Challenges and Potential of Service-Oriented Architectures for Net-Centric Operations

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ABSTRACT

NATO is currently moving away from system-centric solutions based on the exchange of messages between individual systems towards information-centric solutions based on service-oriented architectures. The core idea is to share services in a net-enabled environment to bring all the information a military user needs to him, no matter what he does, where he is, or what system he currently uses. Within the US, the Global Information Grid (GIG) is currently in use and first examples have been implemented to evaluate the feasibility of these concepts. Some of these first components and services were successfully used in Operation Iraqi Freedom.

However, while service-oriented architectures (SOA) technically have the potential to find every piece of information relevant for an operation no matter where it is, they also challenge the user and the developers to ignore thousands of additionally available pieces of information that are not currently relevant. To what extent virtual and augmented reality technologies can help to cope with such issues is the topic of the current research, but it is obvious that technology and education must be aligned to ensure feasibility and usability. This paper gives a short overview of technical constraints, concepts, and implementations. It contributes to the discussion of where Human Factors expertise is urgently required to make these new concepts a success for the military user.

1 INTRODUCTION

Technologically advanced nations are increasingly digitizing their military forces. Operations are no longer conducted by a single service but are Joint and more likely to involve either a coalition of willing countries or existing alliances such as NATO. There has been a growing awareness that the traditional exchange of information that has been limited to data exchange and the use of common message text formats such as Allied Data Publication Number 3 (ADatP-3) and data exchange links such as Tactical Digital Information Links (TADIL) may not be sufficient. In addition, emerging developments are enabling deeper information sharing and the establishment of a Common Operational Picture (COP). The increasing use of commercially supported open standards pushes the information technology (IT) infrastructure from proprietary military solutions towards web-enabled Service-Oriented Architectures (SOA).

Distributed operations will be supported based on a heterogeneous computer grid comprising resources and data from all participating partners in operations that go beyond the military domain. In order to leverage the

Tolk, A.; Gaskins III, R.C. (2006) Challenges and Potential of Service-Oriented Architectures for Net-Centric Operations. In *Virtual Media for Military Applications* (pp. 5-1 – 5-14). Meeting Proceedings RTO-MP-HFM-136, Paper 5. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

power of such a great amount of information, it has to be efficiently and effectively distributed and utilized in a parallel manner. Network Centric Operations and Warfare (NCOW) – or in the NATO context Net-Enabled Capabilities (NEC) – pursue this task within the Armed Forces. NCOW provides a force with access to a new, previously unreachable region of the information domain. The ability to operate in this region provides the Warfighter with a new type of information advantage leading to a Command and Control (C2) advantage. This advantage is enabled by dramatic improvements in information sharing made possible via networking. With this information advantage, a warfighting force can achieve dramatically improved shared situational awareness and knowledge. The transformation of C2 procedures goes hand in hand with these technical achievements. Although technology is the enabler, the driving factor is the transformation of the forces as a whole.

In this context, the ability to achieve a heightened state of shared situational awareness and knowledge among all elements of a force, including allied and coalition partners, is increasingly viewed as a cornerstone of Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) transformation. Emerging evidence from recent military operations and a broad range of experimentation supports the relationship between shared situational awareness and knowledge enabled by NCOW concepts and increased combat power.

The means for accomplishing this in the U.S. Department of Defense (DoD) is the Global Information Grid (GIG). The GIG is a globally interconnected, end-to-end set of information capabilities, associated processes, and personnel through which information is collected, processed, managed, stored, and disseminated on demand to Warfighters, policy makers, and support personnel. The GIG is a key enabler of NCW and is essential for information and decision superiority. It will enable C4I integration of joint forces, improve interoperability of systems, and increase optimization of bandwidth capacity thereby dramatically improving warfighting capabilities. The GIG will enhance operational capabilities while providing a common environment for Command and Control (C2), combat support, combat service support, intelligence, and business functions.

