis Tool.

As a stage one application, ABA staff attended an unclassified academic SME session to understand the bio threat scenario generation process. Using the unclassified *New Horizons* report,[6] all scenarios with associated indicators were extracted and indicator duplicates were excluded. Following indicator extraction, a typical ABA data array was developed. The data array was then presented to the ABA pattern classification methodology to develop weights. The gradient descent pattern classification process returned likelihood, type of agent, and perpetrator type when the application was presented with indicators associated with a given scenario. This recall was 100% accurate. To test the capability of the application to generate outcomes with alternate combinations of indicators, indicators associated with the past TTX (see Appendix A) were presented to the application. This test projected a low likelihood event with a viral agent and a religious perpetrator. Stage 2 was added with the inclusion of classified scenarios and additional associated indicators.

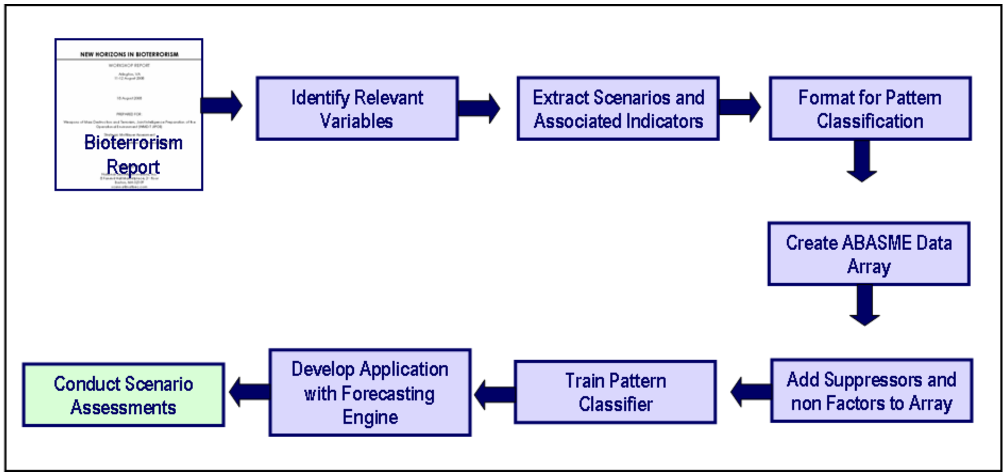

Figure 3. The ABA/SME process as applied to biological threat.

In addition, ThemeMate, an ABA tool, was used to identify *bona fide* data as intelligence injects from *bogus* injects, or noise. This process, based on identifying real data as having internal consistency resulted in 80% accuracy in selecting real from bogus intelligence injects as tested independently by Pacific Northwest National Laboratories (PNNL). The developed application used indicators identified in the bona fide data only as input to the developed ABA/SME bio threat application. Once all testing was completed, the ABA application was developed in C++ and JAVA code. The ABA/SME application consists of an input screen with 170+ indicators presented with checkboxes. To operate the application, one checks the boxes of the indicators of a new scenario to test. By clicking on "run" the constellation of indicators are presented to the trained patter classifiers. Given a description of a biological threat tabletop exercise with sequential intelligence injects, indicators were selected that were present and entered into the ABA/SME application. The result was that the application projected bio threat outcomes accurately across all projected outcomes.

It is clear that ABA may be modified to meet the needs of sparse data with the ABA/SME methodology. By augmenting brief historical examples of behavior with SME-developed scenarios and associated indicators, or with SME scenarios and indicators in the total absence of historical examples, ABA neural network pattern classification engines may be trained as if generated scenarios data were historical. This approach to generating group SME judgment, particularly with scenarios using combinations of indicators not used in pattern classifier training, results in scenarios that are likely to occur. Scenarios constructed of sets of available indicators may be viewed as hypotheses and by entering a sample set of indicators defining a hypothesis, the bio-threat application returns most likely outcomes as a form of hypothesis testing.

Unlike typical rule-based applications in which SME knowledge is captured by a set of static rules that feed back combined SME opinion on specific situations or events, the neural-network-based ABA classifier presents outcomes to unique combinations of indicators. This is a significant difference. For example, an ABA/SME application with a simple dual output (such as attack/no attack) with 20 indicators results in over one million possible combinations of 20 indicators (2^{20}). Each unique combination represents a hypothesis to be tested. For example, if indicators 2, 5, 18, and 20 are present, what is likely to happen? When these indicators are presented to the ABA/SME application, the most likely outcome will be presented even if this specific combination of indicators was not in the training set. An end user may use the application interactively to identify likely outcomes based on sets of indicators representing the occurrences of highly likely events. If the application has multiple outcomes, then future scenarios may be explored. Surowiecki[7] made the value of *collective wisdom* the major focus of his book. Given that knowledge capture of a group of SMEs generates a combined perspective, ABA/SME allows that combined knowledge to go beyond simple rules to likely outcomes given any combination of given indicators in an application. ABA/SME may be a step in the direction of digitizing Surowiecki's concept of *wisdom of the crowds*.

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4.7. Bayesian Assessments of Likelihood, Consequence and Risk for Comparing Scenarios (Sandy Thompson, Paul Whitney, Katherine Wolf, Alan Brothers)

Authors: Sandy Thompson, Paul Whitney, Katherine Wolf and Alan Brothers
Organization: Pacific Northwest National Laboratory
Contact Information: paul.whitney@pnl.gov

When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of the meager and unsatisfactory kind. - **Lord Kelvin** (British physicist)

4.7.A. Introduction

Technology limitations currently constrain efforts to evaluate risk and likelihood outcomes associated with rare event occurrences such as terroristic attacks. Large-scale terrorist activities exemplify rare events, as such situations require intelligence analysts to connect a myriad of information elements to evaluate the likelihood and consequences of a given terrorism scenario. When confronted by numerous information pieces, analysts must successfully identify elements that suggest a group is considering a terrorist attack, associate these elements into a feasible scenario (connect the dots), and evaluate the likelihood that the terrorist scenario will be executed. Consequence evaluation follows scenario creation, to assess the potential damage to human health (mortality), economic indices, and the human psyche.

This white paper describes a data integration framework for quantitatively assessing relative likelihood, consequence and risk for WMD-T scenarios. Current methodologies are limited as they are qualitative in nature, based on expert assessments, and elicited opinions. This section outlines using structural models to organize and clarify WMD-T scenario assessments, including qualitative as well as quantitative factors. Benefits to intelligence analysts would include increased transparency into the analysis process, facilitation of collaborative and other parallel work activities, and mitigation of analyst bias and anchoring tendencies.

4.7.B. Bayesian Inference

Bayesian inference is a branch of statistics focused on using data and information to update an event's likelihood probability. Compared to traditional statistical methods, Bayesian statistics allows for an additional modeling step, applying distributions to model parameters. This additional step incorporates uncertainty about the parameters within the model. When modeling rare events, the Bayesian paradigm formalizes the inclusion of correlated behavioral and social observations that lack obvious and direct causation rational. New observations about a WMD-T scenario update the model parameters, and uncertainty can propagate throughout the model assessment.

The underlying principal of Bayesian statistics is Bayes' Theorem first credited to Sir Thomas Bayes (1763/1958), a theorem describing the relationship between conditional and marginal events. Bayes theorem is:

$$P(A|B) = {P(B|A)P(A)}\big/{P(B)},$$ where $P(A|B)$ is the probability of event A given event B.

This theorem addresses two problems associated with rare event prediction, estimating probabilities and updating probabilities. When estimating probabilities, in many cases one conditional probability statement is easier to estimate than the reverse. For example, the probability of a symptom (headache) given someone has a disease (brain cancer) is much easier to estimate verses the probability of the disease (brain cancer) given a symptom (headache). This is because brain cancer is very rarely the cause of headaches. In WMD-T, Bayes Rule can help estimate the conditional probability of a terrorism event given a set of conditions, by examining the probabilities of a set of conditions given a terrorism event.

The second use of Bayes rule is to provide a mechanism to update probabilities based on new information. In trying to move WMD-T analysis left of boom, an initial event likelihood assessment may be very small. Bayes rule provides a framework to incorporate additional information easily, thereby mathematically supporting or refuting a potential terrorism scenario. If P(A) is the initial estimate of scenario A's probability, $P(B|A)$ is the probability of observing new evidence given that scenario A is true, and P(B) is the probability of observing the new evidence, then the estimate of Scenario A's probability can be updated, given the observed new evidence.

A Bayesian net (BN) is a graphical representation of causal relationships among variables. BNs are compact methods of representing causal interactions in complex environments, where uncertainty is a predominant feature. BNs are especially useful in diagnostic systems that determine the likelihood of one or more observation-based hypothesis. BNs are used in medical diagnosis, decision support for military combat, a myriad of Microsoft software features, and many other applications. Considering a medical example, BNs are useful when considering multiple diseases that relate probabilistically to a variety of diagnostic evidence (symptoms). This example is analogous to WMD-T rare event estimation, because analysts are faced with a variety of hypotheses-relevant evidence and must similarly relate such evidence to the likelihood of the threat. Bayesian nets are a powerful tool and can aid analysts in making such assessments.

4.7.C. Modeling WMD-T likelihoods

When modeling WMD-T activity or event risk, three primary factors drive the analysis: the motivation and intent of the group directing the event, the capabilities of the group behind the attack, and target characteristics.

4.7.C.1 General Threat Model for WMD-T

Figure 1 uses GeNIe (version 2.0 2008) to depict a model designed to represent generic threats. The model is general in the sense that its components are relevant to WMD-T, but the same components are the criteria considered for other threats. The model computes relative risk across scenarios based on currently available information and predicts the likelihood of a scenario's occurrence (Paté-Cornell 2002 presented a model with similarly intended generality).

This General Threat Model (GTM) is a Bayes net representation of the relationship among Motivation, Capability and Target Characteristic factors that contribute to an overall threat. Grey boxes in Figure 1 represent critical concepts for understanding threats, black boxes represent risk, and white represents consequence. The capabilities and consequences model components represent technical aspects, while the Motivation & Intent and the Target Selection nodes capture social and behavioral aspects. This model (and similar models) provides a view that integrates over a period of time. This particular model was constructed to reflect that motivation and intent can drive capability improvement efforts.

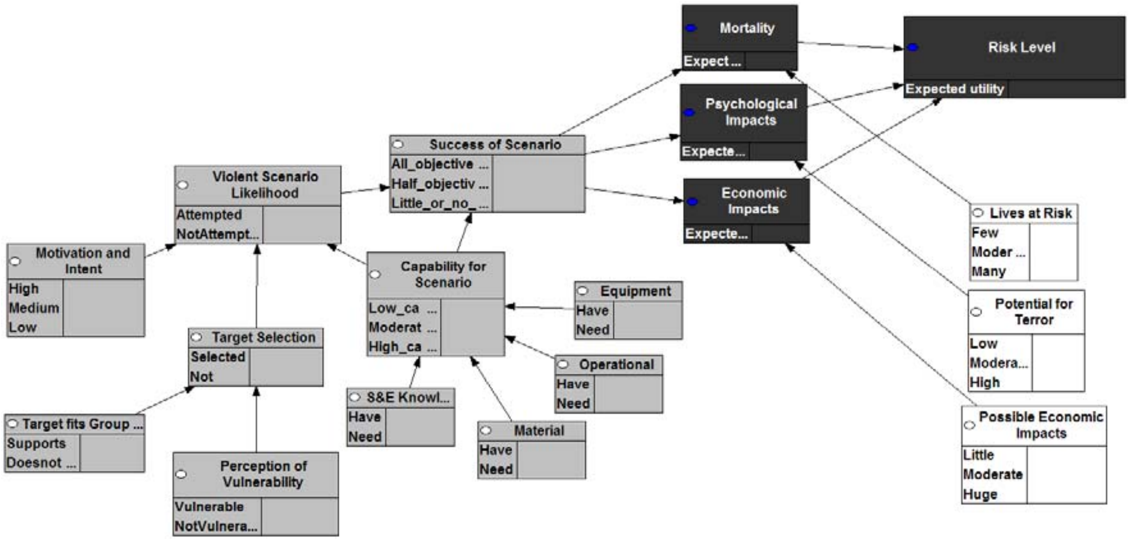

Figure 1: Bayes net representation of a general threat scenario model. This model also calculates risks associated with each dimension of consequence: mortality, terror and economic consequence.

4.7.C.2 Intent and Motivation for Violence Modeling

Evaluating a group's motivation and intent to do violence is difficult and requires incorporating soft factors (social and behavioral influences) as well as technical aspects. Social sciences have made substantial contributions to examining mechanisms associated with a group performing violence, as illustrated by a wide body of available literature. Such literature has been incorporated into quantitative models that reflect social mechanisms behind group violence as well as technical pre-requisites to group violence. Figure 2 displays a Bayes net representation of Sani's 2005 work on the social and psychological model behind group schism. When a group splits, the likelihood is high that one of the resulting groups can be more disposed to violent activities than the other – see McCauley (2008).

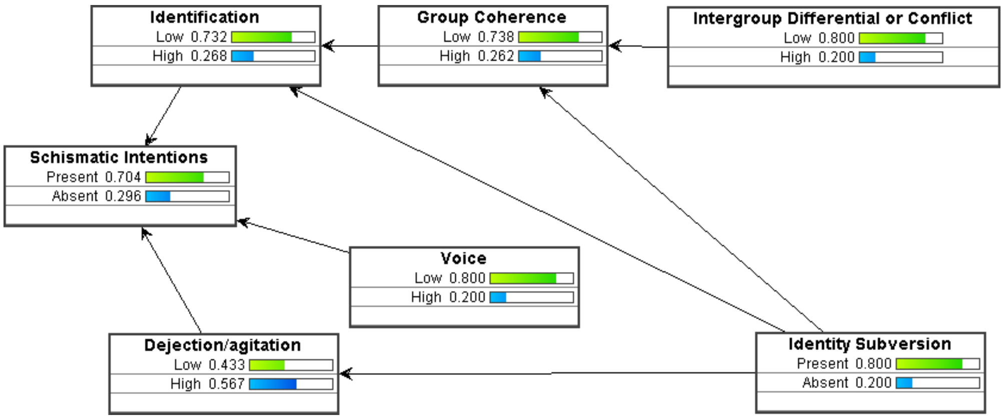

Figure 2: Bayes net representation of model assessing likelihood of a group split. The nodes represent critical concepts identified in the literature. In this model, each concept has two state values (Low/High, or Present/Absent). The numeric values are the marginal probabilities for the state values. The model propagates probability values through the network – so that if a value changes (based on evidence or opinion) in one part of the model, corresponding changes in probability values are observed in the other parts of the model.

Building Bayes networks that represent social mechanisms and relationships as described within social science literature requires identifying key concepts and values from within the literature and then extracting relationships among the concepts. For instance – in the Group Schism model above – the key concepts are identified in the node names. The relationships represented among key concepts reflect the social science literature from which the model was derived. For instance – “Voice” – is an indicator corresponding to the concept of whether a potential faction within a group has an effective means of expressing their position. A low value for voice corresponds to an increasing likelihood of the group splitting. Once the models are constructed, they are verified to be consistent with the relationship statements in the literature. In Figure 2, high intergroup conflict can lead to reduction in group cohesion, which contributes to group identity, and if the group has two identities, that may indicate high likelihood of schism intentions.

By quantifying variables that social science literature only qualitatively describes, Bayes nets help analysts explain their analytic conclusions and reproduce them. Bayes nets encourage analytic objectivity by explicitly reminding analysts of the larger set of relevant indicators.

4.7.D. Using the Models

Two critical aspects of using models such as those shown in Figures 1 and 2 are addressing the use of evidence and obtaining relative risk assessments.

4.7.D.1 Use of Evidence

An evidence item is a representation of a real world fact or observation that is related to the scenario. For example, a newspaper article, eyewitness testimony, intelligence report, photos or other imagery and its interpretation, or sensor data can be evidence items. Schum (2001) provides a basis for modeling how evidence is assessed and incorporated into analytic frameworks (essentially by modeling the human drivers associated with testimony). Three components influence how the credibility of evidence is assessed:

- Veracity – is the source expected to report truthfully
- Observational Sensitivity – the degree to which it is possible for the reporter to observe the event
- Objectivity – stakes in the outcomes

These three components are combined into a ***credibility*** assessment. The other aspect to consider when linking evidence in a network is ***relevance*** – the degree to which the evidence is relevant to the network. PNNL created a prototype tool, BACH, supporting evidence assessment concepts with Bayes net models. BACH (Bayesian Analysis of Competing Hypotheses) combines the strengths of modeling evidence, analysis of competing hypotheses probabilistically with Bayesian network modeling, to provide robust likelihood assessments as functions of entered evidence.

The Figures below exhibit calculations using the general threat model. The sequence shows example output calculations given different conditions – presented in sequence of increasing evidence supporting that the group will execute the scenario. Changes in probability values are useful outputs, but the absolute numbers are not, as the network has not been calibrated against a large number of observed incidents.

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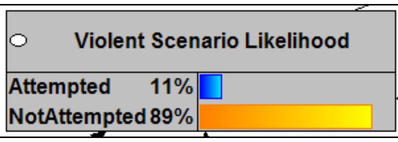
<td>
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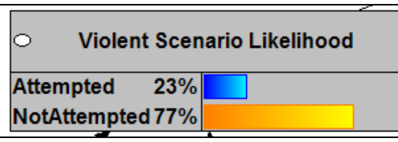
<td>
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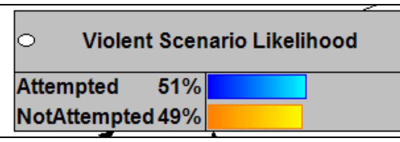
<td>
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<tr>
<td>Figure 3a: High motivation.</td>
<td>Figure 3b: High motivation and capability.</td>
<td>Figure 3c: High motivation, target selection and capability</td>
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4.7.D.2 Relative Risk Assessment

Relative risk calculations have a number of benefits in comparison to risk assessment. First, in rare events such as terrorist attacks, the relative comparison of scenarios can be more open to interpretation. If one scenario has a probability of 10^{-7} of occurring in the next month, and another scenario has a probability of 10^{-8} of occurring in the next month, at first glance they are both rare events. The comparison of the two scenarios shows that one scenario is ten times more likely than the other. Second, relative risk assessments can also compensate for lack of model calibration. The modeling process described above requires considerable parameter calibration, accomplished by using the model to assess current and historical terrorist scenarios. In future work, it may be required to develop unique parameterizations corresponding to different socio-cultural groups.

4.7.E. <u>Summary</u>

The methodology described in this paper is largely motivated by ideas in business forecasting (Armstrong 2001) and in intelligence analysis (Heuer 1999, Clark 2003). The methodologies are intended to address and mitigate bias, anchoring and incorporating uncertainty assessments. Additional considerations in analysis and prediction include taking advantage of problem and model decomposition, and utilizing past experience to calibrate the models. We discuss each in turn.

Mitigating bias and anchoring: Minimizing bias and mitigating challenges to objectivity is desirable in predictive analysis systems. Model-based methodologies support this by bringing attention to the range of relevant factors that can influence outcomes. In principle, this type of modeling can mitigate bias by not exposing the output of interest to analysts – evidence can be attached to individual parts of the model without knowledge of the entire model. Additionally, social science (or otherwise derived) models are obtained based on broader considerations than any single analysis challenge – and so can prompt analysts and information collectors. Anchoring is a cognitive bias that describes the common human tendency to rely too heavily (anchor) on one trait or piece of information when making decisions. Model-based analysis helps minimize this tendency by providing several options for types of relevant information.

Incorporates uncertainty: Individuals are demonstrably poor at self-assessments of uncertainty, as are groups of experts. A calibrated uncertainty assessment is determined by comparison with real-world data.

Decomposition: Rare events are sometimes the result of an uncommon sequence of more common events. Breaking a prediction and/or analysis problem down into smaller factors or submodels can result in more accurate predictions when the smaller factors are assessed more accurately than the overall target. The Bayes nets are decompositions. Additionally, this structure allows different individuals to simultaneously work on attaching evidence to different parts of the model – supporting a human form of a parallel processing.

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4.8. Bounding a Known Unknown: The Role of Decision Theory in Rare Events Analysis (Allison Astorino-Courtois, David Vona)

Authors: Allison Astorino-Courtois and David Vona
Organization: National Security Innovations
Contact Information: aastorino@natlsec.com

4.8.A. Introduction

Predicting "rare events" is by definition a challenging task. Moreover, if we are interested in anticipating one of these events it is generally because it is extremely important, costly, lethal or all of the above. Until recently, in fact, international relations and national security scholars have spent considerable effort studying ways to explain and predict the incidence of a single type of rare event: interstate war.[1] (Although it can seem otherwise, the outbreak of war between nation-states is actually a rare event: only 0.3% of all pairs of countries [*n* = 303,814 observations] were at war from the end of WWII through 1992).[2] Unfortunately, as non-state actors seize larger and more visible roles in world politics, the range of concerning events – wars, revolutions, wide-scale economic depressions and shocks – has grown to include state or terrorist use of chemical, biological, radiological or nuclear weapons.

Today's national security or intelligence analyst faces two related problems regarding rare events. The first is an empirical question: how to assess the likely occurrence of any of a diverse set of major effect rare events? The second is the issue of how to most effectively allocate finite technological and human resources: knowing where, for what and at whom to look. The difficulty, simply put is this: How can we assess not merely the likelihood of deadly, if rare, events but also how to focus our analyses on actors and conditions – known or unknown – most likely to engage in them?

A multi-method, qualitative-quantitative approach will be necessary to advance the nation's ability to explain, anticipate and hopefully deter events such as nuclear weapons use, bio-terror attack, etc. Because the most threatening events are the product of at least one human choice, *subjective decision analysis* – viewing an adversary's choices, costs and benefits from his perspective – can provide invaluable assistance to the rare event analyst. It is important to clarify however, that the type of analysis we discuss (i.e., done without the benefit of EEGs, EKGs or other physiological sensors) is not intended to produce point predictions of rare events, or any event for that matter. Its prime value in this context resides in its analytic framework, i.e., the rigor it imposes on analyses of what can be overwhelming amounts of data and information (e.g., intelligence reports, finished products, open-source materials sensor data, etc.) and the substantive output of the analysis. Let's begin with a brief description of what is meant by *subjective decision analysis*.

4.8.B. "Reconstructing" a Decision Calculus

Kim and Bueno de Mesquita (1995) among others use formal, rational (i.e., game theoretic or expected utility) models to make the case that in settings in which decision makers have complete information the (utility maximizing) perceptions of the decision maker are irrelevant to the final decision choice. This is because under these circumstances simple backward induction suffices to determine the optimal course of action. Perhaps unintended, but nevertheless implicit in their argument is recognition of the important role of *subjective* decision models in real world settings (e.g., the presence of uncertainty and ambiguity, use of decision heuristics that lead to sub-optimal choice, etc.).[3] Addition of "subjective" factors indicates a decision model designed according to *how the decision maker views the world* rather than according to the beliefs of the analyst. Thus, a subjective decision analysis involves constructing a (qualitative) model of an adversary's decision calculus relative to his own perceived costs and benefits of possible actions; it focuses the analyst in on an adversary's *motivations* for action, his *perception* of his decision problem and setting: the goals or interests a particular action serves, what he believes to be feasible and acceptable ways to pursue these goals; and, who else is involved and what they are likely to do.

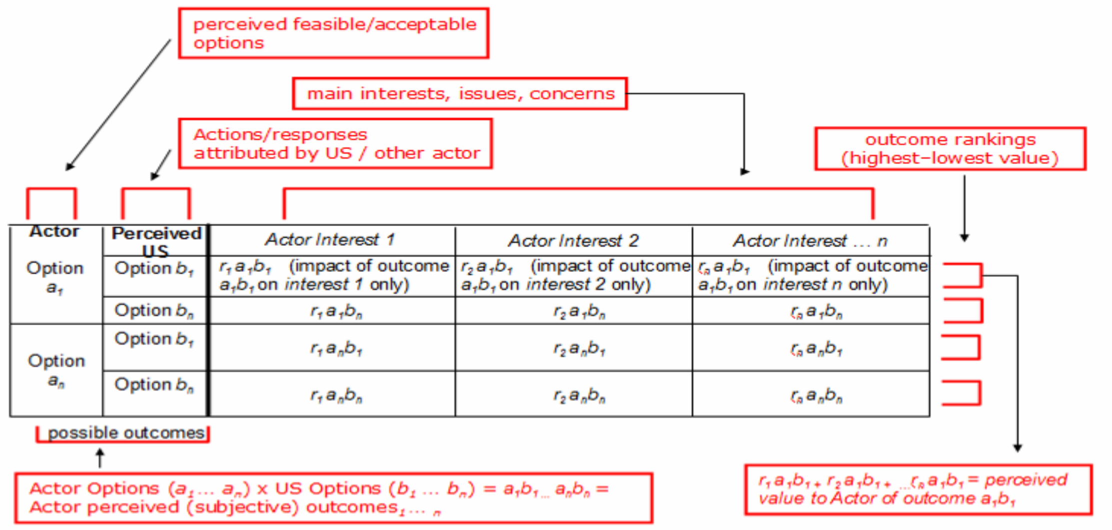

Figure 1: Search-Evaluation Matrix

This "subjective" information can be arrayed in a decision analytic structure called a search-evaluation (S-E) matrix (e.g., see applications in Maoz 1990; Maoz and Astorino 1992; and Astorino-Courtois 1998). As shown in Figure 1, the S-E matrix is a graphic representation of a multi-dimensional decision process. It contains the perceived decision outcomes (typically in rows) that will be judged across the set of the decision maker's key interests relevant to the choice of one of the options. Thus, a decision "outcome" is the joint occurrence of an option the decision maker believes he has and what he believes will be the reaction of his adversary (e.g., the US).

"Reconstructing" an adversary's decision problem in this way relies on three basic assumptions: 1) decision makers are capable of and engage in strategic thought, versus purely myopic or temporally-constrained thought; 2) self-interest is a constant behavioral rule; and, 3) actors use various heuristics to maximize their benefits within the bounds of their own reality. Once the matrix is filled out, each outcome is evaluated and assigned an ordinal ranking on the degree to which it satisfies each interest. These ranks are then aggregated for each outcome across the actor's entire set of interests to produce a multi-interest preference ordering over all his perceived outcomes.[4]

Once formulated, the subjective model can be used to address a number of questions about the conditions under which certain actions (e.g., conduct a WMD attack against the West) would be incentivized either independently or relative to that actor's other perceived choices. Analysis of the completed S-E matrix helps the analyst gain insight into three critical areas:

1. **Motivation**: Which of the adversary's interests or combinations of interests and perceived benefits support (incentivize) the choice of one option over another? Which of his interests represent the greatest barrier to undesirable actions (i.e., are disincentivizing to conducting a bio attack)?
2. **Intent**: How robust are the incentives? The disincentives?
3. **Indicators**: How do the incentivizing and disencentivizing conditions revealed by the decision analysis compare to current conditions as the rare events analyst understands them?

Although the notion of a 'subjective' decision analysis suggests that the decision maker and his interests are known to the analyst, it is actually not limited to situations where precise information is available. Consider the case where the event of concern is nuclear use by an unknown and even as yet undiscovered terrorist group. The analyst can and should use his best intelligence information on violent terrorist groups and the requisites of nuclear use to hypothesize profiles of (unknown) actors with the characteristics of a group perhaps willing and able to use a nuclear weapon. He can then use this profile to build an S-E matrix and explore incentivizing and disincentivizing conditions for an actor of this sort. Similarly, this approach is flexible with regard to the decision context. It can be used to model independent (one-party) decision-making or interdependent situations where, for example, the focal decision maker takes into account the various possible actions/reactions of his opponents.[5] Moreover, the S-E matrix can be expanded to not just support assessment of threats against the US, but may also be used to gain insight into the choices/responses of actors not party to an event, (e.g., under which conditions is a witting or un-witting VNSA sponsor most likely to condone violent behaviors?).

4.8.C. The Rare Event Analyst's Problems

We can now return to the dual challenges confronting analysts responsible for predicting rare events: assessing likelihood, and bounding the problem so that finite resources might be applied most effectively.

First, one of the wide-spread critical deficits of analyses – either for planning or intelligence purposes – of the likely actions of state and non-state actors is a rigorous and transparent method for identifying and assessing our adversaries' motivations and intent to act without projecting our own American-Western perspective on the perceptions of others. As mentioned, rather than producing probability estimates and confidence intervals, the contribution of decision analysis in assessing the likelihood of rare events comes in helping to expose the complex of environmental and perceptual conditions under which a certain behavior (leading to an unwanted event) is incentivized or disincentivized. Thus, when robust, incentivizing conditions for a certain action identified by a carefully-crafted decision analysis are observed, the analyst can make the case that the likelihood of that action occurring has increased.

Second, the major practical difficulty of conducting empirical analysis of rare events (as discussed in previous sections of this report) is *not* the sophisticated math involved. (With advances in computing technologies, applied researchers in medicine, chemistry, even political science continue to make great strides in this area.) The problematic area is actually data collection. In order to capture both the extremely small number of instances of a certain type of event (i.e., the dependent variable), as well as a random sample of "non-events", empirical rare event analyses can require extremely large amounts of data (i.e., data observations in the 10,000s+). In addition, the computational modeler must also collect date on factors presumed to explain or cause the event to occur (independent variables). This is a very large amount of data.

It is computationally challenging, labor intensive to collect and code, and can be costly to maintain.

Decision analysis is well-suited to serve an essential triage role. A list of the variables (e.g., specific motivators, interests, etc.) revealed by a decision analysis can help the researcher focus his statistical or computational modeling on those factors likely to be important in an aggregate study of rare events. Using decision analysis as a reasoned means of bounding the size of a rare events dataset will streamline the modeling process and more efficiently allocate important human, analytic and technological resources. Relatedly, better awareness of likely key variables *prior to* conducting empirical analyses also allows the analyst to employ cost and time-saving data collection schemes (e.g., cohort, or stratified random sampling) that preserve the mathematical benefits of random sampling but do so only on those variables most apt to add explanatory power to the model.

4.8.D. Conclusion

The fundamental premises of subjective decision analysis force a unique view of the problem that can aid modelers and analysts in predicting the occurrence of "rare events." It is not that decision analysis is particularly well suited to "rare events." Rather, we argue that it is a valuable approach because it forces the analyst to look at the issue of rare and dangerous events from the perspective of those deciding to engage in them. The very act of constructing the decision matrix can generate unique insights into the view of the world "from the other side". Such an approach also focuses in on a known or profile leadership's, or even an individual's, motivations for undertaking certain actions. Although we will likely never fully comprehend the choice of dire and thankfully rare acts, gaining insight into the interests and conditions that incentivize them will help us anticipate and ideally deter them.

