2006 CCRTS

Identifying Potential Implications of Technologies on Military and Security Operations

C-120

Mr. Robert N Webb
Co-authors:
Dr. Leonard Goodman
LCdr Brian Staples
Mr. Steven Hughes

Directorate of Science and Technology Policy
Director General R&D Programs
Defence R&D Canada
Department of National Defence
Ottawa, Ontario
K1A 0K2

Telephone: 613-995-6480
Fax: 613-996-5177

E-mail: robert.webb@drdc-rddc.gc.ca

ABSTRACT

Identifying and assessing the potential implications of emerging, disruptive and surprise technologies on military planning and security operations, linking them with future military and security concepts is highly complex. Technology surprise occurs through rapidly emerging technologies and the use of commercial technologies in military and security operations and by adversaries. Predicting the use of traditional, novel or the combination of these technologies in both asymmetric warfare and public security has not yet been solved.

The use of war game scenarios has been suggested, but the resources to carry this out are thought to be too extensive for just one or two nations to fulfill. The writing of future operational scenarios have been also suggested, since war-fighting / peacekeeping capabilities in the future might be predicted by setting a future geopolitical/environmental context, but this requires extensive knowledge in many interdisciplinary fields that might be beyond most forces individual capacity to mount. A full cooperative effort by allies is considered the best way ahead. The challenge is to assess the potential implications of these technologies on military and security operations, linking them with future military concepts. The military needs to be involved in terms of "effects" or "impacts" not just technologies.

OUTLINE

- INTRODUCTION: THE QUESTION, THE ISSUE AND THE DISCUSSION

- WORK TO DATE OF KEY ORGANIZATIONS
  - *NATO SAS Exploratory Team: Technology Watch*
  - *TTCP JSA*

- WORK OF LEADING COUNTRIES IN THIS AREA
  - *United States*
  - *United Kingdom*
  - *Australia*

- FUTURE SCENARIO DEVELOPMENT
  - *Introduction*
  - *Methods Summary*
  - *Methods that Work Together*

- MODELLING, SIMULATION AND EXPERIMENTATION
  - *Developing Scenarios*

- THE PROPOSED SOLUTION

- Appendices A, B, C and D

INTRODUCTION

Over the past few decades, we have seen the change from the Cold War of intelligence gathering to the current global climate of information available over the Internet that challenges the traditional methods of intelligence gathering. The sheer volume of data and information overwhelms the ability of analysts to produce intelligence from new electronic sources. Recent meetings of the Allies at various workshops run by countries such as the United States, the United Kingdom, Australia and Canada and groups such as NATO Research and Technology Board (RTB) panels and The Technical Cooperation Program (TTCP) Joint Systems and Analysis (JSA) panels have started moving from the traditionally developed technology watch lists to developing a system to obviate technology surprise. Much of this work has stemmed from the low technology surprise of 9/11. The allies are aware that if ever a higher technology surprise was used by those responsible for terror campaigns, the results could be devastating for the developed world countries, and likely disastrous for the developing world.

THE QUESTION

How to identify and assess the potential implications of emerging, disruptive and surprise technologies on military planning and security operations, linking them with future military and security concepts? It's Highly Complex!

THE ISSUE

It is relatively easy to look at the lists compiled by different nations from their Technology Watch efforts, and these lists seem to be very similar. Currently, subject matter experts report through "technology watch" and "horizon scanning" efforts, which often are accompanied by a semi-quantitative analysis using Technology Readiness Level (TRL) ratings.

THE DISCUSSION

Technology surprise occurs through the use of rapidly-emerging and disruptive technologies by adversaries in allied military and security operations. Predicting the use of traditional, novel or the combination of these technologies, in both asymmetric warfare and public security has not yet been solved.

Access to the military for the level of discussion required is often not possible due to security issues (such as the need to know mentality) and it is often difficult to see where the spectrum of all technologies can genuinely make an impact. The challenge is to assess the potential implications of these technologies on military and security operations, linking them with future military concepts. The military needs to be involved in terms of "effects" or "impacts" not just technologies.

The use of war game scenarios – as a replacement or supplement to simple technology watch lists derived by the allies from monitoring emerging, disruptive and surprise technologies – has been suggested in various fora (TTCP JSA, NATO RTB etc), but the resources to carry this out are thought to be too extensive for just one or two nations to fulfill. The writing of future operational scenarios have been also suggested, since warfighting/peacekeeping capabilities in the future might be predicted by setting a future geopolitical/environmental context, but this requires extensive knowledge in many interdisciplinary fields that might be beyond most allied nations individual capacity to mount.

The best way ahead is considered by several of the allies as a full cooperative effort by various organizations such as NATO RTB and TTCP JSA or a multinational effort outside these organizations. Much ground-breaking work is required, and to some extent happening) to move the frontier of this effort forward. This paper looks at some of the methods whereby technology surprise can be avoided and thus prepare the allies for potential future asymmetric threats.

WORK TO DATE OF KEY ORGANIZATIONS

NATO RTB Systems Analysis and Studies Panel, Exploratory Team on the Impact of Disruptive Technologies

The objectives of this task group (TG) leading to a full panel project have the following scope. The group will investigate and share insights on expected technology developments and their predicted impact on military capabilities and consequences on Force and System concept level. The goals of the task group are to collaboratively assess and enhance the knowledge in expected and so-called possibly disruptive technology developments and the consequences for military systems and operations when applied by own or opposing forces.

The current planning that supports the above scope and goals include the following. A key driver in NATO future force planning activities is "developments in technology." Technology watch, assessment and forecast are therefore activities that are vital to all NATO partners. The view on future developments at system and/or concept level is an activity that national defence planners often do themselves by putting the components of technology watch, assessment and forecast together. This effort is mostly done on a national level and not at the NATO level. The results are usually not shared with others. It would be more effective and efficient if information on defence technology watch, assessment and forecast on system concept level would be shared between NATO partners.

The meetings of the Systems Analysis and Studies Panel TG on this topic have shown that a number of nations are prepared to cooperate in this field provided that the cooperation adds significantly to the national effort. Interest has also been expressed by NATO organisations such as Allied Command Transformation (ACT).