The next generation of Information Technology (IT) supporting Joint Command and Control (JC2) must be much more agile than the C4ISR systems of today. The stand-alone, database centric and message based methods of informing the Commander ended with the concept of the Common Operational Picture (COP). However, the COP is still a quasi-static display of the situation, with latency issues and in the best case, a geo-spatial representation of logistics and intelligence data. What the Warfighter needs for JC2 is an agile process, i.e., tools that bridge the gap between the information domain and the cognitive domain. There is a clear requirement in the various components of a Net Centric C4I system to utilize Models and Simulations (M&S). These can be the basis for planning and decision support tools, as well as for the information processing required for visualization and presentation of information outside the normal COP's physical, geo-spatial domain. There are explicit and implicit requirements for sophisticated processing of that information for situational awareness, decision support, and operational control. Additional requirements are seamless support of training, procurement of new components, and testing. In other words, the supply of M&S functionality spans the gamut of the operational context of the GIG.

This paper will start with a technical overview of the GIG followed by discussions of operational, technical, and Human Factors implications. We will show that resulting challenges are enormous and the engagement of the Human Factors community is essential to ensure the usability of the GIG for human soldiers of the future.

2 TECHNICAL OVERVIEW OF THE GLOBAL INFORMATION GRID

In order to understand the GIG, the reader must understand SOAs. In order to understand SOA, he must understand the concept of web services. The overall idea is pretty simple: instead of providing systems, the functions important for such systems are provided by services that "float around" on the grid. If a user needs a special functionality, he simply looks for an applicable service that provides this functionality. After he identifies all the services necessary to fulfill his requirements for functionality, he composes these services and quasi generates a "virtual" system on the fly. However, there are a couple of stumbling blocks on the way to composable services.

2.1 Web Services and Service-oriented Architectures

The current software paradigm to cope with the challenges of net-centric operations is to apply services within a service-oriented architectures (SOA). An SOA is a collection of composable services. A service is a software component that is well defined, both from the standpoint of software and operational functionality. In addition, a service is independent, i.e. it doesn't depend on the context or state of any application that calls it. Currently, these services are typically implemented as web services. The advantage of using web standards in an SOA is that the services can more easily handle distributed applications in heterogeneous infrastructures. Nothing in particular has to be done programmatically to the service, except to enable it to receive requests and transfer results using web-based messaging and transportation standards. In many cases, web services are straightforward and existing software can easily be "web enabled" to create new services usable within an SOA. Web Services are a set of operations, modular and independent applications that can be published, discovered, and invoked by using industry standard protocols – Extensible Mark-up Language (XML), Simple Object Access Protocol (SOAP), Web Service Description Language (WSDL), and Universal Distribution Discovery and Interoperability (UDDI). It is a distributed computing model that represents the interaction between program and program, instead of the interaction between program and user. Web services can also be defined as discrete Web-based applications that interact dynamically with other web services.

But how do web services work? Web services send and receive data described in XML. XML is a platform, programming language, and operating-system independent way to structure data and describe these data using tags. SOAP is used to send and receive data packages described in XML. Web services describe their data, operations, bindings, protocols, and all other relevant information in a standardized way, WSDL. This WSDL package is send to a UDDI repository. If a user needs a service, he looks through the WSDLs in a UDDI repository. If he finds what he needs, he prepares the data the service needs as input and uses SOAP to send these data to the service. The service delivers the output via SOAP back to the user. Figure 1 shows how these standards interplay. In summary, web services are procedures with descriptions of data and operations in a common syntax to be found in a known repository. To invoke the service, a simple protocol is used for a general form of remote procedure call.

What makes this concept so powerful? First, with XML the IT community agreed on a powerful standard to promote general data exchange. The application of XML enabled a new level of interoperability for heterogeneous IT systems by enabling separation of data definition and data content. Second, SOAP is an easily applicable and easily implemented protocol available on many platforms from workstations to handheld systems. These two fundamental concepts have been agreed upon by many vendors and IT providers and are supported by many applications. Many tools provide XML migration for legacy systems, such as database applications or client-server oriented structures. The step from distributed systems to web service based systems is relatively easy; the technical integration of web service is a solved problem.