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[1] As per the standard of the Correlates of War (COW) project housed at the University of Michigan, a war is identified as a militarized conflict resulting in at least 1000 total deaths over its duration.

[2] We follow King and Zeng (2001: p. 643) who define rare events in mathematical terms as "binary dependent variables characterized by dozens to thousands of times fewer 1's (events such as wars or coups) than 0's (nonevents)." See also, Maoz and Russett 1993.

[3] Note that in decision analysis, non-rational or non-normative decision behavior does not equate to psychotic or lunatic behavior. Rather, "rationality" refers to the comprehensiveness and equality of the process by which a decision maker identifies and evaluates his alternative courses of action.

4 In fact this is the analytic model upon which the Deterrence Analysis and Planning Support Environment (DAPSE) software tool is built. More information about the DAPSE and examples of its use is available upon request from Dr. Nancy Chesser at Nancy.Chesser@js.pentagon.mil.

[5] Including more than three or four main actors in a single decision matrix quickly becomes difficult to manage. However, although especially nation-states are concerned with the reactions of many other states actors to their actions, it is not typically the case that a decision problem involves more than 3-4 active participants. It is more often the case that concern with other states' possible responses is actually an interest (here a column) rather than a source of strategy alternatives.

4.9. Social Network Analysis for Detecting the Web of Rare Event Planning and Preparation (Elisa Bienenstock, Pam Toman)

Authors: Elisa Bienenstock and Pam Toman
Organization: National Security Innovations
Contact Information: ejb@natlsec.com; ptoman@natlsec.com

Since September 11, 2001, the US Government has become increasingly interested in potentially-catastrophic events brought about through unprecedented human innovation. Such events are very difficult to anticipate and therefore very difficult to defend against. The US Department of Defense (DoD) in an effort to develop the capability to avert attacks of this sort is investigating methods and approaches to recognize the forensic markers of such an event preceding the attack.

Social network analysis (SNA) is both an approach to understanding social structure and a set of methods for analysis (Wasserman and Faust 2005) to define and discover those activities and associations that are indicators of these rare, high impact events. The planning and organization of an event of this type necessarily leaves a trail, as individuals from disparate realms coalesce to assemble the knowledge and skills required to bring about the catastrophe. The strength of social network analysis (SNA) is in identifying and analyzing the latent social structures that are activated to enable such an event.

For instance, immediately following the attacks of September 11, 2001, Valdis Krebs (2008), a social network analyst, published an analysis of the social connections between those involved in the attack. Subsequent SNA studies demonstrated how SNA not only allows for the visualization of ties between small numbers of already-identified individuals, but also provides a framework to understand how people, ideas, and nefarious plots propagate through social institutions. For example, Bienenstock et al. (2006) used SNA to investigate the social connections between ten key Islamic institutions and 38 major terrorist events. Figure 1 illustrates the importance of these institutions in linking together otherwise unconnected individuals into a terrorist network. This type of analysis is valuable for understanding the lifecycle of terrorist events and how they manifest in social networks. It offers a firm basis on which to continue to develop methodologies for revealing, prior to the attacks, the networks in which the actors operate.

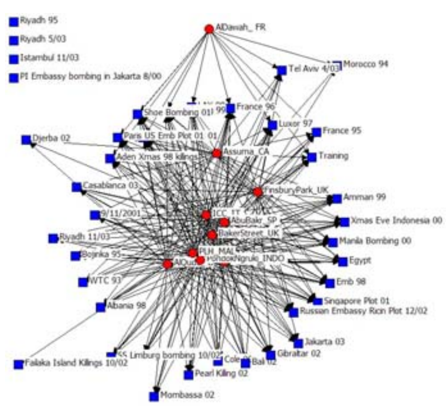

Figure 1. Connections of terror events through Mosque attendance and affiliations.

This paper describes insights from social network theory to propose a manner in which potential rare events may be recognized *a priori* through monitoring social networks of interest. Just as a spider notices strange vibrations in its web, the US Government could recognize changes to the normal state of the web of human connectivity that indicates marshalling of resources for nefarious purposes – before catastrophic events occur – given proper tools and capabilities. In particular, we examine two insights from the field of social network analysis: 1) the innovation necessary to conceive of these rare events originating at the periphery of the terrorist network, and 2) the organization of an event and how it generates activity in new regions of the network.

4.9.A. Characteristics of Rare Events from SNA Perspective

SNA is a broad and interdisciplinary endeavor that includes sociologists, physicists, mathematicians, anthropologists and others interested in exploring the effects of social structure on individual actions. The initial inspiration was to develop methods of analysis that enable the quantification and visualization of social relationships (ties) between people and/or groups (actors). Much of the early work and initial development of metrics and methods were born out of attempts to understand and formalize the social ties within a specific social group under investigation (Bavalas 1960, Coleman et al. 1957). SNA was primarily thought to be a set of tools to capture the implications of interactions within a group. The focus was on developing numerical operations that define social factors such as power, influence, status, discord and solidarity. While this early work focused on bounded groups, researchers quickly recognized the artificiality of bounding groups and began developing methods to traverse macro-level structure and the global network of human interaction (Poole & Kochen 1978, Killworth & Bernard 1979).

While SNA is useful for understanding the dynamics within a group, the more powerful theoretical insights gained from comparative network analysis concern the relationship between social network structure and what might be considered cultural outcomes. Patterns of interaction both define and reify culture which varies with network structure. One of the most basic findings relates network density and the degree of homogeneity to the ability of a social group to enforce normative behavior (Bott 1955, Bienenstock 1990). Related work discovered that structural properties associated with innovation (Coleman et al., 1957 Burt 1987).

The social network literature addressing the origins of innovation is particularly relevant to the rare events problem (Burt 1987, Valenti 2005). SNA research on small, well-bounded groups has discovered that innovation occurs not at the core of the group (or academic discipline), but at the periphery. In other words, it is not those most central to the discipline that tend to originate new movements within the group, but individuals who appear to be less central. Although this seems counterintuitive, it reflects the weakness of close, high-solidarity communities: they become provincial in thinking. From a more global, topological network perspective the periphery of one group is actually the avenue for connectivity between that group and the rest of the world.

In *The Strength of Weak Ties*, Granovettor (1971) argues that the best information on employment vacancies is prone to emerge from individuals outside one's routine social connections. The close friends with whom one speaks regularly cannot contribute the same value of information as those to whom one is connected tangentially. He points out that dense personal networks with high transitivity (where all associates know each other) become stale, as there are no sources for new information or ideas. As a result, from the micro perspective of the individual, there is a benefit in maintaining social connections in addition to one's daily intimate relations; at a macro level, Granovettor's analysis indicates that innovation occurs at the interstices between dense regions of the network. For this reason the sparse areas of the global opened social network (or equally, the periphery of a bounded social network) deserve particular attention from those charged with trying to anticipate highly inventive (rare event) catastrophes.

Additionally, although high network density is strongly correlated with groups that require trust to operate and that value social control, such as covert, ideological or religious groups; few groups can completely enforce social constraints. Some members of these groups may seek relationships with "non-sanctioned" individuals. These peripheral members, who maintain ties both to the group and to others outside the group, are the conduits through which innovation can be introduced and even eventually adopted by the group. Additionally, these conduits expose the world to the unique perspective of that group.

Furthermore, the source of innovation is often the novel confluence of existing ideas. Although some argue that a truly rare event is by definition beyond imagination, others, such as social psychologists and social network analysts, disagree. New ideas are never truly new, but innovatively repackaged. The occurrence of a "new" idea requires sufficient precedent for someone to make the innovative leap; as a result, of course, a handful of individuals often arrive at the same innovation within a short time span. Novel ideas cannot be introduced to individuals from within a stale dense network, however. In order to obtain the freshness necessary to innovate, there must be inputs from the outside. New ideas, thoughts, and strategies are therefore more likely to present at the interstices between cultures and/or less dense network regions, and then be diffused inward to the rest of the network.

Human-engineered rare events imply innovation by definition. For an event to be rare, it requires a new technology, novel intent, available funding, or more likely, the combination of several of these in a previously-unattested form. Although the technology or insight behind a catastrophic rare event may not be obvious (if it were, the event would not be "rare"), the inspiration of that event is not necessarily unique. The event's rareness indicates only that the inspiration combined with intent and capability had not yet converged. The events of 9/11, for instance, were rare not because no one had ever thought about flying airplanes as weapons into buildings; some had in fact (Clancy 1994, Castaneda & Thomas 1994). The occurrence was rare because someone had managed to complete the operation successfully. Therefore, those interested in identifying rare events should pay particular attention to individuals located in groups with the skills or intent to intend such acts who are building connections in sparse regions of an existing social network.

4.9.B. <u>Prediction of Rare Events from the SNA Perspective</u>

Although SNA may prove a necessary tool for anticipating rare events, SNA alone is not a sufficient perspective from which to anticipate the planning or imminence of a rare event. To be useful, SNA must be used as a component of a more comprehensive strategy requiring cultural and domain knowledge, as well as other features. SNA, as an empirical and mathematical approach that derives insight from data, requires a directed and high-quality data collection and produces results in line with its well-founded theoretical orientation. For SNA to be predictive, it will require the development of new tools and methods based on existing theory.

Current theory suggests that intentional rare events would be preceded by activity in sparse regions of the global network. Activity in sparse regions would indicate the emergence of new ties that connect previously-unconnected regions. Detection of this sort of network evolution would require a holistic and multilayered SNA perspective. A web of sensors informed by social network theory could be developed to monitor activity sensitive to particular types of connections. This web of sensors would provide a holistic awareness of the global environment that is also sensitized to specific activities; much like the spider's web alerts her to the location of even slight perturbations.

Although a global and multi-relational approach is recommended, utilizing SNA to anticipate rare events does not require the collection and monitoring of data on the entire network of all individuals at all times. While this would allow the detection of any unsavory connections building up between particular group clusters, it would also provide a large number of costly and invasive false alarms, as SNA focused almost exclusively on understanding bounded, well-defined networks of interest until recently. The recommendation here, rather, is to focus on the emergence of theoretically-determined patterns of ties in specific regions of the network. Connections formed in new regions would indicate: 1) the potential for innovation, as previously discussed, or 2) the gathering of necessary talent and materials to carry out a rare event. Social network theory provides an organizing schema to interpret the data and patterns of interactions.

The development of new ties at the edges of networks and the new involvement of individuals with particular talents and resources with each other serve as flags for the additional attention of the US Government. This approach to identification of potential rare events using SNA cannot be purely inductive, as such an approach would result in an unsustainable number of false positives that must be tracked or investigated. A more reasonable deductive-based approach would rather generate theoretical ideas for high impact events. The generation of theoretical ideas could in turn be informed by analyst knowledge about the thought patterns and interests of the particular groups and individuals between whom connections are ripe to form. With these hypotheses in hand, it would become possible to focus on the networks of groups or individuals with characteristics relevant to the potential event. In particular, analysts could then identify the talents and resources that will be needed for particular events, and look to the individuals in the network who possess these talents and resources. Analysts could then monitor these network regions for changes that might indicate the building of a capability of mass destruction.

Note that for rare events to be anticipated, the scenarios must include the most outrageous and preposterous scenarios imaginable. On September 10, 2001, most people would not have believed what was to happen the following day. Our biggest vulnerability may be the inability or unwillingness to take seriously, despite evidence, the prospect of a rare catastrophic event.

The application of SNA methodology, however is, useless when it is void of theory. Therefore the first and most important step in developing an SNA methodology directed at this type of problem is the development of possible rare event scenarios. This includes a set of possible "attacks" as well as information about what people, skills and materials would be required to implement each attack. Once these hypotheses are articulated, SNA could be utilized to investigate changes or locations in the social network where these components might converge.

4.9.C. Using SNA to Anticipate Rare Events: A Notional Example

Imagine the worst possible scenario, an intentionally produced Mega-Tsunami. In 2000, the BBC produced a documentary arguing that La Palma, Canary Islands, may potentially fall into the Atlantic Ocean. This event would cause a mega-tsunami 650 feet high, crossing the Atlantic at just under the speed of sound. By the time the tsunami met the Americas, the wave would be 3000 feet high. Such an event could potentially kill tens of millions of people and cripple the

United States. The question remains, could a motivated human group cause La Palma, Canary Islands, to fall into the Atlantic Ocean? If they could, what would they require in terms of talent, access, finances and material? SNA could be utilized to monitor the connections between individuals and groups whose convergence would indicate a plan to produce this type of event. Potential predictive / forensic markers on social networks would include: the formation of new ties between sub-networks with intent and individual with needed capabilities, such as physicists, geologists and demolitionists. In addition SNA techniques would link these individuals to the financing, material, political access and infrastructure required to carry out the plan.

The role of SNA in averting this catastrophe would be to:

1. determine what to monitor,
2. distinguish indicators of the formation of threat enabling ties, from the routine activity on the network,
3. posit, based on information available, the existence of ties for which there is no data,
4. identify critical points in the network that can be used as points of entry into the network to gather more data and investigate more deeply the motivation of the observed activity, and
5. determine the nth order effects on the network of COAs aimed at disrupting the planned activity.

Even if the La Palma event were not in planning, the data collection and analysis used to track these indicators may turn up evidence of another, not yet conjectured plot. The tools and talents needed for his type of catastrophe are not unique, another plan may be underway that could require much the same materials and people. The SNA approach described above, while designed for one purpose is not a stovepipe. By defining one scenario, as a target, the real utility of SNA is a general search for classes of social behavior that leave a tangible trail, that can be interpreted through the lens of social network theory as early warning indicators of plans to do harm.

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4.10. System Dynamics and Systems Thinking: Anticipation versus Preparation (Ritu Sharma, Donna Mayo and CAPT Brett Pierson)

Authors/Organizations: Ritu Sharma and Donna Mayo (PA Consulting Group, Inc.) and CAPT Brett Pierson (Joint Staff J8/WAD)
Contact Information: ritu.sharma@paconsulting.com, donna.mayo@paconsulting.com, brett.pierson@js.pentagon.mil

Following their introduction at Massachusetts Institute of Technology in the early 1960s, System Dynamics (SD) techniques have been used to address some of the most challenging strategy and policy questions facing business and government over the past 40 years. There exists an impressive record of successful applications of this analytical method. For instance, the 2001 winners of the Franz Edelman Prize for excellence in management science included a team from General Motors who developed a System Dynamics model to develop a successful strategy for launch of the Onstar system (Huber et al 2002). Additionally, a 2007 Department of Defense Award for Excellence in Modeling and Simulation was awarded to a System Dynamics model of Counterinsurgency that has yielded valuable insights into the analysis of Irregular Warfare (IW) within the Department. There is now growing interest in applying SD techniques within the Department of Defense and other US Government entities to deal with systemic solutions to complex adaptive problems and the consequences of rare events.

Thus, this paper (1) provides a summary of what we believe to be the most critical characteristics that underlie the SD method; (2) explores some of the ways in which this technique can contribute to the understanding of “rare events”; and (3) concludes with a discussion of strengths, and challenges/limitations to implementing the method.

4.10.A. System Dynamics was developed to facilitate change in complex environments

Systems approaches, such as systems thinking and System Dynamics, were invented at the Massachusetts Institute of Technology (MIT) in the late 1950s to help government and businesses design durable improvements to complex problems. Professor Jay W. Forrester developed the field of System Dynamics by applying what he learned about systems in his work in electrical engineering and control theory to other kinds of systems involving organizations and complex behavior.

What makes System Dynamics different from other approaches to studying complex systems is its focus on identifying the key dynamics that drive behavior over time and the explicit consideration of feedback loops. For illustration, Figure 1 contains a very simple example of two interacting feedback loops. Here, the loop on the left side of the figure shows how terrorists, by committing terrorist acts, can increase their notoriety and funding to enable the support of more terrorists. This self-reinforcing loop will dominate until the number of terrorist acts triggers concern and response from the US (a balancing loop), which can reduce the number of terrorists. The behavior over time of this simple system will look something like the right side of the figure. In most complex systems, numerous feedback relationships interact to produce the observed behavior.

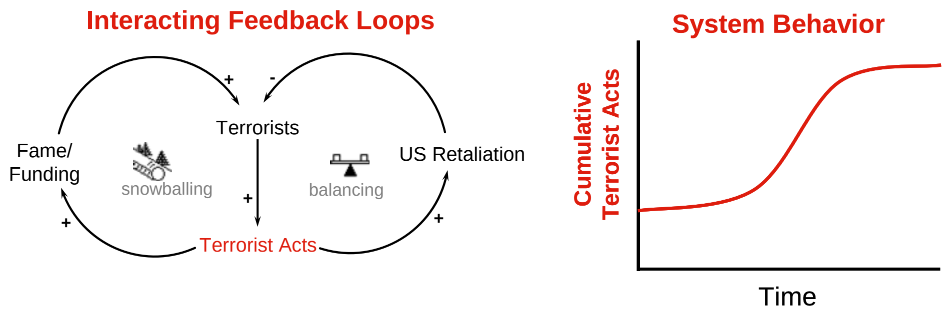

Figure 1: A simple example of interacting feedback loops

4.10.A.1 Systems thinking makes visible the key dynamics operating within a complex environment

Systems thinking – a qualitative form of System Dynamics principles popularized in the mid-1990s by Professor Peter Senge of MIT in *The Fifth Discipline* (Senge 1991) – focuses on creating an accessible visual representation of "how the system really works." Creating this view commonly involves research, interviews and investigation of available data to view the observed behavior as well as consideration of real world constraints and applicable theory. This is shown below in Figure 2.

The goal of the systems framework is to produce a distilled and accurate strategic-level view of the most important dynamics. Getting to this point can be very challenging however.

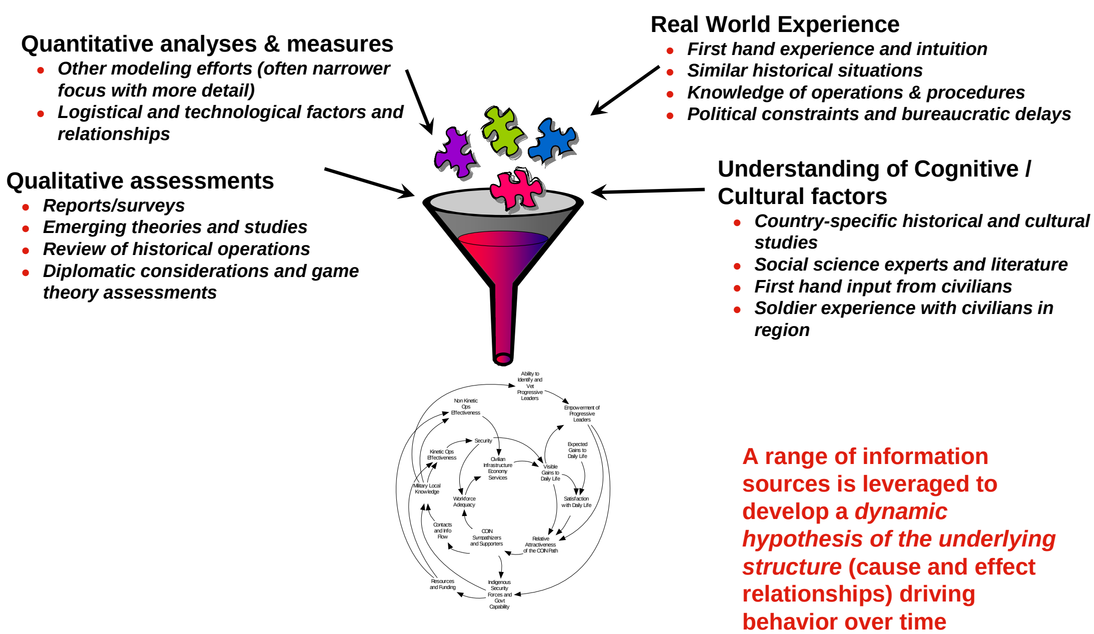

Figure 2 Systems thinking and System Dynamics integrate information

In grappling with complex systems, it is common to encounter conflicting information from different sources. It is critical to rigorously reconcile these inconsistencies. Failure to do so and to take steps to confirm the correctness of the framework with, for instance, appropriate subject matter experts can yield a distorted picture of the system that will obscure rather than enlighten understanding of the problem.

Some of the benefits attributed to a systems thinking approach include:

- Enabling rapid development and iterative improvement of a working hypothesis of underlying drivers and tradeoffs over time to provide enhanced and shared understanding of 'how the system works'
- Including important hard and soft factors, real world delays, and constraints to push towards a realistic hypothesis
- Organizing assumptions and integrating knowledge in a way that facilitates disciplined, productive discussion of possible strategies
- Providing an objective framework for thinking through, particularly in a multi-actor environment, how proposed actions will impact other parts of the system
- Enhancing the ability to communicate the logic and rationale behind policy choices, including the nature of softer, more difficult to quantify, expected benefits
- Directing further research and data efforts towards key factors and uncertainties
- Providing the "blue print" for a quantitative System Dynamics simulation model if desired

While the development of a systems framework is often followed by development of a quantitative model, there are instances when it may not make sense to go beyond systems thinking. These include situations in which there is so little quality data and information available, whether from knowledgeable people, reports or databases, that it would be too difficult to create a simulation that could be validated to provide insights beyond what was learned in the creation and analysis of the framework. Also, modeling may not be required in the case where questions of timing of actions and impacts are secondary to prioritizing among a basket of potential actions to discern which are best to undertake in general.

4.10.A.2 System Dynamics models enable exploration of a broad range of "what if" scenarios

A quantitative System Dynamics model replicates in a computer (via a set of interlinked mathematical difference equations) the cause-effect relationships and feedback loops documented in the qualitative "blue print." Stocks are used to represent anything that accumulates (e.g. people, bank balances, reputation); flows are used to represent any activity or action (e.g. new hires, deposits, changes in reputation). In calculus terms, the stocks are the integrations, and the flows are the derivatives.

Computer software is used to create the equations that represent the full complex web of cause-effect relationships, with their circular causality (feedback loops), time delays, and non-linearities. This web of relationships describes "how the system works" and forms the test bed for analyzing the impacts of potential actions or changed conditions. "What if" testing allows us to experiment safely with the system to understand the full, long-term consequences of potential proposals, actions, or changing conditions. Proposals can be considered both individually and in combination, allowing identification of those actions which are synergistic (i.e., the combination delivers a higher level of benefits than analysis of each one individually would suggest) and those that conflict with each other and wipe out the intended benefits. Additionally, it allows experiments that address the phasing of proposals to see if the intended order of execution makes any difference to the outcome.

Fundamentally such models and analyses help to find actions that produce the largest desired benefits as well as determine vulnerabilities that could severely hurt performance of the system and identify and mitigate undesirable consequences that arise under a potential set of actions. It is also worth noting that all of the benefits attributed above to systems thinking apply also to System Dynamics.

4.10.B. <u>System Dynamics is a way to cope with and understand rare events</u>

Even though there is a tremendous desire to forecast and predict rare events, building a model that can accurately predict the future is impossible. However, a System Dynamics model can help us prepare for, and hopefully mitigate the adverse effects of, rare events by:

- **understanding which rare events generate the most harmful impacts**. These are the ones that are potentially the most important to focus on and guard against.
- **highlighting the factors and causal logic that would drive a rare event.** Zeroing in on the underlying drivers can help isolate the best opportunities for disruption and prevention of rare events.
- **identifying the highest leverage areas for focus and mitigation**. With many possible uses for scarce resources, it is important to identify and choose those actions that provide the best "bang for the buck".

A systems approach is particularly useful in understanding the full structure of a problem even as complex as a terrorist attack. The process of building a SD framework reveals the factors that could cause a rare event such as a WMD attack and the factors that would need to be in place in order to execute such an event successfully. The approach integrates multiple mental models, sources of information, and views about the cause-effect relationships that drive outcomes. A framework leveraging information from different perspectives results in a richer and more complete picture of a complex situation. System Dynamics can add value to the process because it forces you to put assumptions regarding the structure of the problem and your thoughts regarding internal and external relationships on the table where they are exposed to the scrutiny of other experts. Because this process forces us to state our assumptions explicitly, developing the framework often highlights flaws in our "mental models" and enables us to "see" things more clearly. With this clarity comes an enhanced chance for identifying potential threats that would otherwise have remained invisible. Forcing assumptions into the open may make the players realize that they were wrong and potentially headed for a disaster they would not otherwise have seen coming.

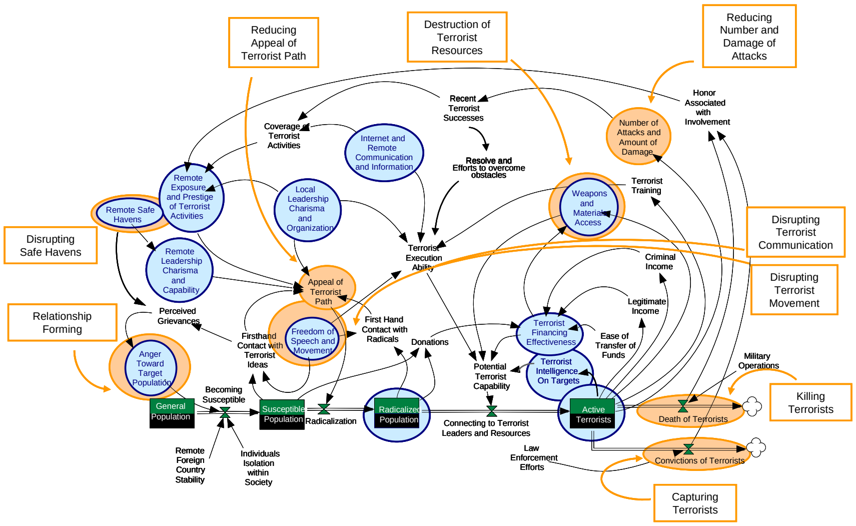

Figure 3. Sample Causal Framework

A causal framework of a situation can be used to review assumptions, identify gaps in understanding (e.g. factors that are well understood vs. those that are not), and assess leverage points for defending against a WMD threat or preparing in order to reduce the impact of a rare event. For example, the causal framework above (Figure 3) contains a simplified representation of the key levers for disrupting terrorist activities. When executed well, this type of framework is a high payoff effort that provides a systemic structure to react to, iteratively improve upon, and facilitate discussions that might be undisciplined at best and counterproductive at worst.

In addition to helping to deal with a rare event, the SD framework and/or model can help spot problems and underlying weaknesses earlier. For example, comparing the different levers and their relative benefit with current DoD investments and initiatives can point to areas that could use more, or less, attention and funding. The result is that shifts in funding and priorities are introduced earlier so that the "right" end products can be put to work sooner in a given environment.

With a quantitative model that approximates the performance of the real system reliably, it is possible to analyze all variations of the many impacts that may stem from rare events – magnitude, timing, combinations, etc. – to assess the full range of potential outcomes. Such analysis provides valuable insight into which variations of impacts are the most damaging. With such knowledge, we can then analyze potential actions that can be taken in advance to reduce negative consequences – in essence, find those actions that provide practical "insurance" against the most harmful impacts and thereby narrow the range of possible outcomes. Where investing in "insurance" is impractical due to cost or other impediments, we can continue the analysis to outline effective contingency steps that we should be prepared to act upon in real time in the face of a rare event. If we can identify a plan (and actually embark upon it!) that enables the system to function within an acceptable range, we may have *prepared* ourselves for the "Black Swan" rare event *without predicting* it. This is theoretically possible but there can be no guarantees of successful preparation against all possible impacts, some of which we cannot now even envision. However, we can guarantee that our understanding of the system – its vulnerabilities, its strengths, and its potential to recover under duress – will be greatly improved.

4.10.C. Strengths and cautions about this approach

We have previously described some of the strengths of a systems approach. To recap, System Dynamics can integrate valuable experience, research, and insight into a coherent framework to help refine and accelerate learning, facilitate discussion, and make the insight actionable by identifying key leverage points and creating a platform to test impacts of various strategies.

With systemic frameworks and models we can:

- Provide a more realistic integrated "big picture" view of complex issues
- Integrate a range of research, expertise, qualitative information, and data into a visible framework without simplifying to the point of distortion
- Illustrate connections among hard factors and soft factors, explicitly organizing assumptions on complex relationships
- Reflect real world behavior such as delayed feedback, conditional effectiveness, resource and organizational constraints, non-linear responses, and trade-offs over time
- Provide a structure to react to, improve upon, ask 'what if', and quantify the impact of specific actions and strategies across a range of scenarios

There are no simple, static, universally relevant answers, but this approach can rapidly improve understanding of leverage in complex adaptive environments and help identify potentially high payoff areas.

Systems approach limitations and risks must also be understood and acknowledged to avoid heavily biased conclusions, inappropriate precision and inefficient use of analytical funding. It is relatively easy to develop systems frameworks and working models; however, there is a steep learning curve to develop rigorous frameworks and useful models:

- Model validity is difficult to measure
  - Analysts may show (or audiences may interpret) outputs that are far more precise than they should be, given confidence levels
  - It can be difficult for end users to discern which efforts are more rigorous than others (e.g., you can draw loops on a whiteboard quickly, but what are they based on? Are they the ***right*** loops?)
  - For topics where data is limited, there is limited opportunity to check model logic and biases; cross-checking and triangulation methods depend heavily on analyst experience and judgment
- Communication and establishing credibility can be difficult
  - It is difficult to distill down to the most important factors – you need to capture the complexity, but in the simplest form possible, such that it is still digestible but not so simple that it no longer represents the system
  - This type of modeling is broader thus less 'deterministic' than most other types of analysis
  - It is often more appropriate to communicate insights from both the process and analyses rather than present quantitative output
  - Audiences are more familiar with quantitative models of more deterministic situations (e.g., physics based kinetic warfare), and expect the same confidence and validation from inherently more complex models

As is true with any other modeling method, poor analytical skill, lack of experience or weak integrity can lead to biased and/or immature analyses and findings, wasted resources, and lack of credible insight. While it may be true that there is no such thing as a crystal ball, it is equally true that there will always be charlatans who will try to sell you one. ***Caveat emptor***.

4.11. Complexity-Based Reasoning (Carl Hunt, David Schum)

Authors/Organizations: Carl W. Hunt (Directed Technologies, Inc.) and David Schum (George Mason University)
Contact Information: carl_hunt@directedtechnologies.com and dschum@gmu.edu

4.11.A. Introduction

The purpose of this paper is to present potential mitigating strategies to the problem of forecasting unanticipated events using techniques that harness the sciences of probability and Complexity Theory.[1] In many operational planning situations, hypothesis testing is conducted based on statistical evaluation of what has transpired before. While there are multiple ways to test hypotheses, this paper presents useful methods that involve quantitative measures of probability for unforeseen events that have not yet occurred, considered in the light of the multidisciplinary perspectives of Complexity Theory.

