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Commercial Information Technology Possibilities:

Perspectives on its Future Role in Military Operations as Inspired by Visits to Selected Sites

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Executive Summary

There has been a substantial amount of discussion in the DOD community about the availability of commercially funded R&D products capable of supporting on-going and anticipated military operations. Those who doubt the availability of such technological products point to the past necessity of military R&D investment to assure American technological superiority. Pundits who hold that commercial investments are currently producing products relevant to military operations point to the incredible growth of various consumer markets, e.g. electronics, telecommunications and personal computers. This report describes the efforts of the Center for Technology and National Security Policy (CTNSP) to assess the availability of Information Technology to support current and future military operations. In short, we wanted to consider whether there exist technological winners—or keepers—derived from research and development (R&D) investments initiated and sustained by private-sector firms. Based on the case studies derived from this study's purposive sample, we believe strongly that *currently available* technological products can easily be adopted by users and institutions within DOD. Moreover, we assert that these technologies will be able to support future operations effectively.

In support of these assertions, this report describes a number of information technology R&D efforts initiated and funded by private-sector firms. While these products do not arise from DOD investments, they, as well as variants of the underlying technology, are capable of supporting future military operational concepts and addressing anticipated national security challenges. Included in this report are detailed case studies of relevant firms and the results of their R&D efforts, as well as reflections on the process of identifying relevant technologies in the commercial sector.

This report identifies a number of firms producing technologies associated with three categories important to current and future operations:

- Assured information infrastructure availability
- Information retrieval and collection
- Information visualization and knowledge creation

These categories were considered because of their relevance to future operations such as network-centric warfare, asymmetric threats (terrorist and transnational criminal networks), and next-generation information operations. The author used a purposive sampling approach to select eight sites to visit across the nation. The sampling strategy was based on identifying technologies that allowed for *finding, moving, manipulating, and understanding* information. These characteristics are supportive of the aforementioned technology categories.

It is important to note that identifying appropriate technologies capable of fulfilling future needs requires the exploitation of personal contacts to gain insights into the proprietary R&D efforts of a firm. Thus, future efforts to

appropriate commercial technologies will benefit from an improved ability to broker, manage, and maintain professional contacts in acquisition agencies as their staffs change over time. Additionally, DOD needs to develop a more appropriate approach to understanding and the R&D cycle of private firms and to adopting commercial technology. As products continue along the development path, consumers—in this case DOD—increasingly loses the ability to modify the product prior to deployment or marketing. Thus, while this inverse relationship provides cost incentives to delay DOD engagement (i.e., the private firm incurs more of the development costs the further the technology proceeds along the development path) it also results in a decline in DoD ability to influence the design of the product.

Another argument for earlier engagement with industry is that a marketed product is much easier for an adversary to access and exploit. It may be necessary to acquire these technologies earlier in the development pipeline not only to improve U.S. ability to operate, but to reduce an adversary's ability to reduce U.S. operational superiority—especially in the case of potential breakthrough technologies.

Introduction

As portrayed by many in the popular press and academic literature, the information revolution is transforming social structure and dynamics. This will likely manifest itself in the form of additional changes in how institutions operate on a daily basis and pursue objectives. One institution where such IT-inspired changes will likely continue is the U.S. military.

It is anticipated, and in fact desired, that information technologies will serve as a means to further differentiate U.S. forces qualitatively from other military forces, facilitate force projection over substantial distances, and deal with asymmetric threats. At the heart of this expectation is the assumption that the military will be able to exploit *revolutionary* and *evolutionary* developments resulting from commercial sector R&D investment. Implicit in this assumption is a belief that commercial entities working under typical market incentives are in a better position to develop and produce advanced IT products more rapidly than institutions operating under traditional acquisition rules. The integration of such technologies into military operations should allow for improvements in capability and afford a greater opportunity to realize future operational concepts and missions. Of course, it is important to note that moving off-the-shelf technologies into a fully operational combat unit is dependent on factors beyond the R&D process.

This report identifies currently available technological products that can easily be adopted by users and institutions within DOD to effectively support future operations.

Case Study Strategy

What follows in this report are three detailed case studies that describe innovative technologies that may well advance combat concepts. The three detailed cases arose from eight site visits around the United States and are reflective of three categories of technologies that will better enable DOD to address future threats:

- Assured information infrastructure availability
- Information retrieval and collection
- Information visualization and knowledge creation

These categories were considered because of their relevance to future operations such as network-centric warfare, asymmetric threats (terrorist and transnational criminal networks), and next-generation information operations. In support of these case studies, the author made use of a purposive sampling approach to select eight sites to visit across the nation. The sampling strategy was based on identifying technologies that allowed for *finding, moving,*

manipulating, and understanding information, characteristics that are supportive of these three technology categories.

The first category speaks to the necessity of maintaining a flow of information between military actors to assure military operations. The second category relates to the likely existence of many types of data and information in future operations. The ability to gather, access, and store structured and unstructured data will be incredibly important in the operations of a digital-based force structure.

With respect to the third category, it will be increasingly important in a data/information-rich environment to be able to visualize relationships between data elements that may allow for the identification and exploitation of emerging opportunities in a novel threat environment. Moreover, the ability to add value to data—to create information and knowledge that enables decision and the consideration of consequence—is also extremely important to taking advantage of latency in the adversary's observe-orient-decide-act (OODA) loop.