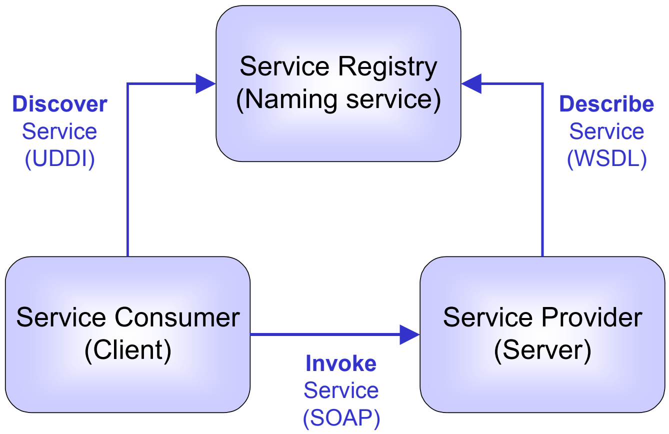

Figure 1: Web Service Standards.

However, composability has many layers. The Levels of Conceptual Interoperability Model (LCIM), developed at the Virginia Modeling, Analysis & Simulation Center (VMASC), identifies several layers of interoperation. It starts with technical interoperability (exchange bits and bytes), syntactical interoperability (common formats), semantic interoperability (unambiguous definition of data), pragmatic interoperability (unambiguous definition of the context of data exchange), dynamic interoperability (unambiguous definition of effects of data exchange in participating systems), and conceptual interoperability (common concepts and models). XML and web services are only covering the technical and the syntactical level; hence, web services are not sufficient to fulfill all requirements for composable services, but they are a solid technical basis and support a common syntax. We will cope with this issue more in the following sections.

2.2 Global Information Grid

The underlying IT infrastructure of the Global Information Grid (GIG) will support all layers of decision-making, all levels within the military hierarchy, all participating non-military organizations, and all other participants in the Command and Control process with the necessary information and the necessary applications (including collaboration tools and decision support systems) in a parallel, emerging, and secure manner, including multiple levels of security. The means envisioned and partially specified for accomplishing this in the U.S. Department of Defense (DoD) is the GIG, a globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to Warfighters, policy makers, and support personnel.

The GIG is a key enabler of NCOW and is essential for information and decision superiority. It will enable C2 integration of joint forces, improve interoperability of systems, and increase optimization of bandwidth capacity, thereby dramatically improving warfighting capabilities. The GIG will enhance operational capabilities while providing a common environment for conventional and nuclear C2, combat support, combat service support, intelligence, and business functions. In particular, the GIG will support:

- Ability to operate with reduced forces at high operational tempos where dynamic planning and redirection of assets is the norm.
- Delivery of information concerning targets, movement of forces, condition of equipment, levels of supplies, and disposition of assets to joint commanders, their forces, and the NCA within specified time frames.
- Ability to obtain and use combat and administrative support information from national, allied, coalition, and other widely dispersed assets.
- Collection, processing, storage, distribution, and display of information horizontally and vertically throughout organizational structures across the Battlespace.
- Rapid, seamless flow and exchange of information around the globe, enabling collaborative mission planning and execution from widely dispersed locations and at different levels (to include strategic, operational, tactical, and business).

The GIG is a system of systems that provides a set of value-added functions operating in a global context to provide: processing, storage, and transport of information; human-GIG interaction; network management; information dissemination management; and information assurance. These functions are fully interrelated, integrated, and interoperable with one another in order to achieve overall interoperability across the GIG. As a result, the GIG is an information environment comprised of interoperable computing and communication components.

In summary, the GIG will become the dominant if not the exclusive IT backbone for future DoD IT business, which includes virtual worlds for training, procurement, or operational support. The GIG will provide every user – soldier, decision maker, homeland security expert, or disaster relief operator – with the necessary information, if it is available in the GIG. The organizational means to make sure that the information will be available is the Net-Centric Data Strategy.