Participating members will, where appropriate, exchange on a voluntary basis, studies and results regarding technology watch, assessment and forecast and lists of (planned) work. They will share and further develop insight in technology developments, and conduct workshops (probably with support of war gaming-like exercises) on the usability and impact of new technology developments. Conferences on the results and outcomes of the workshops will be convened and the results will be published. The task group has been formally approved in March 2006, and plans to finish their activities within a period of 3 years.

During the week of January 23, the NATO RTB panel solidified the Terms of Reference (TOR) and the Program of Work (POW) that was defined and elucidated January 2006. The POW outlines the planning for a war-gaming exercise to be held as a pilot study in November 2006. In the construct of the game, individual disruptive technology are formatted onto paper cards as a consolidation of the member Nations' original lists of future disruptive technologies. These are subsequently summarized into Idea of Systems (IoS) cards (as a method of consolidating into themes). There will be upwards of 50-80

individual technology cards, and 10-15 IoS cards. The game structure includes the following players: 1. technology group; 2. technology subgroup; 3. Intelligence/Policy group; 4. Military Group, and 5, Ops Floor consisting of the Red and Blue Forces. In the war game, IoS cards used for played in the war game are distributed through the Technology groups, then on to the Red and Blue Teams. An Analyst Group captures the results of the war game, and will be supported by impartial game coordinator and referee. The game scenario will be borrowed from the NATO School Ogerammergau, and is the well-known Zoran Sea Crisis (this was chosen since it is well recognized and appropriate to trial the game initially). Other scenarios will be utilized at later stages (e.g., 3-block war/non-symmetrical urban environment, terrorist attack, natural disasters). Prior to the formal war game, a pilot war game will be undertaken in November 2006 in order to fine-tune and modify. Deliverables will be a report on the final war game process/exercise, followed by a NATO conference. Charts and explanations from the SAS panel meeting in Germany will be included in the CCRTS meeting of June 2006.

The Technical Collaboration Program (TTCP), JSA Action Group/Technology Panel on Concept Development & Experimentation (CD&E)

Formation of an Action Group (AG) or a Technology Panel (TP) on Concept Development & Experimentation was among the recommendations of a pan-TTCP Workshop (early 2005) in Ottawa, Canada and then Washington, DC. The TTCP technology linkages to CD&E is the basis of the proposal that had JSA create a new panel to champion CD&E within TTCP and to contribute to the S&T linkages with the military CD&E communities of the nations. The JSA-sponsored Workshop on Emerging Disruptive Technologies and the Implications for Defence advanced the view that TTCP should examine the potential of emerging disruptive technologies to inform the early stages of concept development. JSA TP-3 has been exploring emerging concepts and will be holding a workshop on the subject in early 2006.

Finally, the TTCP Deputies have recommended that JSA take on a pan-TTCP role in the coordination of technology watch activities. Therefore, it was decided that a "consensus-building" meeting of national POC would be conducted in September 2005 to further explore the panel's scope and work program.

The September meeting concluded that the exploration of emerging technologies is not sufficiently integrated into the CD process, which may result in limited exploitation of the possibilities enabled by future S&T and inadequate guidance from the CD process for the future S&T program. Consequently, S&T programmes need to be better aligned to support the development of future operational concepts. As part of their consideration, the TTCP group feel it is critical to understand the requirements of the concept development community. The purpose of the new panel (JSA TP 7 "CD&E Sciences) is to champion CD&E within TTCP, alleviate these shortfalls and promote better practices between the S&T and CD&E communities.

Three “Focus Areas” are proposed initially. They are: Science of CD&E - Advancing the understanding and analytical foundations for CD&E; Integration of CD&E within the Defence Enterprise - Fostering the integration of CD&E processes within the overall Defence approach to development, acquisition and delivery of new military capability; and Defence Implications of Future Environment - Establishing connections between concepts for future operations and emerging trends in S&T.

Given that elements of concept development and experimentation can be found within a number of technical panels in the different TTCP Groups, one of the challenges facing TTCP in general and the new Technical Panel on CD&E Sciences in particular will be identifying and, where appropriate, coordinating these activities.

The first formal opportunity to begin this coordination work was the Defence Experimentation Symposium, 28-30 March 2006, in Sydney, Australia. The Technical Panel on CD&E Sciences hosted two workshops at this symposium: the first workshop was on the ontology of CD&E; the second on CD activities in the TTCP nations. The objective was described as “developing a broader understanding of experimentation issues and how it can provide Defence with a capability to investigate and evaluate concepts, capabilities, technologies, tactics and organizations.”

The output of these workshops defined a focus (advancing science and fostering the practice of CD&E in National/International programs) and concepts (S&T informed Concept Development: Emerging and Disruptive Technology; Technology Wargames). Collaborative Activities were defined as: Fostering the integration of CD&E processes (TP-3 &TP-4); NCW Experimentation and NCW Strategic Integration Team.

WORK OF LEADING COUNTRIES IN THIS AREA

United States

Considerable effort is being undertaken in the United States to track technologies globally, which includes the usual technology watch lists, but also includes at least two databases being built to track a) technologies by all countries of interest and b) countries by technologies of interest. One was built to respond to questions from congressional members, the other through the intelligence community.

There was also a report commissioned by the DOD through "Committee on Defense Intelligence Agency (DIA) Technology Forecasts and Reviews, National Research Council" entitled "Avoiding Surprise in an Era of Global Technology Advances" – see appendix A for an abstract. This report through three findings and recommendations pointed to:

The "Need for New Collaboration and Engagement"
Through Finding one, where "a multitude of evolving technologies for which advances are being driven by the nongovernmental, global, scientific and technical communities" was stated; recommendation 1 suggested that the "DIA Technology Warning Division (TWD), together with the related intelligence community components that focus on technology warning, should establish an ongoing collaborative relationship with the scientific and technical communities in the industrial and academic sectors."

The "Need for New Indicators"
Finding two, stated that "New intelligence indicators are likely to be needed to provide technology warning for the diverse spectrum of evolving technologies that are being driven by commercial forces in the global marketplace" and recommended the "DIA TWD, in collaboration with the related intelligence community components that focus on technology warning, should establish, maintain, and systematically analyze a comprehensive array of indicators pertaining to globalization and commercialization of science and technology to complement and focus intelligence collection and analysis."