The staff process that supports military commanders and agency leaders often relies on the mathematics of probability to determine possible courses of actions and likely outcomes.[2] Unfortunately, statistical analysis of events, based on previous outcomes or probabilistic distributions, does not always apply. In order to move beyond the apparently obvious, staffs may need to apply probabilistic reasoning on evidence that is unique or happens only rarely. Probabilistic analysis of such situations is still useful if the right mix of methods is applied.

Probabilistic inferencing finds mutual support with the emerging science of complexity theory as it enhances the application of probabilistic reasoning to military and agency decision-making. While statistical reasoning may involve probability, not all probability involves statistics. In light of this, there are advantages for staffs to consider their decision-making challenges in light of complexity theory. One such advantage is in understanding the rareness of an event juxtaposed against the credibility of sources providing evidence about such events. Probabilistic reasoning augmented by complex systems theory offers worthwhile insights in assessing the dynamic and nonlinear interrelationships of the evidence the commander must consider in order to frame meaningful hypotheses about questions of unique or rare events.

4.11.B. Challenges the Commander/Director Face

The White Paper of which the current paper is a part presents many of the challenges the commander/director faces while assessing the emergence of unanticipated events. For that reason, this present paper only touches on two areas about evidence of unanticipated events: interrelationships and interactions. How does the evidence of an unanticipated event manifest itself through relationships to the hypothesis about an event, and how does it interact with other evidence or events to lead to surprises and unanticipated events?

The staff must be cognizant of these two characteristics of evidence about events to improve chances of mitigating surprise. Staffs must understand the interrelationships of items of evidence to each other and to the sources from which information is available about these items. They must also understand how evidence interacts with its environment to dampen or amplify the effects of unanticipated events. Finally, they must understand co-evolution and emergence, potential mitigating principles for dealing with these sorts of events. These are the challenges in which this paper seeks to help the staff find success in the light of ambiguity or non-precedence.

4.11.C. Mitigation Strategies through Complexity Based Reasoning

4.11.C.1 The Theory and Sciences of Complexity

Complexity theory represents a multi-disciplined approach to the study of relationships between elements of nature. It seeks understanding of the world through more realistic modeling of varied components, capable of demonstrating the effects of nonlinear emergences. Complexity theory embraces many sciences including biology, physics, economics, computational sciences and social sciences. Modelers of complex systems use "agents" as tools for discovery about their interactions. Agents in this sense are software objects that possess distinctive traits, often representative of people or events that transpire in the world.

A recent work on complexity theory and nonlinearity, published by the National Defense University, highlights several key factors that staffs must regard in considering the evidence before them and how it all interacts to present an assessment of the current situation:

- Nonlinearity is not proportional, additive or replicable; inputs and outputs are not proportional; its properties do not conform to those qualities found in linearity
- The demonstrations of cause and effects are ambiguous
- The whole is not quantitatively equal to its parts, or even quantitatively recognizable in its constituent components. Complexity may be easier to see than to understand
- Results cannot be assumed to be repeatable—the same experiment may not come out the same way in successive attempts[3]

Nonlinear, agent-based modeling may represent entities that are as finely grained as a single individual or an entire collection of individuals, such as an economy or culture. The agents in these models exhibit behaviors based on the notion of few rules and many, often unprogrammed, interactions between their fellow agents and the environment.

Complexity modelers look for emergent behaviors of agents that exhibit self-organization. Determining emergent behavior is not necessarily a deductive matter. In fact, complexity theory defines emergence as the rise of higher-level properties and behaviors that are not typically deducible from lower-level properties with which an agent may have started; they may be non-linear. Emergence plays an important role in discovering the interrelationships between items of evidence the commander/director must examine in hypothesis formulation and testing.[4]

Self-organization represents significant importance for complexity-based modeling and simulation. In fact, self-organized criticality is likely the basic engine for producing complexity in the real world.[5] Self-organized criticality can occur when a complex system discovers an area within its environment that facilitates evolution. Some complexity theorists call this area the *edge of chaos*, a site for innovation or adaptation. Recognition and analysis of adaptation and innovation are important capabilities for the commander/director and staff to harness in forming hypotheses on singular or unique evidence. It is the signs of interactions and emergences that will tip off the staff that an unanticipated event is about to occur.

Adaptation and co-evolution are important features of complexity theory. Complexity scientists identify a complex adaptive system as one that co-evolves with its environment and other agents within the environment.[6] In the behaviors of these agents, we find global order from their local interactions with each other and the environment in which they exist. Co-evolution suggests that change in one entity influences the actions of other entities (or even the environment). Again, the commander/director who can recognize and understand the effects and results of co-evolution within the evidence he or she must assess will have an edge in decision-making.

4.11.C.2 The Process of Discovery as a Bridge between Complexity and Probability

The notion of *discovery* as a formal process may not receive sufficient credit in the business of intelligence analysis and planning. Discovery, as a formal process, cannot be mandated or set into a standard operating procedure, but serves as one of the most creative and useful methods of orienting and learning about the emergence of unique events that are difficult to anticipate.

What is the process of discovery and how might we understand its role in any kind of reasoning with singular or unique evidence (particularly probabilistic reasoning)? We may define discovery with metaphor in a search for definitions that are more formal. "When asked how he came to discover the theory of relativity, Einstein replied that he imagined how the world would look if he were riding on a beam of light."[7] In a sense, Einstein not only saw the light, as it were, he became the light—he saw the world differently. If there is a way to introduce some formality into discovery-based thinking, it might be to provide a mechanism to think outside oneself. Arthur Koestler wrote that discovery "often means simply the uncovering of something that has always been there but was hidden from the eye by the blinkers of habit."[8]

Discovery clearly involves seeing the world differently—perhaps even seeing things in a way that no one has seen them before. Curiosity is at the root of this approach to thinking.[9] Therefore, it seems prudent to stimulate curiosity in assessing evidence the staff must shape into a hypothesis about some current situation or future action. Another formal method of reasoning that has recently found favor in the artificial intelligence community is what is known as abduction. Of the three major forms of inference—deduction, induction and abduction—it is abduction that seems to invoke curiosity and discovery.

Abduction, according to American philosopher Charles Saunders Peirce, is an instinct for guessing right. "I perform an abduction when I so much as express in a sentence anything I see. The truth is that the whole fabric of our knowledge is one matted felt of pure hypothesis confirmed and refined by induction," Peirce wrote.[10] Peirce allowed that the price paid for the necessity of deductive conclusions is their vacuity, the conclusions do not tell us anything not apparent in their premises. As far as induction is concerned, it involves the testing of hypotheses that have already been generated by other [e.g., abductive] means. In this sense then, one of our greatest thinkers has formalized the way discovery and abduction work in our inference models.

Schum notes that if Peirce is correct, "new ideas emerge as we combine, marshal or organize thoughts and evidence in different ways."[11] The French mathematician Jacques Hadamard adds: "Indeed, it is obvious that invention or discovery be it in mathematics or anywhere else, takes place by combining ideas."[12] We find then that combining ideas and information, in ways that others before us have not, forms the core of the process of discovery. This helps us to see how abduction, induction and deduction work together in this process, with abduction being the stimulus for us to integrate our own thoughts and intuition into the process to ensure that our hypotheses rise above mere deductive recantations. This is crucial to the process of enhancing the commander/director's experiences in hypothesis formulation without reducing the process to merely planning by standard operating procedures. Discovery is a bridge between understanding complex systems and applying formally accepted methods such as probability.

4.11.D. The Uses of Probability for Evidence Assessment in Anticipating Unique Events

Probabilistic reasoning can be just as useful for hypothesis testing for staffs in cases of singular or unique evidence as it is in cases where rich statistical data exist. As a general observation in the case of unique, unanticipated events, the enumerative methods required of statistical reasoning are not possible. The method below is useful in assessing the complexity of the relationship of evidence to hypothesis and to the events that actually transpired or are likely to transpire. In many instances, these same methods can apply to singular or unique evidence and assessing the rich, complex interrelationships between items of evidence and hypotheses. The probabilistic methods described below can be useful in uncovering complex interrelationships of evidence we may discover and in forming possible hypotheses about unanticipated events.

There is one opening caution on any approach that involves probability in disciplines such as military operations or law and criminal court cases: through the years courts have had chronic difficulty with statistical and probabilistic evidence in terms of relevance.[13] It is normally difficult in a court of law to introduce historical information such as statistical distributions and try to establish how such "evidence" is relevant to the case at hand. The same may be true in the staff's decision-making process. The commander/director faces the difficult challenge of applying history to the present situation—it just does not always fit.[14] The courts seek evidence that is clearly relevant and credible, and the commander/director must also.

We noted earlier that even physical evidence requires testimonial evidence (such as briefings and intelligence summaries) to "glue" this evidence into the larger body of evidence. It is important for the commander to confidently assess the credible and objective nature of the evidence (and its sources) and try to avoid complicating hypothesis generation. As noted below, Bayes' rule can also assist in this matter.

Finally, the staff can apply the legal system's technique of assessing the probative force of the evidence involved in military decision-making. Force, or weight, of evidence is the first place we clearly see the application of probabilistic reasoning applied to hypothesis formulation. This consideration of evidence requires grading the strength or weight in probabilistic terms. "We know that these gradings must be probabilistic in nature, given that the evidence we have is incomplete, inconclusive, and lacks credibility to some degree," notes Schum.[15] Corroboration from independent sources is an example of assessing the credibility of the source. Generally, evidence must have credibility and probative force, and it must be relevant to the given situation. We will argue the concept of force of evidence in greater detail below, in the discussion of a method to probabilistically reason with singular or unique evidence.

Commanders and directors planning for a future action and investigators preparing for adjudication in courts of law (where juries render outcomes) face similar situations. They both must deal with evidence that is incomplete and often inconclusive. Additionally, this evidence is usually dissonant, ambiguous, and imperfectly credible. This means that like it or not, we must apply some sort of probabilistic inference to assess the effect a particular piece of evidence will have on our decision-making. And compounding this situation, evidence often interacts in unpredictable ways that make it even more difficult to prepare rational plans for the future. For this reason, staffs need to understand the thinking behind complexity theory, discovery and the benefits complexity-based models can provide to their decision-making environment.

We have shown how the three methods of inference (abduction, deduction and induction) can interact to introduce the process of discovery into the formulation of hypotheses for operational decision-making. When backed up with the tools that complexity theory-based modeling can provide, we see that the staff can have a visual interface to evidence and the interrelationships between the evidence and their hypotheses. What of the process that occurs to build and test these complex interrelationships? Now we come to the power of probabilistic reasoning and its support to operational decision-making, even in cases of singular or unique evidence.

The power that brings together probabilistic reasoning and complexity theory is based on Bayes Theorem. The first component is a feature of Bayesian analysis known as conditional non-independence. Recall that Bayes Rule (or Theorem) is a form of conditional probability that accommodates a more accurate assessment of the introduction of new evidence. In essence Bayes Rule helps us calculate the probability of hypothesis *H*, given event *A* has occurred, set against the probability of event *A*, given that hypothesis *H* has occurred plus the probability of event *A*, given that hypothesis *H* has *not* occurred.[16] The odds/likelihood ratio form of this rule shows how likelihood ratios grade the extent to which prior odds are revised into posterior odds in light of evidence. The concept of conditional non-independence, so important in Bayesian conceptions of probabilistic reasoning, helps us capture a very wide array of complexities or subtleties in the evidence we encounter.

This is of course a very simple explanation of Bayes Rule, but it demonstrates the importance of considering both the occurrence and non-occurrence of a given event in assessing the overall effect of one event upon another. Also, note how an analysis of evidence in this light depicts the sensitivity to initial conditions in this method in terms of the relationships between the occurrences and lack of occurrences of a given event. A grasp of initial conditions of an operational environment follows from an understanding of emergence and co-evolution.

Consider that event *A*, from the earlier example, is an item of unique evidence (e.g., has not been previously accounted for in any sort of statistical distribution maintained in a military table or standard operating procedure). Each item of evidence may have its own influence on the commander's existing hypothesis, but when considered together, indicate an influence that the commander has never seen before. In such a situation, items of evidence are said to be possibly non-independent, conditional upon the occurrence or lack of occurrence of the given hypothesis. The determination of the sensitivity of these items of evidence in relation to the hypothesis is measured by a concept known as a likelihood ratio. This ratio is a measure of the odds of the occurrence of hypothesis *H* and the odds of the occurrence of *not H* (or *H* '), all subject to the influence of the items of evidence.[17] It shows how much the evidence has changed our prior odds to posterior odds. The idea of conditional non-independence is one of the most important features of Bayes Rule for capturing subtle interactions between evidence.[18]

We showed how this approach generally applies to unique items of evidence and uncovering interrelationships between them in hypothesis formulation and testing. Now let us consider how this concept allows us to weigh singular items of evidence. The key concepts behind this method include the effective use of generalizations and ancillary evidence (or meta-evidence). As Schum notes, "no statistics, even if available, are relevant to these assessments, nor would any canvassing of our past experiences involving other people and situations be relevant."[19] Recall that evidence must be relevant, credible and possess some probative force to be useful and reliable, although experience and intuition do temper this process, as noted above.

We must avoid the trap of trying to introduce statistical but irrelevant evidence to a situation. We should instead rely on broader generalizations about certain events, backed up by ancillary evidence that helps make general applications more specific and useful. A generalization as used in this context is simply some action or item that usually happens when something else happens. For example, when there are dark, thunderous clouds overhead, it normally rains (but not always; there is some uncertainty). We can generalize from the evidence of the clouds that rain is likely, but it would be helpful to have some sort of ancillary evidence to help us better prepare for the likely event of the rain, such as a recurring inflammation in a joint.

At this point we apply Baconian reasoning and pay as close attention to what we do not consider as to what we do consider in assessing our evidence. The Baconian method can help us eliminate evidence or hypotheses that do not pass the tests we set for them.[20] In this way we are better able to build "helping", or ancillary inferences to make generalizations more applicable to the singular or unique evidence in view. Ancillary evidence focuses on aspects of credibility of evidence. It examines such attributes as veracity, objectivity and observational sensitivity of the source of evidence. Ancillary evidence can help to increase (or decrease) the utility of a generalization to build support for *H* or *H'*. This ancillary evidence provides more probative force that can strengthen or refute our generalizations.[21] It should be noted that the Baconian view is not at all antagonistic to a Bayesian view. Baconian probability grades how complete is our evidential coverage of evidence viewed as relevant, and the Bayesian view grades how strong this existing evidence is.[22]

4.11.E. Conclusions

It is a popular Yogi Berra-ism that prediction is tough, particularly when it is about the future. Anticipating unique events certainly falls into the same category. Commanders, Agency Directors and their staffs face a significant challenge in any attempt to reason about evidence that may or may not foretell the occurrence of an event that has never transpired before, but they do have useful tools when synergizing Complexity Theory, Probability Theory and Discovery. The key now is to ensure we teach our leaders and their staffs to exercise these tools and augment their experiences and intuitions. The science is there for them – they just have to use it.

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[1] Complex adaptive systems approaches are also known as the sciences of Complexity, or Complexity Theory. In fact, it is our belief that complexity theory may form the backbone of the next revolution in military affairs and particularly in military decision-making. For example, see: TRADOC Pam 525-5-500, *The U.S. Army Commander's Appreciation and Campaign Design* (CACD), HQs, US Army Training and Doctrine Command, Ft. Monroe, VA, 28 January 2008.

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4.12. Augmented Paranoia (Eric Bonabeau)

Author: Eric Bonabeau
Organization: Icosystem Corporation
Contact Information: eric@icosystem.com

4.12.A. Introduction

Our inability to predict low-frequency, high-impact events in human and manmade[1] systems is due to two fundamental cognitive biases that affect human decision making: *availability* and *linearity*. Availability heuristics guide us toward choices that are easily available from a cognitive perspective: if it's easy to remember, it must make sense. Linearity heuristics make us seek simple cause-effect relationships in everything.

Our decision heuristics have evolved over thousands of years to help us deal with the most common situations, or, more precisely, situations most commonly encountered by our hunter-gatherer ancestors. When response speed is essential to one's survival, ignoring complexity is probably better than embracing it. An availability-based heuristic works well in repeat situations because it "caches" pre-existing solutions in memory so they are easy to access when the right stimulus comes up. Internet caching is indeed an apt metaphor: it works well when predictable patterns can be obtained, but does not work so well for unexpected events, such as spontaneous flash crowds, where the system can break down. A linearity-based heuristic is often a good choice because there usually IS one cause A and one effect B, and an increase in A DOES usually produce a proportionate increase in B. Except when things are more complex.

But even in today's complex world, imagine someone who would not "suffer" from any of these biases, someone who never takes anything for granted (does not use availability) and does not accept any simple cause-effect explanation for anything (does not accept linearity). Such an individual would surely be a great recruit for the intelligence community but would not be socially viable. Mild forms of what I just described are known as paranoia. However, what is needed to anticipate rare events is not just the mild form. What we need is *augmented paranoia*. How it can be achieved (without threatening our viability as individuals) is the topic of this short paper.

4.12.B. The Decision Framework

4.12.B.1 From heuristics to biases

As a starting point, let's define the decision framework to be used throughout the paper. The framework is borrowed from the field of Operations Research, whereby solving a problem entails two high-level tasks: (1) generating options (a task that includes framing the problem and establishing a set of working assumptions about it) and (2) evaluating them. Each of these tasks is subject to varying levels of complexity. Human decision heuristics are biased along these two dimensions[2]: there are *generation biases* and *evaluation biases.* Table 1 provides a selection of generation and evaluation biases. A disproportionate amount of attention has been given to evaluation biases, but I think they are less dangerous and not as deeply ingrained as generation biases. That's because our brains have evolved to come up with quick solutions: we often come up with good enough solutions, even if biased, but we are never good at spending time exploring the space of possible solutions –not to mention near-impossible solutions.

Biases	Descriptions
Generation Biases	
Self-serving bias	Seek to confirm assumptions
Social interference	Influenced by others
Availability bias	Satisfied with easy solution
Self-confidence	Believes to have found solution
Anchoring	Explores in the vicinity of anchor
Belief perseverance	Keeps believing despite evidence
Stimulation bias	"Only knows it when seeing it"
Evaluation Biases	
Linearity	Seeks simple cause-effect
Local vs global	Confuses local and global
Statistical bias	Not good at statistics
Pattern obsession	Sees patterns where there is none
Framing	Influenced by presentation
Hyperbolic discounting	Dominated by short term effects
Endowment bias	Aversion to risk, loss

Table 1. Generation and Evaluation Biases

4.12.B.2 Availability

Interestingly, all of the generation biases point to one common issue: they limit our ability to search for, and seriously hinder our ability to consider, alternatives, by forcing early convergence. In other words, you stop the search before you should, leaving potential nuggets undiscovered. The speed at which we make decisions seems to matter more than the quality of the decisions. All generation heuristics more or less fall under the banner of availability.

To understand availability, consider the following example. When asked if they think there are more English words starting with the letter 'k' than words that have 'k' in third position, most people answer with the former. It is just a lot easier to come up with examples of words that start with 'k' than it is to find words that have 'k' as their third letter, but there are, in fact, many more words that have 'k' in third position. That's an example of availability: when looking for a solution, you go with the first that comes to mind. Availability makes you think you have found the solution and prevents you from searching further.

The advantage of availability as a decision heuristic is that it works well when contexts don't change abruptly and the past can be used to predict the future –which is most of the time in our daily lives. The high and lasting impact of: the last thing you have heard, the things that are easy to memorize, something several people have told you, the first (wrong) thing you heard about an event before being corrected, or the stuff that confirms your assumptions –these are all illustrations of availability.

To be able to predict truly unusual events, one would have to turn down all availability. Think of a jury that needs to be shielded from all external influences to be able to make clear judgments. The problem, in the age of always on, is that availability is enhanced by, well, the constant availability of *selected* information from many sources. The information is selected because people, for example, find it exciting. That's why people worry more about plane crashes than car accidents: the ratio of reported to actual clearly favors the perception that plane crashes kill more humans than car accidents. Applied to the prediction of rare terrorist events, it is easy to see that availability is not a good thing: are we spending so much time worrying about airline passengers with one-way tickets that we are not paying attention to what really matters?

4.12.B.3 Linearity

We tend to assess situations with an additive mindset, which is particularly problematic when there are nonlinear interactions between the constituent units of a system. Along the same lines, we also have a tendency to look for clean cause-effect relationships when there is often a more complex causal web at play. For example, it may sound intuitively obvious that adding a lane to a highway will ease traffic, while in fact, because of myriad nonlinear interactions between cars, it has been shown that it may actually increase traffic. Traffic is a great example of the failure of our linear decision heuristics.

In the context of predicting rare events, the linear approach will fail to prepare us. That's because ALL rare, very large events in human and manmade systems involve some form of nonlinear synergies among a system's constituent units. Black Swans are intrinsically nonlinear events that will not be predicted with a linear mindset. *Cognitive preparedness* requires nonlinear training.

4.12.C. Toward Augmented Paranoia

4.12.C.1 Against availability (1): collective intelligence

The first strategy against the availability bias is based on the following assumption: if we as individuals suffer from biases, perhaps these biases can be corrected by tapping the collective intelligence of people in a group[3]. I have found three very general types of strategies (Table 2) – which can sometimes be combined:

- ***Outreach*** consists of reaching out to individuals or groups beyond traditional boundaries (which could be the walls of the organization as well as, for example, hierarchical or functional barriers inside the organization) to collect ideas (generation tasks) or assessments (evaluation tasks). The value of outreach is in numbers: broadening the decision-maker or solver set, or broadening the consideration set. There are people out there, not where you would expect them, who may be able to help. One example is Open Source: "with many eyeballs, any bug is shallow", is a famous expression.
- ***Additive Aggregation*** consists of collecting ideas (generation tasks) or assessments (evaluation tasks) and performing some kind of averaging. Additive aggregation may be a way to aggregate information from traditional decision groups, or it may be combined with outreach to aggregate information from a broader set of people. Here, the whole is, by definition, the sum (or some average) of the parts. The simplest examples involve the direct application of the law of large numbers (e.g., how many jelly beans in the jar?). More complex examples involve market designs, such as information markets. The key is to maintain a balance between diversity and expertise - both are needed. In fact, in the simplest form of additive aggregation, it can be shown mathematically that collective error = average individual error – diversity. The average individual error is a reflection of how knowledgeable individuals are, and diversity means diversity of opinions.
- ***Self-Organization*** consists of mechanisms that usually involve interactions among group members so that the whole is more than the sum of the parts. While the other mechanisms improve decision-making, self-organization makes collective innovation

possible in the decision process. The downside is that, if the mechanisms are designed improperly, the whole can end up being less than the sum of the parts. Groupthink and hijacking are two examples of interactions gone bad. Information markets, while firmly in the previous category, do sometimes self-organize when the behavior of participants becomes correlated, either because they are directly communicating, or because they are all biased in the same way and respond to the same stock price –which is a form of indirect interaction. The problem is that information markets are expected to perform a different function (manifested in the desire for market efficiency), so that self-organization in a market is usually not a good thing. Deviations from market efficiency, however, do provide insights into the behaviors of the participants. There are also more constructive examples of self-organization, where interactions create additional value: Wikipedia, the CIA's Intellipedia (a version of Wikipedia for the Intelligence Community) or Digg, where participants create value by deleting from, and adding to, other participants' contributions.

Biases	**Possible mitigation by collective**	**Possible strategies**
Generation Biases		
Self-serving bias	Diversity of assumptions	Outreach
Social interference	Independent participants	Additive aggregation
Availability bias	Diversity of "easy" solutions	Outreach
Self-confidence	Diversity of solutions	Outreach
Anchoring	Diversity of anchors	Outreach
Belief perseverance	Diversity of beliefs	Outreach
Stimulation bias	Diversity of stimuli	Outreach, self-organization
Evaluation Biases		
Linearity	Nonlinear interactions	Self-organization
Local vs global	Nonlinear interactions	Self-organization
Statistical bias	Law of large numbers	Additive aggregation
Pattern obsession	Diversity of pattern detectors	Additive aggregation, outreach
Framing	Diversity of influences	Additive aggregation
Hyperbolic discounting	Diversity of time scales	Additive aggregation
Endowment bias	Diversity of risk profiles	Additive aggregation

Table 2. Possible Strategies

From studying the publicly available literature about collective intelligence, it is clear that it can be successful in alleviating some of the individual biases, especially by broadening the range of possible solutions, which clearly addresses our availability issue. A collective intelligence tool, properly designed, can therefore increase our collective paranoia without increasing individual levels - a very good thing in the context of this paper.

4.12.C.2 Against availability (2): tapping the creative power of evolution

Are there ways to dampen availability on an individual basis? I can't pretend to have all answers, but here is a potential approach. When problems are extremely complex and the space of options is combinatorial, the answer may come from a powerful force in creative problem solving: biological evolution. Indeed, there is an intriguing parallel between biological evolution and the two dimensions of decision making: generation and evaluation are similar to variation and selection. Nature thus provides us with a powerful metaphor for *creative* problem solving. Computational techniques known as artificial evolution or evolutionary computation replicate *in silico* the way that biological evolution works. Since its introduction thirty years ago, evolutionary computation has proven highly successful at solving a wide range of decision problems. It sometimes leads to surprising solutions and can find previously unknown weaknesses in complex systems. For example, we have worked with the US Navy for several years on a tool that evolves challenges to a complex shipboard control system[4]. Not only can the evolutionary algorithm test more configurations and challenges than human beings, it can also do so *creatively*, that is, it can come up with entirely new ways of “sinking” the ship. Using evolutionary computation for generation purposes can be very powerful.

Another method consists of combining the power of evolution with the expertise of human beings. In fact, we humans have been using this technique for hundreds of years, it is known under various names such as breeding, animal husbandry, or directed evolution. To name one famous example, corn was bred about 9000 years ago by Mexican farmers. Teosinte, the plant they started with, is so different from modern corn, that it was originally classified in a different genus. Teosinte is barely edible, while corn is today one of the leading sources of calories for human society. The story of how such a transformation was made possible, by the combination of careful selection by farmers with a genetic structure that enabled dramatic morphological changes, is still being uncovered by ongoing research. Which means that humans have been using a powerful biological engine called variation which they did not understand at all; all they knew was that it worked for producing the requisite amount of variation and they could provide selective pressure. Imagine now the same process with the biological engine responsible for variation being replaced by a computing device. The result is called interactive evolution or IE. Artificial evolution with human evaluation, a technique pioneered by evolutionary biologist Richard Dawkins[5], is very useful when the space of potential solutions, designs or strategic options is large AND the goodness of a solution is difficult to formalize. For example, there are many situations where the decision maker doesn’t know ahead of time what the solution looks like – “I know it when I see it” kinds of situations. Starting with a more or less randomly generated population of solutions, the evolutionary technique will search the space of solutions by picking the fittest individuals *as defined by the user*, will mutate them and breed them, and the offspring will again be evaluated by the user, etc., until solutions emerge that satisfy the user.

Now consider the job of an analyst. When looking for the unexpected in structured or unstructured data, the analyst doesn’t know ahead of time what to look for. At a high level of description, the job of an analyst can be regarded as the process of discovering potential vulnerabilities, threats and opportunities from multiple, sometimes numerous, multi-modal, multi-lingual sources of data with various levels of uncertainty, completeness and noise. One typical task is to discover interesting patterns in the data, where "interestingness" is not specified exactly. The analyst often does not know beforehand what “interesting” means, or even where to look for patterns, which data to use, which data to discard, how reliable the data may be, or how to display the data. On the other hand, when presented with patterns or examples, the analyst usually knows whether they are interesting or not. Thus the problem is that the analyst’s advantage, which can be summarized as “I’ll know it when I see it” (ikiwisi), is not an easily actionable discovery principle when the “it” is not known beforehand. The technique described in this article is aimed at making ikiwisi actionable. To search for patterns in data, experts in a given domain use search hypotheses or search models.

But the space of search models is obviously high dimensional. How can one reconcile the need to search through an extremely large space of models (potentially thousands or millions of models) with the need for proactive human evaluation of each model? Obviously human beings cannot be asked to come up with, and/or evaluate thousands or millions of alternatives. The classical solution is to narrow down the search and focus on evaluation. Unfortunately, when applied to the analyst’s job, this approach by definition precludes the discovery of novel patterns, since the only patterns that can be detected are those that don’t fit “normality” according to predefined criteria, leading to a large number of undetected patterns that may be of crucial importance. At the other end of the spectrum, many deviations from “normality” are of minor importance and generate false positives from automated methods, while a human expert would easily recognize the pattern as an acceptable deviation.

There is therefore a need for an approach that would enable analysts to discover the unexpected. Interactive evolution addresses these issues. There have been a number of business applications over the last few years and the trend is accelerating. Honda is helping its designers explore the space of car designs using interactive evolution. The problem with car design is that it is highly constrained: a designer has to satisfy hundreds of technological constraints simultaneously (such as wheelbase length, windshield angle, and size of engine compartment) while at the same time remaining *creative*. In other words, automobile designers must balance aesthetic considerations with technical specifications, an often frustrating juggling act resulting in a lengthy trial-and-error design process. The tool enables the designer to engage in a guided exploration of the design space: it is first presented with a number of initially random designs; the designer picks the ones that come the closest to what he is looking for –they are the fittest individuals; artificial evolution takes the fittest designs, mutates them and breeds them to create a new “virtual generation” of designs, which the designer evaluates again. The results are spectacular: in just a few iterations, a car designer can be highly creative in a way that is consistent with the constraints. Designers can create and compare a vast number of designs in a short time, greatly streamlining and accelerating the design process.

Exploratory, interactive hypothesis generation is a natural application of interactive evolution for the prediction of rare events –and a step toward our objective of creating *paranoia aids*.

4.12.C.3 The nonlinear mindset

To understand the nonlinear mindset, consider a toy example: a (manmade) sandpile. Most of the time, the addition of one grain of sand will trigger the displacement of one or two other grains of sand. These are small events. Therefore, if you use the past to predict the future, you will only predict small events like the ones you have witnessed. A catastrophic event, an avalanche that sweeps the entire sandpile, is possible, due to nonlinear interactions between grains of sand. It is, however, a rare event. You’re unable to predict it on the basis of just looking at the past. In order to predict the occurrence of future avalanches, one must build a causal, mechanistic model of the sandpile. It is the sandpile’s internal dynamics that create the potential for rare but extremely large events, such as triggering avalanches. Two decades ago, physicists introduced a simplified description of the sandpile. In their model, when the addition of a grain of sand creates a local slope that is too steep, the grain and its neighbors topple, potentially triggering the toppling of other grains, and so on. This has the potential to trigger large avalanches, despite the fact that you see only small avalanches most of the time. In other words, the model was able to capture the large events in the system.