It should be emphasized that these three technology categories applied to only four visits of the eight. (These four visits are in boldface in the chart below.) The other four visits, while consistent with these themes, did not identify low hanging fruit, in that the technologies are not yet products that users can just pick-up or download. Three of the four Commercial IT R&D efforts are characterized by some non-trivial investment on the part of a private firm. However, these firms are awaiting, or rather actively pursuing, additional investment or government brokering to move them to a stage of development that is amenable to acquisition. (One of these three efforts appears as an entry in the appendix of this report.) This effort, associated with the firm BBN, was not included because it was a proof-of-concept effort started at the behest of DOD. While the initial research efforts were fruitful, the creation of a specific product will require subsequent DOD development funding.

Site Visits

Vendor/Firm	Technology Category	Product
BBN	Information Retrieval	Sensor-webs: Java-based networks for networking and fusing varied battlefield sensors
CETP Experiment	Information Retrieval	Video compression and feedback synthesis approach
Eternal Systems	Information Assurance	Eternal, FTORB: Software approach for assuring information system up-time using either CORBA architecture and OS code
Microsoft	Information Retrieval	Scale-free network research in support of network and P2P searches
Pacific Northwest National Laboratory	Information Visualization	Starlight, SPIRE: Environments for the visualization complex relationships and corpus collections
Palo Alto Research Center	Information Visualization	Hyperbolic Tree: A means of structuring data for improved inferencing in support of decisions
Perceptronics	Information Visualization	Metacognitive support level: Variation of structured argumentation tools to support option generation
QL2 Software	Information Retrieval	WebQL: SQL-variant for extracting non-structured information from on-line data sources.

I. Assured Information Infrastructure Availability

Fault Tolerance

It is likely that the future battlefield, as well as increasingly important CONUS-based operations, will be populated with numerous mission-critical computer-based applications, the failure of which could dramatically impact the performance of military and security forces. Thus, operational concepts and technologies based on assured capability, also known as *maximum uptime*, will be important to forces dependent on networking and digital systems. Assured capability will become increasingly important as the pervasiveness of these systems increases. As important, future network or operational architectures will not reduce the importance of achieving maximum uptime.

This section briefly describes the importance of high availability of computational and telecommunications capabilities (information assurance) in military operations and the particular approach of one corporation.

Military Operations and Information Assurance

One of the underlying assumptions about operating in a network-centric environment is availability of a connectivity infrastructure. Many assume that the infrastructure includes not just telecommunications "pipes" through which information moves from one actor or system to another, but also the applications that generate information. The types of applications, e.g. databases or information fusing algorithms or visualization packages, used in battlefield operations vary, but each is essential to assuring successful operational outcomes.

Some type of downtime relative to system performance is a fact of life with computer systems. A system capable of persistent, un interrupted operations is not plausible or possible, and creating complete redundancy across all computer applications is likely prohibitively expensive. One strategy employed by firms and agencies to maximize the uptime of the most critical applications is to assure to recovery from catastrophic server or application failures by storing copies of databases off-site. This approach has the disadvantage of requiring a certain amount of recovery time. The latency between failure and re-instantiation of the system could have substantial impacts on a firm's business or an agency's operations. It is easy to envision how a catastrophic application failure—a failure resulting from a mean time failure or intentional cyber-attack—could cause severe damage to a force's capabilities.

One means of assuring on-going information assurance, inclusive of application performance, is to devise a means of maintaining application uptime. Some attempts at resolving this problem has been to add high-availability code to applications. Unfortunately, these code additions are often extensive and error-prone. Another approach, identified by Eternal Systems, Inc., of Santa Barbara, California, achieves high availability by extending the capabilities of the operating system rather than the applications..

Eternal Systems

Eternal Systems, Inc., is a spin-off from the School of Engineering of the University of California at Santa Barbara and arose as a result of a market need identified by the company's founders Michael Melliar-Smith and Louise Moser. As they define their core competencies, Eternal System's products enable mission-critical environments in enterprise, data center, communications, aerospace/defense, transportation, medical, and industrial automation. The corporate logo contains the slogan, "run reliably forever," a reference to the company's claim to assure high availability and fault tolerant operation.

Implementing high availability and true fault tolerance usually is a costly and time consuming custom operation that requires specialized knowledge and programming skills. Eternal Systems claims to provide the required levels of availability and performance in an inexpensive, easy-to-use, and easy-to-maintain solution that can be quickly configured into clustered environments.

As noted in a white paper provided by Eternal Systems, *Fault Tolerance for Multi-Vendor Defense Systems*, military systems must provide continuous service despite hardware and software faults and the necessity of upgrading hardware and software. Under conditions of warfare, faults will occur frequently because of damage, hostile intrusions, or the use of hardware or software that is rushed into service without adequate testing.

As a general notion, fault tolerance is based on redundancy or replication of hardware or software so that if one replica becomes faulty another is available to provide continuous service. The use of redundant components is a fairly common approach in the design of complex systems. As an example, complex space launch systems such as the space shuttle will only operate if a majority, or quorum, of its primary processing units is operational. The intent is to assure that critical capabilities are always available to the system or user.