2.3 Net-Centric Data Strategy

The current data created “stovepipes.” C4I system design and underlying doctrine failed to make data available until after processing by the appropriate entity, often after it is tactically used by another community. The strategy is called TPED, which stands for Task, Process, Exploit, and Disseminate. The producer of data processes and exploits the data before disseminating the results to other user he thinks should know about his findings.

One of the most radical changes is the data policy in the GIG. This is based on the Net-Centric Data Strategy that postulates all data, regardless of the final consumer, will be available to selected users (theoretically anyone, anywhere with granted access) on “publish-subscribe,” “smart-push-pull,” or query-response type mechanisms. It is called TPPU, which stands for Task, Post, Process, and Utilize. The producer of the data posts the raw data as well as every interim solution immediately to the GIG so that everyone who needs it can pull it into his evaluation process.

One of the major challenges is to enable the user to find the data. This is where the ideas of web services come into play; the data descriptions are posted to a common repository where data users can find producers of the data they need. One of the flagships to prove the concept is Blue Force Tracking (BFT), which was successfully used in the recent Iraq operations. Every blue system sent its position and other basic data using a common XML description on a permanent basis to the BFT server. Whoever requested these data simply subscribed to the BFT service and received the most recent information of every system, independent of the service or branch or organizational constraints of the system. One simply has to know the used data XML scheme and where to find the location to subscribe to the service. This was a radical change and resulted in an accurate situational awareness of the situation for all participants at a quality never before reached. Figure 2 shows the principle structure.

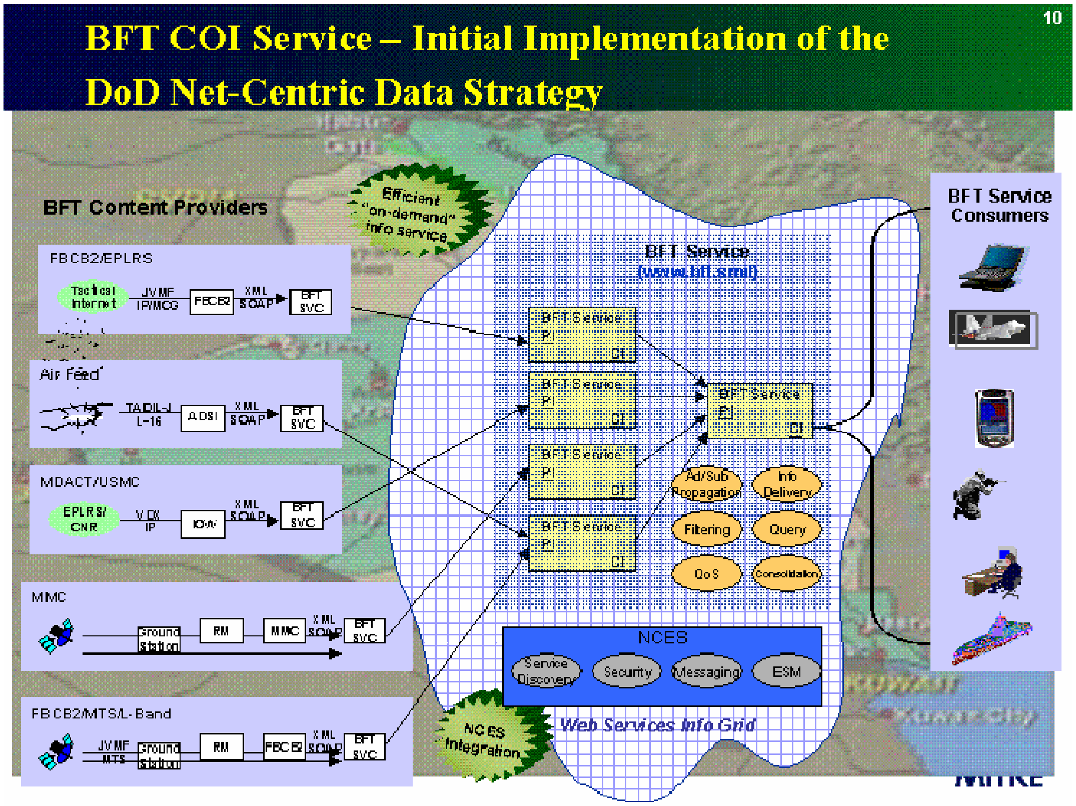

Figure 2: Blue Force Tracking.