What are the grains of sand in the search for terrorist threats? How do they interact? In simulation modeling, we would call them “agents”, and the method the physicists used is called agent-based modeling (ABM). In ABM, systems are modeled as collections of autonomous decision-making entities, called agents. Each agent individually assesses its situation and makes decisions based upon a set of rules. Agents may execute various behaviors appropriate for the system they represent – for example, listening, spreading a rumor, planning an attack. Repetitive interactions between agents are a feature of agent-based modeling, which relies on the power of computers to explore dynamics out of the reach of pure mathematical methods[6]. At the simplest level, an agent-based model consists of a system of agents and the relationships between them. Even a simple agent-based model can exhibit complex behavior patterns and provide valuable information about the dynamics of the real-world system that it emulates. In addition, agents may be capable of evolving, allowing unanticipated behaviors to emerge. Sophisticated ABM sometimes incorporates neural networks and genetic algorithms to allow realistic learning and adaptation.

In providing a way to capture the emergent phenomena (including very rare large events) that result from nonlinear interactions among agents, ABM makes it possible to test assumptions that are not constrained by our linear heuristics. Doing so constitutes yet another step toward *computer-aided paranoia*.

4.12.D. The Case

The case I am making is simple: what makes us human also makes us ill-equipped to deal with rare events. The ideal rare event predictor would be someone suffering from acute paranoia. I have introduced tools and methods for making "normal" human beings *temporarily* more paranoiac. Should these tools be deployed, we would achieve cognitive preparedness.

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[1] I want to stress the difference between large natural events (earthquakes, tsunamis, hurricanes) and events occurring as a result of human activities. Although natural events may have complex causes and a lot of nonlinearity, it is often possible to examine historical data to model and predict the future. That is because the same broad set of mechanistic causes will lead to the same type of event, an observation that does not usually hold for human systems. Indeed, any human system's response to a large adverse event tends to be to adjust to avoid a repeat.

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4.13. Unconventional Red Teaming (Fred Ambrose, Beth Ahern)

Authors/Organizations: Fred Ambrose (US Government) and Beth Ahern (MITRE)
Contact Information: bigfoote@aol.com, bahern@mitre.org

4.13.A. Background

Many have criticized the Intelligence Community (IC) for a failure of imagination in not indentifying the 9/11 attack in the planning stage. In fact, if a failure occurred, it was a failure to understand the role of professional cultural norms, language, intellectual capital, and problem-solving methodology rather than a lack of creative thought.

Even casual inspection of the intellectual capital of the planners and principal actors of the 9/11 attack unveils the rich intellectual capital of the adversary. From Usama Bin Laden to Khalid Sheik Mohammad, and ultimately to the actual planners and operators such as Mohammad Atta and Said Bahaji, *all* fit the profile of technically trained, experienced, and highly motivated individuals. Leaving aside religion and motivations, their professional cultures differ radically from the professional cultures of the national security professionals tasked with predicting and preventing their activities.

How might intelligence, military, and law enforcement personnel understand and ultimately prevent the conception, planning, and execution of a concept of operations (CONOPS) such as that behind the 9/11 attacks? How might we train members of one profession to think and understand the intellectual capital and the culture of another? A new type of red teaming, based on an understanding of professional cultures and individual technical expertise, can give the national security community greater insight into the capabilities and potential plans of our adversaries.

4.13.B. Conventional Red Teaming

Businesses, civilian government agencies, and the military use red teaming to test concepts, hypotheses, and operational plans in a controlled manner using understood tactics, techniques, and procedures (TTPs) or situations. For example, businesses use red teams to simulate the competition; government organizations use red teams as "hackers" to test the security of information stored on computers or transmitted through networks; the military uses red teams to address and anticipate enemy courses of action. In all these cases, the red teams play against blue teams representing the business, government, or military organization trying to counter the red team's actions.

Traditionally, red teams follow scripted scenarios that build on the initial positions and capabilities of the enemy. Such an approach requires *a priori* knowledge of the adversary's capabilities, intentions, and CONOPS. Moreover, the teams typically consist of personnel drawn from the communities that reflect the parent organization. Thus, these teams embody not only the knowledge and experience of their parent organizations, but also, in large measure, the parent organization's mission focus, prejudices, and culture.

Conventional red teaming therefore provides valuable information as to how certain known combinations of defense and aggression may play out in a highly controlled environment. However, such red teams cannot serve as a predictive tool to assess unexpected actions, and are not particularly effective in "unbounded" war games that allow aggressors to operate in an environment defined by their own culture. Insight into the personal or professional culture of known groups can help red teams to accomplish the general goals of predictive war gaming.

4.13.C. Professional Cultures

Most people define "culture" by race, religion, ethnicity, and the memes[1] associated with those common observable differences among people. Each culture has its own language, ways of thinking, approaches to solving problems, time horizons, and views of the physical world. Certain cultural identities may compete with others; for example, military versus civilian culture, or the culture of "hard" (physical) versus "soft" (social) science.

Consider the struggle within the joint world of the Army, Navy, Air Force, Marines, and Coast Guard. In the twenty-two years after the Goldwater–Nichols Act the different elements of the "purple" world have made massive improvements in understanding each other's culture, but many significant challenges remain. Moreover, the post-9/11 era has seen the emergence of joint task forces that draw members not only from the military services, but also from the Justice, Homeland Security, and Treasury Departments, as well as non-governmental organizations.

An interagency task force composed of law enforcement, military, or intelligence professionals must fight a continual uphill battle to understand and anticipate an adversary's actions and the severity of the consequences – especially if the adversary's cultures do not match those of the task force members. The task force then runs the risk of failing to understand the significance and potential meaning of the information it may already possess about the adversary.

4.13.D. Unconventional Red Teaming

Red teams constructed on the basis of professional cultural identities and an understanding of the social networks of known threat groups can overcome the limitations of conventional red teams and lead to predictive insights regarding the adversary. Two foundational concepts underlie this approach to red teaming.

4.13.D.1 KESALT

The concept of KESALT – knowledge, experience, skills, access, links, and training – augments the core disciplines of ethnography and cultural anthropology by providing a way to look more deeply into the motivation, intent, and morality that characterize different professional cultures. KESALT can serve as the defining lens through which to examine cultural identity and understand how members of a given profession think, reason, communicate, and execute their actions. In essence, KESALT "contextualizes" professionals' language, outlook, and actions: people with the same KESALT share an understanding denied to those who lack that KESALT, while the absence of common KESALT effectively camouflages, conceals, or prevents such understanding.

Knowledge of KESALT has special value because all members of a professional or social grouping identify with their own culture and recognize that they have a common language, experience, and understanding with people from all over the world who share that same profession or social group. For example, despite individual and national differences police officers, engineers, or medical doctors can easily communicate in great detail with their counterparts around the world and reach a common understanding. Conversely, members of those communities find it far more difficult to discuss the same topics with people outside their respective professional cultures, even if they share other attributes such as nationality, educational level, or socioeconomic status.

4.13.D.2 Social Prosthetic Systems

The concept of social prosthetic systems (SPS), developed by Dr. Stephen Kosslyn of Harvard University, can help analysts to understand the roles that culture, language, intellect, and problem solving play for our adversaries as they form planning or operational groups. Kosslyn devised SPS to describe how successful people in business consciously or unconsciously select people to carry out their ideas and plans. SPS derives from the realization that even the most successful person cannot know, be skilled in, and carry out all aspects of a business, research, or other multifaceted enterprise. Therefore, a leader deliberately chooses specialists from different disciplines to act as the “prosthetic extensions” that can “make him/her whole.” Each specialist provides intellectual and/or physical capabilities that integrate with the capabilities of other members of the team to achieve the enterprise’s goals.

In this sense, just as a person missing a limb obtains a physical prosthetic to replace a lost capability, so each team member selected for particular skills and abilities provides a component of the social prosthetic system, or network. Both the creator and the prosthetic members are part of the social network. Thus, the composition of a group offers clues as to the particular.

4.13.E. Using Red Teams for Predictive Analysis

A red team based on the professional cultural identities of suspected threat teams, and operating in an unscripted war game, can transcend the limitations of conventional red teaming and generate predictive insights regarding the adversary. Where conventional red teams might fail to detect subtle indications of actions, intents, and outcomes, Red teams staffed according to SPS and instructed to use their individual KESALT can effectively model adversarial threat action planning. Thus, by creating a red team based on the KESALT of known or suspected groups and their SPSs, the IC could gain a much greater insight into the most probable courses of action that such a group might devise, along with the greatest potential to carry out these actions successfully.

Red teams engineered around the concept of SPS can also provide invaluable insights into and bases for new collection opportunities, as well as definable indications and warning. Additionally, such teams can help to create the basis for obtaining structured technical support for a blue team or joint task force. In this sense, such red team efforts can lead to unique training opportunities for joint task force officers.

4.13.F. Conclusion

As the world grows ever more complex with the globalization of knowledge, ready access to dual use materials, and instantaneous communication among members of transnational groups, the national security community must develop new methods to avoid future attacks like 9/11. The United States must anticipate technological surprises from non-state actors and nation-states alike. Using unconventional red teams based on the KESALT and SPS of known or suspected threat groups expands the potential to predict asymmetric attacks. This approach aids in the prediction of emerging threats grounded in observable and measurable characteristics of groups and their capabilities. It can also lead to the establishment of new collection concepts and priorities as well as the development of new counter courses of action, ideally allowing the United States to interrupt, mitigate, or respond to future attacks.

[1] A **meme** (pronounced /mi m/) consists of any idea or behavior that can pass from one person to another by learning or imitation. Examples include thoughts, ideas, theories, gestures, practices, fashions, habits, songs, and dances. Memes propagate themselves and can move through the cultural sociosphere in a manner similar to the contagious behavior of a virus. Wikipedia, www.wikipedia.org

4.14. Strategic Analytic Gaming (Dan Flynn)

Author: Daniel Flynn
Organization: Office of the Director National Intelligence
Contact Information: daniejf@dni.gov

> *"If I always appeared prepared it is because before entering an undertaking I have meditated long and have foreseen what may occur." -- Napoleon*

> *"Plans are nothing. Planning is everything." -- Dwight D. Eisenhower*

Anticipating "rare events" is difficult because by their nature such events involve a great deal of complexity and uncertainty. This complexity and uncertainty are often the result of interactions between two or more competing actors whose independent choices will govern the character and development of a future "event." Failure to understand the unique perspectives of these actors and the choices available to them and to foresee how their actions might interact with the actions of other key actors often leads to unanticipated results and surprise.

- In complex and rare situations involving multiple actors and high degree of uncertainty, standard analytic techniques relying on past observations to make linear projections about the future are often inadequate to fully anticipate emerging interdependencies and factors driving key actors toward certain outcomes.

Strategic analytic gaming is an analytic methodology that can be employed to reveal new insights when complexity and uncertainty are the dominant features of an issue. Gaming techniques allow participants to play the roles of key actors in future situations and simulate their actions based on their respective political, military, economic, and security interests and leadership mindsets. The outputs of such games are not predictions or rigorous solutions but rather an increased understanding and insight into the complexities of an issue and the prevalent factors that are likely to drive future outcomes. Such insights can help analysts open their minds to potential events that they might otherwise miss and inform the development of strategies designed to encourage positive developments and hedge against negative possibilities.

4.14.A. The Games People Play

Strategic analytic games[1], such as those conducted by the Intelligence Community, are most often focused on the strategic-level political-military decision-making and interactions among key actors in a particular situation. Although such games often deal with conflict situations, they usually will subordinate or abstract the details of combat operations to place emphasis on the strategic actions and decisions of key actors. Such games differ, therefore, from military **wargames,** such as the DoD's Title X games, which are designed to emphasize warfighting operations and often subordinate or abstract issues at the strategic level such as national-level decision-making processes, domestic politics, and international diplomatic relations.

Strategic analytic games utilize teams of experts to represent opposing sides (e.g., militaries, political factions, terrorist groups, nation-states, etc.) in a postulated scenario. The objective of the game is to play through a particular situation to gain insights into how the key actors involved might respond and to identify implications for US interests. The teams are asked what actions they believe the key states or actors they represent would undertake in response to the postulated situation based on their understanding of that state's or actor's strategic interests and capabilities. A "Control Team" acts as game manager organizing negotiations and issuing demarches and communiqués produced by the teams. The game is played in a series of turns or “moves.” Each move represents a specific length of time in real life (e.g., a day, a week, a month, etc.) over which each team would undertake its specified actions. At the end of each move, the Control Team adjudicates the actions of the multiple teams—using the inputs from the game participants, expert opinions and/or computer-aided simulation tools—and determines the likely outcomes of the proposed actions. The Control Team develops an updated game scenario based on the results of the teams’ actions and presents it to the players at the beginning of the next move. Game play then resumes and will continue in this way for a specified number of moves or until the game’s objectives have been met.

Within the overall realm of strategic analytic gaming there are several types of games that are employed to address particular kinds of issues or problems. Among the most common are:

- **Crisis Games**: In these types of games, the players are presented with a scenario describing a future crisis situation, such as the heightening of tensions between two rival states or a successful military coup in an important country, to assess how key actors would react if such an event were to take place. In crisis games, the players are assigned to multiple teams to represent the key decision-makers of specific actors, usually nation-states, involved in or affected by the postulated crisis event.
- **Path Games**. The purpose of path games is to develop insights into how the future might unfold as a result of strategic actions and developments undertaken by a number of key actors over a period of time. As opposed to crisis games which focus on the responses to a single critical event, path games explore the actions of key actors over a number of months or years as they pursue their desired strategic objectives. For example, a path game to assess the future of the Middle East might explore what actions key states in that region are likely to take in pursing their own national interests and strategic objectives over the next ten years. By assessing the “paths” that the players take in the game as a result of their actions and the interdependencies created with other key actors, one can build a prospective “history of the future” and gain insights into possible emerging challenges and opportunities.
- **Strategic Red Teaming Games[2]**: The objective of strategic red teaming games is to assess prospective foreign responses to specific (usually US) actions or policies. Such games allow the “test running” of a proposed US policy or military action to assess potential responses and to discover possible unintended consequences that might result. The outcome of a red teaming exercise is used to refine policy and military planning options and to support the development of hedging strategies to mitigate the impact of undesirable foreign responses. For example, a new US negotiation strategy for a future international arms control agreement could be “red teamed” beforehand to assess potential foreign reactions that might need to be addressed.

4.14.B. The Value of Strategic Analytic Gaming

Gaming techniques are well suited to developing insights into how and why future events might unfold. Although analytic games cannot “predict” the future, they can provide enhanced understanding of the key underlying factors and interdependencies that are likely to drive future outcomes. Strategic analytic games allow analysts to identify, explore, and assess potential outcomes that were not foreshadowed in previous “linear” analysis. In this way they are an invaluable research tool for contemplating future “rare” events and identifying the challenges and issues such events might produce.

- Strategic analytic games are valuable for uncovering emerging relationships—political, security, temporal, etc. – that are otherwise difficult to discern.[3] The interactive nature of games provides analysts with a clear sense of the types of interdependencies that might emerge in a future event.
- Strategic analytic games are also useful for identifying "signposts" (i.e., leading indicators) that if observed would suggest that the future is unfolding along a particular path. For example, a game positing heightened tension between two countries that leads to war could reveal a set of indicators that analysts could seek to observe in real life that would warn of an increasing possibility of conflict.

Strategic analytic games are also useful for combating pre-existing mindsets of analysts and planners. A common problem in considering "rare events" is that analysts can fall into the trap of mirror imaging and under-appreciating potential outcomes based on the assumption that it would not make sense for actor X to do Y because it is not what "we" would do in the same situation.[4] In a well-executed game, however, participants are obliged to consider events from the perspective of the actor they represent in the game. By viewing developments through the lens of an actor's strategic objectives, political and security interests, and cultural and historical mindsets, analysts can attain a fuller appreciation of the factors that are likely to drive a particular actor's behavior under a given set of circumstances.

Another advantage of strategic analytic games is that they can acquaint organizations with each other.[5] When the game's participants are drawn from multiple government, military, and private sector organizations, the gaming exercise itself provides opportunities for those organizations to familiarize themselves with each other and to identify the expertise and value-added each organization can bring to a particular issue. Such games might also expose weaknesses in current processes and interactions among organizations that prevent important synergies from being realized. They can also be valuable in gaining consensus among different organizations as to the potential solutions and strategies for dealing with emerging issues. Having actual policymakers and defense planners as participants in a game also helps to familiarize those officials with the capabilities that are available to support their decision-making as well as sensitizing them first-hand to the potential consequences of their policy and planning decisions. In this way, strategic analytic games reinforce President Eisenhower's observation that "Plans are nothing" but "Planning is everything."

- Participating in analytic games also has important educational benefits because they provide opportunities for analysts and experts of various backgrounds and proficiencies to share ideas and experiences.

4.14.C. <u>Getting the Most Out of a Game</u>

When it comes to the quality of the results derived from a game, the effort expended before and after the game is as important, if not more so, as the conduct of the game itself. The first step in developing a quality game is to ensure the objectives of the game are clearly defined and well understood. The overall game design needs to be crafted in a way that ensures the key objectives of the game are met. This includes designing a game scenario that will focus the teams' efforts on addressing the key questions or issues at hand. A scenario that is overly elaborate, for example, might be comprehensive but risks obfuscating key elements of the issue that is to be gamed, thereby diluting the participants' focus into areas unimportant to the objectives of the game.

A key to an effective game is having the right expertise. Part of the planning process for a game is to recruit participants who have knowledge of the strategic objectives, interests, and leadership mindsets of the relevant actors involved. In particular, it is important to have participants who can empathize with the values and perceptions of the actors they will represent in the game. This is critical to ensuring that responses the participants undertake in a game likely reflect the decisions the actual actor would make in real life under similar circumstances. Teams of experts are also often used to represent a single actor to make sure that various organizational viewpoints, differences in expert opinions, and multiple aspects of an actor's interests—i.e., political, military, economic, etc.—are considered and integrated into the team's responses during a game. Using teams of experts to develop a consensus response also helps to avoid spurious findings that could result from individual analytic biases.

Assessing the results of the game also requires experience and expertise. It is easy to overstate what can be learned from an analytic game.[6] As mentioned previously, strategic analytic games are not predictive, but if interpreted successfully they can provide increased understanding of complex situations. It is a mistake to think the game itself is the final product. The most important analysis begins when the game ends.[7]

Games are complex affairs that almost always produce more information than their designers intend to generate.[8] Assessing the findings of a strategic analytic game requires experience in discerning real insight from "game artifacts" i.e., outputs from the game that result from artificialities of the game design. For example, because of time constraints and restrictions on the availability of participants for each team, the number of negotiations that can take place between teams during each game move is limited. In assessing the political relationships that were revealed during a game, therefore, an analyst must be careful not to ascribe a lack of negotiations that were caused by inherent game constraints as a decision by an actor to eschew diplomacy.

- Once such "game artifacts" are considered and eliminated, reviewing the results of a game to identify the actions the key players took and the reasons behind their decisions will likely reveal new insights regarding the complexity and interdependencies involved in the issue or event under consideration.

4.14.D. Strategic Gaming's Application to "Rare Events"

Through strategic analytic games, events that are "rare" but imaginable, such as a WMD terrorist attack, can be explored and their implications assessed. In addition, strategic gaming can reveal emerging issues and relationships that were previously unanticipated but could result in future challenges and surprise if not addressed. While such games can not eliminate surprise entirely, they can provide useful insight into future possibilities and relationships that can guide intelligence collection strategies and the development of indicators to help warn against the emergence of new threats. They can also highlight emerging issues or planning assumptions that need to be tested in subsequent gaming exercises. The findings of strategic analytic games, therefore, can be invaluable to the development of hedging strategies that can help to mitigate the most negative consequences of surprise when it does occur.

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[1] Also referred to as "strategic decision simulations."

[2] "Red Teams" are traditionally employed to emulate the perspectives and actions of an adversary in military wargames and exercises. For the purposes of this paper, "strategic red teaming games" are distinguished from "Red Teams" in that they can be used to assess planning decisions, assumptions, and prospective operations from the perspectives of enemy, friendly, and/or neutral actors.

[3] Robert Rubel, The Epistemology of War Gaming, Naval War College Review, 1 April 2006.

[4] Harold Ford, The Primary Purpose of National Estimating, Defense Intelligence College, 1989 – available at http://www.dni.gov/nic/PDF_GIF_anal_meth/tradecraft/purpose_of_estimating.pdf

[5] Robert Rubel, The Epistemology of War Gaming, Naval War College Review, 1 April 2006.

[6] Ibid.

[7] An analogy can be made to public opinion polling. Similar to the results from gaming, raw public opinion polling data must first be interpreted in the context of key factors such as the demographics of the respondents and sampling size before correct insights can be attained.

[8] Robert Rubel, The Epistemology of War Gaming, Naval War College Review, 1 April 2006.

4.15. Co-evolutionary Gaming for Uncertain Futures (Jeff Cares)

Author: Jeffrey Cares
Organization: Alidade Incorporated
Contact Information: jeff.cares@alidade.net

4.15.A. Introduction

Most aspects of life in the modern world are changing at an extraordinary rate. Long-standing plans are invalidated, doubt is cast on closely held beliefs and new forces usurp incumbents while neither competitor fully understands why.[1] Heavy industries, for example, struggle for survival against agile, information-based competition. Elements of national power are being re-assessed as viable new threats seemingly emerge out of thin air. People are increasingly connected so that their collective behaviors, whether represented by markets, traffic patterns or *ad hoc* activism, are harder to predict, influence or comprehend. Paradoxically, scenario-based planning, the best tool for exploring competition in uncertain business, military and public policy contexts, has barely changed in decades. This paper describes an innovative approach to planning for uncertain futures, called "Co-Evolutionary Gaming."

4.15.B. Risk, Uncertainty and Uncertainty

Planning for the future is not merely a condition under which leaders make decisions with incomplete information. Rather, there is a continuum of information conditions from *risk* to *uncertainty* to *complexity*. An environment characterized by *risk* is one in which the probabilities of all possible outcomes are known. Decision makers examine the odds that certain states will result from different actions and determine a course of action based on risk-reward assessments. For example, if a course of action is 70-per cent likely to succeed, then a good decision maker can decide to assume the risk and try for success. An *uncertain* environment is one in which it is possible to know future states. In these conditions, decision makers can gather more data to drive out uncertainty and deal with the risk in the environment. A *complex* environment is one in which trajectories to future states cannot all be known in advance because of strong dependencies among states. Good decision makers in complex environments recognize that it is a fool's errand to merely gather data and improve the precision of statistical estimates. They know that the decision process should be directed at discovering the motives, dynamics and long-term evolutionary behaviors of competitors in the environment.[2] Scenario-based planning should help decision-makers navigate such dynamic environments, explore potential behaviors and define attractive contexts.

4.15.B.1 Characteristics of Existing Gaming Methods

Most methods of scenario-based planning, however, keep context independent of outcomes. They are more effective for planning under conditions of risk than for uncertain futures. Problematic characteristics of these existing methods include:

- *Scenario Approval Prior to Play*: Strategic planning efforts are usually commissioned by an organization's corporate headquarters, where competition among staff elements often requires pre-game consensus on even the most mundane scenario particulars. Force structure war games in the Pentagon, for example, are not valid for budgetary decisions unless the scenario is on an officially approved list. This is not just a military condition: any savvy executive knows that controlling the assumptions can significantly influence the outcome of analysis. Not surprisingly, the results from such games usually reinforce the status quo.

- O*ver-emphasis on Computer Simulation:* The last twenty-five years has seen extraordinary advances in computer simulation technology. At one end of the spectrum are full-motion virtual simulators, which are very effective and safe for training airplane pilots or law enforcement officers. A perfect virtual representation of a market, theater of operations or a society, however, is prohibitively expensive. So rather than explicitly model reality using "virtual reality" techniques, analysts implicitly represent reality using equations to approximate relationships between factors and outcomes of their interactions. The relationships and causal connections for uncertain futures are very poorly understood; in fact, there is a strong argument that existing models have never been very good representations.[3] Nonetheless, the scenario-based planning community continues to use ineffective and inaccurate computer simulations for gaming uncertain futures, often compensating for a lack of understanding with more simulation detail. The computer simulation becomes the reality in which decisions are made with little regard to whether the simulation comports with real competition. The simulation not only reinforces the status quo, it becomes the status quo itself.
- *Scripted Inputs:* Because of pre-game influence and the need to feed models that have themselves become the status quo, inputs to scenario-based planning events have become heavily scripted. Pre-game efforts are commonly devoted to planning conferences and data calls, during which the scenario is negotiated and confirmed, the approved data set is selected and friendly and adversary behaviors are scoped out. Games can come to resemble a theatrical performance, with actors responding on cue, sticking to script and keeping within character, while an army of production assistants toil behind the scenes, entertaining the audience with props, scenery and special effects. Although such games can be very professionally executed, facilitated and analyzed, their results are nonetheless predictable, serving to even more strongly reinforce the status quo.

The impact is profound. In US military war games, for example, Blue is always technologically superior to its adversary, Red. Blue and Red forces are determined by separate, isolated analyses prior to game play. War game participants are therefore often exposed to biased representations of Blue and Red military capabilities. Moreover, these war games explore only a limited, predictable set of outcomes -- outcomes in which Red is rarely victorious. Perhaps as a result of these assumptions, Red team analysis usually remains an input to (rather than an output from) the game. Moreover, most analyses of Red focus on what Red has for equipment, not how Red behaves. In those rare cases when Red is competitively gamed, well-known problems with "mirror imaging" (ignoring cultural differences in decision processes), "professional Red" players (whose professional reputation depends on an idiosyncratic portrayal of an enemy) and "Blue Dominance" (Blue-centric perspectives) confound the broad exploration of the problem space required for scenario-based planning under uncertainty.

4.15.B.2 Characteristics of New Gaming Methods

Current practices in the gaming community constrain outcomes because the context and inputs are constrained. Constrained thinking, however, is of little help when planning for uncertain futures. The characteristics of a method for scenario-based planning that more creatively explores the potential decision space should include the following:

- *Game Play is More Important than Specific Outcomes:* Many games are run to provide input for strategic decisions so executives and players have great interest in game results. Specific outcomes, therefore, can become more important than the games themselves. In uncertain environments, however, outcomes are context sensitive; results that look like winners in one context may lead to disaster in another. Moreover, players cannot know how to resolve issues, make decisions or answer questions that have not yet presented themselves; introducing a wide range of issues, decisions and questions should be an objective for scenario-based planning under uncertainty. In addition, issue resolution can also be less important than conditions that gave rise to the issues, decisions can be less important than alternatives not selected and answers to questions can be less important that questions that remain un-asked. Deep understanding of dynamic, uncertain environments comes from the different paths that players choose, even those that seem outlandish at first blush. Gaming for uncertain futures should focus more on learning and adapting than on winning a particular contest. Play itself is the most important part of the game.

- *Many Perspectives are Explored:* Games in which the competitive context is controlled by dominant beliefs serve only to reinforce those beliefs. A method of planning for uncertain futures must provide a wide range of contexts and explore them from many different perspectives. A diversity of opinions and perspectives should be given high priority, even to the point of including players from other professions, industries or cultures. This also guards against mirror imaging, professional Red players and Blue Dominance. As an additional note, there are many circumstances for which irrational perspectives are perfectly appropriate.

- *Games Are Run in Multiple Iterations:* A limitation of existing games is that game designers choose "typical" scenarios. With uncertain futures, however, the most likely contexts can be the most misleading: gadgets and ideas honed for one context can fail utterly in others. Also, an adversary might overcome disadvantage not by directly challenging technical or operational innovation but by changing context. Innovations must be successful in a wide range of contexts to be truly transformational. Context is a dynamic environment changed during the course of play by the actions of the players themselves. Each game can have only one outcome, so games should be run many times to explore as many outcomes, from as many different initial conditions, as possible.

- *Games are Easy and Inexpensive to Design, Play and Analyze:* Technically speaking, one cannot know all the futures created by competitive play; predetermining and evaluating all futures is not only costly and exhausting, it is also impossible. A good gaming method, however, must sample as many diverse futures as practical and should therefore be clearly designed, quick to set up, easy to play, inexpensive to execute and simple to analyze. It has been said that gaming is at once the grandfather and the orphan of Operations Research (OR).[4] Indeed, before the field of OR was recognized as such, planners and gamers at the Naval War College used rudimentary analysis techniques to design and referee their games. Their equipment was unsophisticated: tile floors, toy hulls, wooden speed leaders and paper search arcs. But because the games were exceptionally well designed, these simple tools provided compelling support for radical transformations like carrier aviation, the WWII Pacific Island hopping strategy and modern amphibious warfare techniques. A well-designed game needs little overhead to produce value for players. This is not the industry standard, however. Many US military games are complicated affairs requiring more than six months to design and up to one hundred people to execute, adjudicated by expensive computer simulations and hosted in large, exclusive gaming facilities. They can also be so complex that players are prevented from reaching their full competitive potential during play; so much effort is required just learning to play that productive competition is stymied.

4.15.C. Co-Evolutionary Gaming

Co-evolutionary Gaming is a method of planning for uncertain futures with which players can quickly and inexpensively explore an extremely vast landscape of possibilities from many perspectives. This method re-introduces classic elements of scenario-based planning that the gaming community abandoned in favor of automated analyses and closely scripted games. Alidade Consulting has married these classic elements with recent developments in evolutionary biology to effectively sample a large space of possible futures, seamlessly include diverse perspectives and iterate many times at a low cost in effort, time and money.

4.15.C.1 Elements of Classic Games[5]

Co-evolutionary Gaming employs classic elements of scenario-based planning. These classic elements are also reasons why scenario-based planning is preferable to other types of analysis for planning for uncertain futures. These elements include:

- *Multiple Actors*: Game Theory is replete with examples in which the mere coexistence of competitive perspectives produces dynamic games with multiple possible outcomes. Most traditional Operations Research techniques provide only answers, often from closed-form equations or statistical estimates. A competitive game is the best method to fully explore the interaction of multiple perspectives. As CAPT McCarty Little of the Naval War College wrote in 1912, the advantage of gaming is that “the secret of its great power lies in the existence of the enemy, a live, vigorous enemy in the next room waiting feverishly to take advantage of any of our mistakes, ever ready to puncture any visionary scheme, to haul us down to earth …”. Without multiple actors, clear-eyed assessment of all facets of an innovative technology or concept is in doubt.