In the case of Eternal System's approach, the units are in the form of computer code, computational processes, or microprocessors. With respect to code, the Eternal Systems approach exploits the modularity and distributed-nature of Common Object Request Brokerage Architecture (CORBA) and Java Objects. CORBA is the industry standard for distributing objects on different platforms across a network. It provides distributed object programming, location transparency within a distributed system, portability of application or programs across diverse platforms, and interoperability between diverse platforms and vendors. The use of distributed networks, which is likely the nature of application implementation on the distributed battlefield, will make substantial use of CORBA protocols. A similar story is associated with the object-oriented nature of the Java programming language and its portability across platforms. Encapsulating important and often repeated, code processes as objects will facilitate modification of computational capabilities to support evolving operational demands in a fashion that is consistent with a highly reliable system.

Regardless of whether the units replicated by Eternal Systems products are CORBA Objects, Java objects, processes, or even processors, the redundancy approach allows for highly reliable performance. These replicas can be combined to form groups of objects that are dynamic in total number (i.e. a member can be added to or removed from a group because it has been deemed faulty or repaired). The scheme can be used to develop certain types of replication strategies that assure high availability.

The products developed by Eternal Systems include *Duration* and *FTORB*. The former focuses on the operating system performance, while the latter is concerned with the performance of standard CORBA middleware. Each of these application types will likely be important as we increase the connectivity of the battlefield and the use of automation and telecommunications (e.g. router software).

Federal funders of supporting research in this area include the National Institute of Standards and Technology and the Defense Advanced Research Projects Agency.

II. Information Retrieval and Collection

Exploiting Data

Few would dispute that the interconnecting of computing machines and data sources has created the potential for fundamentally changing how organizations and institutions operate. Literature generated by scholars in a variety of fields such as organization theory, policy analysis, information theory, and operations research have often touted the importance of information in the performance of institutions. The gist of the literature from these fields is that by taking advantage of data and value-added artifacts of data, such as information and knowledge[1], individuals and institutions are better able to understand themselves and their position relative to others in their environment. Thus, data in its various forms allows for adaptation (read as transformation) or exploiting the situation or attributes of an adversary or competitor.

Of course, the "fly in the ointment" is whether an institution is capable of effectively retrieving information from relevant data sources and repositories. Challenges abound in accessing on-line data. Some of these challenges arise from the lack of structure imposed on the creation of databases and documents. Data formats may differ substantially across applications and through time and this may impact how well data, information, and knowledge can be used in decisionmaking. And it is important to note that data that is formatted consistent with standard information retrieval approaches, e.g. database query languages, is often only a small fraction of what may be available across all relevant databases. As such, much of the information universe is not exploited. Moreover, it is argued by many that currently available data could yield insight that institutions would be well served to access, e.g. by connecting transactions for an individual or group across different datasets. This ability is a major premise underlying such governmental development efforts as the Novel Intelligence from Massive Data program and DARPA's Terrorism Information Awareness program.

The problem of extensive yet underutilized data holdings is not unique to government agencies. Private sector entities also are struggling with this issue. Examples are searches of discount airline flights and a structured amalgamation of current event resources across multiple search engines to provide insights for corporate intelligence officers. A number of solutions from the vendors in the knowledge management field, as well as various large-scale database systems, have been touted. Most are somewhat capable when

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[1] Typically, data is viewed as a collection of facts in either a qualitative or quantitative format. Data that explicitly takes into account context, e.g. when a given data element is valid, is called information. The next item in this continuum of data is knowledge, which is defined as decision-enabling information. Other categories follow this continuum and the most common noted is that of wisdom. Wisdom tends to be viewed as knowledge that appreciates the existence of consequences, i.e. I know I can act but should I?

handling formatted data, but are often challenged when faced with unformatted data.

Military Operations and Information Retrieval

In order to more appropriately address future challenges, particularly those of an asymmetric nature, it becomes more important to make use of all available assets. In the past, these assets were likely to be in the form of human capital, military equipment, and doctrine that synchronized these assets into an effective fighting unit. Information, generally as intelligence, was considered relevant but not necessarily the primary factor for operational success. In a world populated by a different type of threat, it has become more important to make use of all relevant assets and to possibly reconsider their relative importance in operations. Information may well constitute such an asset in that it allows for increasingly precise targeting and an ability to address threats by sub-national actors with other than high-mass weapon systems.

Agencies particularly concerned with the efficacious use of strategic, operational, and tactical information include the Defense Intelligence Agency, Joint Warfare Analysis Center, Intelligence and Security Command, and National Ground Intelligence Center. These organizations spend a substantial amount of time coordinating the use of analytical staffing in collection, assessment, and presentation of information in a fashion that assists decisionmakers to make better choices. One of the big challenges for these organizations is acquiring all of the relevant information from the plethora of *all-source* data repositories now available. Such collaborative analysis would be greatly aided by an improved ability to retrieve information and structure in a fashion that allows for synthesizing disparate data sources/concepts and proposing novel hypotheses.

One means of improving success in the face of evolving threats is to make more effective use of unstructured, on-line datasets. Most approaches for locating and extracting data have fairly steep learning curves, which makes it difficult to integrate them into most analytic communities.

Use of a traditional query language, such as SQL, will likely reduce the time to proficiency for many military and intelligence analyst. One company that takes this approach is QL2, which has developed a product called WebQL that provides a means for mining the web and managing unstructured data.

QL2 Software

QL2 Software has been in existence only since April 2000 and already has begun to establish a niche in the areas of knowledge management, business intelligence, competitive intelligence, and application development. QL2 produces Web mining and unstructured data management tools and solutions that demonstrate strengths in data *locating (*finding sources housed on various servers*), pinpointing (*identifying elements of interest in specific documents*),*

*extracting (*moving the data from source documents or corpus*) and repurposing (*restructuring data in a form consistent with the needs of the client*)*.