In summary, web services and XML allow us to describe data and services in a technical way to share information more efficiently than previously possible. The GIG is the enabling technical backbone. Every user of the GIG producing data posts these data for the use of others as soon as it is available. In contrast to sending the data where a data producer thinks it is used he feeds a service to which everyone who really needs the data can subscribe. This ensures the availability of necessary data. As the underlying systems are based on open and commercially supported web-based standards, everyone can get the information as long as he supports these standards.

3 IMPLICATIONS OF THE GLOBAL INFORMATION GRID

To show the importance of information in the GIG, Major General Soligan, Chief of Staff of the US Joint Forces Command, compared our current situation in IT with traditional warfare challenges. During the second World War (WW II), the Circular Error Probability (CEP) radius for a bomb, the circle into which 50% of the bombs will be falling, was approximately 1,000 ft. During Vietnam, this radius was reduced to

300 ft by technical improvements. Today, the CEP is less than 1 ft. In other words, while in WW II more than 7,000 bombs were needed to kill a point target, today one bomb is sufficient. Our information efficiency must undergo a similar improvement. Using the search tools of today, critical information is in danger of being buried in a bulk of similar information. We need a better way to structure and tag information in order to find relevant information and make it visible to the user. If we look for information on the GIG and the research results in 7,000 web links, this result is as efficient as WW II bomb technology has been for point targets. What we need for the long term is an unambiguous way to find information and identify exactly the web link with the information for which we are looking.

The following section will highlight some challenges but also potentials of the GIG and related NATO Service-oriented Architectures with focus on the human components.

3.1 Operational Implications

One of the obvious operational implications of the GIG and its TPPU paradigm is a reorientation of Intelligence, Surveillance, and Reconnaissance (ISR). Data will be freely available – under the constraints of security – to military users wherever they are, whatever they need, and whatever system they use to access the GIG, be it a PC or a hand-held device. The elements of the situation currently relevant to the operation can be displayed and will enable a new quality of support. As Alberts and Hayes write in Power to the Edge,

> *Power to the edge is about changing the way individuals, organizations, and systems relate to one another and work. Power to the edge involves the empowerment of individuals at the edge of an organization (where the organization interacts with its operating environment to have an impact or effect on that environment) or, in the case of systems, edge devices. Empowerment involves expanding access to information and the elimination of unnecessary constraints.*

This requires new procedures and new behavior patterns of the users. However, this is only the first step. Current technical solutions are focusing on the exchange of data and the report of situations, which is more or less static information potentially enriched with some historical data in the form of tracks. To measure the support of operational tasks, the Net-Centric Value Chain (NCVC) used within the US Department of Defense distinguishes between:

- Data--factual information;
- Information--completeness, correctness, currency, consistency and precision of data in context;
- Knowledge--procedural knowledge and information, such as capabilities of own and hostile forces;
- Awareness--using the information and knowledge for new insight, such as possibilities and alternative hypotheses concerning the development within the domain.

When we used messages connecting otherwise more or less stand-alone systems, we supported the data level. When the common operating picture (COP) was introduced, data was exchanged embedded in their context, raising the value onto the information level. Experiments conducted with message-oriented systems and COP enabled systems showed an increase in the C2 quality by an order of magnitude (a picture says more than 1,000 words). We assume that we will see similar increments of an order of magnitude whenever we reach the next level of value. In order to raise the information support to become knowledge support, we must apply procedural knowledge and information. The most IT oriented ways to capture procedural knowledge are algorithms and programs. In other words, military simulation systems that once executed show the development of a situation and how things interplay will say more than 1,000 pictures. If we are able to capture the assumptions and constraints on different levels of interoperability in a way that IT can use them to evaluate the composability of approaches, we can start to use intelligent software agents to support the evaluation of potential solutions, tracking of current developments, and possibilities and alternative hypotheses. In other words, if the right data about data is available (also known as metadata), and if this metadata is used to tag the applications and services, future IT may be applicable to support all levels of net-centric operations. The following figure exemplifies this idea.