- *Indeterminate Information Conditions:* Game dynamics are extremely sensitive to who knows what, and when and how they know it. Since much of the information in a competition is created by the stress of conflict, it is impossible to prescribe all the information conditions for a large system. The outcomes, then, are sensitive not just to multiple perspectives, but also to the information conditions created by the competition between multiple perspectives. A game is one of the best ways to explore the different outcomes that might arise from such indeterminate information conditions.

- *Need for “Doctrine” in Competitive Situations:* An apparent paradox in Game Theory is that a significant component of competition is in fact cooperation. For example, competition disintegrates unless players can agree on rules, scoring and referees. Similarly, players on a team must learn to cooperate with each other to defeat their opponent while smaller scale competitions exist between teammates. Tension between cooperation and competition creates a need for doctrine: a device that explains processes, intent and causal connections. Doctrine arises out of games; alternative doctrines can be explored by playing games. In many cases, doctrine is not an "answer" derived by analysis but a set of best practices that emerge from success or failure in a competitive context. New technologies and concepts must be evaluated with new doctrine so that *in situ* value judgments can precede full-scale adoption. Games are excellent methods by which doctrine can be created, analyzed and tested.

- *Decision Maker Involvement in Analysis:* Objective analysis provides inputs to decisions without requiring the decision maker to be intimate with the problem at hand. Gaming, by contrast, improves a decision maker's appreciation of competitive situations and the consequences of decisions.
- *Reduced Constraints on Sound Decision:* Objective analysis does not typically explore the extremes of a problem. In fact, most analytical methods are designed to eliminate extremes. Gaming creates an environment in which extremes arise and alternate paths are unveiled, allowing one to ask "What if?" in a more dynamic way than objective analyses.

4.15.C.2 Elements of Evolutionary Search

In addition to the classic elements of scenario-based planning, Co-evolutionary Gaming also employs elements of "landscape search" strategies inspired by recent developments in evolutionary and mathematical biology. These techniques are useful for searching very high dimensional spaces without resorting to brute force sampling. Characteristics of evolutionary search strategies include:

- *Efficiency*: A focus of evolutionary biology is the study of genetic material (biological messaging systems that influence the molecular makeup of an organism) and the methods by which nature searches for improved fitness. Consider an organism with *N* different genes. For simplicity, assume each of these genes can be in two different states, 0 or 1. The number of possible genetic descriptions of the progeny of this organism is 2^N. Even the simple *E. Coli* bacterium has 3000 genes, so the potential "genotype space" would be $2^{3000} = 10^{900}$. For comparison, there are only 10^{80} particles of matter in the known universe, so this space is very large indeed.[6] Similarly large spaces exist in business, the military and society. The *E. Coli* example underscores an important point: nature routinely solves problems of this magnitude without resorting to brute force (brute force, in this case, would be creating 10^{900} genetically different *E. Coli* offspring in each new generation). A new field of mathematics, evolutionary computation, has been inspired by nature's evolutionary search techniques. Co-Evolutionary Gaming uses the logic behind these techniques to more efficiently search the total space ("landscape") of uncertain futures.
- *Mutation:* Many techniques in evolutionary computation depend on mutation, the intentional or accidental "flipping" of states in genetic material. Which states flip and when they are flipped has great impact on the search for improved "fitness." Simply stated, if an organism's fitness is very low, then almost all changes improve fitness. If fitness is very high, then almost all changes decrease fitness. If fitness improves too quickly, then the organism has not been stressed enough by the environment and future

generations could have much lower fitness than if fitness improved at a slower rate (and was thereby more informed by the environment). The most stressing environments are competitive: in addition to struggling against nature, an organism must also struggle against competition. An organism may enjoy competitive advantage for a few generations, yet the advantage can induce mutations in future generations of competing organisms, dramatically altering the competitive context and negating the advantage. Co-Evolutionary Games are designed to identify and explore these dynamic behaviors resulting from mutation. Of course, technical innovation, new operational concepts and substantial strategic investments, are all types of mutation.

- *Robustness*: Optimization is the hallmark of traditional Operations Research but optimization is inappropriate for uncertain futures. Interestingly, optimization is also short-lived in nature. If the fitness of an organism is very high, then almost all changes to the organism decrease fitness. Since dynamic environments induce mutation, highly evolved organisms are adaptive and robust, not specialized or optimal. Identifying the robustness of solutions is also very important in planning for uncertain futures. Co-Evolutionary Games are designed to identify the value of strategies for a very large number of contexts.
- *Recombination to Correct Runaway Selection:* Another phenomenon in nature is that very evolved organisms that no longer experience stressful environments can mutate for the wrong reasons, resulting in characteristics that are no longer useful in stressful environments. The classic example of such “runaway selection,” is the peacock, which leads a relatively predator-free life, maintaining extraordinary plumage rather than, say, developing defensive capabilities. Market leaders, peacetime militaries and political incumbents can all succumb to similarly misplaced evolution. Co-Evolutionary Games are designed to ensure competition in an appropriately stressful environment and to widen the “gene pool” so that more diverse characteristics, even those previously de-selected, can be explored. Such re-combination can correct the effects of runaway selection.

Co-Evolutionary Games allow players to explore many contexts determined by a broad range of initial conditions. They also leverage the diverse perspectives of multiple players and the adaptations learned from previous games. It is obvious, therefore, that each game can produce no general conclusions: what is learned during a game is a function of context. Significantly different results can result from different contexts from other games (even games that start with the same initial conditions). By design, the games are intended to be iterated many times so that broad patterns, if they exist, can emerge from competitive perspectives, indeterminate information conditions, doctrine exploration, decision maker involvement and alternate pathways derived from play.

Co-Evolutionary Games use a seminar format with vigorous, contemporaneous multi-sided play. Each side completes multiple moves representing decision points in competition. Scenarios do not refresh between moves, so the results of previous moves impact the current and future strategies of both sides.

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1 Christopher Meyer and Stanley M. Davis, Blur: The Speed of Change in the Connected Economy, (Little Brown & Company, New York, 1999), Kevin Kelly,

New Rules for the New Economy : 10 Radical Strategies for a Connected World (Penguin, New York, 1999) and James Gleick, Faster: The Acceleration of Just About Everything, (Pantheon Books, New York, 1999) are good surveys of these phenomena.

2 Scott E. Page, "Uncertainty, Difficulty and Complexity," Santa Fe Institute Working Paper 98-08-076, 12 June 1998.

3 This "base of sand" problem is explored in Paul K. Davis, New Challenges for Defense Planning: Rethinking How Much Is Enough, (Rand Corporation, Santa Monica, CA, 1995)

4 John T. Hanley, Jr., "On War Gaming," Ph.D Dissertation, Yale University, 1990. The work is out of print, but authorized copies can be obtained from the author.

5 Drawn from Hanley, "On War Gaming."

6 Stuart Kauffman, At Home in the Universe (Oxford University Press, New York, 1995), 162-163.

4.16. <u>Gaming from An Operational Perspective (Bud Hay)</u>

Author: Bud Hay
Organization: Retired Chair of War Gaming Research, Naval War College, Newport, RI
Contact Information: ohay@verizon.net

In the years between World War I and World War II, senior research students at the Naval War College in Newport, Rhode Island explored various ways a Pacific oceanic war between the United States and Japan might play out. Known as Operation Orange, this was part of the Rainbow Series of war planning efforts. The series of games provided a venue to explore new operational concepts regarding employment of aircraft carriers and amphibious operations. More important than the various scenarios examined was the ensuing understanding of the overall theater of war. It was in that context that ADM Nimitz made the statement that nothing that the Japanese Navy did in World War II was a surprise other than the Kamikaze attacks at the end of the war.

After WWII, war planning became the responsibility of the Joint Chiefs of Staff and war games were often used to examine the execution of the plans. Over the last decade there has been an extended effort within the Department of Defense to renew our understanding of the operational level of all military actions. It is an ongoing process. The current effort is essentially different from that of the past in that it is about joint combined arms operations, addresses the full spectrum of potential military actions, and provides links to integrate with other instruments of national power.

4.16.A. <u>Anticipating "Rare Events"</u>

Military war games are designed to explore hard problems. They can provide a context for future concepts or weapons systems (for both doctrine development and the rationale for acquisition), and give deploying Commanders and their staffs an opportunity to "experientially encounter" the latest information about the crisis situations they will soon be facing. They also are useful vehicles for sensitizing commanders to a wide range of potential scenarios, including very low probability/high impact events. A rare event that has been anticipated in a gaming situation is usually much easier to deal with in real life.

Rare events do not just come out of thin air. Even in natural catastrophes there is a chain of events that precede their occurrence. So it is with terrorist events. Strategic surprise is a phenomenon that occurs when an unexpected gambit is put into play that is beyond or outside the current planning and preparedness of the victimized target community. WMD in the hands of terrorists is a horrendous challenge to cope with, but the dimensions of the problem must be realistically considered in terms of size, scope, and scale as well as assessing the secondary and tertiary consequences. Operational gaming continues to be a useful technique to sort out the various dimensions of this potentially catastrophic problem. Gaming provides a venue to:

- Examine the environment in context.
- Develop trade space characteristics and metrics.
- Challenge assumptions.
- Explore options and assess Courses of Action.
- Identify potential trends that merit more in-depth examination.
- Test concepts and capabilities to address the problem.

A common error in thinking about rare events is to begin by focusing on the worst possible case. Too often that approach precludes examination of the policies, strategy, capabilities, and context from which the terrorist’s acts are formulated. A better way to get started is to address more fundamental issues, such as: What is the adversary trying to achieve? What are its overall interests and objectives? What assets are needed to accomplish those objectives? What are the rules of engagement? What alternative paths are possible to achieve success?

The answers to these questions help circumscribe the option space within which the terrorist acts will likely fall. This is true of both state and non-state actors. Seldom are major events spawned from whimsy. They usually take years of preparation and meticulous planning.

What distinguishes state from non-state actors is their differing political beliefs, objectives, and rules of engagement. For example, although both would calculate a response to their actions based on perceived enemy capability and resolve, a state actor would have to seriously consider a nuclear response as a possibility and would have to weigh that as a deterrent to their potential attack. A non-state actor might consider a nuclear retaliation to its host nation, however remote, as beneficial to their cause.

Many contemporary novels conjure up various plots about how mythical terrorist groups acquire WMD devices and attempt to perpetrate acts of catastrophic damage. These novels actually provide a service to the reading public by portraying imaginable circumstances, describing factors that fuel protagonist’s perceptions and offering the hope of averting such calamities. In a similar manner, the operational gamers and researchers provide the service of exploring the various paths and sequels of how such catastrophes could happen and the opportunities to thwart them. When approached systematically, this process provides an “operational trade space” to use as a framework for selecting more detailed research and informing the senior decision process.

4.16.B. <u>The Ontology of Gaming</u>

The operational game starts with a building process. The game should be tailored around the research issues that are to be addressed – what do we want to know? There are many tools in the gaming toolkit that may be employed to enhance exploration of issues, assumptions, and hypotheses and can be applied as appropriate. The key to designing a successful game is to get at the core research issues “in context” and as efficiently as possible in a synthetic environment.

An effective game design:

- Starts by gathering what information is known. Key assumptions are clearly stated and gaps in knowledge are described.
- Acquires expertise on the adversary’s perspective, capabilities, and known operating patterns.
- Specifies the strengths and weaknesses of doctrine and planning factors (both attack and defense).
- Builds an appropriate framework for the problem set by ensuring that participants are armed with as full a set of information as is available to tackle the problem.
- Games the problem. Players have the opportunity to execute their planning assumptions in an interactive forum within the game framework.

- Defines the shortfalls and opportunities for all game protagonists. If a problem looks too hard to accomplish or defend, then alternate routes to success can be devised – such "out of the box" solutions are good candidates for "rare events" consideration.
- Queries the results. Does the action "answer the mail" for the perpetrator and for the defenders?
- Identifies elements of the chain of events that "should be" observable.
- Reviews relevant products for evidence which would substantiate a particular process or chain of events.
- Adjusts assumptions based on new evidence and refines the process.
- Considers a range of options based on the predilection of the prominent leaders' doctrine and motivation.
- Surfaces the assumptions and transforms lessons learned into requirements for further collection and research.

4.16.C. Environment First, Scenario Second

As in battle, understanding the context within which the particular problem set is to be examined is a necessary first step. In current practice the following generalities apply:

- Experimentation games tend to focus on the future – either as an extrapolation of today's situation and force structures or by introducing breakaway technologies and concepts that would radically change the nature of future confrontations.
- Training games tend to target the latest understanding of the current situation to better prepare Commanders/Leaders and their staffs with a sense of the current mission space.
- Acquisition games tend to use notional scenarios and force structures to provide a uniform framework within which the Services can argue for procurement of future platforms, technologies and force structures.
- Other scenario-based games establish the parameters for testing new weapons systems.

Currently these efforts are not closely aligned. Without consistency and continuity across these four disciplines, seams are created that are potentially vulnerable to exploitation.

An old military adage states that amateurs think tactics and professionals think logistics. The analogue in gaming is that amateurs think scenarios and professionals think environments. Storyline and context are not the same thing. If the focus is limited to creating a good storyline, the potential for surprise is heightened.

It is important to identify a baseline of comprehensive information. Often this can benefit from a relationship to a geospatial or functional context from which to work. Starting from the working framework (with its holes and assumptions) it is possible to identify a range of possibilities, to parse them, and to prioritize them according to risk and likelihood. This establishes the storyline or scenario for the game and provides the context for setting the problem statement with the corresponding research questions to be examined. Grouping scenarios within geospatial environments also enhances the value of comparative examination across multiple games.

4.16.D. Natural Impediments

There are three primordial imperatives that participants bring to every game that need to be reckoned with. These are natural and almost uncontrollable instincts - and for good reason.

1. Fighting the scenario - players are placed in an artificial setting that is lacking full environmental context. This elevates the sense of uncertainty and lack of control. That is why building the environment first and the scenario second are so important.
2. Requesting more resources. The normal support resources available to a decision maker are not available in a game. Building the environmental context–including support mechanisms–mitigates much of this sense of dislocation. Players should have at their disposal the resources available for operations in the time frame being addressed. It is also important to capture what else they require to solve for success.
3. Trivializing the process. It is a natural instinct to simplify a problem by limiting the variables that need to be taken account of in any endeavor. However, unduly closing the field of view of consideration can be extremely dangerous to combatants, law enforcement officers, senior decision makers, or anyone working in an unfolding crisis situation. A primary value of operational level gaming is to make explicit the range of possibilities and the consequences of various actions.

4.16.E. Four Principles of Operational Gaming

A significant reason for the lack of institutional knowledge about decision making at the operational level is that it essentially occurs in the mind of the decision maker, mostly hidden from view. An important objective of operational gaming is to make that decision-making process more transparent and expand it as a learning activity for all who are involved. This can best be accomplished when the game is designed around the following key principles:

- Naturalistic Decision Making
  - 95% of leaders choose their course of action within minutes of being confronted with a crisis.
  - They do so, drawing from a combination of personal life experiences.
- Experiential Learning
  - Individuals who make decisions in realistic simulations gain real-life experiences.
  - Such experiences form the basis and background for later decision making.
- Building Trust
  - Personal relations enable individuals to interact in a distributed and collaborative environment in an immediate and effective manner.
  - Such trusting relationships must be established prior to a crisis.
- Knowledge Sharing
  - Many individuals have significant experiences in dealing with large-scale disasters that they will readily share.
  - Embedding subject matter expertise in simulations is another proven knowledge transfer mechanism.

Operational level gaming can be a valuable technique for planners and operators to anticipate surprise, evaluate various courses of action, and sharpen understanding of critical factors regarding potential crisis situations. By examining the congruence of capabilities and intent, it helps decision makers better anticipate rare events. This provides a contextual framework from which to postulate likely, and not so likely, terrorist attacks and to evaluate readiness and preparedness against them.

4.17. Knowledge Extraction (Sue Numrich)

Author: S. K. Numrich
Organization: Institute for Defense Analysis
Contact Information: snumrich@ida.org

> **Opinion.** A belief or conclusion held with confidence but not substantiated by positive knowledge or proof.[1]
>
> **Expert Opinion.** A judgment based on special knowledge and given by an expert: *a medical opinion.* [2]
>
> *"A little group of willful men, representing no opinion but their own, have rendered the great Government of the United States helpless and contemptible"*[3]
>
> Woodrow Wilson (1856–1924)

4.17.A. Statement of the Problem

In coming to terms with a problem that requires specific expertise beyond that commonly available, we routinely rely upon the opinion of subject matter experts (SMEs). In most cases the understanding sought lies beyond current knowledge and addresses an issue for which there is no firm evidence or proof.

The rare events of greatest concern to the military are not of cosmic origin, but arise in foreign populations among people whose customs and patterns of thoughts are not well understood, largely through lack of familiarity. The expert in such cases is someone who has spent considerable time living with and studying the population in question, often someone of that culture who has spent time in the US and can translate between the two cultures.

The problem with relying on expert opinion is that it is only opinion and all observers, including SMEs, have perspectives or biases. The issue, then, is how to elicit expert opinion in a manner that adds understanding without leaving the "Government of the United States helpless and contemptible" for selecting the wrong experts or interpreting their statements incorrectly.

In the end, expert solicitation is all about understanding the population, finding out about how the country really works, and in the process minimizing the effect of biases.

4.17.B. Elicitation, Polling and Biases

Elicitation of information from SMEs differs from polling in two very important ways. In polls, significant effort is made in selecting a sample that is representative of the demographics of the group as a whole to extract the opinion commonly held, as distinct from the opinion of a SME. Thus while a poll on space exploration seeks the response of the "man on the street", expert elicitation seeks the statement of the "rocket scientist". The second difference lies in the questions asked. In expert elicitation, the questions must be designed to extract the type of information reflective of the expert. Thus, if there are ten experts involved, the set of questions may differ from expert to expert by virtue of the specialized background of the individual expert.

An issue that is always present and requires careful resolution is personal bias. There are two major ways of recognizing and dealing with bias. The first is to interview as diverse a set of experts as possible. The second is to have some set of common questions for all experts whose answers tend to reveal specific personal perspectives. Such questions must be designed carefully to be largely neutral while allowing the person interviewed to expound upon his or her individual perspectives rather than speaking from expertise.

4.17.C. Where to Begin – Finding the Experts

The first step is to acquire the most extensive background possible in the time allotted. Time constraints normally limit the initial background to the equivalent of an introductory course rather than a doctoral dissertation. One aim of that crash course should be the identification of a trusted, internationally recognized, academic expert on the country in question - someone who has studied the country for a long time and whose study has included significant time spent in the country learning about the people, their culture, thought patterns, and leadership.

The purpose of identifying an academic expert is to persuade him/her to provide a highly condensed introduction to the country concentrating on the information that is most relevant militarily. A good academic will also provide references and suggest others to consult who can speak from different perspectives.

Another important role of the academic expert is to describe the manner of discourse common to the people of the country of interest. Unlike Americans who want to come to the point quickly, the culture of the other country may demand an extended period of hospitality and what appears to be "small talk" before the topic of interest can be broached. Understanding and interpreting the nature of discourse of the people is critical if interviews and written materials are to be correctly understood.

Other US agencies may have significant expertise in the target country including the Department of State, USAID, Department of Commerce, and Department of Agriculture. All of these agencies work with foreign countries and often with countries in crisis or where stability is threatened. Many non-governmental organizations (NGOs) have significant experience in many countries, particularly countries experiencing problems that could give rise to public unrest and insurgency. The business community is often neglected as a source of information about a foreign country. Globalization has forced most large corporations to develop relationships with many foreign countries including poor countries with rich resources or developing markets.

The process of interviewing will also yield a significant number of written sources and additional subject matter experts to be consulted. Having a large pool of potential interviewees with different perspectives can help minimize the effect of biases.

4.17.D. Structuring the Interviews

The first issue to address is whether to interview individually or use a workshop format. The answer to this question is culturally dependent. When interviewing Iranians, both expatriates and Iranian-Americans, our academic expert advised against group interviews based on the lack of trust among Iranians. In contrast, one of our most productive interviews with Sudanese took place when a Sudanese economist from the World Bank brought with him to the interview six other Sudanese representing different, and at times opposing, segments of the population. Although there was tension at times among opposing views, it was manageable and the resultant exchange of opinions provided highly useful information as well as an understanding of local biases.

To facilitate freedom of discourse, interviews should be conducted "off the record" whenever possible. If attribution is desired for some reason, the interviewee must agree before the interview and should be given editorial rights if the interview is to be recorded and published even in a limited fashion.

Early interviews should be used to provide background to the issues involved. It is important to understand the history of the region, the long term conflicts and their roots, the persistent values of the different factions in the country and the roots of the current disagreements. Using this background, the initial set of questions can be developed. For example, the initial interview questions developed for Sudan included the following:

- *How do you view the current situation in Sudan?* This question provided the subject matter expert an opportunity to expose his/her assessment of what constituted the "current situation". A southerner would choose the Comprehensive Peace Agreement while someone from the Darfur region would pinpoint the role of Khartoum in supporting local militias.
- *What is the role of religion in the current conflicts*? This brought to the fore the opinion of the subject matter expert on the practicality or rationale for imposing Sharia law.
- *Is the Khartoum government willing to give up power over the peripheral areas?* This allowed the perceptions of separate and unequal treatment of the different regions to surface. It also demonstrated the divisions among the South, the West and the East as well as the tension between Khartoum and all the peripheral areas. Uniting the periphery against Khartoum would be an extremely difficult process.
- *Will the Comprehensive Peace Agreement between Khartoum and the South endure?* The view of the South was consistent in noting that Khartoum was not living up to the demands of the Agreement. The West and East were not consistent in making that observation as they were far more interested in gaining the same type of agreement for their regions. Government sympathizers were quick to point out that Khartoum was complying with the requirements of the Agreement, but the South was not capable of reciprocating.
- *What is happening politically? Who is likely to run in the 2009 elections? What are the strategies of the different parties angling for power? Will the 2011 plebiscite take place and what will be the result?* These questions allowed each political faction to express its opinion freely.

These general questions were designed to begin the conversation. As the interview progressed, the nature of the questions changed to make use of the specific background of the subject matter expert. If the individual was a professor at one of the Sudanese universities, questions were directed toward the nature of courses, text books, preferred languages for instruction, the degree of control exerted by the government and the demographics of the student body. Representatives of the Government of South Sudan were asked about the full range of relations between the South and the Government of National Unity in Khartoum. They also explored the leadership in the South, the future of the oil reserves and revenue sharing with the North, the importance of settling boundary disputes and the ability of the South to unite in its own governance. Questions for economists involved the ability of Darfur to rebound economically from the environmental problems and the warfare, the issues with investing the proceeds from the oil economy, and the influence of economic issues on internal unrest and stability.

All interviewees were asked about the media sources about Sudan that they felt were most reliable. Each was encouraged to talk about how the US might work to resolve the crisis in

Darfur or work to support the Comprehensive Peace Agreement. Most interviewees also chose to discuss the Janjaweed – who they actually were and what was behind the conflict.

4.17.E. Understanding Biases – Ours and Theirs

The first step in mitigating the effect of biases is to understand the source of our own biases. While we have initial impressions, it is vital to be open to changing these impressions as we absorb more information. It is also necessary to understand that academics, aid workers and government officials will have different perspectives. For example, aid workers normally deal with disenfranchised populations and tend to be less supportive of the government because of its neglect. Anthropologists who study primitive cultures tend to take a dim view of the government as it tries to enforce modernization at the expense of ethnic subgroups. Commercial entities working with the country will assess it based on its ability to function in commerce and banking, on its receptivity to foreign investment and trade policies. All of these perspectives are biases on our part.

The most accessible representatives of another culture are the immigrants from that country to the US, many of whom may have fled their native country because of some type of persecution. The first observation about the immigrant population is that it is here and not there. Thus it may not be representative of the people currently living in their country of origin. Most are likely to have strong biases against whatever faction caused their migration to the US. Thus their extremely valuable views must be balanced by the views of immigrants from other areas of the country who have very different reasons for leaving.

Elicitation information from a significant group of SMEs, perhaps 12 to 20, is important to sorting out biases and understanding the population of the country in question. However, it is not the number that matters, but the breadth of perspectives included. In working on Sudan, the most difficult task was finding someone who could represent the views of the government in Khartoum. One would think that an official diplomatic representative to the US would be such a person; however, that was not the case. The Government of National Unity divided cabinet responsibilities, placing the Government of South Sudan in command of the foreign office. Thus the diplomatic representative would be from the South. In fact, the current diplomatic representative from Sudan to the United States is actually an immigrant from the South who left his post at a US university to assume his diplomatic role. Without this background knowledge, one might assume a totally different bias on the part of Sudan's diplomatic representative.

To understand biases it is essential to understand the history of a country, its origins as a nation and its experience under colonial rule, its ties to historic neighbors and current economic partners, its links to transnational groups of all types including religious organizations, the factions that make up the population and the values upon which the social and economic structures are built. These factors and more provide the context in which elicitation of subject matter experts is done and against which their testimony must be evaluated.

4.17.F. Resources and Technical Assessments

Over the past thirty years, academic attention has been turned toward the use of SMEs and the biases inherent therein. The issues arose in complicated technical problems where expert opinion was used in establishing ranges and probability distributions for model input parameters. The various approaches used by experts in making their judgments about a probability distribution for a parameter can lead to biases in the estimate.[4] Although most of the cases for which expert elicitation was studied involved providing probability estimates for discrete questions, the insight into the elicitation process derived from these studies is applicable to the use of subject matter experts to explore broader, less technically framed questions[5]. The formal studies have become part of the body of knowledge on decisionmaking.

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[1] American Heritage Dictionary of the English Language, Fourth Edition, Houghton Mifflin, 2000
[2] Ibid.
[3] Woodrow Wilson (1856–1924), U.S. president. Address to the country (March 4, 1917).
[4] H . Christopher Frey, "Briefing Paper part 1: Introduction to Uncertainty Analysis", North Carolina State University, 1998, http://legacy.ncsu.edu/classes/ce456001/www/Background1.html
[5] Steven G. Vick, "Degrees of Belief, Subjective Probability and Engineering Judgment", ASCE Press, ISBN 0-7844-0598-0, July 2002

4.18. Open Source Methods to Anticipate WMD Activities (Frank Connors, Brad Clark)

Authors/Organizations: Franklin M. Connors (Division of Chemical and Biological Defense, Defense Threat Reduction Agency) and Bradley A. Clark (Trinity Applied Strategies Corporation)
Contact Information: Frank.Connors@dtra.mil and b.clark@tas-corp.com

4.18.A. Introduction

The prediction of any human behavior is a daunting task. It is best done, and even then it is difficult, for large populations and broad behavior types. Anticipating general terrorist behavior is somewhat easier because their strategic objectives remain relatively constant with time. The tactics used by a particular terrorist, or terrorist group, are highly adaptive, which can be very difficult to anticipate. In this paper, we describe open source methods with promising potential in assisting detection and recognition of behaviors and events that are likely to help anticipate the use or development of WMD by state actors, non-state terrorists and state sponsors of terrorism.

Social scientists conducting research and statistical analysis of terrorist behaviors employ methods to correlate certain behaviors or conditions with terrorist behaviors, including the transition to the conduct of hyper-violent acts. This report includes descriptions of such analyses. The identification of such behaviors is an important step, providing useful information to the community that is trying to prevent terrorism. Such social-science-based analyses of a particular group, country, or region are based on data obtained from governments and updated periodically, typically annually. Because the underlying data is assessed on long time scales, such analyses cannot treat short-term changes in any of the relevant factors, e.g., economic conditions, government stability, and feelings of safety and security in the population

Open (unclassified) sources make a wide array of information available to us. Certainly the terrorist has demonstrated the use of the same information exchange methods to enhance their capabilities. Open source information provides information and insights on regions throughout the world; including evidence of changes in the social factors that may be correlated with terrorist behaviors. Open sources can provide instant feedback into changes in the social factors; waiting for the annual update is not necessary. Thus, changes in the relevant situational parameters can be recognized and understood very rapidly.

As used in this paper, the objective of open source analysis is to provide insights into local and regional events and situations. There is full recognition that there can be significant uncertainty in open source information, but it can identify conditions that can be investigated and resolved using all available sources of information. In this sense, open source analysis provides a tipping and cueing function to support all-source analysis. Open source information must be integrated with all other available information to arrive at accurate, actionable conclusions.

4.18.B. Open Source Methodologies

Open Sources

Open source information collected and translated into an actionable intelligence context is not a new concept. The late Allen Dulles, Director of Central Intelligence from 1953 to 1961 realized that approximately 80% of all intelligence collected is from open (unclassified) sources.[1]

There are distinctions that separate open source information (OSINF) from open source intelligence, (OSINT). OSINF consists of volumes of multi-media and multilingual information gathered for further processing and consideration. OSINT, in sharp contrast, integrates world-class human expertise with an integrated technical process to produce only "just enough, just in time" intelligence-information tailored to support a specific decision.[2]

The OSINT Process includes four key elements:

1. Discovery. "Knowing who knows" and "knowing where to look" are the heart of a global OSINT process, which leverages distributed centers of expertise and archival knowledge. *80% of the information needed to create useful OSINT is not online, not in English, or not available within the US.*[3]
2. Discrimination. Careful discrimination between good and bad sources, current and outdated sources, relevant and irrelevant sources, and finally, between cost-effective and cost-prohibitive sources, is part of the unique value of the OSINT process.[4]
3. Distillation. The most important value added by the OSINT process is that of distillation, so that the final OSINT report can be as short as a paragraph or a page, and can communicate to the decision maker the essence of the collective wisdom pertinent to the decision under consideration. The OSINT process permits the out-sourcing of first echelon analysis, and allows world-class expertise to be placed in the service of the in-house analysts and their customers.[5]
4. Delivery. The best intelligence is the world is useless if it cannot be delivered to the customer in a timely fashion, in a media compatible with the in-house system, with adequate provision for security, and in a format that can be easily understood.[6]

OSINT is ***not*** a substitute for classified "all-source" analysis. However, if the term "all source" is to have any true value then it should include OSINT where necessary and applicable. OSINT is often the only intelligence available during routine times and is the necessary first body of knowledge when the national intelligence community and policy makers are shifting toward the increased coverage required by crises. OSINT is widely acknowledged as an essential element for:

- Tip-off. The most experienced intelligence analysts acknowledge the vital role played by open sources in tip-off regarding intentions, new weapons systems, and emerging crises.[7]
- Context. The expertise, historical, and (in some cases) cultural knowledge to assess a situation rapidly.[8]
- Collection Management. A solid OSINT foundation is essential to those responsible for classified collection management, both within the consumer agencies and within the producer elements, because it permits the focus of classified capabilities on "the hard stuff".[9]
- Cover. Even when classified intelligence is available, OSINT can be used to protect sources and methods while still communicating essential insights and key findings to coalition partners, the press, and the public.[10]

For any private or government open source entity to function, there are several critical components of the organizational model.