QL2 Software's approach to information retrieval involves making use of structured query language (SQL) a common tool for data extraction. Use of SQL reduces the learning curve for most analysts by not requiring mastery of computer languages that support artificial intelligence-based approaches to symbol manipulation. The strategy is to pull from a variety of source documents that are hosted on the Internet or maintained by subscription services or internal network servers. This data, once located, pinpointed, and extracted, is then repurposed by converting and storing it in a format of use to the client, such as a spreadsheet or graphic.

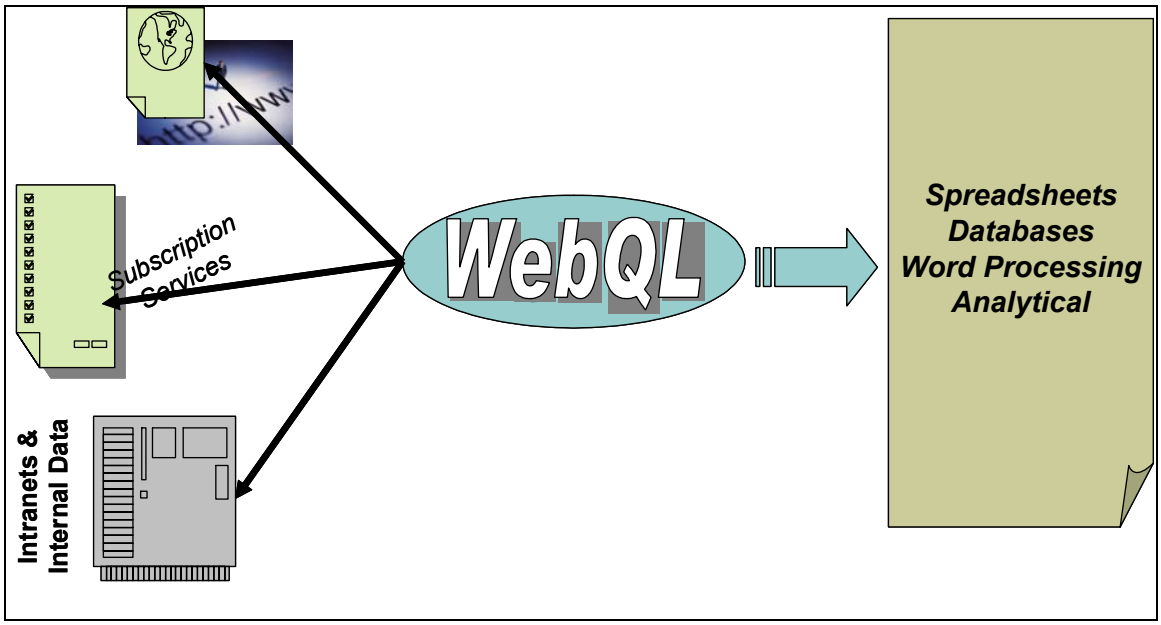

Figure 1: WebQL data extraction scheme

QL2 Software has three classes of products:

- **WebQL,** the company's core capability and product. The software provides a means of automating the tedious process of extracting information from the Internet and other unstructured data sources then reformatting it into structured formats.
- **QL2 Solutions,** generalized solutions based on the WebQL software that can be used to support the requirements of firms and institutions interested in knowledge management, business intelligence, competitive intelligence, and application development.
- **QL2 Hosted Services,** an extensive knowledge management and application hosting service for hosting firm or enterprise-specific applications used by the client and providing value-added products.

QL2 management claims that these services and products have improved business processes and the competitive positions of firms in the

pharmaceutical/bio-tech, travel, high-tech, telecommunications, and energy industries.

While the firm has not established a major presence in the defense sector, the WebQL software, as well as a few of the tailored solutions, will likely be of benefit to certain agencies in DOD. Acquisition of the WebQL software or modifications of the firm's generalized solutions will likely be of interest to agencies involved in open-source and all-source intelligence assessment, as well as effects-based operations and operational net assessment,. It is easy to envision the integration of these tools into the workflow of intelligence analyst, operations researchers, and social scientists in such tasks as populating databases supporting social network analysis.

III. Information Visualization and Knowledge Creation

Pacific Northwest National Laboratory and Palo Alto Research Center—Information Visualization

One of the major challenges faced by organizations and enterprises is to make better use of extensive information holdings in a fashion that allows for an improved understanding of situations and to provide a firmer grounding for making decisions in complex environments. One reason for the challenge of using information is that it is difficult to visualize the relationships between the elements of multidimensional and disparate data and information. As an example (and caricature) most visual analytical efforts suggest there are generally only two dimensions or variables of interest in describing how a particular phenomenon operates within the world. Of course, most persons involved in producing analysis for decisionmakers understand that this is not true and that the use of a two-dimensional visual model is only an artifact of our primary medium for conveying and storing information, i.e. paper. Moreover, it is a challenge for individuals to cognitively appreciate and assimilate the visualization of more than three-dimensions. Thus, in deference to our traditional tools of visualization and the typical decisionmakers are taught analysis, the presentation of complex data relationships has not made substantial use of visualization beyond 2D graphs in the form of scatter plots.