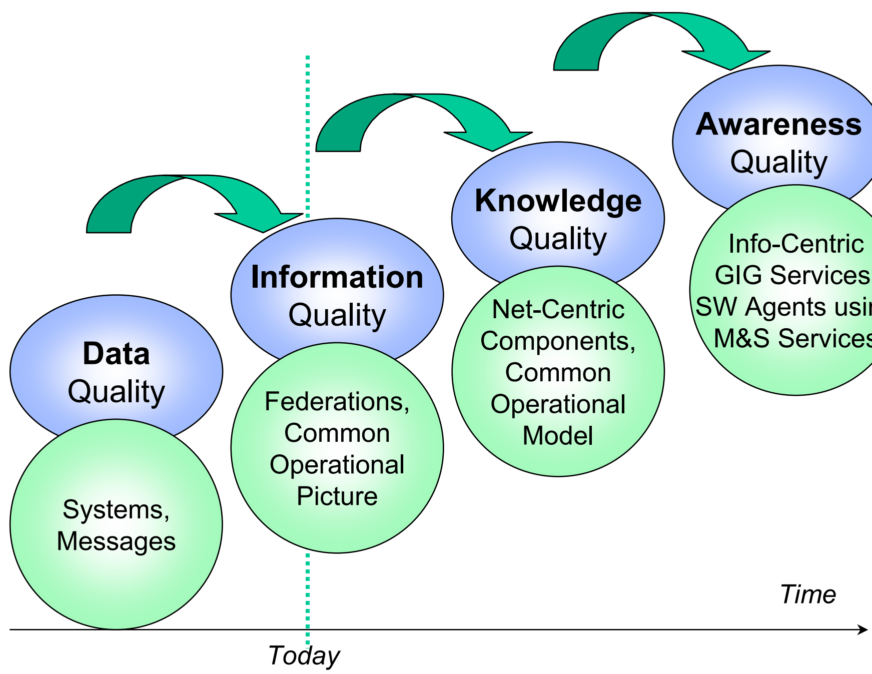

Figure 3: Net-Centric Value Chain and M&S Services.

The current standards for metadata and tags under consideration are not sufficient to support this vision as they are focusing on situation descriptions within and between different communities of interest. The section on technical implications will evaluate more details.

3.2 Technical Implications

As mentioned earlier in this paper, the main challenge lies in coming up with composable services. A standard family on the technical and procedures on the management side, ensuring that M&S and operational services can exchange data and descriptions unambiguously defining what is done and what must be exchanged, is needed. A common language for web services of the GIG to share their contributions will fulfill this need.

The current idea underlying the Net-Centric Data Strategy is that communities of interest will be responsible for their data, what to share, and how to share it with other users. After bad experiences with enterprise wide data models, which ignore the cultural barriers against trust and data sharing, the Data Strategy focuses on using a comprehensive, integrated approach to deliver the foundation for net-centricity. While so far the approach to standardize and control data elements, definitions, and structures was the focus of administrative efforts, the current way is a modified data paradigm for data management: Systems and services describe their data in three sections of a shared space: Discovery Metadata necessary to identify the service; Structural Metadata to describe the information exchange needs; and Data Contents. A user in need of the service can discover him using the Discovery Metadata, can structure his data and decipher the answer based on the Structural Metadata, and can interpret the result based on the Data Content. The following figure shows the scope of the Net-Centric Data Strategy.