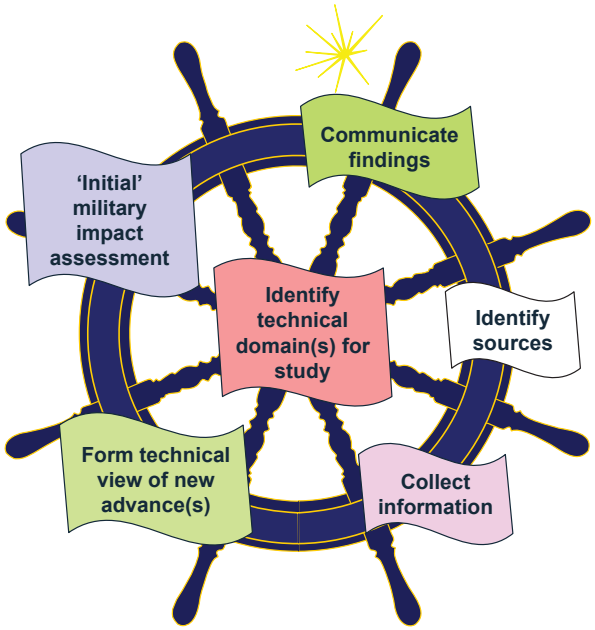
The "Need for Framework Methodology"
Where Finding three contends that "The landscape of potentially important evolving technologies is both vast and diverse. A disciplined approach is thus needed to facilitate optimal allocation of the limited resources available to the technology warning community" and recommends the DIA TWD, in collaboration with the related intelligence community components that focus on technology warning, should adopt a capabilities-based framework within which to identify and assess potential technology-based threats.

The report concluded that the technology warning community is facing unprecedented challenges. It points to the vital role this community has in advising military leadership, and that BLUE force strategies are increasingly dependent upon technology enabled capabilities assembled from building block technologies in which U.S. technological leadership is no longer assured. Globally the same building block technologies are often via the commercial marketplace. The CIA has used a "Futures" model from the University of Utah to assist in their analysis of technologies.

United Kingdom
As part of the NATO SAS ET, the UK presented Methods for Horizon Scanning and Assessment used by DSTL in a recent panel meeting. They described their program of technology watch and outlook. They presented some of their components of Technology Watching, mainly "Identifying which technologies to watch;" but also "In depth studies of areas (in UK principally done in collaboration with academia and industry – range of size projects);" "Understanding the implications (eg using wargames and experimentation);" and "Developing and exploiting them (using technology and capability roadmaps)."

They considered the "Myth of Disruptive Technology" for which they stated the term is somewhat oxymoronic. The UK believes that technology is only disruptive if you have not prepared for it (surprise!), otherwise it is evolutionary. In their research in to the term "Disruption" related to technology, they contend that disruption occurs from four areas: greater speed of introduction (procedural); synergy between technologies; reduced moral/legal/ethical constraints (cultural); and how the technology is used. Therefore a methodology that reduces the element of surprise will reduce the potential for technology to be disruptive. *This needs to be balanced against the need to produce a technology edge for the UK forces*.

UK Basic model for horizon scanning



The UK DSTL has several international collaborations on Technology Outlook NATO RTO SAS Exploratory Team; the TTCP JSA Action Group/Technology Panel on Concept Development & Experimentation (CD&E) for potential collaboration on technology war-gaming, addressing the "so what" question; and a Letter of Intent Nations (UK, Germany France, Sweden, Italy and Spain) which will probably be addressing disruptive aspects of fuel cells and batteries, robotics, information and data fusion and infrared sensors.

They agree there are limitations of current methods to move forward with technology scanning/outlook as these principally use material published on the Internet. There are cultural issues with each assessment. There is lack of understanding of potential synergies between technologies and how the technology could be used. There is also a limited pool of expertise and current lack of industrial input.

Australia
Having Watched Technology and made Lists, How do we understand the REAL implications? The question is: "SO WHAT?"

Problems in various countries include technologies being stove-piped and continue to develop, and the developments are accelerating. At the same time technologies are now beginning to merge, developing along co-operative and co-developmental pathways. Technological expression of these technologies is accelerating and diversifying. There appears to be interface between the current technology paradigm and the new approach in the next decade or so.

To give context to areas of understanding of how technology will evolve and how it will be used: we need to understand "*What's happening*" of the evolving nature of the world; in the culture / societal arena we need to determine "*Why it's happening;*" and we need to understand the nature of the enemy. From a technological view point we need to understand "*What's doing it*" or what are the causes. For a technological perspective, there needs to be the "*Striking (of) a balance between Conventional and Asymmetry.*"

In the area of experimentation we must understand the changing nature of warfare. Are Conventional Operations STILL valid? Can Asymmetry cover all military contingencies? Can we test the proportional relationship between the differing systems? Can we explore the evolutionary relationship between conventional systems and upgrades with emergent technology? Can we define revolutionary discontinuities?

Australia has been partnering with the United States to assist in their work giving context to areas of how technology will evolve and how it will be used. The work Australia completed in this area found that they would need more resources than available in Australia to continue this work.

FUTURE SCENARIO DEVELOPMENT

Introduction

During his time as Science and Technology Counsellor at the Canadian Embassy in Washington, DC, (1998-2002) the author of this paper was involved in the Millennium Project being organized by Jerome C. Glenn. Much of the initial work by this group included science representatives from the allies. The work continued beyond the Millennium and captured in a work entitled The Futures Research Methods Series.[1]

This work provides a convenient window in to the various methods of futures analysis, some of which, or a combination of several, could provide a link to experimentation for technology outlook. However, there is still much work required to bridge the gap between some of these analysis techniques, through the use of simulation and modeling and then on to experimentation in both the virtual and real world.

This part of the work based its raison d'etre on looking back three decades to when most people would never have believed that by the year 2000, millions of people would simultaneously search key documents from millions of computers in less than one second. It also states that many people might be quite surprised today that in just 25 years, collective intelligence would be dramatically increased. It quoted a recent study by the Millennium Project that found 70% of an international S&T panel believed dramatic increases in collective human-machine intelligence are plausible by 2025. If so, then such collective intelligence could create global participatory feedback mechanisms to make long-range thinking far more common.