With the advent of increased, pervasive, computational capabilities and an increased need to consider multidimensional data in a variety of scientific fields of study, many involved in the cognitive and information sciences are revisiting first principle issues of how people can interpret and use high-dimensional data. An explicit hope expressed by many in this field, including cognitive and user-interface scientists at the Palo Alto Research Center in Stanford, California, is to amplify thoughts by improved visualization.

Military Operations and Information Visualization

Many military decisionmakers and strategic planners seek ways of better understanding complex situations either while engaged in combat (tactical and operational) or in the development of actions that will result in longer-term advantage (strategic). Such phrases as shared situational awareness[2] and policy/analytic visualization have been used to describe the effort. [3] to generate intuitive images of high-dimensionality data for use by fighting forces and analysts.

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[2] A firm called Thoughtlink, www.thoughtlink.com, has been extensively involved in the arena of shared situational awareness. One product demonstrated by the firm is called SCUDHunt.

[3] Recent investments in the area of collaborative analysis include DARPA's Genoa and Genoa II programs, as well as past efforts by the analysis and planning office of the Pacific Command in Honolulu, Hawaii.

It is important to note that numerous efforts under numerous guises have been made to make more information accessible to military operators. Integration of improved graphics on dashboards of armored vehicles and in the cockpit of high performance aircraft has been a long-standing focus area of ergonomic specialists. While this focus is of great importance on the tactical level, it is worth noting that investments in the improved visualization of operational and strategic level information will likely yield even greater returns on the operational level and strategic planners/decision-makers. Given the lack of emphasis on this area relative to ergonomic-related visualization, as well as the increased need to incorporate high-dimensionality analysis in planning, it is likely that increases in effectiveness will arise from such an investment. (High-dimensionality analysis is consistent with and necessary for the increased emphasis on operational net assessment and effects-based operations.)

Information visualization, as defined by Stuart Card of the Palo Alto Research Center, is the use of computer-supported, interactive, visual representations of abstract data to amplify cognition. The premise for initiating and continuing R&D in this field, including the work pursued under the Starlight (http://starlight.pnl.gov/) program at the Pacific Northwest National Laboratory (PNNL) on behalf of the CIA, is that visualization is a powerful tool that will enable humans to make rapid, efficient, and effective comparisons across large collections of possibilities.[4] In such endeavors as information operations (e.g. psychological operations) and global targeting as it is currently being considered by the Strategic Command, information visualization provides an effective means of developing targeting strategies and considering the their implications and consequences. Moreover, these considerations can be shared between decisionmakers and discussed in real-time.

Pacific Northwest National Laboratory and Palo Alto Research Center

PNNL is a Department of Energy laboratory managed by the Batelle Memorial Institute. The Palo Alto Research Center (PARC) is a subsidiary of Xerox Corporation that conducts pioneering interdisciplinary research in physical, computational, and social sciences. PNNL focuses on meeting specific objectives in the fields of environmental, energy, health and national security, while PARC works with strategic partners to commercialize technologies created by its cadre of scientists. Both exploit computational advancements to support the acts of amplifying cognition and sensemaking.[5]

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[4] It is important to note that Starlight only constitutes one thrust of the PNNL work on information visualization. (See http://www.pnl.gov/infoviz/). Other efforts by the laboratory include SPIRE and IN-SPIRE.

[5] While it is difficult to attribute this term to any one individual, it has gained great prevalence in the circles of planners at the Office of the Secretary of Defense as a result of research performed by the CCRP of ASD/C3I (NII) under the auspice of Dr. Dave Alberts. Sensemaking can be defined as the methods to analyze, represent, visualize, and make sense of the contents of large, heterogeneous document collections.