- Security. The OSINT provider's key personnel must be sensitive to the security needs of a government or private sector customer. The OSINT provider has the capability to serve many many clients and provide clients with the same kind of obscurity and discretion that a bank provides its most valued private accounts. When finding an expert (or several experts) to respond to a particular requirement, the OSINT provider should not reveal the requirement to the expert or contract with the expert until the client has reviewed a resume of the expert's qualifications and approved employment of the expert for the specific requirement.[11]

- Foreign Language. Apart from languages spoken by the core management team, the OSINT provider's approach to foreign language qualifications should be identical to its approach to substantive qualifications. Many other capabilities use graduate students with native fluency in Arabic, Russian, Vietnamese, Korean, and numerous other languages. [12]
- Source Validation. The normal concern of decision makers with source validation, report integrity, and the reliability of the process upon which the open source intelligence reporting is based merits special attention.[13]

The OSINT provider should employ the traditional rigor of the intelligence community analysis process, in that every source should be clearly and explicitly evaluated in terms of its authority, currency, and confidence level. In particular, the OSINT provider should be conscious of personal, political, cultural, and other biases associated with Internet, commercial online, offline, and individually-produced source material.[14]

- All-Source Access. The OSINT provider is a support activity. While it is capable of serving as the open source intelligence stovepipe, at no time should the OSINT provider assume the role of the all-source analyst, or staff action officer. Initially, as a new client and their personnel become familiar with the quality and range of the OSINT provider's capabilities, there will be a tendency to "drill down" into the underlying sources. The OSINT *provider should deliver the briefest possible answer, in the shortest possible time, at the lowest possible cost--and focus on answering the question of the moment rather than on inundating the analyst with unfiltered source material.*[15]
- Finally, consider cost. The Community Open Source Program is on record as stating that the National Foreign Intelligence Program (NFIP) spends 1% of its budget on open sources, and that this returns 40% of the all-source product. [16] A future funding initiative to increase the investment could have a *significant positive impact on intelligence production* as well as policy, acquisition, and combat operations.

4.18.C. Project Argus

Project Argus is an open source capability initially designed to track Avian Influenza. As the capability of Argus expanded, other biological events were subsequently detected expanding Argus capability to detection of a wider set of biological events on a global scale. The core capabilities developed for Project Argus enable the potential expansion of Argus into other areas of WMD detection and/or other areas of customer interests.

Consistent with the literature that 80% of open source information is not in English, the greatest strength of Project Argus is the magnitude of its linguistic capability coupled to a supporting information technology infrastructure.

The core capabilities are approximately consistent with literature sources cited. About 50 personnel are fluent in over 30 foreign languages. All personnel are college graduates and a modest number hold graduate degrees. The majority of the personnel with foreign language fluency are native born speakers with an additional understanding of the culture and the cultural nuances of the language. Subject matter experts provide technical guidance and training to assist each linguist on what to look for in their daily data searches.

The scale of daily open source document retrieval ranges from 250,000 to 1,000,000 articles each day with archiving of relevant articles. Machine and human translation is utilized in conjunction with Bayesian networks developed in each foreign language performing key word searches for event detection. Currently, over 100 million screened articles are stored to provide data for retrospective studies if a customer so requests.

Bayesian networks are configured in three areas of direct, indirect, and enabling indications and warnings (I&Ws). Direct I&Ws are defined as reporting consistent with the event. Indirect I&Ws are observables of resulting consequences of an event. Enabling I&Ws are reportable indicators of a condition or set of conditions, be it precursor actions, anticipatory actions, and/or supportive actions, providing precursor conditions to the event.

Constant evaluation of a capability such as Argus is required and is ongoing. The value added of any open source capability is primarily dependent upon the factors of accuracy and time. Project Argus is no different as the "tip and cue" ability sharply focuses "where to look." Hopefully, these actions occur in minimal time within the event time frame providing the gathering of other information and affording the decision/policy maker the time to act.

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[1] Allen W. Dulles, "*The Craft of Intelligence*," 1963, The Lyon Press
[2] Steele, R.D, Lowenthal,M.M., Open Source Intelligence: Private Sector Capabilities to Support Policy Acquisitions, and Operations, http://www.fas.org/irp/eprint/oss980501.htm
[3] Ibid
[4] Ibid
[5] Ibid
[6] Ibid
[7] Ibid
[8] Ibid
[9] Ibid
[10] Ibid
[11] Ibid
[12] Ibid
[13] Ibid
[14] Ibid
[15] Ibid
[16] Ibid

4.19. The Role of ACH and Other Structured Analytic Techniques (Randy Pherson, Alan Schwartz, Elizabeth Manak)

Authors: Randall Pherson, Alan Schwartz, and Elizabeth Manak
Organization: Pherson Associates, LLC
Contact Information: rpherson@pherson.org, alanschwartz@policyfutures.com, and eliz.manak@gmail.com

By definition one is not expected to see the unexpected. Indeed as human beings, we all tend to assume that the future will be an extension of the past. Although we know intellectually that the past is not a reliable guide to the future, our brains are pre-wired to use the past to project what will happen because this is the most efficient way to process data. The good news is we do not have to accept defeat; there are tools that can help us imagine how the future might surprise us, help us wind tunnel possible strategies, and reliably track signposts that can tell us where we are, in fact, going.

Peter Schwartz said it simply: "What has not been imagined will not be foreseen ... in time." We discuss here the ways in which one can imagine the multiple futures that we must foresee—whether that future is tomorrow or months or years from now.

There are two related challenges. First, in some cases the evidence is in front of our eyes, but we do not see it, or do not recognize the significance of what we are seeing. We are surprised by the result. Alternatively, there are occasions when the evidence is not a reliable guide to sudden shifts. This is often referred to as the Black Swan problem discussed in Section 3.3. In both cases, surprise results.

4.19.A. The Value of Diagnostic and Reframing Techniques

Recent history has shown that engrained mindsets are a major contributor to analytic failures. Despite widespread recognition of the problem, past experience demonstrates that analytic traps and mindsets are easy to form and surprisingly difficult to change. There are myriad reasons why mindsets are difficult to dislodge. Most often, time pressures lead analysts to jump to conclusions and to head down the wrong path. As more information becomes available, analysts are increasingly inclined to select that which supports their lead hypothesis and to ignore or reject information that is inconsistent. Contradictory information becomes lost in the noise.[1]

A wonderful example is set out in a 1989 examination of the failure to anticipate the Japanese attack on Pearl Harbor.[2] Analysts ignored available indicators of an imminent attack because they:

- Assumed that such an attack would be irrational behavior.
- Were disdainful of the capabilities of Japanese aviators.
- Discounted the technological, diplomatic and military capabilities of the Japanese.

Experience shows how difficult it is to overcome the tendency to reach premature closure, embrace "groupthink," and avoid analytic traps. Overcoming mindsets relies on employing structured forcing mechanisms that require analysts to seek out new perspectives and possibilities. Without the use of structured analytic techniques, analysts are less likely to identify and challenge key assumptions, think critically about the evidence, reframe analysis, and, most importantly, avoid surprise. Such techniques also impose a greater degree of transparency, consistency, and accountability. They work most robustly with the participation of a diverse set of participants bringing a variety of perspectives to the table**.**

One of the most valuable techniques an analyst can use is the **Key Assumptions Check**. By preparing a written list of one's working assumptions at the beginning of the project, the analyst will identify both the specific assumptions that underpin the basic analytic line as well as the developments that would cause him or her to abandon an assumption. By testing one's assumptions, i.e., explicitly recognizing that one is dealing with an assumption rather than a fact, the analyst is able to establish the level of confidence that should be accorded to what is, in essence, a belief.

Should new information become available that renders a key assumption invalid, surprise can be averted. It is a simple process: List the key assumptions and future events that would indicate that the assumption was no longer valid. If some of the indicators begin to appear, the assumption needs to be reevaluated. For example, in 1989 it might have been sensible, based on the evidence to date, that the primary threat to aviation was from bombs in unaccompanied luggage. The assumption was based on two underlying assumptions: (i) that the hijacking problem had been largely solved, and (ii) that bombers would not knowingly go down with the plane. But by 2001, the latter assumption, i.e., that people did now want to kill themselves, had been undermined by the large-scale use of suicide bombers in Sri Lanka, Israel, and the West Bank. Unfortunately, in 2001 it had been seven years since a hijacking had been attempted on an American flag carrier. The assumption appeared valid because it had not been tested.

Another technique that forces analysts to challenge mindsets is **Analysis of Competing Hypotheses (ACH)**, which involves the identification of a complete set of alternative explanations (presented as hypotheses), the systematic evaluation of each, and the selection of the hypothesis or hypotheses that fit best by focusing on evidence that tends to disconfirm rather than to confirm each of the hypotheses. ACH helps analysts overcome three common traps or pitfalls that can lead to intelligence failures:

- being overly influenced by a first impression based on incomplete date, an existing analytic line, or a single explanation;
- failing to generate a full set of explanations or hypotheses at the outset of a project; and
- relying on evidence to support one's favored hypothesis that also happens to be consistent with alternative hypotheses and, therefore, has no diagnostic value.

ACH can help overcome what is called "confirmation bias," the tendency to search for or interpret new information in a way that confirms one's preconceptions and avoids interpretations that contradict prior beliefs.

Related to the Key Assumptions Check, is a technique known as **Quadrant Crunching**. Rather than testing key assumptions, the technique forces the analyst to move away from their comfort zone by systematically exploring the implications of contrary assumptions**.** Should new information become available that renders a key assumption invalid, surprise can be averted. For example, if analysts assumed that the Japanese would attack the Philippines; this technique would assume another target, e.g., Pearl Harbor. The technique initially was developed to help counterterrorism analysts and decision-makers discover all the ways radical extremists might mount a terrorist attack. But analysts can apply it more broadly to generate a wide range of potential outcomes—many of which have not previously been contemplated. The technique forces analysts to rethink an issue from a broad range of perspectives, systematically flipping all the assumptions that underlie the lead hypotheses.

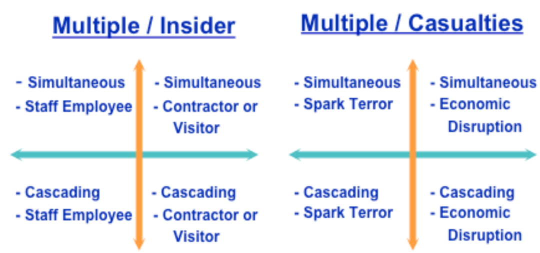
So, for example, one might test the conventional wisdom that a terrorist attack against the water supply would involve the following assumed elements: (i) a single large attack, (ii) carried out by a terrorist group, (iii) against drinking water, (iv) by contaminating the water, (v) to kill a large number of people. Using quadrant crunching, each element is flipped, so the attack might involve the following new elements: (i) multiple attacks, (ii) carried out by an insider, (iii) against waste water, (iv) by using water as a weapon, (v) to cause economic injury. By combining these new and old elements in matrices (each with four quadrants, hence the term quadrant crunching), the analyst can examine the implications of a variety of new attack scenarios, as set out below.

Figure 1. Quadrant Crunching:
Terrorist Attacks on Water Systems

Key Assumption	Contrary Assumption	Contrary Dimensions
Single attack	Multiple attacks	- Simultaneous - Cascading
Contamination	Other strategies	- Denial of service - Water as a weapon
Drinking water	Waste water	- Treatment plants - Sewage pipes
Outsider	Insider	- Staff employees - Contractors/visitors
Major casualties	Minor casualties	- Terrorize population - Economic disruption

From Randy Pherson, *Handbook of Analytic Tools and Techniques*, Pherson Associates, LLC, 2008.

Figure 2. Sample Matrices:
Terrorist Attacks on Water Systems



From Randy Pherson, *Handbook of Analytic Tools and Techniques*, Pherson Associates, LLC, 2008.

The Pre-Mortem Assessment is a systematic assessment of how a key analytic judgment, decision, or plan of action could go spectacularly wrong. It is conducted prior to finalizing an analytic judgment or decision. The primary goal of the Pre-Mortem Assessment is to reduce the risk of surprise and the subsequent need for a post-mortem investigation.

Poor group decisions are often driven by the desire for consensus; group members tend to go along with the group leader, with the first group member to stake out a position, or with an emerging majority viewpoint. The tendency is to support the consensus because members of a group assume the rest know what they are doing, are concerned that their views will be critically evaluated by others, or believe dissent will be perceived as an obstacle to progress or disloyalty. The benefit of The Pre-Mortem Assessment is that it empowers those who have unspoken reservations about the team consensus to speak out in a context that is consistent with perceived group goals. The technique provides them with both a totally unbounded and a highly structured mechanism to explore all the ways an analysis could turn out to be wrong.

Other techniques that can be employed to reduce the chances of surprise include:

- **Devil's Advocacy** should be performed if there is widespread unanimity on a critical issue or if analysts have been working the issue so long that they have developed a mindset. Devil's Advocates can expose hidden assumptions or mindsets, identify contrary data that was ignored or faulty logic that undercuts the analysis, and suggest the need for alternative hypotheses.
- **Deception Detection** consists of a set of checklists analysts can use to help them determine when to look for deception, whether deception actually is present, and what to do to avoid being deceived. Without such aides, analysts have to consider the possibility

that all the evidence is open to question and no valid inferences can be drawn from the reporting.

- **Red Hat Analysis** prompts an analyst to change his or her point of reference from that of an analyst observing or predicting an adversary or competitor’s behavior to someone who must make decisions within an existing operational culture. The technique works best when you are trying to predict the behavior of a specific person or adversary.

4.19.B. Using Imagination Techniques to Anticipate Black Swans

The diagnostic and reframing techniques described above provide a systematic and rigorous check for analysts to assure themselves that their assessment about “what is” is as accurate as possible. They are designed to uncover untested assumptions, examine alternative explanations and perspectives, and uncover hidden analytic traps. But what if the problem is not with what you know now, but in anticipating changes that could occur that would alter your assessment? Take, for example, the challenge of anticipating that someone would use an airplane as a weapon. How does one anticipate events that have few, if any, historical antecedents?[3]

The answer is not to try to predict the future. Instead, the analyst’s task is to anticipate multiple futures (i.e., the future in plural) and identify observable indicators that can be used to track the future as it unfolds. Armed with such indicators, the analyst can warn policy-makers and decision-makers of possible futures and alert them in advance, based on the evidence.

The cornerstone of any technique to anticipate the future is **Indicators**. Indicators provide an objective baseline for tracking events if they are: observable, accurately measurable, reliable (mean the same thing to those observing them), stable (useful over time) and ideally are unique (only measure one thing or phenomenon, alone or with other indicators). Indicators provide the early warning to avoid surprise. But how does one develop indicators if one does not know what the future will look like? The answer is to envision several futures that can plausibly develop, and develop stories that describe how each future might unfold.

One way to develop those futures is **Alternative Futures Analysis,** which is most useful when a situation is viewed as too complex or the outcomes too uncertain to trust a single point prediction. Usually there is high uncertainty surrounding the topic in question and a wide range of factors that are likely to influence the outcome. Alternative Futures Analysis has proven highly effective in helping analysts, decision-makers, and policy-makers contemplate multiple futures or scenarios, challenge their assumptions, and anticipate surprise developments.

- Scenario analysis is based on an understanding of underlying forces and trends, and of the uncertainty related to the development of those forces and of the impacts they may have.
- Scenario analysis makes no assumptions regarding historical continuity or change. Instead, scenario analysis requires that possible outcomes be justified by plausible developments in underlying forces and trends.
- Because scenario analysis recognizes and embraces the uncertainty inherent in complex situations, multiple outcomes and the developments that produce them are always considered. Single-outcome forecasts are not allowed.
- The analytic goal of multiple scenario analysis is not to forecast what a system will look like in the future. The goal is to estimate the range of behaviors the system can exhibit within a given time period.

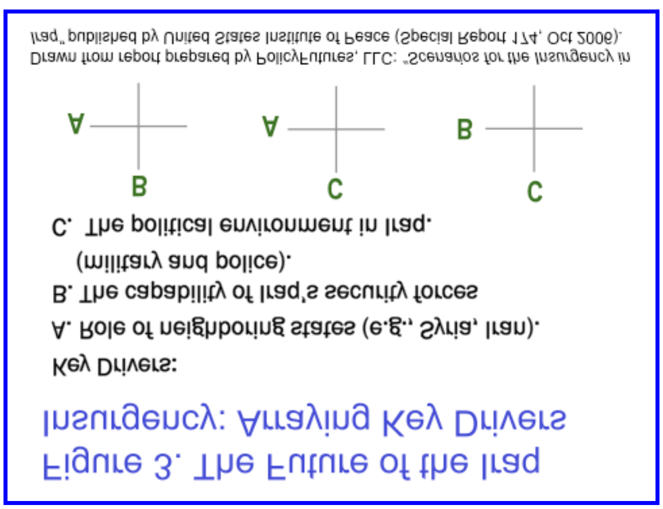
Moreover, as an analytic strategy, scenario analysis allows for the inclusion of a wide range of disciplines, conceptual frameworks, and analytic techniques. While individuals can undertake scenario analyses on their own, teams generally produce better results, especially if their members differ on the perspectives they bring to bear on the focal issue.

Unlike most academic and intelligence analyses—which focus mostly on information that is known with confidence—scenario analysis focuses equal attention on uncertainties. The term "uncertainties" refers to factors or forces for which the development or impacts are impossible to forecast accurately. Although it is impossible to forecast the future state of uncertainties, there is much value in exploring how uncertainties might behave. It is possible to speculate on how rapidly a factor might change or how much improvement or deterioration in a condition is possible within a given time period. This kind of speculation provides insights into the volatility of situations and the constraints on change that exist in complex systems; it opens our eyes to what is possible and what is impossible.

Another technique is **Multiple Scenarios Generation,** which helps analysts and decision-makers expand their imagination and avoid surprise by generating large numbers of potential scenarios. In Multiple Scenarios Generation, analysts build upon combinations of drivers or matrices. By generating multiple matrices, each with four quadrants, the analyst is exposed to a much larger, but manageable, number of scenarios. The analyst then selects the scenarios that are most deserving of the attention of the policymaker or decisionmaker based on a set of criteria, such as which scenarios:

- Are most likely to come about.
- Reflect key trends that are just now beginning to emerge.
- Represent a serious downside risk.
- Would have major repercussions despite their low probability.

Below is an example of how three drivers concerning the future of the insurgency in Iraq might be arrayed:



4.19.C. <u>Conclusion</u>

None of these diagnostic, reframing, or imagination techniques guarantees that all unforeseen events will be anticipated. Intelligence surprises are inevitable, but use of these techniques will ensure a greater rigor to the analysis and reduce the chances of surprise. If analysts continually test, probe, and indeed attack their assumptions and mindsets, they will be more capable of knowing what they know and discovering what they did not realize they did not know. Use of these techniques helps analysts anticipate what might occur in the future and better prepare themselves to track developments that presage dramatic change. In the end, decision-makers will benefit from the more thoughtful, comprehensive analysis that results from employing these techniques.

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[1] This essay draws largely from Richards J. Heuer, Jr., "*The Psychology of Intelligence Analysis*," Pherson Associates, LLC, 2007, and Randy Pherson, *"Handbook of Analytic Tools and Techniques,"* Pherson Associates LLC, 2008.

[2] Harold Ford, The Primary Purpose of National Estimating, Defense Intelligence College, 1989 – available at http://www.dni.gov/nic/PDF_GIF_anal_meth/tradecraft/purpose_of_estimating.pdf

[3] Interestingly enough, there was some precedent for the use of aircraft as a weapon. In 1994 terrorists hijacked a French airliner with the goal of crashing it into the Eiffel Tower. This prior evidence was essentially lost because analysts saw it as an anomalous event and not a potential harbinger.

4.20. The Case for Use of a Multi-Method Scientific Approach for Anticipating a Rare Event (Renee Agress, Alan Christianson, Brian Nichols, John Patterson, David Porter)

Authors: Renee Agress, Alan Christianson, Brian Nichols, John Patterson, David C. Porter
Organization: Detica Federal Inc.
Contact Information: jpatterson@detica.us.com

4.20.A. Introduction

The concept of a rare event and our coordinated ability to anticipate it is a compelling discussion for the times. In many instances the rare event is seen as a terrorist threat. The traditional response we have today to this threat is to pull at known threads, collecting and processing ever-larger amounts of data in the hope of spotting or predicting the "needle in the haystack". Even more common is the conceit by many that a one-method solution exists to facilitate anticipation. There are many efforts to try to find a model from one of the sciences into which we can map this problem.

We must move from chasing threats to anticipating them well ahead of time. More importantly while there are many powerful methods to use, no one alone can facilitate an answer across the whole series of problem sets. We must hypothesize threat blueprints or 'threatprints' that can be broken down into their component parts. We must coordinate the use of the best of methods available to anticipate a rare event. Our objective must be to foresee needles before terrorists or criminals have even thought to place them within the haystack – even before the terrorist or criminal has been radicalized or recruited in the first place.

The approach of this paper is to facilitate an open discussion on the premise that the rare event is primarily the culmination of a series of actors, processes, and interactions. The ability to anticipate the rare event therefore requires we anticipate the mandatory events required to actuate a rare event. This paper highlights the use of a multiple method approach against a situational example of a rare event. Through this example scenario we explore methods that could be used. This discussion will also speak to the strength of the multiple-model analysis approach to anticipate rare events.

4.20.B. Requirements for Understanding Rare Events

4.20.B.1 Actors

In order to develop models that may help in the identification of a rare event, it is essential that we identify the actors and their motivations. This information will help researchers identify when actors are most likely to act and how they are likely to act.

It is important to understand that there are different motives for different actors. What drives the leader of a terrorist group to choose a path? What causes an individual to join a terrorist cell? It is very likely that the primary motivation of a leader varies from that of a foot soldier. There are also different risks and rewards associated with these two roles within a terrorist group.

Understanding the motivations of the leaders will help us to better understand what a terrorist group is going to target, what type of weapon the group is most likely to use, and when the group is most likely to strike. Understanding the motivation of the foot soldier will help us understand why they join a terrorist organization and thereby permit us to develop tactics for disrupting the recruiting function of an organization.

4.20.B.2 Resources

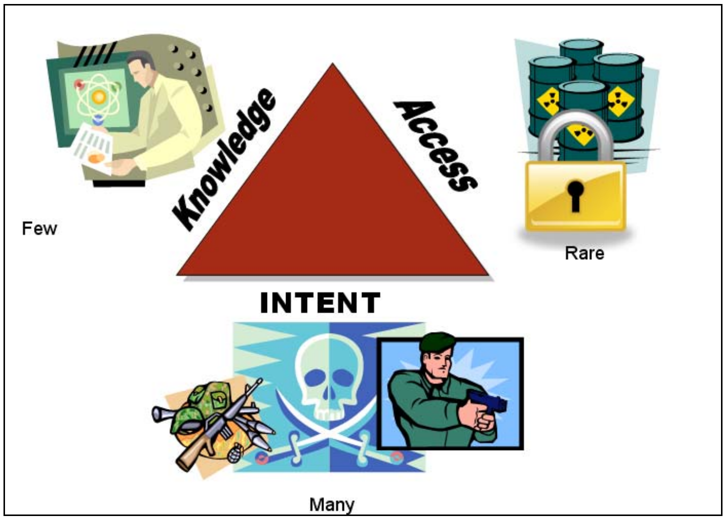
The rare event anticipation analysis is incomplete without a model that captures an understanding of required resources. This model needs to incorporate the following factors: accessibility, quantities available, quantities required, quality required, geospatial issues with supply, temporal issues associated with handling, handling requirements, technical knowledge, and training in the materials development. Without consideration of these issues, the rare event anticipation analysis process will be incomplete.

4.20.B.3 Processes

In order to manage facilitating a rare event there are a multitude of process steps that must occur. Process design may vary from simple to complex depending on the actors. Regardless, understanding the required steps and action needed to facilitate a rare event must be completely mapped in order to facilitate an effective analytic anticipation of the event.

4.20.B.4 Example Scenario

The example scenario we will use for our discussion involves a violent non-state actor committing an attack using a weapon of mass destruction. Taking a multi-method approach enables us to look at the actors and resources initially. Knowledge and access to materials are constraining items.



There are three primary prerequisites to a rare event of a "WMD terrorist attack:"

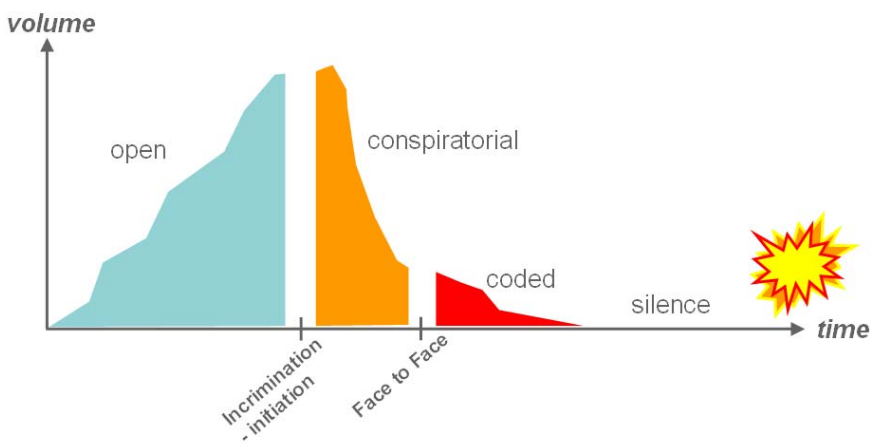
- **Intent.** There is a group of individuals who are motivated to make such an attack.
- **Capability**. The group possesses or obtains the technical knowledge and skills necessary to carry out the attack.
- **Access.** The group gains access to materials and devices to be used in the attack.

In each of these areas, there are data sources that can assist in threat identification and anticipation. Examples include:

- **Intent.** An individual makes incendiary postings on a monitored web site.
- **Capability.** An individual is enrolled in a technical academic graduate program specializing in nuclear physics.
- **Access.** A medical equipment supply company has been burglarized, and a device containing radioactive materials has been taken.

While each of these items may or may not be alarming in isolation, if we are able to identify a nexus of individuals and activities spanning the three areas, then we will be able to anticipate a credible threat.

However, anticipating the rare event becomes more difficult as time approaches the day of execution. In the preceding weeks or days, the members of the group will be very careful to not leave a data signature. They may choose to forgo using all telephones. In the months preceding the execution, the group may limit its use of email and the internet.



The diagram above illustrates that in the early stages of plot development there will be a more likely open data trail that can be followed. Individuals must find each other, convince potential collaborators to join, and gather information to support their plan. Once the alignment of individuals to conspiracy is achieved there will be a change in the signature of the communication and the relationship. There will be a movement to private IP-based communications (private chat rooms), gaming environments, and dark web areas. Following a commitment the communications will become coded, decrease, and finally move to face-to-face.

4.20.C. <u>Assessing the Requirements to Facilitate a Rare Event Using a Multi-Method Approach</u>

4.20.C.1 Methods

There are many viable approaches that can, and should, be used in an attempt to anticipate a rare event such as a terrorist attack using a weapon of mass destruction. There is increasing evidence that advocates using an approach that draws on a series of methods as opposed to relying on a single method. There is a series of processes that must be completed in order for a terrorist group to initiate any kind of assault. Terrorist cells must recruit and train members. They must decide what type of attack to make and with what weapons. They must acquire or manufacture the weapons. Different methods will be more appropriate for understanding the actions of terrorist groups as they attempt to complete these processes.

4.20.C.2 Case Study Approach

The case study approach allows an individual to choose an instance, whether it be a specific event or location, and analyze that event or location. Many times the analyst will choose one country or region of the world to study. In some cases, he or she may choose to study one specific town or village.

The case study approach provides valuable information regarding the culture, politics, economy, and history of a given location. When studying a specific group, a case study can provide in-depth information about the group's agenda, political structure, areas of commonality and conflict, and economic resources.

Case studies provide valuable detailed information but they also have some significant weaknesses. Case studies can be heavily influenced by an individual's preconception. It is not unusual for different researchers to study the same region in the same time period and come to very different conclusions. The people who are the subject of the research could be wary of the researcher and change their behavior thereby changing the results of the study. Additionally, the people who belong to a group or region being studied could fear repercussions for what they say or do and choose to lie to the researcher.

4.20.C.3 Econometric

While acts of terrorism are rare events, unfortunately there have been enough such attacks that allow us to apply econometric techniques to the collected data. While econometrics is most broadly defined as "the systematic study of economic phenomena", the tools and techniques that have been developed are regularly employed in fields such as political science, sociology, business, and other fields.[1] These techniques include, but are not limited to, logistical regression, probit, time series, and simultaneous equations.

In the scenario posited in this paper, econometrics can be used to analyze the conditions that lead to terrorism, the individuals who are most likely to join a terrorist organization, the individuals who are most likely to participate in suicide bombings as opposed to organized attacks, and the type of attacks groups are most likely to participate in. As such, econometric models can be used to predict behavior across time. This type of analysis can help in developing interventions that may be able to prevent the rare event by decreasing the likelihood that an individual joins a terrorist group or by making it more difficult for a terrorist group to purchase weapons.

The data used in econometric models can come from open source material as well as classified material. The data itself can come from reports on the ground, information found in media outlets, information found on websites, case studies, interviews, and other sources.

Econometric techniques are not without their flaws. The quality of the results is driven by the quality of the data, the selection of the appropriate technique, and the use of the proper diagnostic tools. If the data are poor, or the wrong technique is used, or the proper diagnostic tools are not employed, then the results of the model will be flawed.

4.20.C.4 Game Theory

"A game involves situations in which individuals are aware that their actions affect one another. To study the strategic interaction of individuals, we use game theory."[2] Game theoretic models allow us to study how actors interact with each other, the outcomes of interaction, and what variables influence those outcomes. To develop such a model, one must identify the actors, their preferences, variables that are believed to influence the decisions made by the actors, the outcomes of the interaction, and the type of information available to an actor. This information can be found by drawing on case studies and econometric models.