A reason to use a range of futures methods today is that the understanding of time is changing such as in the Agricultural Age, where the perception of time tended to be cyclical; the Industrial Age, where the perception of time tended to be more progressive and linear; the Information Age, where the perception of time is more open. Hence, the Futures Project contended that a contemporary focus on forecasting to determine what is possible and desirable, is a far more complex task, requiring a range of methods.

In the same way as is being sought in technology outlook, the futures project states that futures research is likely to make a systemic or fundamental difference over the next 10 to 25 years or more. The Futures Research Methods project contents that futures research does not produce completely accurate or complete descriptions of the future, but they do help show what is possible, illuminate policy choices, identify and evaluate alternative actions, and, at least to some degree, avoid pitfalls and grasp the opportunities of the future.

However, studying the future is an issue due to futures research not being an organized body of assumptions and methods with a more formal academic tradition. It can be thought of as an art in that it is creative and/or as a craft in that it applies knowledge with skill. Normative work is based on norms or values. Hence, normative forecasting addresses the question: what future do we want? What do we want to become?

Exploratory forecasting explores what is possible regardless of what is desirable. This general division of futures work into normative and exploratory can be misleading when applied to methodology. Many techniques can be used for both normative and exploratory forecasting. For a more detailed exposition the reasons to use futures methodology, see appendix B.

Futures methodology can be used to systematically explore, create, and test both possible and desirable futures to improve decisions. Futures research can target simple single scientific disciplines or complex multidiscipline technological issues, in the next five years or twenty five years or more. The further out, particularly in the S&T arena, the less the prediction is likely to be accurate. The outcome of futures studies depends on the method or mixture of methods used. It is also dependant on what simulation and modeling techniques have been developed around various futures methods. Its methods can be highly quantitative or qualitative.

Of the 26 analytical methods, plus the integration of a selection, there are about NNN that could apply in an integrated fashion to technology outlook. These methods are shown as:

> Environmental Scanning, The Delphi technique, The Futures Wheel, Trend Impact Analysis (TIA), The cross-impact method, The Scenarios Method and the Prospective Tool Box, The Systems Perspective (historical method 19C), Decision modeling, Statistical modeling, Technology Sequence Analysis (TSA), “Relevance Tree" an analytic technique, Scenarios and Interactive Scenarios, Participatory Methods, Simulations and Games, Genius Forecasting, Intuition and Vision, Normative Forecasting, Science or Technology Roadmaps, Field Anomaly Relaxation (FAR) , “Text Mining for Technology Foresight,” Agent modeling, The State of the Future Index (SOFI), Full-scale Implementation of SOFI, The Multiple Perspective Concept, A Tool-box for Scenario Planning, and Causal Layered Analysis (CLA).

A number of methods can and have been used in technology outlook such as environmental scanning that has been applied to technology watch consistently – see above regarding the UK approach to technology watch. However, a combination of the integration of methods and the application of simulation and modelling has yet to be developed. Some methods in the above list that might usefully be applied to Technology outlook are described below.

a) The Delphi model has been applied throughout the latter part of the nineteen century, but in some modern applications of Delphi questions relate to the value of independent variables that are used in quantitative simulation models. In this way, a consensus is not required; the extremes can be tested in quantitative models to determine whether or not the difference has any important significance. The primary strength of Delphi is its ability to explore, coolly and objectively, issues that require judgment; a weakness of Delphi is the ease with which questions can be asked for which better techniques exist. At one extreme are questions about the future for which factual answers exist and thus require minimal judgment.

b) In the Futures Wheel, a trend or event is written is the hub, then spokes are drawn from the center and primary impacts or consequences, then secondary impacts of each primary impact form a further ring outside the original ring. This method continues until the implications of a trend occur, from the series of impacts and/or consequences. The method is best used for such requirements as: think through possible impacts of current trends or potential future events; organize thoughts about future events or trends; create forecasts within alternative scenarios; show complex interrelationships; display other futures research; develop multi-concepts; nurture a futures-conscious perspective; and aid in group brainstorming.

c) The cross-impact method is applied analytically to the probabilities of an item in a forecasted set and its potential interactions among the forecasted items. Many events and developments in science and technology are in some way related to other scientic or technological discoveries and developments. It could be argued that unrelated occurrences permit or cause an event and/or development.

d) Scenarios and interactive scenarios: Herman Kahn (1967) defined scenarios as narrative descriptions of the future that focus attention on causal processes and decision points. Scenarios should be interesting enough to make the future look real (rather than virtual), so as to positively affect the decision making of the forecaster. They must therefore be plausible and consistent. However, using interactive scenarios, a cross impact analysis is studied including a forecasting method based on the interaction between future events. The probability of each event is considered independently and provided by the analyst as an alternative. The cells of a Monte Carlo style matrix are filled with judgments about conditional probabilities.

e) Field Anomaly Relaxation (FAR) is Lewin's social field theory[2] to the effect that we all live within 'fields' of interactions with other people and events.

f) Text Mining has been enhanced recently through the use of more sophisticated software such as intelligent search engines that "learn" the requirements of the user. There is no doubt that as this "intelligent" software is further developed, extracting key related information from the Internet and databases will provide key associated and relational links between information sources that will enhance technology forecasting and outlook techniques. An N-dimensional array could then built by creating new subsets of the data on one dimension and crossing lists for given variables (informationally related topics).

g) Agent Modelling relates to very simple systems that can produce complex behaviour (Stephen Wolfram 2002) and systems that are apparently random that may in fact contain Order (again Wolfram in the search for strange attractors that may be present in chaotic systems and in the study of self-organizing systems).

h) The State of the Future Index (SOFI) is a quantitative time series that indicates the changing state of the future and shows whether conditions promise to get better or worse. A description of the method and its first applications appeared in the State of the Future,

2001 and 2002 reports of the Millennium Project of the American Council for the United Nations University. The 2003 report included a third example of the process.