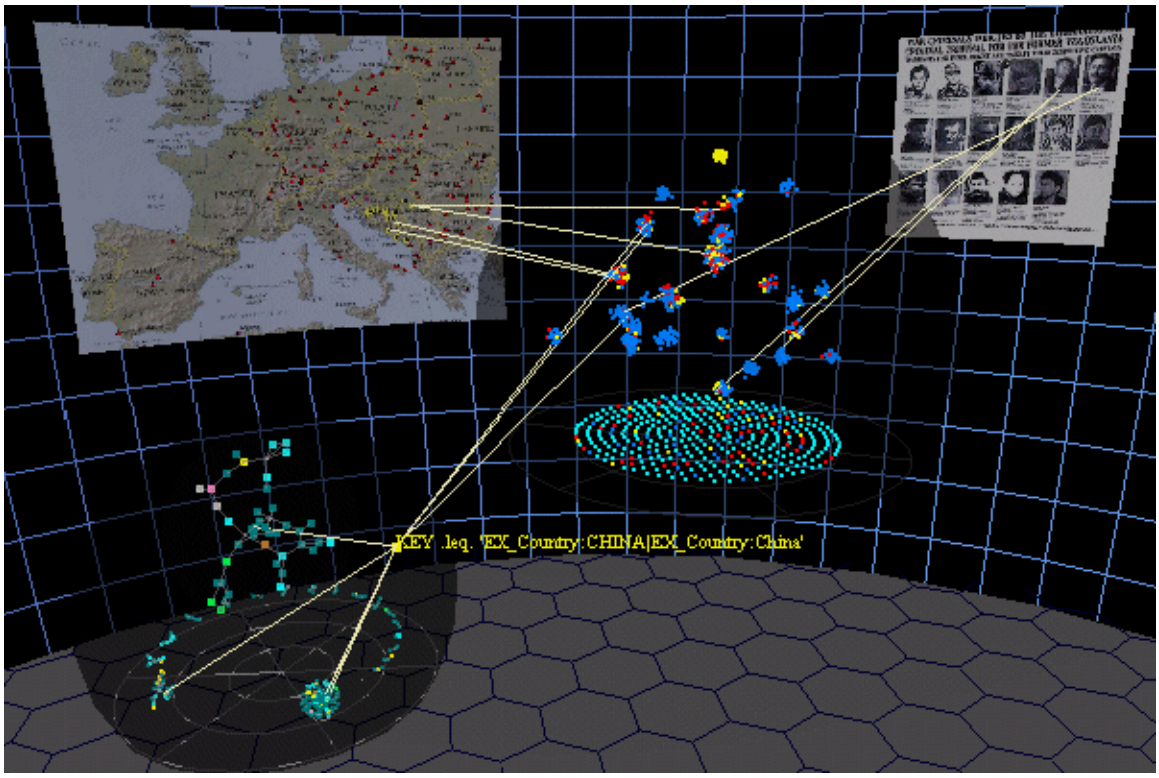


Figure 2: Example of relationship visualization

For PNNL, the information visualization program has made extensive use of information models to instantiate the relationship between information and information objects in an effort to support information integration, complexity management, workflow continuity, accelerated interpretation, and improved understanding. To that end, the programmatic thrusts of information visualization at PNNL have focused on relating and analyzing information, as well as analyzing documents.

The environment for relating and analyzing information is called Starlight. One aspect of this effort is illustrated in Figure 2, which suggests how the application is capable of quickly relating individual actors, geographic features, resource control, and sources of information one to another. The combination of these characteristics is defined as an information model. The information model used by the Starlight environment makes use of a wide breadth of the relationships. Relationships considered and incorporated into the information model, as illustrated in Figure 3, allow for representing discrete property (field/value pair) co-occurrences, free-text similarity, temporal relationships, parent-child associations, network relationships, and spatial (including geospatial) relationships.

Relationship Type:	General Similarity	Explicit Reference	Field/Value Co-occurrence	Parent/Child	Spatial	Temporal
Model Type:	*Vector-space* 	*Network* 	*Multidimensional Index* 	*Hierarchical* 	*Spatial* 	*Ordinal Index* 
Examples:	*Reports, articles, DB records*	*References & citations, hyperlinks*	*DB records, document metadata*	*File paths, taxonomies, IP addresses*	*Geolocations, CAD models*	*Event descriptions*

Figure 3: Starlight information model relationship index

The ability to quickly assess relationships will be of great interest to individuals involved in intelligence analysis and strategic planning and national security policy analysis. Moreover, the visualization allows an analyst or decision-maker to explore and interact with the visualization in support of hypothesis testing and inquiry speculation.

Another PNNL product is IN-SPIRE, a text-mining tool. This particular effort has become increasingly important because of the near exponential increase in corpus production. The ability to identify like themes in large collections of documents has become increasingly important not only in such activities as intelligence analysis, but in the administration of large offices and enterprises. The capability to represent important themes in documents, for example by providing a relief map where the highest peaks represent the prevalent topic in a collection, takes advantage of human ability to rapidly comprehend visual images.

PNNL uses an interesting licensing scheme for users, including government. To some extent, licensure income is used to cover support costs associated with distribution and use of the software.

Researchers at PARC want to further develop methods that provide novel and more efficient mechanisms for analyzing websites and structuring document collections. This would enable, the development of systems that respond to the pattern and purpose of community interactions in order to help community members make sense of their work environment. General work in sensemaking by PARC includes a number of programmatic thrusts. Of particular interest is the work in user-interface research, which focuses on developing user models and novel user interfaces for information-intensive tasks and collaborations, especially concerning the Internet and its successors.

A substantial amount of this work is based on information foraging theory,[6] which is a theory of information search behavior embodied in a product called

[6] The Office of Naval Research funded some of the work used to develop this theory. A definition of the theory appears in the article" Information Foraging" in *Psychology Review* that appeared in 1999. (Article originally written in January 1999.) The theory reflects an effort to understand how strategies and technologies for information seeking, gathering, and consumption are adapted to the flux of information in the cultural environment.

Hyperbolic Tree. This software approach provides a tool for displaying and manipulating large hierarchies and graphs as trees. This tree structure facilitates exploration of complex data sets by enabling rapid translation along themes and pruning of hierarchy to reduce to the collection space observed. This information visualization product helps analyst and planner alike explore document collections and explore outcome/option space.

Closing Thoughts

There exist in the realm of information technology interesting solutions to extremely challenging national security problems. However, gaining entrée to the individuals developing these technologies is not necessarily easy. Personal and credible contact counts for much in this arena. Many entrepreneurs work outside traditional defense acquisition networks in praxis communities that often require them to develop business plans geared toward traditional consumers. For example, game developers look at markets for pre-adolescent males purchasing on-line subscriptions, not towards supporting the efforts of STRICOM or the recently initiated Massively Multi-player On-line Gaming Consortium effort. Thus, DOD acquisition specialists tend not to list these firms in their "vendor rolodexes," and the marketing offices of these companies typically view DOD as a market characterized by high barriers to entry. The long-lead times necessary to become the part of the POM or to complete contracts with DOD is often too great a burden for burgeoning firms. It is important to create more professional relationships with producers of technology that more realistically account for business and government practice. Moreover, initial attempts should develop such relationships should not wan as a result of changes in government personnel.