Additionally, the wide variety of game theoretic modeling techniques allows individuals to choose the appropriate technique for the question at hand. For example, game theoretic models can be developed that explore the likelihood of a terrorist group committing an attack with a weapon of mass destruction or the bargaining that occurs within a terrorist group to decide what type of attack to launch. The former would be modeled as an incomplete and imperfect information game solved using a perfect Bayesian equilibrium while the latter would be treated as a bargaining game.

Game theory is a powerful technique because it requires the modeler to explicitly discuss the assumptions, the actors, the actors' preferences and their origins, the temporal sequence of events that produces an outcome, the outcome itself, and the relevant variables. These assumptions can be relaxed or tightened as deemed necessary by the author or the sponsor. Game theory provides insight into how changing the variables can influence the outcome of the model.

Game theory is a powerful tool; however, like every other method, it has its problems. Many of the social and economic variables that are involved in the models are not easily quantifiable. As such, the models equilibrium solution will help us to understand the likelihood of a specific outcome but will not give us a definitive answer. Additionally, if the wrong type of model is selected, such as a prisoner's dilemma model as opposed to a bargaining model, the results will not accurately represent the scenario.

4.20.C.5 Social Network Analytics

Social network analytics has generated a considerable amount of interest in the advanced analytics space. Utilization of this technique allows for the evaluation of the potential nexus of actors who possess the three prerequisites identified. When properly applied, this tool allows us to identify and monitor the sequencing of actors and resources across temporal and geospatial dimensions. Actors move in layered networks of complex relationships and interactions via a variety of mediums. These networks share commonalities. There can be relationships among groups, close contacts, and friends. Many may only communicate within their own group, while others may act as "connectors" between a disparate set of groups. The connections between groups control the flow of information, moving new ideas from one group to another and influencing the behavior of individuals and their groups. These connectors are the "influencers" and the information "gatekeepers" in any network. The identification of people with this role is therefore critical to anyone who is trying to understand, influence, or anticipate the effect of that social network.

This approach has been useful for explaining many real-world phenomena. Social network analytics has been used in epidemiology to help understand how patterns of human contact aid or inhibit the spread of diseases. This same approach can be used to analyze and anticipate an actor's communication sequences well enough to formulate an intervention that might prevent the occurrence of a rare event.

4.20.C.6 Combinatorial capability

We are attempting to identify methods that can be used to anticipate a rare event. In this case, we are interested in when a terrorist group may choose to initiate an attack with a weapon of mass destruction. The rare event is the last action in a series of actions taken by a terrorist organization. A multi-method approach improves the resolution on our understanding of how terrorist groups recruit new foot soldiers (especially those with the necessary skill to develop a WMD), how they plan attacks, how terrorist groups fund their activities, and then the attack itself. This simple chain gives an analytical team four opportunities to identify terrorist activities. By extension, it provides a state four opportunities to prevent a terrorist attack.

Yet selecting one research method hinders the possibility of breaking the chain of events because no one method can be used across all the phases in our scenario. The recruitment of new members and subject matter experts is something that is best understood using social network analytics. If there is enough data regarding captured terrorists and their backgrounds it may be possible to use econometrics in order to identify recruiting trends. Game theory and case studies can be used to understand how a terrorist group selects its method and target. Econometric models can be used to predict what type of targets may be attacked.

4.20.D. Strength of multi-method approach

4.20.D.1 More information allowance

The primary strength of using multiple methods is that it allows for the inclusion of a great deal more information in analysis than simply using one method in isolation. Each approach uses different types of information, all of which provide clues to anticipating the rare event. Excluding a method could lead to the exclusion of information that could have helped in anticipating a terrorist attack.

Econometric techniques can use the data to determine trends across different types of terrorist groups. These trends provide us with valuable indicators that can be used to identify conditions that may lead to a terrorist attack. The econometric approach will help point to the conditions normally found before an attack but it might not be able to tell us what type of target a specific group might attack or what type of attack a group is likely to use. This could be due to the lack of sufficient data at the smaller scale.

The case study approach allows the inclusion of cultural, political, and economic nuances that cannot be found in econometric analysis alone. It helps us to understand the likelihood that a specific group will use specific methods and what types of targets that group is likely to attack. Case studies could also point to emerging trends that are not found in the larger data sets used by econometrics because there is not enough data for the trend to be found.

Game theoretic models are developed using information gleaned from case studies and econometric research. The assumptions of a more general model of terrorism can be relaxed or tightened based on the needs of a specific terrorist group. This allows researchers or analysts to better understand how the different variables are affecting the specific case using mathematical rigor. It can help to incorporate the nuances found in the case study approach but in mathematical rigor. The hypotheses generated in the case study approach can be tested with and used to inform the other more methodologically rigorous approaches.

4.20.D.2 Validity and reliability checks

It is possible that any one of the approaches discussed in this paper could lead to an inaccurate model. An econometrician could use the wrong statistical technique. A game theorist could use the wrong type of game or solve for the wrong equilibrium. The case study could be prepared by well intentioned researchers whose findings are biased based on their expectations or because the local population chooses not to participate.

Using a combination of methods increases the likelihood that faulty results will be discovered before any damage is done. If the econometric models findings are opposite to the findings of a game theoretic model or a case study then the analytical team will be more likely to enter into a discussion of why the differences exist. This overlap provides a check on the validity of the results.

4.20.E. Conclusion

The ability to anticipate a rare event has always been a prime objective in the protection of national security. With the advent of powerful new technologies coupled with increased tensions, the stakes have been raised considerably. Whereas the inability to predict the enemy’s next move might have resulted in a lost battle in simpler times, now it may result in an event posing an existential threat to a country or global region.

The acceptance of a multi-method approach to anticipating a rare event is a key milestone in our ability to actually achieve anticipation. We are at a cross roads--we can continue to apply the often-repeated approach of deploying the single “best” mathematically based model or approach to the problem of anticipating a rare event, but our efforts will likely be met with sub-optimal outcomes at best or failure at worst. This myopic approach can be equated to the adage “when all you have is a hammer every problem looks like a nail”.

We significantly elevate our prospects of success by holistically applying a multi-method approach to the anticipation of rare events. Through the analyses of actors, resources, and processes, and the application of a multi-method approach, we will uncover more opportunities to anticipate the rare event and implement interventions that lead to more desirable outcomes. The devastating consequences of failure demand that we maximize our chances of success by drawing from the best of all relevant disciplines.

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[1] Spanos, Aris, *Statistical Foundations of Econometric Modelling.* 1986. Cambridge: University Press.
[2] Gates, Scott and Brian D. Humes. *Games, Information, and Politics. Applying game theoretic models to Political Science.* 1997. Ann Arbor: University of Michigan Press. Pg 1.

4.21. Instantiating Federated Strategies: Command and Control through the Nexus Federated Collaboration Environment and the Flexible Distributed Control Mission Fabric (Carl Hunt, Terry Pierce)

Authors/Organizations: Carl W. Hunt (Directed Technologies, Inc.) and Terry Peirce (Department of Homeland Security Science & Technology Directorate/US Air Force Academy)
Contact Information: carl_hunt@directedtechnologies.com and terry.pierce@usafa.edu

4.21.A. Introduction

It's difficult to jump-start inter-organizational dynamics, particularly within environments as complex as the relatively new interagency nature of federal, state, local and tribal government and non-governmental entities. Even more challenging, once initiated, these interactions are even less subject to conventional organizational controls. Traditional methods such as interagency memorandums of agreement and standing operating procedures, while useful, tend to pre-suppose the conditions under which various organizations might work in often unpredictable yet demanding environments. These methods often fail to anticipate unforeseen challenges individual organizations might face in trying to be a worthy member of a team effort, testing even the most flexible command and control tools and processes available. Today's challenges demand maximum flexibility and adaptation, and the capacity to marshal forces and processes to accommodate emergent, unanticipated problems.

This paper presents a potential integration of two proposed concepts currently being considered by the Strategic Multilayer Assessment (SMA) leadership in support of the WMD-T Joint Intelligence Preparation of the Operational Environment (JIPOE) SMA effort. The integration considers a synergistic approach to empower enterprise-wide transparent collaboration built on a biologically inspired innovation known as the Flexible Distributed Control (FDC) Mission Fabric. The FDC would provide a potential substrate for organizational interaction known as the Nexus Federated Collaboration Environment (NFCE). Both the NFCE and the FDC are described below, with general observations for the ways in which the two approaches could synergize and produce optimal outcomes for inter-organizational dynamics.

4.21.B. Challenges for the JIPOE Mission Leadership and Team

The White Paper of which this current article is a part presents many of the challenges individual commanders and directors face while assessing the emergence of unanticipated events. This paper has not addressed in any detail the challenges of global command, control and cooperation of local organizational entities operating within a JIPOE distributed environment. While the director/commander of a centrally authorized JIPOE "cell" might ultimately be responsible for outcomes related to the JIPOE mission area, he will require the cooperation and contributions of many diverse organizations to succeed. Managers of a complex problem-solving federation of organizations may not even be able to anticipate optimal mission and task organization as the operation kicks off – organizations may even come and go throughout a mission. Traditional command and control techniques will be tested and likely found inadequate in such a mission.

4.21.C. The Nexus Federation Collaboration Environment

4.21.C.1 Overview of the NFCE

People, processes and technology, connected by their critical linking foundation, information, compose the heart of the modern organization. None of them, including the organization itself, stands alone: interconnected and interdependent, people and organizations interact in order to thrive. The WMD-T JIPOE SMA is about how to best leverage our nation's top people, processes and technology to overcome the challenge of weapons of mass destruction in the hands of terrorists. To succeed in this critically important objective, we as a nation must know how to enable people, information and processes to build, explore, and exploit a networked federation of diverse organizations to make timely decisions regarding adversary goals and behaviors concerning the accumulation and/or use of weapons of mass destruction.

Any environment for empowering people, processes and technologies must enable sharing, mutual cooperation and common goal setting and execution; it has to empower collaboration. Such an organization must transcend traditional boundaries and organizational equities. It must:

- be an environment rather than a place or cellular-based collective of organizations
- be capable of thriving in a virtual setting enabling the multidisciplinary talents of many government and non-government organizations to interact and succeed in ways that exceed the sum of their constituent parts
- facilitate the materialization of an interagency culture.

To meet these types of demands, the WMD-T JIPOE SMA conceived the Nexus Federated Collaboration Environment, or NFCE.

This NFCE construct comprises an aggregate of several key attributes. In its objective state it is inclusive of all relevant stakeholders while possessing built-in transparency and maximum visibility of trade-offs and risk. The NFCE is adaptively structured, while empowering collaborative consensus-building. It is built on a multi-layer/multi-disciplinary decision-making platform while maintaining an evolutionary design orientation. The NFCE seeks to highlight and mitigate biases through visibility of objective processes, while accommodating incentives for resolving competing objectives. While these are lofty objectives, the means to integrate and synergize the attributes of the NFCE are coming together in bits and pieces throughout government and industry.[1]

4.21.C.2 The Sciences Applied to Our Own Organizations

The WMD-T JIPOE SMA seeks to leverage social and behavioral sciences to better understand and even interdict potential WMD-T adversary behaviors, as noted throughout the entire JIPOE SMA report. The social science network tools described throughout this current White Paper and throughout all of the JIPOE SMA reports apply to our own behaviors, as well. A convergence of important contemporary organizational and information management capabilities, augmented by recent discoveries in social science of what are known as "weak ties" suggest an approach to improving timely collaboration and decision-making, a major objective of the NFCE.[2]

The mission of JIPOE WMD-T demands the application of the individual talent, organizational capabilities, and collective wisdom of the whole of government and other organizations that support the government. The dispersion of this national talent and information, combined with the diversity of organizational cultures and management systems, challenges the suitable exchange of information, association of goals and objectives, and critical timeliness of decision-making processes. The response to these requirements lies in proper alignment of people, process, and technology through relevant social network structures as mentioned above and described below. From conventional supply network operations to internal collaboration, many businesses seeking improved efficiency and effectiveness are leveraging the capabilities of a new breed of advanced Business Process Management and Modeling enablers.

Driven by market forces and in recognition of significant return to business operations, a new category of enablers has emerged. Business Process Management Suites (BPMS) now provide much deeper and broader support for business operations. They seek to improve the transparency, integration and interoperability of formerly discrete capabilities for Enterprise Application Integration, Business Process Management, Process Simulation and Modeling, Business Intelligence, Enterprise Content Management, Knowledge Management, and collaboration tools for both distributed and local environments.[3] When aligned to appropriate forms of team-based incentives, leveraging the power of network sciences, these capabilities synergize across a new kind of mission-enabling fabric that enables and promotes self-organization and emergent communities of interest that rise to tackle hard problems rapidly and flexibly.

New knowledge-based BPMS capabilities ensure that relevant lessons are learned and available for reuse. But, knowledge, when shared effectively, requires an infrastructure for access, movement, collaboration and storage, all within a maximally secure environment.[4] Obviously, an effective mission-enabling fabric is critical to success. We seek the synergy of people, processes and technology within a flexible distributed control fabric, hence the FDC.

4.21.D. <u>The FDC Mission Fabric</u>

Flexible Distributed Control (FDC) is a proposed concept for creating an instantaneous means to distribute and modulate control of the pervasive flow of information in the digital network.[5] FDC offers the ability to focus and align social networks and organizations. This contributes to the means to virtually eliminate group coordinating costs and encourages self-organization of members of ad-hoc organizations that are otherwise difficult to command and control and/or may come and go throughout a mission.[6] Put simply, FDC weaves the virtues of social networking into a group-action mission fabric that is based on collaboration and self-organization rather than on layered hierarchy and centralized control.[7]

FDC is the overall process to create the means within federated organizations to accomplish Distributed Operations, Self-Organizing Edge Groups, and Distributed Mission Planning and Execution. The engine for executing FDC is the *mission fabric* – a new situational awareness architecture enabling collaboration and decision-making in a distributed environment. The mission fabric is a network-linked platform, which leverages social networking and immersive decision-making.

4.21.D.1 Challenges – The Missing C2 Layer

Despite huge investments in advanced information systems we remain relatively poor in generating distributed knowledge that we can use directly and effortlessly. Instead, our command and control (C2) systems generate non-distributed knowledge that we can only utilize through slow and laborious work – done by individuals and organizations.[8] In general, the best we can do today in generating distributed knowledge is to use chat and time-delayed PowerPoint briefs.[9] Consequently, we lack a situational awareness layer that can distribute knowledge directly and effortlessly for enabling the Force to maintain alignment, advance the plan, comply with procedure, counter the enemy, and adjust apportionment.[10] We call this situational awareness layer the mission fabric. The mission fabric is how we can conduct flexible distributed control.

FDC is a networked process for *how* we distribute control, share human connections, extend understanding of the situation, and self-organize and disperse to create a decisive warfighting advantage. In practice, FDC is particularly useful in generating collective action in distributed operations where edge units and individuals are often widely dispersed, even to the point of isolation.[11] FDC thereby is an effort to increase tempo by widening the span of control without increasing coordinating costs, which means increasing the number of distributed subordinates that can self-organize. To be successful, distributed operations require a flatter organization on the periphery where layers of command have been reduced. Consequently, the organization becomes faster and more responsive.[12]

How do we widen the span of control? Our plan is to field test social networking tools within a command and control mission fabric for reducing the coordinating cost of conducting distributed operations. The mission fabric is a distributed digital network consisting of cognitive nodes – people, software agents, advanced routers with embedded java blades, advanced servers with embedded java blades, and computers – that embed control processes, logic, and social networking applications.

In this federated environment, the key proposition is that FDC reduces transaction and coordinating costs for the collective force. Thus, FDC bestows a remarkable leap in our ability to share, cooperate, and take collective action all outside the framework of centralized C2. The value is that self-organizing dispersed groups can immediately shift and synchronize their efforts for all opportunities – including those conducting edge or peripheral operations – to sustain the commander’s supported and supporting efforts. This is a quantum leap forward in enabling federated strategies.

To get a feel for this new innovation, let us consider the federated organization to be a collective that has constant access to a Situational Awareness C2 layer composed of a grid-like digital structure we call the mission fabric. The mission fabric is composed of communication tools and is flexible enough to match our social capabilities, and giving rise to new ways of coordinating action, along with providing more human context and meaning.[13] One remarkable change is the capability of individuals to *publish-then-filter* instead of *filter-then-publish*.[14] Typically, group efforts have been filtered through centralized C2 because of the complexity of coordinating groups. This filter-then-publish approach was necessary because self-assembled groups had difficulty working together. Consequently, we see the rise of the intelligence community that gathers the warfighters’ inputs from sensors; filters it into silos, and then shares it with selected individuals.

FDC, however, has collapsed most of the barriers to group action, and without those barriers, individuals can publish-then-filter into the mission fabric. Thus, every individual is a potential provider and consumer of intelligence, a prosumer, as Tapscott and Williams note.[15] Essentially the mission fabric of the federated collective acts as a clearing house for breaking events and the means for edge operations to self-form and then dissipate.

With the emergence of the FDC mission fabric, the relative advantage of a closed hierarchical organizational system historically managed in layers has disappeared. The new mission fabric supports a more open system mission control. The mission command and control protocols and processes will be embedded in the mission fabric and should lead to a new core function of modulating C2 protocols and processes that lie within mission fabric.

FDC's command and control support structure is the mission fabric. To understand how the mission fabric functions, we will review the functions of command and control.

4.21.D.2 Command and Control (C2)

C2 is both a *process* and a s*ystem* by which the commander decides what must be done and sees that his decisions are carried out.[16] To be effective, C2 – both the process and the system – must be able to cope with effects of time and uncertainty.[17] Command includes the authority and responsibility for effectively using available resources for planning, directing, coordinating, and controlling his forces. Control is the means by which a commander guides the conduct of operations. The commander controls by monitoring and influencing the action required to accomplish what must be done.[18] There are two essential layers of C2:

- *C2 Cognitive Layer – the process of command.* The cognitive layer of command is the process translating vision into action.[19] To translate vision into action, the cognitive process turns data gathered from the environment into knowledge and understanding. How we turn data into knowledge and understanding is the key to the entire decision and execution cycle, because it influences the way we observe, decide, and act.[20] This decision and execution cycle is a continuous process at each echelon of command. Put simply, senior and subordinate commanders are gathering information and working through decision and execution cycles at their respective levels. To generate knowledge and understanding (situational awareness), each commander is working through a cognitive hierarchy of gathering data; processing the data into information; generating knowledge through cognition; and applying judgment that transforms the knowledge into understanding – the act of understanding why.[21]

- *C2 Systems Layer – the system of command.* Each commander monitors and guides the actions of their forces through a command and control system (C2 System).[22] A principal objective of the C2 system is to enhance the abilities of commanders to make and execute decisions in supporting the focus of effort, as well as assist secondary and tertiary efforts or edge operations.[23] The C2 System encompasses the facilities, equipment, communications, procedures, and personnel essential to a commander for controlling operations.[24] It also provides the critical distributed forces with each other and the main force and facilities providing information to commanders and subordinates.[25] In comparing the C2 process and C2 system, the *process* is more important than the *system*.[26] The entire C2 process depends on the shared understanding of distributed commanders, which can be greatly enhanced by an efficient C2 system,[27] particularly when enhanced by a federated collaboration environment like the NFCE.

A <u>critical vulnerability</u> exists between the interface of the C2 process and C2 systems layers, however. Our focus must shift to the C2 process layer and the development of a digital decision support layer bridging the C2 cognitive and C2 system gap. The decision support layer is the *mission fabric*.

4.21.D.3 Mission Fabric – A Thought Leadership Platform

The mission fabric, through the use of social networking tools and distributed control capabilities, will create a thought leadership platform bridging the C2 gap and achieving more efficient distributed operations. The leadership platform will enable better decision making by using collaboration environments generated from more social networking, unified communications, fusing of information, and collaborative workspaces through fixed or ad hoc distributed network environments. The power of the mission fabric comes through its digitally connected distributed networks, where logic, coordination, and control modulation takes place within the networking fabric: this is the heart of the flexible distributed control concept.

Mission Fabric -- The Layer. We propose to build a mission fabric where inputs from machines, people, video streams, newsfeeds, sensors, cognitive agents, and social networking are digitized and placed onto the network. In building this mission fabric, we can create content and knowledge incorporating collaborative decision support technology services. By fusing voice, video, location, and social networking assets, the mission fabric harnesses the power of the collective to rapidly transform data into knowledge for each echelon subordinate commander and bridges the C2 cognitive and system layers by connecting people, processes, and knowledge, thereby enabling faster, better distributed decision making.

We have attempted to bridge this gap by replacing centralized (or star) hierarchies with decentralized star networks (see Figure 1 A and B, below). Unfortunately, tactical distributed units cannot yet share common operating pictures nor support each other's efforts in real time. One approach for bridging the cognitive and technology C2 gap is to use advanced and emerging technologies to create a distributed (grid or mesh) cognitive network (see Figure 1 C).[28] We call this distributed network the mission fabric. We are currently generating the necessary measures of effectiveness (MOEs) and field tests for building the mission fabric.

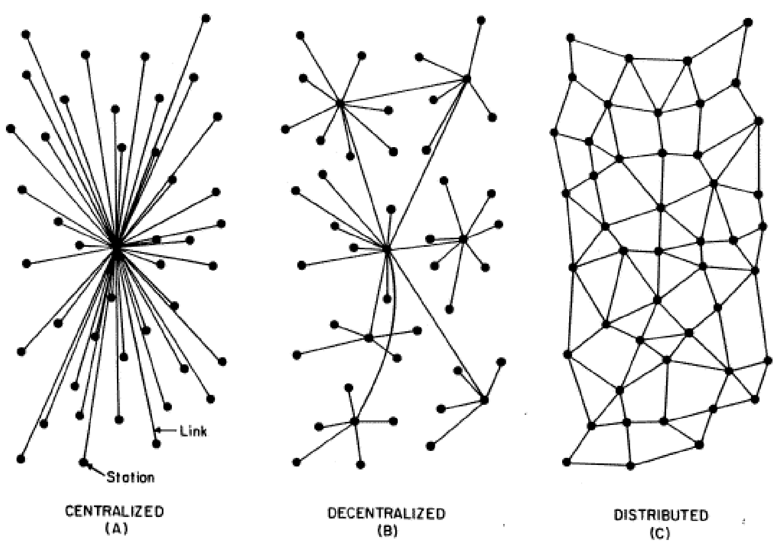

Figure 1 - Centralized, Decentralized, and Distributed Communication Networks[29]

Mission Fabric Network Attributes. The mission fabric is a high level network architecture that is packed with intelligence to integrate applications. In this model, software programs that support communication functions are called services and the network functions as a non-intelligent pipe to transmit data. Typically these software applications reside on computers, called clients and servers, which are dedicated to providing services to end users on a network. This approach has lead to a siloed or stove-piped system, which inhibits flexible distributed operations.

The mission fabric, however, is application-oriented networking that embeds application intelligence into the network. In general, the mission fabric is about the novel linkages of virtualized resources – network resources, application and service resources, human resources, and ultimately the policy management for all these. By embedding logic into the network, the network becomes an intelligent complex adaptive system as opposed to a dumb data pipe. This enables mission fabric to create an IP-based virtual network that is capable of converging data, voice, and video. Thus the mission fabric is an evolution of the network from stove-piped systems to a virtualized and integrated network. This virtualized mission fabric enables us to provision services in the network; we envision that these services could accommodate the characteristics of the NFCE.

4.21.D.4 Building the Mission Fabric

To create a mission fabric that supports FDC, collaboration must be a distributed process where information and decision making occur throughout the network—not just at specific aggregation points. This means the mission fabric must connect all nodes on the network—data, machines, objects, and people. A means for connecting all the nodes is advanced routers, which link the layers in a novel way.

Novel Linkages of Layers.[30] Typically, routers function in the *network* and *transport layers* in which they are calculating paths to destinations, reading addresses on incoming packets, and then forwarding the packet toward its final destination. By design the *network* and *transport layers*, like all the seven layers of the Opens Systems Interconnection (OSI) model shown on the let in Figure 2, are self contained so that the tasks assigned to each layer can be implemented independently. This enables the solutions offered by one layer to be updated without adversely affecting the other layers. The *Upper Layers 5-7* deal with logic, process, and application issues and generally are implemented only in software. The *Lower Layers 1-4* handle data transport issues and are implemented in hardware, firmware and software.

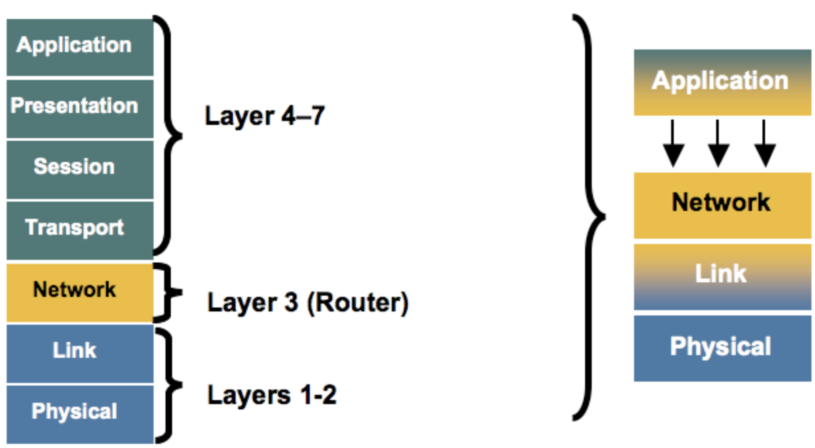

Figure 2. Blending the Technical Layers of the Network Model to Utilize Each Other

Advanced routers, however, now have the capacity to move some of the capabilities in the *Upper Layers* into the *Lower Layers* and utilize information from the *Lower Layers* to enhance the

Upper Layers. Stated differently, advanced routers can move the processing power of *Layers 5-7* into the *Network and Data Link Layers 2-3,* as depicted on the right in Figure 2.

Mission fabrics are multilayer problems that demand the technical communication layers work together and be aware of one another. Communications networks will need to be self-configuring, -managing, and -healing. They will mimic social networks rather than technical boundaries. The technology will mold to fit policy and interaction of people, rather than people molding to fit the technological constraints.

One part of the mission fabric can be the mobile ad hoc network (MANET). A MANET is an independent set of distributed nodes that communicate over bandwidth-constrained wireless links. Each node is a self-sufficient network resource: a transmitter, receiver, relay, or a combination thereof with varying capabilities. The mobile nature of MANETs affects the utility and quality of the network since the variable communication environment influences radio signal loss and fading.

Network utility and quality is directly related to radio link quality (signal strength and bandwidth), which ultimately affects the routing topology. The network may be stable one minute, but then be unstable or unpredictable the next. Since MANETs are normally decentralized, there are no central controllers or designated routers to determine routing paths as the topology changes. Thus, all of the calculations and packet forwarding must be done by each node on a peer-to-peer basis. To enhance the network, cross-layer feedback can be used to blend the layers of the network reference model.

One part of cross-layer feedback takes information from the radio and provides it to the router. Generally, nodes may move into or out of radio range. Each time a node joins or leaves, the network must be logically reconstructed by the routers. The radio notifies the router each time a link to a neighbor is established or terminated. Normally the radio (Layer 1) and the router (Layer 3) utilize Layer 2, but not one another.[31] Changes are being made to update routers with Layer 2 link metrics. As the radio reports changes in variations with established radio links, they are made available to the router. The router gets influenced by what is transpiring at a lower layer, rather than making a decision in a vacuum. By applying this feedback, the router makes more intelligent decisions faster. Figure 3, below, illustrates this.

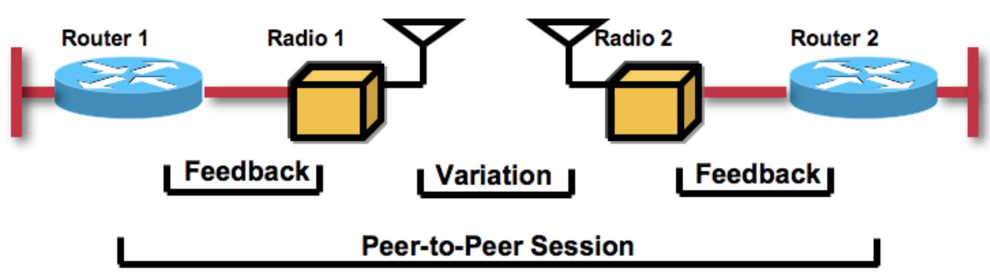

Figure 3. Radio-Router Interface[32]

Additionally, routing protocols need to be optimized. When a router floods information, all neighbors are affected. Intelligent flooding minimizes the information that is sent, reducing the level of congestion, as depicted in Figure 4, below.

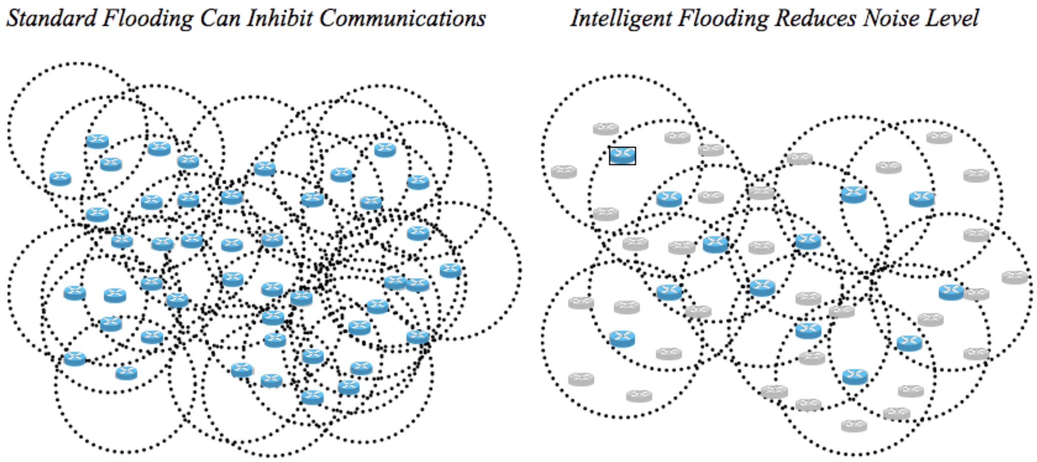

Figure 4. Router Flooding Protocol Effects

Although the technical issues should get solved in time, there will still be other types of issues to be addressed, including creating policy and network addressing, to name two. Policy will have to be set by personnel and that policy will have to be updated from time to time. Network addressing might also be a concern, depending upon how it is allocated within different organizations. Adherence to standard DoD IPV6 naming conventions will be essential.