Government agencies and private research organizations involved in futures research construct scenarios. The military have been ramping up their use of this method for predicting alternative pictures of the future. Simulation is frequently used as a foundation for confirming policies based on the outcome of scenarios and their implementation through simulation and/or games, including experimentation. In exploring and evaluating scenarios, simulations can provide an exceptionally useful tool, whether they are used alone or in combination with other research techniques.

Rather than games that implicate emotional behavior, simulations are often used to organize the planning process and to guide the way those participating will be involved. By using the same starting scenario, participants have a common base from which to build. Simulations help to assemble the combined talents and experiences of participants within the process and to focus them sharply on the task.

Among other mapping schemes, futures studies have been divided into three overlapping research dimensions: empirical, interpretive and critical. A fourth emerging perspective is that of action research. Each dimension has different assumptions about the real, about truth, about the role of the subject, about the nature of the universe, and about the nature of the future.

The Causal Layered Analysis **(**CLA) approach as stated by The Futures Research Methods Series, is unique in that it uses all four research dimensions: empirical, interpretive, critical and action research - that is, it contextualizes data (the predictive element of the empirical approach) with the meanings (interpretive) we give them, and then locates these in various historical structures of power/knowledge. This entire process however must be communicative, that is, the categories need to be derived through doing in interaction with the real world of others - how they see, think and create the future.

A way of organizing and comparing the methods is by areas of use, as shown in the following table:

When You Want to:	**Use**
Collect judgments	Genius Delphi Futures Wheel Group meetings Interviews
Forecast time series, and other quantitative measures	Econometrics Trend Impact Analysis Regression analysis Structural Analysis
Understand the linkages	System Dynamics

between events, trends, and actions	Agent Modeling Trend Impact Analysis Cross Impact Analysis Decision Trees Futures Wheel Simulation Modeling Multiple perspective Causal Layered Analysis Field Anomaly Relaxation
Determine a course of action in the presence of uncertainty,	Decision Analysis Road Mapping Technology Sequence Analysis Genius
Portray alternate plausible futures	Scenarios Futures Wheel Simulation Gaming Agent Modeling
Reach an understanding if the future is improving	State of the Future Index
Track changes and assumptions	Environmental scanning Text Mining
Determine system stability	Non linear techniques

MODELING, SIMULATION AND EXPERIMENTATION

The investigation in to writing, modeling and simulating scenarios to cover technology outlook has not been researched in any significant way to date. The most recent frontier in this area is work by the NATO SAS panel on disruptive technologies. Some of this work has been summarized in the section above on this NATO RTB panel. Summarized in this section are a few possible manual and computer methods of developing scenarios that will lead us to a method that could analyze and produce worthwhile intelligence reports on the potential future use of technologies. These will analyze the possible combinations of a range of technologies (both high and low) that, when used in combination could surprise or disrupt the life, culture or events of the future.

Proteus – Protean Critical Thinking Game
At the turn of the millennium, NRO sponsored a research project called Proteus. Insights into different ways of "seeing" things were un-expected outcomes of this research. These "insights" were only metaphorically described. At the Naval Postgraduate School Professor John Hiles stretched, pulled, and examined these metaphors, trying to understand their meaning; their use and how they could be thought. He gave them shape, form and meaning and put them in a context that made sense to end users. He developed definitions. Resulting from testing is the Protean Media. The first setting selected for Protean Media is contemporary Iraq. *The Protean Media may be adapted to many other settings or subjects of interest.*

Protean Media is designed to give players a complex dynamic problem world in which they can learn and try out new ways of thinking and in making decisions. It is designed to expose real-world complexities and unintended consequences, elicit unconventional solutions, and help decision makers overcome cognitive and other biases.

Three characteristics distinguish Protean Media from other games and wargames. Firstly, instead of a zero-sum game with a single well defined, overall goal, the world of this wargame may contain as many conflicting, ambiguous, and hidden goals as there are players. Secondly, insights into future requirements for Intelligence (taken from the late 90's NRO project Proteus) have been transformed into forces that guide, focus, and amplify the classical politico-military forces used in the game; and lastly human facilitators and software combine to weave the multiple perspectives and alternate images of game play into a single narrative that is the subject of after-action review and the explicit take-away for each player.

Protean Media can have 8 or fewer factions. To envision the day, imagine a large room with 8 tables placed in some circular fashion. At each table is a Leader with their Facilitator and 1 or more aides. There is a Leader for each of the 8 factions in the game. Each table will have a laptop on a wireless local network interacting with the "game" laptop. Projected on a large screen with be the map of Iraq, our region of play. With contemporary Iraq as our setting, the 8 factions are: American/coalition; Sadr Shiites; Sistani Shiites; Sunni-Arabs; Sunni-Kurds; Insurgents; Iraqi government; Secular and civil groups such as NGO's and UN-groups.

ZETA and the Zoran Sea Crisis - The NATO school Ogerammergau
ZETA is a multi-criteria decision-making tool that is specifically modified for each scenario. ZETA links effects, actions and resources to analyze predicted outcomes of a selected military course of action at the operational level. It provides feedback on the status of the system under study at the aggregated and actor/element level and the degree of achievement of the operational level military end-state over time. Two scenarios are currently modelled: Virtual NATO Exercise Scenario (Zoran Sea Crisis) and the Farah Province in Afghanistan for MNE4.

GAMMA used to support MNE 4 as decision support tool
GAMMA stands for “Global Aggregated Model for Military Assessment” a decision support tool to assess operational plans (what if / analysis) by exploring action-effect options and consequences (functional view) a framework for a family of models which provides a ‘plug and play’ architecture for the integration of specific models for the assessment in symmetric and asymmetric environments (technical view). GAMMA is used by NATO HQ OA Cells and has been selected to support MNE 4 as decision support tool. ZETA and GAMMA[3]

THE PROPOSED SOLUTION

This paper discussed the state of the art in looking for solutions that could obviate technology surprise through various analytical methods, modeling and simulation techniques, experimentation and scenario development looking out 15 to 30 years. It is likely that software will have to be developed to match a combination of relevant analytical methods. The output of the analytical methods would likely determine what simulation and modeling programs and the experimentation based on the S&M techniques probably built around the card-based techniques (NATO RTB SAS panel).