A second hurdle for DOD acquisition professionals is related to how the R&D cycle is defined and acted upon. Identifying technologies in their completed form often results in a decreased ability to influence the utility of products in emerging systems. Moreover, identifying technologies at this point in the R&D cycle results in a substantially smaller pool of candidates. Of course, while moving further back in the R&D cycle may result in a greater ability to influence design and increase utility, it also provides a greater challenge in identifying possible technologies. Thus, the low-hanging fruit criteria may be a win for rapid acquisition, but may result in failure to take advantage of soon-to-emerge products.

The ability to act earlier in the R&D cycle is important for two reasons. First, and as noted earlier, it provides a means of influencing design and increasing utility. Second, it affords DOD an increased ability to deal with competition. Given that commercial R&D products are available on the open market, what benefits DOD can benefit potential competitors or threats. Controlling for operational concept and competence of personnel, this availability can provide competitors with a similar capability, or at least a means to counteract any gains in capability afforded by using the new technology. As a result, identifying "mid-level fruit" may be beneficial.

The author has identified three technology development thrusts in this category that are of possible use to future military operators and national security planners. These include:

- *CETP Experiment—Real-Time Image and Video Compression and Forward Error Correction*: This particular effort reflects an interesting

collaboration between two vendors that was brokered by individuals associated with Office of the Secretary of Defense's Center for Excellence in Technology Partnerships. The government agents in this case identified a synergy between two firms and provided an incentive for them to collaborate. The experiment produced an outcome that allowed for near-real-time 300:1 compression of video signals that could easily be passed via low-bandwidth telecommunications channels on the battlefield. This is not yet a product, but additional funding could move this technology in that direction.

- *Cognitive Engineering in Support of Structured Argumentation: A Metacognitive Support Layer*: This development is an extension of work pursued in the field of structured argumentation, which is a means of making more explicit the assumptions in inferences derived from intelligence data as well as a means for updating these arguments and inferences as subjective beliefs change. This particular effort is being pursued by a small firm called Perceptronics. The initial effort is based on generating additional option or decision paths for the consideration of decisionmakers in complex, yet explicitly defined, environments. This work has been funded by the firm and will benefit from additional government funding.
- *Theory Division of Microsoft Corporation:* This division of Microsoft pursues a variety of theoretical issues, such as work in scale-free network theory that supports the development of improved search engines for exploring Internet and Peer-2-Peer (P2P) resources. The increased use of open-source documents in all-source analysis as well as the increasing prevalence of P2P collaborative environments by DOD entities will likely benefit from the work of this division. Given its nascent stage of development, it may be an opportune time to interact with this division in order to consider the role of these emerging technological approaches in information retrieval.

These technologies differ from the low-hanging-fruit case studies because of their position in the development cycle and by their developmental path. They arise from firms of varied size, R&D resources, and current and past levels of interaction with DOD. What is necessary to adopt these technologies—and to make a strong case for a business partnership—is an appreciation for each firm's R&D strategy and the roles the technologies can play in DOD operations. Also essential is a champion to act as liaison between the firm and the DOD acquisition process.

IV. Appendix

This section contains descriptions of corporate R&D efforts that are of possible interest in the long-run but are not consistent with this effort's focus on currently available products.

BBN—Information Collection (Sensor Webs)

A prevalent assumption about the highly connected future battlefield is that it will be possible to take advantage of the information space to achieve more effective decisions and coordinated actions. Such a capability suggests the necessity to refine data into a value-added form that allows for the creation of context and ability to make decisions. While the creation of information from pervasive data is important, it is equally important to find means to mine this data from the battlefield environment. One means of capturing relevant data is to make use of sensor webs or networks. Such a capability is not only important for future battlefield operations, but will provide an ability to shape the security environment prior to conflict.[7]

One firm offering a solution to the battlefield aspects of this challenge is BBN. What follows in this section is a brief description of the role of sensor webs in military operations, as well as the approach offered by BBN.

Military Operations and Sensor Webs

The current battlefield is characterized by the existence of numerous sensors of varying types, including :

- Acoustic sensors
- Digital video
- Environmental sensors
- Infrared cameras
- Passive infrared receivers
- Radio frequency receivers
- Seismic sensors

The existence of these sensors can be advantageous to operations, but even more important is the ability to share information between sensors and to meld sensor information into a scene of shared awareness. One means of this is to create a large-scale, distributed, intelligent sensor network, and to then provide interfaces that allow for visualizations of the battlefield environment across a number of platforms.