Deep Packet Inspection. In addition to being able to read the address on the IP packets and move about in a geographic space, another part of the mission fabric will be that of Deep Packet Inspection (DPI). Advanced routers will read ***all*** the information contained in each packet. Since we can bypass applications but we can never bypass routers, we now can create a mission fabric where the advanced routers are able to distribute many of the control and application functions throughout the mission fabric. Most importantly, senior leaders also have the ability to modulate this distributed control throughout the fabric.

What is the significance of this innovation that moves many router functions of the *Upper Layer* into the *Lower Layers*? Senior leaders and tactical commanders can distribute and modulate control within the nodes (using advanced routers) of the mission fabric. No longer does network content have to travel through a central bus, as it does in the client/server and Service Oriented Architecture (SOA) architectures we are now building. Also, the mission fabric is event driven. As events happen, an intelligent network gives federated social networks and organizations the ability to understand a situation more fully, and allows dispersed personnel to simultaneously and accurately evaluate and respond to each situation.[33]

4.21.E. <u>Conclusions: The FDC as an Interaction Substrate for NFCE</u>

Any networked environment, whether communications, commercial, or social, requires an undergirding medium. In biology and chemistry, these undergirdings are often known as substrates, the sites where molecular interaction and transformation occur. It appears as though the FDC could serve well as a substrate for the interactions we envision that will occur in a fully functional federated collaboration environment such as the NFCE. Adaptation, self-organization, co-evolution and transformation are desirable characteristics of the NFCE, as noted above and well documented in the NFCE report.[34]

It is through these processes that C2 emerges more efficiently as both an enabling and connecting process and system. A mission fabric such as the FDC is critical to the interactions we have described. In fact, the notions of mission fabric and substrate align well. The NFCE concept is built on the notions of transparency, bias mitigation and collaboration, all important functions for effective C2. The SMA team is exploring the feasibility of testing the convergence of NFCE capabilities riding over the FDC mission fabric. The potential for synergy looks good at this point, and the integration of the two could result in the emergence of a worthy environment of advancing command and control for operations at all levels.

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[1] Hunt, C., Snead, E., Zych, J., "The Nexus Federated Collaboration Environment: A Final Report in Support of the WMD-T Joint Intelligence Preparation of the Operational Environment Strategic Multilayer Assessment Project," Office of the Secretary of Defense, Director of Defense Research and Engineering, Rapid Reaction Technology Office Strategic Multilayer Assessment Director, 2008.

[2] The ideas on "weak ties" are based on Mark Granovetter's groundbreaking paper, "The Strength of Weak Ties," American Journal of Sociology, Vol. 78, Issue 6, May 1973. See also Barabasi, A.-L. *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*. New York: Plume, 2003; and Watts, D. J. *Six Degrees*: *The Science of a Connected Age. New York*, W.W. Norton, 2003. Network theory is an important component of the social science tools discussed throughout the WMD-T JIPOE study. For other points about the perceived utility of social networking and weak ties included in A-Space, the Intelligence Community's new collaboration and social networking capability see: http://en.wikipedia.org/wiki/US_intelligence_community_A-Space. A-Space was formally implemented on 22 September 2008 on the Joint Worldwide Intelligence Communications System (JWICS).

[3] For a general primer on Business Process Management, see the *Wikipedia* entry at: http://en.wikipedia.org/wiki/Business_Process_Management.

[4] Hunt, Snead and Zych's NFCE Report discuss relevant issues of security and risk relative to federated collaboration environments.

[5] Pierce, T. "Flexible Distributed Control," *NDIA Disruptive Technologies Conference*, 4 September 2008

[6] These ideas emerged from a discussion with Major Nick Hague, USAFA, and Terry Pierce on 15 July 2008. Pierce holds the private documents from this meeting in his personal collection.

[7] Tapscott, D. and Williams, A., *Wikinomics: How Mass Collaboration Changes Everything,* Portfolio Penguin Group, New York, 2006, p. 1.

[8] Hiles, J., "White Paper Comments to Terry Pierce," July 2008. Pierce holds in his personal files. Hiles' examples of direct and effortless connection to knowledge are looking at a good map or watching an engaging movie. Hiles' examples of slow and laborious links to external knowledge are interpreting a spread sheet or reading a field manual.

[9] Pierce, T., et. al., discussion on C2 gap layer, NPS meeting, 12 August 2008.

[10] These C2 tenets are collectively called the "Willard C2 Wheel," coined by Admiral Robert "Rat" Willard, Commander of the Pacific Fleet.

[11] USMC, Command and Control, MCDP 6, October 1996, p. 52

[12] MCDP 6 Command and Control, USMC, 4 October 1996, p. 92

[13] Clay Shirky, Here Comes Everybody: The Power of Organizing Without Organizations, Penguin Press, 2008, p. 20; Also see J.D. Stanley, Digital Swarming: The Next model for Distributed Collaboration and Decision Making, Cisco Public Sector Practice, Cisco Internet Business Solutions Group, August 2008, p. 2

[14] Clay Shirky, pp. 96-98, 249; Publishing vs. Filtering is one of the big translation insights from Shirky's book

[15] Tapscott and Williams, op.cit.

[16] NDP 6, Naval Command and Control, 19 May 1995, p. 6

[17] NDP 6, Naval Command and Control, 19 May 1995, p. 51

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[18] NDP 6, Naval Command and Control, 19 May 1995, p. 9
[19] NDP 6, Naval Command and Control, 19 May 1995, p. 17
[20] NDP 6, Naval Command and Control, 19 May 1995, p. 19
[21] NDP 6, Naval Command and Control, 19 May 1995, pp. 22-23
[22] NDP 6, Naval Command and Control, 19 May 1995, p. 10
[23] NDP 6, Naval Command and Control, 19 May 1995, p. 42
[24] NDP 6, *Naval Command and Control*, 19 May 1995, p. 10
[25] NDP 6, *Naval Command and Control*, 19 May 1995, p. 32
[26] NDP 6, *Naval Command and Control*, 19 May 1995, p. 66
[27] NDP 6, *Naval Command and Control*, 19 May 1995, p. 66
[28] See Art Fritzon, Lloyd W. Howell Jr., Dov S. Zakheim , *Military of Millennials*, Resilience Report, Booz Allen Hamilton, 10 March 2008. The paper discusses the Millennium Generation Efforts in Social Networking.
[29] Paul Baran, "On Distributed Communications: Introduction to Distributed Communications Network," RAND, August 1964. Paul Baran argues that distributed structure offers the best survivability. Also see http://images.google.com/imgres?imgurl=http://personalpages.manchester.ac.uk/staff/m.dodge/cybergeography/atlas/baran_nets_large.gif&imgrefurl=http://personalpages.manchester.ac.uk/staff/m.dodge/cybergeography/atlas/historical.html&h=415&w=554&sz=19&hl=en&start=1&tbnid=yymRkkXrCdwXjM:&tbnh=100&tbnw=133&prev=/images%3Fq%3Ddistributed%2Bnetworks%26gbv%3D2%26hl%3Den%26sa%3DG
[30] Mike Tibodeau, Cisco Systems Network Architectural Engineer, provided these inputs on explaining the Mission Fabric and the blending of OSI layers (7-1).
[31] Note that these layers refer to the OSI 7-layer model from figure 2.
[32] Mike Tibodeau inputs
[33] Mike Tibodeau inputs, continued.
[34] Hunt, Snead, and Zych, op. cit.

4.22. Epilogue (Jennifer O’Connor)

Author: Jennifer O’Connor
Organization: Science and Technology Directorate, Department of Homeland Security
Contact Information: Jennifer.O'Connor@dhs.gov

To speak of “forecasting” devastating consequences of “rare events” seems to treat “rare events” not as a label we attach to the convergence of various unusual contingencies, but as the culmination of an identifiable pattern of precursors which develop and grow in predictable ways from different issues, at different times, and under different conditions. The idea of “forecasting rare events” suggests that we have access to a framework which allows us to isolate definite precursors of such events, whether causal or symptomatic, enabling us to speak of incongruities within this framework as “technical surprise” or even “black swans”. The notion of forecastable rare events counsels an attitude of vigilance towards rare events-in-the-making, for we ignore precursor signs at our peril.

But perhaps the concept of “forecastable rare events” is an oxymoron. We must ask if the framework behind this idea is justifiable. Perhaps “rare events” are nothing more than movements in culture, politics, science, and technology that accumulate or combine to create stochastically expected but practically unpredictable tragic consequences. From this perspective, to speak in terms of “forecasting” is to confuse historical antecedents with generative causes as a result of a natural human tendency to create coherent narratives explaining “what happened”. This stance toward “forecasting rare events” justifies an attitude of complacency because “nothing can be done.”

This epilogue like the papers in this volume takes the more optimistic “something can be done” view. Its goal is to provide a general framework and suggest a set of avenues for thinking productively about rare-events-in-the-making. To this end, I shall seek to summarize this compendium’s contributions to resolving the complexities of rare event forecasting, to stimulate thought about other potential remedies, and to provide a context for further discussion. I shall not, however, articulate a final position. Much needs to be learned before this is possible.

The best anticipatory approach to mitigating the harms associated with catastrophic “rare events” may focus less on enhancing our ability to forecast such events and more on strategies aimed at preventing rare event harms from materializing, thus mediating the two opposing attitudes listed above. From this perspective identifying and recording elements associated with and preceding “rare events,” including terrorist attacks and other catastrophes rooted in human volition, is important. But its importance is not because the information will allow us to pinpoint the time and place of a catastrophic event but rather as a signal that efforts to prevent a catastrophe must be increased, and as information that will allow us to more effectively intervene in a stream of events that might otherwise, although not inevitably, lead to a catastrophe.

What this approach and the forecasting approach have in common is that each is rooted in the belief that we can identify patterns and other signs of rare-events-in-the-making. Thus improvements in forecasting tools will not only allow for more effective prevention strategies, but can also highlight matters currently overlooked in both forecasting and interdiction models and indicate which scientific and technical problem-solving tools are needed to secure the highest payoffs. There are also synergies going in the opposite direction. By noting the effects of different interdiction strategies, forecasters will be able to better sort out variables of likely importance to their models, a capacity that can be further advanced if some interventions are undertaken with the goals in mind of testing forecast hypotheses and/or enabling better forecast models.

As Ackerman notes, effective forecasting requires information sharing, the collaboration of scientists and practitioners and automated tools that aid in information collection, assembly, integration, and analysis. The need for these elements is a recurring theme in the articles in this compendium, including those that seek inductively to remedy deficiencies in rare event forecasting. There is, unfortunately, also a consensus that these elements, although few in number, are, as a general matter, lacking. A framework based wholly upon an inductive approach to identification of already known and suspected rare events leaves out an entire path of forecasting. Noting this, Ackerman advocates integrating approaches that are deductively (and futuristically) based with the inductive approaches. This combined approach is reflected in the articles making up the Remedies section of the compendium.

Remedies for dealing with the complexities of "rare events forecasting" must confront the problem of the surfeit of information available to an analyst. While in principle more information is better than less information, an excess of information may allow crucial facts to "hide in plain sight." As Fenstermacher and Grauer point out, by definition "rare events" pose a low signal to noise ratio problem. Popp and Canna echo this concern and emphasize the need to make both front-end and back-end approaches to rare event forecast analyses more manageable. They suggest that this can be done by automatically culling large amounts of data so that, without losing important information, the data presented to the analyst can be limited and the signal to noise ratio improved. Complementing this approach are tools that are being or have been developed to provide a scientific foundation for strong analytic reasoning – force multipliers for human intellect if you may.

If data assembly and the capacity to more rationally evaluate evidence were the only barriers to forecasting rare-events, the path to remediating current deficiencies would be clear. Building on and extending current efforts should allow us to provide policy makers and responders the information they need to avoid rare catastrophes. But as the authors of the articles in this volume indicate, this is not enough. First, even if we have adequate data, there is, as Kuznar et al note, little empirical statistical research on predicting catastrophic rare events, although what exists suggests that some widespread intuitions, such as the idea that state sponsorship and specific religious motives relate to WMD terrorism, appear wrong. Other promising observations, such as an apparent relationship between a group's willingness to use WMDs and the number of connections it has with other violent groups must, despite some preliminary empirical confirmation, be regarded as hypotheses in need of further testing rather than as established fact. A similar judgment must be made of Beinenstock and Toman's intriguing article. They describe an empirical approach known as social network analysis which has allowed researchers to recognize *a priori* perturbations in a social network that can be linked over time to innovation and the gathering of the talent and materials needed to create a "rare event." There is, however, still much to be done to bring these ideas from general observations of patterns to specific indicators of impending violence. Other modeling approaches (early-warning indicators, dynamical systems, Markov models, etc.) may also have value in their ability to identify indicators that challenge conventional wisdom and to unmask biases that inhibit foresight of "rare-events-in-the-making." But their utility for these purposes remains to be proven.

GIGO (garbage in garbage out) remains, however, the order of the day. Complex mathematical models are only as good as the information available to be modeled or reviewed. Other inferential approaches, integrating deduction and abduction are necessary. Attention to contexts is also important. If we can find the "swamp" from which actors might arise, application of gaming, automated behavior analysis, scenario comparison, decision theory, complexity-based reasoning, and red teaming all can become more detailed with concomitant gains in what we learn from them.

Automation coupled with modeling holds great promise. Aided by these resources, operational assets can better focus the collection of information (most of which is available in the open source – just not in English, not in the US, and not on-line). As the speed of alternatives generation increases and the process becomes more dynamic, problem-spaces can be more thoroughly searched. Human analytical enhancements (ACH, Quandrant Crunching, Key Assumption Checks, etc.) combined with information extraction; content analysis, modeling and gaming tools allow analysts and policy makers to get "left of the boom." But deciding on the most effective way to proceed poses a chicken and egg argument of sorts. Does one recognize the precursors to something infrequently occurring in the past or does one work forward with as open a mind as possible to think through how "rare-events" might come about. Or, perhaps "cures" just happen accidently (such as with the discovery of the small pox vaccine) and it is up to the "watchers" to catch this process and harness it to create inoculations. As one author notes, we can often learn as much from what does not happen as from what does. But as Arthur Conan Doyle noted, and behavioral science research later confirmed, people find it easy to overlook the messages sent by dogs that don't bark.

Even being able to determine the precursors to catastrophic rare events will not, however, do everything we need to do. The signal must be noted. Yet some empirical evidence suggests that the first people who notice low intensity signals are only weakly or indirectly tied to networks that will utilize that information. The problems this poses are obvious. The ability to get an early detector's information noticed and disseminated across a network is essential to effective utilization, and when it comes to countering planned catastrophes timeliness is paramount. A prevention network has to know there is a need for action as well as be capable of taking action against the "rare-event" threat – QUICKLY. The final technical article in the Remedies section presents a way forward. It suggests that a Federated Distributed Control (FDC) could serve as the substrate upon which adaptation, self-organization, co-evolution and transformation can occur. In this connection, recent empirical research suggests that when it comes to hard problems, latticed networks most quickly reach a workable solution, primarily because they do what many of the authors in this section suggest – search the problem space long enough to find or create novel problem solutions.

The articles in this compendium add complexity and depth to the question of whether catastrophic "rare events" can be forecast, and at the same time suggest means by which we can observe more astutely contemporary forecasting trends. There are, however, no easy ways for the necessary and sufficient preconditions of a catastrophic "rare event" to be isolated. Even if we knew more, complexities caused by masses of information, low signal to noise ratios and surface similarities between diagnostic and non-diagnostic information would pose major problems. (There are many potentially confounding dynamics which must be considered: individual biases; accuracy of statistics reported by unstable regimes; and the ability of terrorists to change tactics on the fly, to name only three). Innovations in predicting rare events are needed. Attention to data quality and improvements in how data is processed and supplied to analysts is important, as is the development of models and tools to help analysts in evaluating available information. The development and validation of theories about rare event precursors and their dynamics can be foundational. Many of the tools and methodologies discussed herein aim at remedying current deficiencies in these and other areas. Indeed, simply by laying out the issues one comes closer to solving a problem. The strategy of inoculating against "rare events" holds special promise, for it allows us to mediate a path between the view that all that is needed to anticipate rare catastrophes is sufficient vigilance and a complacency born of the feeling that when events are sufficiently infrequent nothing in the way of forecasting is possible. Taking this less traveled path intermediate allows us to raise important questions in new areas, and moves us away from poorly tested generalizations based on the past experience and future-oriented alarmist projections.

Appendix A. Tabletop Exercise (TTX) on Bio-Terrorism

Exercise Overview[1]

The Joint Intelligence Preparation of the Operational Environment (JIPOE) Tabletop Exercise (TTX) was held 9-11 June 2008 in Chantilly, Virginia. The exercise was planned and executed by the Office of the Director of National Intelligence (ODNI) with support from SAIC and MITRE. Nearly 60 participants were drawn from several offices, agencies and departments within the US Government as well as from non-government organizations. The objectives of the JIPOE TTX were to:

- test and evaluate proposed JIPOE methodologies to anticipate the WMD-Terrorist (WMD-T) threat for sparse or missing evidence cases,
- assess how well the JIPOE Nexus Federated Collaboration Environment (see Section 4.21) and associated tactics, techniques and procedures work in handling the WMD-T problem set,
- capture JIPOE process requirements (data, resources, etc.) and
- assess interagency coordination.

The JIPOE TTX was designed to assess analytic methodologies by simulating a terrorist plot to carry out a biological attack. The TTX scenario was developed jointly by MITRE and SAIC. The exercise involved three moves played out by three groups:

- The JIPOE Team (about 25 total) was recruited to provide a wide range of operations, intelligence collection and analysis, bio-terrorism and interagency representation and experience. The team was split into three groups to ensure that the team would produce an adequate set of differing hypotheses and to simulate interagency coordination and collaboration.
- The Request for Information (RFI) Team (about 15 total) provided subject matter expertise (SME) support not available on the JIPOE Team and also examined RFI responses for accuracy and appropriateness.
- The Control Team managed the overall conduct of the game to ensure the game objectives were achieved. Additionally, Control managed the flow of RFIs.

The exercise began with "commander's guidance" and intelligence information to set the stage for the bio-terrorism plot. The JIPOE Team was asked to apply the techniques of Analysis of Competing Hypotheses (ACH) and Social Network Analysis (SNA) to help define and categorize the threat. To add realism, the team was forced to deal with several "red herring" inputs (accurate but irrelevant intelligence data) throughout the exercise. During move one, the three analysis groups examined the initial information provided, began developing hypotheses and requested additional information via the RFI process. The groups then came together in a plenary session to synthesize their hypotheses and down-select the overall number of hypotheses.

For move two, the JIPOE Team was provided additional intelligence information from Control and the timeline was advanced about six months. The JIPOE Team used the additional information and the RFI process to further refine their hypotheses. At the end of the exercise the JIPOE Teams prepared a briefing to participants representing members of the National Security Council. All TTX players then participated in a "hot wash" session where the TTX participants suggested ways to refine and improve the analysis process.

Following is a summary of the main insights and implications produced by the exercise.

- **The JIPOE Team must be trained, balanced and multidisciplinary.** The membership should be drawn from all parts of the Intelligence Community, and the representatives should generally be senior analysts and technical specialists with reachback into their organizations.
- **Analysis should utilize and synthesize a combination of top-down contextual strategic assessments and bottom-up evidence based analysis.** In an operating environment well upstream from a terrorist incident, it is a significant challenge to generate named areas of interest (NAIs) and likely terrorist courses of action (COAs), as well as tracking and refining COAs based on intelligence and current analysis. The analytical process must therefore emphasize continual iteration where COAs and NAIs are constantly evaluated and adjusted against on-going collections and analysis.
- **Analysis must take advantage of hypothesis-generation tools and aids.** This could include red teaming, brainstorming and identification of Red techniques, tactics and procedures (TTPs). New, as yet undeveloped software may be necessary, such as a package that allows for on-the-fly social network analysis as well as a tool that enables the community to generate and "stack" timelines deemed important.
- **Social Network Analysis must be better integrated with intelligence collecting techniques to maximize SNA's value.** While many intelligence analysts are familiar with first order social network analysis, there is less familiarity with the type of SNA practiced in the academic community. As such, an effective analytic cell would need to incorporate a fully trained social network analyst with a background in intelligence analysis and capable of guiding cell members in the conduct of SNA.
- **The JIPOE process requires focused collection strategies coupled with analysis that drives collection and identification of warning indicators.** In a sparse data case the cell cannot rely solely on on-going collections efforts and/or data and analyses passed to it from the federated communities of interest, but rather must work closely with collection to design creative collection strategies that stand a good chance of uncovering data directly relevant to the competing hypotheses.
- **Data collection and analysis focused on bio-terrorism face unique challenges.** The experience in the TTX suggests that much work needs to be done to expand the body of knowledge regarding bio-terrorism; especially if the focus is both global and "left of boom." It is important to note that the capabilities to produce and deploy biological agents are highly globalized and "dual use" in nature. The characteristics of potential biological weapons make the establishment of specific geographical named areas of interest for key elements of the bio R&D process very difficult; particularly left of boom.
- **A clear delineation of what is known, inferred, believed and unknown in briefing COAs to senior leaders is critical for establishing a foundation for recommended actions.** It is particularly important that in a sparse data case analysis that there be a clear delineation in briefings to senior leaders of what is assumed, what is known and unknown, inferred details and beliefs.

Discussion

ACH: To structure data, each of the three analysis groups made use of ACH and the Palo Alto Research Center's (PARC) version of ACH software. There was nearly unanimous agreement among the three groups that the ACH methodology was useful in allowing the teams to organize their thoughts, document links between actors and events and to focus on a broad range of potential threats and targets. However, the difficulty of fully grasping the ACH methodology (as well as mastering the ACH software) caused the players to either abandon use of the software and attempt to use ACH via other means, or to cease using the ACH methodology entirely and fall back on the methods more familiar to them. Group 1 at one point resorted to “red teaming” (or thinking about the plot from the perspective of the scenario’s terrorist group) and ceased its use of ACH and evidence based analysis to develop their case. Group 2 also commented that ACH seemed like a good tool to help conduct an analysis, but that in a data sparse environment there simply wasn’t enough evidence to use it effectively. Without a clear method to structure data, the group became frustrated that it could not narrow down the number of possibilities regarding the threat. By the second day of the exercise this group was still essentially unclear as to how to best use ACH. Group 3 was not able to effectively use ACH given their inexperience with the tool, but did report that it felt ACH had the potential to be useful in analyzing the leadership structure of a terrorist group if the team had the necessary training and familiarization with the concept and tool. Indeed, Group 2 attempted to use ACH to identify the most likely terrorist leader, although it did so by inputting their conclusions (rather than raw data) into the tool.

Hypothesis Updating: A key element in analyzing a sparse data case is updating and refining hypotheses in light of new or re-evaluated data. In the exercise, new data was collected both via RFIs and information “drops”. This simulated both on-going and analysis-cell-directed intelligence collection over a period of months. Each analysis group utilized to some extent the updated data to refine its current hypotheses and redirect and refocus RFIs. This resulted in shifts in focus on the geographic areas investigated, the potential biological agents that might be employed by a terrorist cell, and which of the various cells and social networks mapped out were most likely to have the intent and capability to conduct the attack. The group that retained the use of ACH in moves two and three incorporated the additional intelligence into the ACH software as potentially discriminating data points. The groups that had de-emphasized the use of the ACH software continued to evaluate each data point via the method suggested by ACH, but tabulated and incorporated the data using more traditional methods such as a white board. In updating hypotheses, it became increasingly clear that the key issue was the nature of hypotheses being evaluated. The more specific the hypotheses, the easier the process of updating and refining based on new data. One community struggled to discriminate between their competing hypotheses because all those under consideration were very broad and strategic. Much of the incoming intelligence was rated as unimportant because it did not tell the analysts anything regarding eliminating the hypotheses under consideration. Additionally, the players appeared to feel that the amount of information swamped ACH. Teams struggled to structure their discussions when faced with grading dozens of new data points against up to ten hypotheses. While a real-world analysis cell would likely have more time available than the TTX provided, evaluating and comparing dozens of discrete items against multiple hypotheses presents an analytical challenge that may not necessarily be alleviated simply by adding more time. Finally, the groups tended to exhibit “anchoring”; that is, they tended to fix upon initially-generated hypotheses and resist re-evaluating them or eliminating them in light of additional data. Because a sparse data, “left of boom” scenario is often very ambiguous, much of the initial intelligence appeared relevant to the communities’ problem set. As a result, groups continued to fixate on red herrings even when subsequent evidence pointed them in a different direction. This resistance to scrapping certain hypotheses, though quite understandable, may have hindered the overall analysis of the problem.

Outbrief: The final element in the sparse data case analytical effort involved the JIPOE Team merging to present a threat classification and COA analysis to senior level policy makers. The team split into two groups and, in that configuration, presented two competing hypotheses to the policy makers. The first was essentially a null hypothesis assessing that the current information on the biological terrorism plot was too limited to prompt direct action. This team recommended additional collection efforts to clarify the situation and monitor targets of interest. The second hypothesis identified several potential terrorist cells with the means and motive to conduct a biological attack. The potential terrorist cells were evaluated based on the level of threat they might pose, and prioritized as targets for national action based on this threat classification. This team recommended actions against each that combined additional collections with options for direct and indirect action to disrupt the cells' activities; however, the team did not recommend any specific actions to the policy makers.

Measures of Success: The JIPOE Teams were successful to varying degrees, such as in applying analytical tools like ACH and SNA and their own inherent skills to narrow down the sparse data problem set presented to them, as well as in focusing future collections and analysis on what they believed to be the greatest threats to US interests. It should be noted that each of the three analysis groups uncovered some important elements of the overall plot. In some cases, the groups remained focused on red herring activities and social networks or on groups conducting illicit activities otherwise unrelated to the biological attack plot. Finally, the JIPOE Team was not able to discern and piece together key elements of the plot with a level of fidelity sufficient to recommend any action other than continued monitoring of the situation. Though the intelligence information "well left of boom" will likely be ambiguous at best, the limited progress towards unraveling the plot suggests more work needs to be done to develop a process that can be institutionally and effectively deployed.

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[1] This Appendix is based on the JIPOE Tabletop Exercise Final Report 27 June 2008, FOUO.

Appendix B. Pearl Harbor Estimate (Harold Ford)

Harold Ford, The Primary Purpose of National Estimating, Defense Intelligence College, 1989 – is referenced numerous times throughout this white paper. It is available in pdf format at http://www.dni.gov/nic/PDF_GIF_anal_meth/tradecraft/purpose_of_estimating.pdf

This article was published in conjunction with the 50th anniversary of the Japanese attack on Pearl Harbor. It is part of an award-winning unclassified monograph, "The Purposes and Problems of National Intelligence Estimating, " published in 1989 by the Defense Intelligence College.

The article is written as fictionalized excerpts from Special National Intelligence Estimate (SNIE) 10-41 of 4 December 1941, entitled "The Likelihood of Japanese Military Attack. "

Appendix C. Acronyms

Organizations:

AFRL	Air Force Research Laboratory
DDR&E	Director, Defense Research and Engineering (in OSD)
DHS	Department of Homeland Security
DoD	Department of Defense
DTI	Directed Technologies, Inc.
DTRA	Defense Threat Reduction Agency
GMU	George Mason University
IDA	Institute for Defense Analysis
IPFW	Indiana University-Purdue University Fort Wayne
JS	Joint Staff
ODNI	Office of the Director of National Intelligence
NSI	National Security Innovations, Inc.
OSD	Office of Secretary of Defense
PAL	Pherson Associates, LLC
PNNL	Pacific Northwest National Laboratory (Department of Energy)
RRTO	Rapid Reaction Technology Office (OSD/DDR&E)
SAE	Security Analysis Enterprises
SAIC	Science Applications International Corporation
SecDef	Secretary of Defense
SOCOM	Special Operations Command
START	Study of Terrorism and the Responses to Terrorism (START), Center at University of Maryland
SUNY	State University of New York
TAS	Trinity Applied Strategies Corporation
U Conn	University of Connecticut
U MD	University of Maryland
USAFA	US Air Force Academy
USG	US Government

Other Acronyms:

4GW	Fourth Generation Warfare
ABA	Automated Behavior Analysis
ABM	Agent-Based Modeling
ABS	anticipatory black swan (see also TBS)
ACH	Analysis of Competing Hypotheses
AI	Artificial Intelligence
AP	Adaptive Planning
APEX	Adaptive Planning and Execution System
BACH	Bayesian ACH (Bayesian Analysis of Competing Hypotheses)
BN	Bayesian Net

BPMS	Business Process Management Suite
C2	Command and Control
CAC	Common Access Card
CAS	Complex Adaptive Systems
CBRN	Chemical, Biological, Radiological, and Nuclear
COA	Course of Action
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
DNA	Deoxyribonucleic acid, a nucleic acid that contains genetic instructions
EEG	Electroencephalography, measurement of electrical activity produced by the brain
EKG	Electrocardiogram (German Elektrokardiogramm),. measurement of electrical activity of the heart
FDC	Flexible Distributed Control (FDC)
GLASS	Gallup Leading Assessment of State Stability
GTD	Global Terrorism Database (START, U MD)
HMM	Hidden Markov Modeling
HRAF	Human Relations Area Files (Yale University)
HUMINT	Human Intelligence
I's (3)	Information, Interrogation and Instrumentation
I&W	Indication and Warning
IC	Intelligence Community
IG	Information Gain
IP	Internet Protocol
IT	Information Technology
IW	Irregular Warfare
JIPOE	Joint Intelligence Preparation of the Operational Environment
JPEC	Joint Planning and Execution Community
KESALT	Knowledge, Experience, Skills, Access, Links, and Training
LE	Law Enforcement
MANET	Mobile Ad hoc NETwork
NAI	Named Area of Interest (may or may not be geographical)
NFCE	Nexus Federated Collaboration Environment
NGO	Non-Governmental Organization
OCM	Outline of Cultural Materials
OPSEC	Operational Security
OR	Operations Research
OSINT	Open Source Intelligence
POLRAD	Politically Radical – Gallup Model
Q/CSS	Quantitative/Computational Social Science
RFI	Request for Information
SD	System Dynamics
SE	Search-Evaluation (Matrix) in decision analysis
SMA	Strategic Multilayer Assessment

SME	Subject Matter Expert
SNA	Social Network Analysis
SNIE	Special National Intelligence Estimate (see Appendix B)
SPS	Social Prosthetic Systems
SVM	Support Vector Machine
SVMR	Support Vector Machine Regression
TBS	True Black Swan (see also ABS)
TTPs	Tactics, Techniques, and Procedures
TTX	Table Top Exercise
VNSA	Violent Non-State Actor
WMD	Weapons of Mass Destruction
WMD-T	WMD-Terrorism