Questions remain as to if software exists for this type of purpose, and if not what software needs developing. The futures methods described above may work together to produce the best result for technology outlook. Does simulation and modeling software exist for these methods? Further can software simulate the proposed integration of methods? What priority should the allies put on this type of work?

The NATO RTB SAS panel seems to be the furthest ahead in a POW (approved by RTB in March 2006). Currently, the TTCP JSA panel is not as advanced in this area.

Australia, the United States and the United Kingdom individually have made the most progress in this area, but all consider there is benefit in pooling resources to move forward, due to the enormous resources required to move forward. Canada continues to work in this area through the NATO RTB and TTCP JSA panels, and is monitoring the work of individual countries. Other NATO countries are also involved and monitoring work in this area.

This is an unfinished paper by definition, as the state of the art in this field has been and is currently moving ahead in leaps, with pauses to review the status quo by various groups. The fact that there are panels working towards this end in an area of pioneering does give recognition to the fact that the allies believe this is an important area. Not surprising, as to be able to predict the use of multiple converging technologies against any traditional military force is a very strong reason to work in this field.

7 April, 2006
Mr. Robert Webb, Defence R&D Canada, Department of National Defence, Canada
Co-contributors:
Dr. Leonard Goodman, Defence R&D Canada, Department of National Defence, Canada
LCdr Brian Staples, Department of National Defence, Canada
Mr. Steven Hughes, Canadian Forces Experimentation Centre, Department of National Defence, Canada

Reference: 2006 CCRTS Submission #C-120

Note:
Until approved by the Department of National Defence (Canada) as a paper for publishing within the department, the views above of those of the authors.

APPENDIX A
AVOIDING SURPRISE IN AN ERA OF GLOBAL TECHNOLOGY ADVANCES

SUMMARY OF FINDINGS AND RECOMMENDATIONS [4]

Need for New Collaboration and Engagement

Finding 1: There is a multitude of evolving technologies for which advances are being driven by the nongovernmental, global, scientific and technical communities.

The information technology, biotechnology, microtechnology, and nanotechnology families will increasingly provide foundational building blocks for militarily relevant capabilities for RED (adversary) and BLUE (U.S.) forces alike. The fact that significant advances in these technologies will be driven largely by commercial demand—on a global scale—versus military-specific investment suggests the need for the technology warning community to establish a sustained relationship with the nongovernmental scientific and technical community in order to bolster its understanding and anticipation of technology trends.

Recommendation 1: The Defense Intelligence Agency Technology Warning Division, together with the related intelligence community components that focus on technology warning, should establish an ongoing collaborative relationship with the scientific and technical communities in the industrial and academic sectors.

The committee believes that the National Academies, through the National Research Council, provide both a window into these communities and an appropriate institutional mechanism that could assist in this endeavor.

Need for New Indicators

Finding 2: New intelligence indicators are likely to be needed to provide technology warning for the diverse spectrum of evolving technologies that are being driven by commercial forces in the global marketplace.

Traditionally, the United States has assumed that it leads the world in science and technology. This perspective leads the technology warning community to look for indications that external actors are trying to "catch up," or to exploit known technologies in new ways. Projected future trends suggest that it should no longer be automatically assumed that the United States will lead in all relevant technologies. This revised perspective imposes a new burden on the technology warning community, generating the need for it to search in different places and in different ways to be able to warn against technological surprise.

Recommendation 2: The Defense Intelligence Agency Technology Warning Division, in collaboration with the related intelligence community components that focus on technology warning, should establish, maintain, and systematically analyze a comprehensive array of indicators pertaining to globalization and commercialization of science and technology to complement and focus intelligence collection and analysis.

The committee believes that the observables identified in this report provide a useful baseline. However, it acknowledges that the first step in a more disciplined approach in technology warning should be to decompose the broad trends into potential observables more systematically and then to evaluate the utility and applicability of analytic techniques for technology warning already in use in Open Source Intelligence analysis. The committee also acknowledges that since

not all relevant advances will stem from the global commercial open source environment, such an approach should complement but not supplant other collection techniques.

Need for Framework Methodology

Finding 3: The landscape of potentially important evolving technologies is both vast and diverse. A disciplined approach is thus needed to facilitate optimal allocation of the limited resources available to the technology warning community.

While it is relatively easy to create lists of technologies that will have military significance in the coming years, it is harder to identify those specific technologies that are potential game-changers in the hands of U.S. adversaries. The committee reviewed a diverse array of lists of technologies—each prioritized from a different perspective. Some lists focus on potential "disruptive" technologies that could have catastrophic consequences in the hands of adversaries, while others focus on technologies with significant commercial potential that may erode this nation's technological edge. The committee believes that the technology warning community would benefit from a disciplined approach to the identification and prioritization of the evolving technologies that may threaten U.S. military preeminence.

Recommendation 3: The Defense Intelligence Agency Technology Warning Division, in collaboration with the related intelligence community components that focus on technology warning, should adopt a capabilities-based framework within which to identify and assess potential technology- based threats.

The committee believes that a capabilities-based methodology enables a systematic approach to technology warning while reducing the tendency to focus only on advances in discrete technologies. The methodology presented as a prototype in this report was derived from the operational concepts and enablers described in Joint Vision 2020. It is offered as a starting point; the committee acknowledges that additional refinement is needed.

In Conclusion

- The technology warning community, which plays a vital role in advising military leadership, is facing unprecedented challenges. BLUE force strategies are increasingly dependent upon technology enabled capabilities assembled from building block technologies in which U.S. technological leadership is no longer assured. Foreign governments and nonstate actors are gaining access to the same building block technologies—often via the commercial marketplace. The committee applauds the Technology Warning Division's recognition that unprecedented challenges require new approaches and commends the efforts already underway.

APPENDIX B
From The Futures Research Methods Series [5]

TIME

- A reason to use a range of futures methods today is that the understanding of time is changing:
- In the Agricultural Age, the perception of time tended to be cyclical. An important use of forecasting was to predict when each part of the cycle would recur.
- In the Industrial Age, the perception of time tended to be more progressive and linear. An important use of forecasting was to predict how technology will become more efficient.
- In the Information Age, the perception of time is more open. Hence, the contemporary focus on forecasting to determine what is possible and desirable, which is a far more complex task, requiring a range of methods.