BBN

BBN Technologies is a wholly owned subsidiary of the Verizon Companythat has developed innovative solutions for agencies such as DOD for over 50 years. BBN

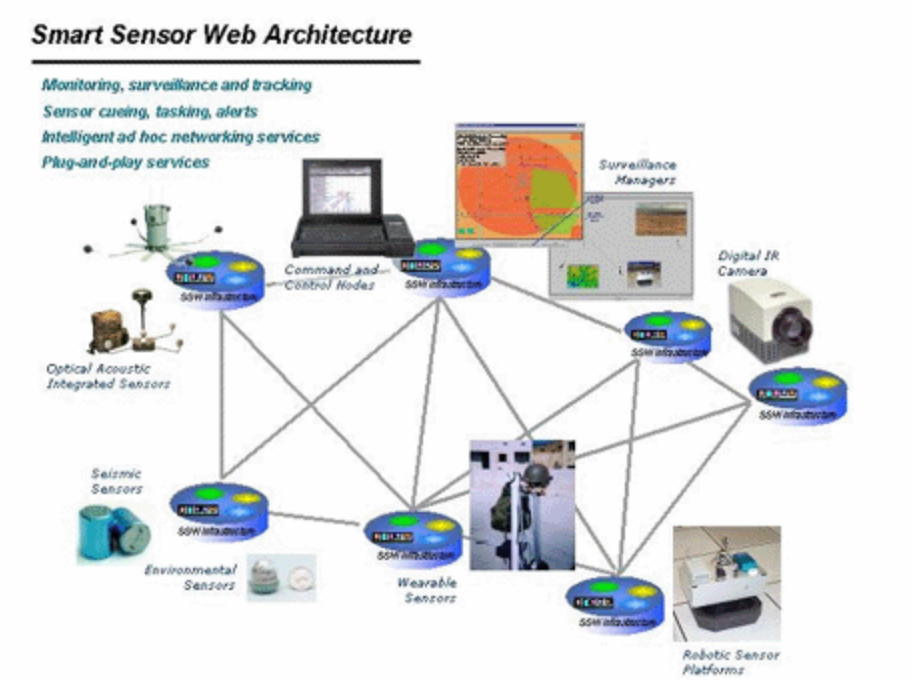
[7] Relevant efforts related to *security environment shaping* include DARPA's Terrorist Information Awareness network and ARDA's Novel Intelligence from Massive Data programs.

implemented and operated the ARPANET and was involved in applied research related to military uses of networking[8]. BBN offers a sensor web architecture based on the XML messaging standard that is capable of supporting the collection and synthesizing of data from a variety of sensors across a number of operational regimes. The regimes, as defined by BBN, include:

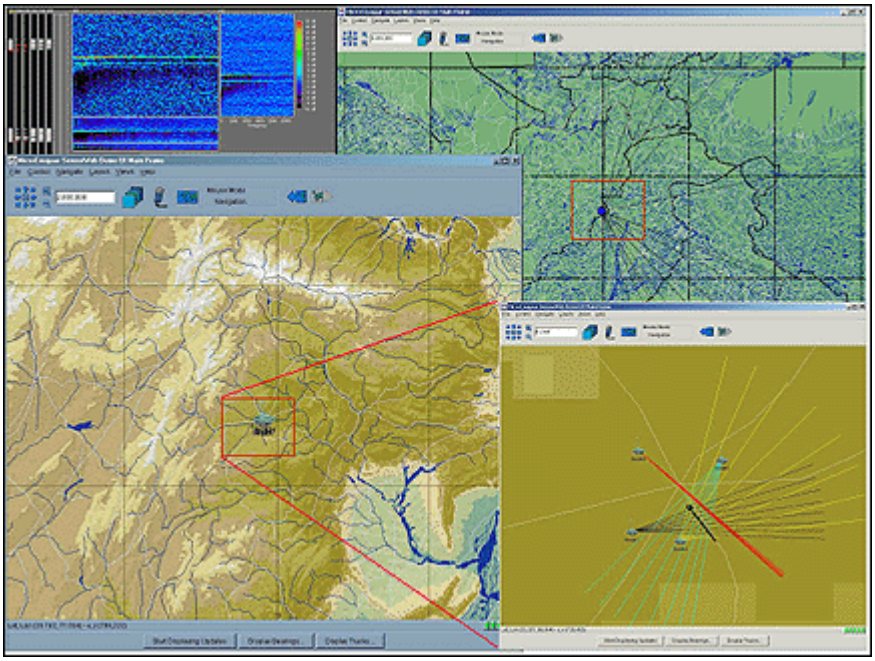
- **Homeland Security and Defense.** Homeland security systems based on Smart Sensor Web technology have been designed for building and infrastructure defense, border patrol and surveillance, and detection and warning of chemical or biological hazards.
- **U.S. Army Future Combat System and Objective Force for the Warrior Program**., Smart Sensor Web systems have been developed for the U.S. Army to link and coordinate unattended ground sensors with the movements of autonomous robotic vehicles and unmanned aerial vehicles for battlefield operations.
- **DOD Intelligence, Surveillance, and Reconnaissance Missions.** Smart Sensor Web technologies have been applied for managing strategic and theater-wide intelligence, surveillance, and reconnaissance assets (airborne and overhead) and for the subsequent processing, use, and dissemination of the collected information.

This sensor network infrastructure is based on Java, and provides a flexible means of distributing information arising from the collected data across numerous platforms in a Peer-to-Peer (P2P) manner. These platforms include Command and Control units and PDAs as illustrated in Figure 1.

[8] These efforts in networking include the creation of the first packet switch, the first router, and the first person-to-person network e-mail. BBN Technologies was involved in designing, building, and operating the Defense Data Network.



BBN has also developed a number of display tools such as the Open Map User Interface[9]. A screen shot of this map, which is displayable on numerous devices, is shown in Figure 2.



[9] Open Map is a suite of mapping applications and tools for building mission-critical, Internet-based geographic decision support systems. Using this client-server technology, you can access data from legacy applications, in-place or in a global setting, and display that data with data from other sources.