Studying the Future

- To study the future is to study potential change - not simply fads, but what is likely to make a systemic or fundamental difference over the next 10 to 25 years or more. Studying the future is not simply economic projections or sociological analysis or technological forecasting, but a multi-disciplinary examination of change in all major areas of life to find the interacting dynamics that are creating the next age.
- Methods of futures research do not produce completely accurate or complete descriptions of the future, but they do help show what is possible, illuminate policy choices, identify and evaluate alternative actions, and, at least to some degree, avoid pitfalls and grasp the opportunities of the future.

How to Study the Future?

- One day, futures research may become an organized body of assumptions and methods with a more formal academic tradition; in the meantime, it can be thought of as an art in that it is creative and/or as a craft in that it applies knowledge with skill.
- Normative work is based on norms or values. Hence, normative forecasting addresses the question: what future do we want? What do we want to become? Exploratory forecasting explores what is possible regardless of what is desirable. This general division of futures work into normative and exploratory can be misleading when applied to methodology. Many techniques can be used for both normative and exploratory forecasting.

APPENDIX C
From The Futures Research Methods Series [6]

Methods That Fit Together

Forecasts may use one and only one of the methods described in this series, but use of these methods in combination often provides efficiency and makes the forecasts more robust. For example:

- Environmental Scanning using Delphi, Text Scanning, and group Participatory Techniques can identify trends;

- Future Wheels can show potential consequences of these trends and future events, and improve the understanding of the trends and potential events;

- with this better understand of the trends and/or events, they can be used in Cross-Impact Analysis to raise the important questions to be addressed in Scenario Construction;

- Scenario assumptions can be tested by Causal Layered Analysis, Multiple Perspectives, Gaming-Simulations, and Roadmapping;

- Trend Impact Analysis (TIA) can be used to provide estimates of the probability of possible future events and these estimates can be obtained through Delphi methods;

- Cross impact tables can be included in a Systems Dynamics Model so that the model would reflect the effects of interacting external events;

- Scenarios can contain quantitative Time Series estimates of variables important to the future world they depict; and

- SOFI used Delphi to identify and weight variables and TIA to find a range of variation of the variable over a ten year time series that comprise the index.

Many combinations are possible. Imagine large matrix with all methods in the CD listed down the right column and repeated across the top row. One could explore a new combination by asking in each cell of this matrix: *How can the methods in the first column create new and improved uses of the methods listed in the top row of the matrix.* A third dimension of the matrix could list new conditions or technologies, such as globalization, nanotechnology, virtual reality, ubiquitous computing, etc. Hence, one cell would pose the question: how could Future Wheels be improved by Delphi in a tele-virtual reality nano-technology environment?

In this section, we explore some of the most potent of these combinations.

Cross-Impact Analysis requires a large number of judgments about conditional probabilities. These judgments can be provided by experts through the use of Delphi methods, focus groups, interviews, or as Godet describes (1993) in the Toolbox. In addition, genius forecasting or participatory processes might be used if the matrix is small. Finally, the analysts might benefit if s/he has a reference scenario to help guide the conditional probability judgments.

Decision Analysis is the analytic study of the validity of contemplated decisions and their intended and unintended consequences. This method usually involves estimation of costs and benefits, consideration of risk and uncertainty, and articulation of a decision principle, such as minimizing downside potential. To the degree that expert judgment is used, Delphi methods may be employed. Estimation of risk and uncertainty may be based on Monte Carlo or other quantitative method of analysis, or judgment.

Regression analysis, future wheels, and econometric models can help establish relationships useful in estimating the consequences of decisions. One or more scenarios may be used to define the assumptions on which the analysis is based.

Decision Analysis Trees, Roadmaps, and future wheels fall within the general classification of decision analysis. This method involves the construction of branching diagrams that illustrate downstream decision points and other consequences that flow from a currently contemplated decision. Inputs used to construct such diagrams can flow from a single expert assessing alternatives, a group at a meeting, a series of interviews, or a more conventional Delphi.

Decision models and structural analysis are multi-attribute models that simulate the decision processes of policymakers, other actors, or consumers in choosing among alternatives that require judgment. If the decision model were designed to simulate a market, the required data could be obtained using conventional market research methods. If the model were designed to simulate a policy choice, interviews with the policymakers themselves or Delphi can be used.

The *Delphi method* is a primary technique for gathering judgments from experts. A Delphi exercise can be enhanced by other methods in several ways:

> experts can be shown a number of time series in a questionnaire, including forecasts prepared by curve-fitting procedures, and asked to assess, in quantitative terms, how future events might impact on the curves;
>
> forecasts presented in these curves can be derived by many different techniques, including regression analysis and simulation modeling;
>
> relevance trees and morphological analysis can assist in defining the questions to be asked; genius forecasting can be used to form the initial questionnaire.

Econometric models are deterministic and based on statistically established historical relationships. Such models are used not only to produce quantitative forecasts but also to estimate the sensitivity of outcomes to any changes in the variables included in the models. Expert judgment collection methods can be used to obtain estimates of the independent variables used in sensitivity analysis. Scenarios can provide the backdrop for econometric analyses and help ensure the internal self-consistency of external assumptions. If a cross-impact matrix of future events were introduced into an econometric analysis, then, through the use of Monte Carlo methods, the new random selection of independent variables. This process produces a range of results of the dependent variables; in the case of technology sequence analysis, the range of dates at which the intermediate technologies or final system will be available solution could become probabilistic rather than deterministic. To accomplish this, simultaneous equations could be solved a large number of times and the results displayed as a range of possibilities. Further, the outcomes could be tested to determine the sensitivity of the outcome to the probabilities of events and their interactions. Similarly, TIA can be used to create forecasts of external variables used in econometric models.

Genius Forecasting benefits from data. Presenting the results of a simulation model or a TIA to an individual who is trying to imagine a desirable future or assess the impacts of a particular series of developments will, hopefully, inform the judgments.

Future Wheels can give just enough structure to foucs the mind without preventing free thinking and leaps of insight in genius forcasing, brainstorming, and focus groups.

Morphological Analysis and Relevance Trees have been improved through the use of expert input. For example, a researcher can form a tentative morphology and perfect the morphology by asking experts in interviews to change the diagram. Often, an individual can form the top levels of a relevance tree but require expert assistance to complete the lower and more detailed levels of the diagram. When such assistance is required, Delphi's or interviews are helpful.

Participatory methods can use scenarios to great advantage. Imagine showing to a group of people a scenario that depicts the consequences of current policies and then asking if the picture that emerges is desirable. An example of the use of both methods can be found in the Millennium Project's Science and Technology Management study in which scenarios—generated in part by Delphi rounds--were presented to a global Delphi panel. The scenarios contained blanks, which the participants were invited to complete. Following the scenarios were policy questions such as: "If you believed this scenario was likely, what actions would you take now?"
<http://www.acunu.org/millennium/st-scenarios-rd2.html>

In a *regression analysis,* the first step is to "specify" the equation; that is to identify the independent variables to be tested in the regression. This step, of course, can be the subject of environmental scanning, Delphi, genius forecasting, a Futures Wheel, or a series of interviews that explore possible chains of causality.

Scenarios can be completely qualitative or largely quantitative. Scenarios are usually presented in sets, differing in terms of their initial boundary conditions. Key measures of the success of a scenario are plausibility, internal self-consistency, ability to make the future more real, and utility in planning. When multiple scenarios are involved consistency must exist among the scenarios. There are a number of techniques that help assure plausibility and self-consistency.

The use of TIA in conjunction with a scenarios study is particularly powerful. Recall that TIA requires identification of a series of events that can deflect historical trends. Many of these events will affect more than one time series and more than one scenario. Internal self-consistency of a scenario is promoted with the use of TIA since, whenever an event appears in a given scenario, it has the same probability. Cross-impact analyses, while more complex in many ways, can serve the same purpose.

The narrative statements often included in a scenario can be given quantitative power if they are derived systematically. Simulation modeling serves this purpose. For example, the Club of Rome's world model established a completely consistent (instructive, but flawed) scenario that could then be tested for the effects of changes in initial assumptions. Similarly, the Millennium Project used a multi-equation model prepared by International Futures to give quantitative backbone to an otherwise purely qualitative scenario. See <http://www.acunu.org/millennium/scenarios/explor-s.html>. For more information about the model used can be found at:
<http://www.du.edu/~bhughes/ifs.html >

Of course, environmental scanning, and expert judgment, collected through Delphi or other such means, is a usual method of obtaining inputs for a scenario. These inputs might include, for example, the "scenario space" to be employed, principal drivers, the time series to be included, the lists of events that can impact on baseline forecasts, and the policies to be tested in the scenarios.

The Millennium Project has also experimented with a computer program for obtaining and accounting for changes in previously prepared scenarios. In this approach a cross impact matrix is created “behind the scenes” to indicate the interaction among statements in the scenario. Then when the user changes an entry the cross impact matrix is brought into play to ask the user how related statements in the scenario might be affected by the change they suggest.

Systems Dynamics models are not completely dependent on statistical relationships, but rather are based, at least in part, on perceptions about the relationships that exist among variables in the model. Therefore, the techniques mentioned earlier for collecting expert judgments all apply. Systems Dynamics models are usually deterministic. They can be made probabilistic by linking the elements of the model to prospective events through cross-impact and trend-impact methods. These methods permit the models to show a range of outcomes and provide the ability to accomplish sensitivity testing to identify which of the expected events are important to the outcome.

Technology Sequence Analysis begins with establishing a network of sequential and interlocking technological or policy developments. Since such networks involve many facets of expertise, interviews with experts have proven productive. In these interviews, experts are asked not only to perfect the network, but also to provide judgments about the time or costs involved in progressing from one step to another. In addition, relevance trees can help structure the exercise.

Trend Impact Analysis adds perceptions to time series forecast about future events that can deflect the trends. The specific judgments required are: specifying the list of events, probabilities of the events vs. time, and impacts of the events, should they occur, on the time series variable under study. All of the techniques mentioned earlier for collecting expert judgment apply here. In addition, while most TIAs have been based on time series methods to establish a "baseline" forecast, the method can use regression analysis or simulation modeling to make this baseline projection.

APPENDIX D

Developing Scenarios – an example from the Royal Military School, Canada

A far future scenario, can futures methods assist as in assessing if and when this scenario "*The Future and Tele-presence?*" will happen?
Imagine being able to control the functions of a humanoid robot simply by thinking about it: http://www.sony.net/SonyInfo/QRIO/top_nf.html. Then combine an intelligent humanoid robot with a network based interface and you could think about what you wanted your tele-robot to do and it could do so - its own intelligence functions compensating whenever there was a network lag or interruption: http://world.honda.com/ASIMO/technology/intelligence.html. Then imagine the feedback from the robot returning directly to your brain: http://www.sciencedaily.com/releases/2004/03/040324071203.htm providing tactile sensation http://motorcortex.huji.ac.il/research.asp#4 as well as visual http://www.mdsupport.org/library/chip.html and auditory information http://www.nidcd.nih.gov/health/hearing/coch.asp. You could therefore 'be there' without ever leaving home. Potentially, if the sensory feedback information were at a sufficiently high resolution, in your mind, you would actually be there. (Regan Reshke – Reshke.RG@forces.gc.ca , RMC, Kingston, Ontario, Canada.)

---

[1] The Futures Research Methods Series By Jerome C. Glenn, Millennium Project (Second Draft, 18 February 2005)
[2] Lewin, Kurt. 1997. *Resolving Social Conflicts and Field Theory In Social Science*. Washington, Dc. American Psychological Association.
[3] MORS Workshop on Agent-Based Models and Other Analytical Tools in Support of Stability Operations. Dr. Uwe Dompke, Dan Eustace and Stephan Leitner in McLean, VA, October 2005.
[4] Committee on Defense Intelligence Agency Technology Forecasts and Reviews, National Research Council ISBN: 0-309-54916-7, 138 pages, 8 1/2 x 11, (2005)
[5] The Futures Research Methods Series By Jerome C. Glenn, Millennium Project (Second Draft, 18 February 2005)
[6] The Futures Research Methods Series By Jerome C. Glenn, Millennium Project (Second Draft, 18 February 2005)