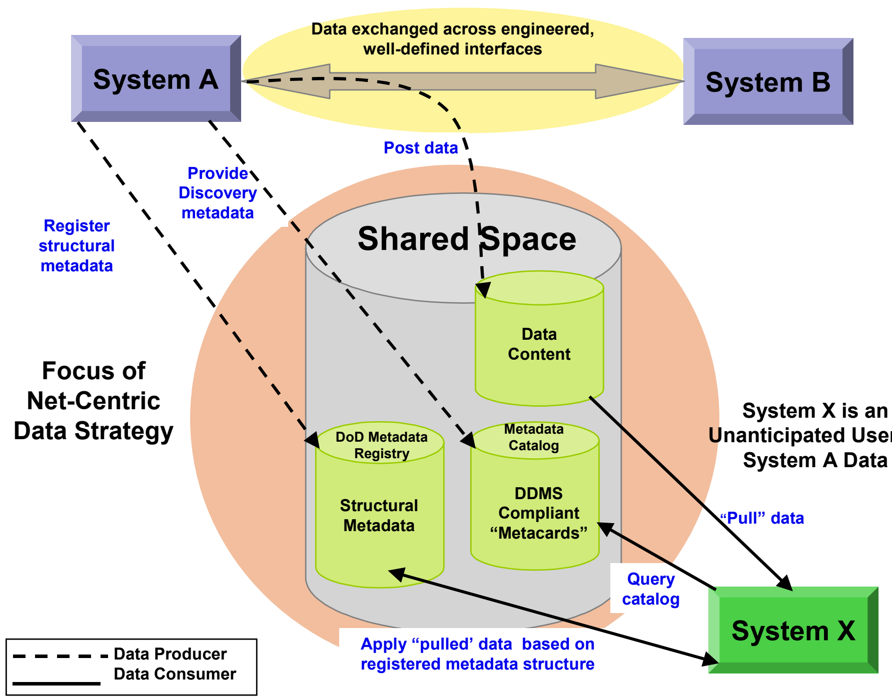

Figure 4: Scope of the Net-Centric Data Strategy.

In other words, every application of the GIG will have to fill out these descriptions. These metadata should be sufficient to understand the data as well as the application and, as indicated earlier, in the long-term become machine readable and understandable as well. While technically this is not a big issue, the underlying organizational effort is enormous.

3.3 Human Factors Implications

The Global Integration Grid is complex in nature, involving a great deal of disparate information shared across a distance and with heavy time constraints. For instance, in the limited time available during a crisis, the commander and staff cannot collect all information on everything. In conjunction with time constraint considerations, the commander and planning staff are often faced with complex situations that require them to make sudden changes with evolving information and understanding. This abundance of information with time constraints requires the commander and staff to make quick assessments of the entire situation. This is but one example of the many Human Factors issues that designers and developers should consider in these early stages of the GIG system development. Building models for human behavior representation especially with modeling the cognitive architecture is an ongoing challenge and should be addressed and backed by solid empirical research, such as cognitive task analysis and cognitive work analysis throughout each of the issues.

Here we outline a number of general human factors issues and areas with the goal of identifying relevant areas for future research to support human behavior representation in general and cognitive modeling in particular.

3.3.1 Situation Awareness

Endsley (1995) defines situation awareness (SA) as the perception of elements in a particular environment within time and space, the comprehension of their meaning and the projection of their status in the near future. As a psychological construct, situation awareness can be divided into three distinct levels, each varying in cognitive complexity. Level 1 (SA) involves perceiving the status, dynamics, and attributes of critical environmental elements. Level 2 (SA) involves understanding the relation among these elements and forming a complete understanding of them in light of mission goals. The highest level of SA, projection, refers to the ability to predict future events based on the perception and comprehension of these elements.

Situation awareness is an important cognitive skill that is essential for expert performance in any field involving complexity, dynamism, uncertainty, and risk. The failure to perceive a situation correctly may lead to faulty understanding. Ultimately, this misunderstanding may degrade an individual's ability to predict future states and engage in effective decision making (Gaba & Howard, 1995). Gonzalez, et al. (2006) is working to build cognitive models of situation awareness utilizing a tool that automatically builds the cognitive models with ACT-R.

Success in team-oriented exercises, such as those that characterize military operations, requires shared situation awareness (SSA) among team members (Millward, 2005). Developing shared situation awareness (SSA) is assumed to involve four specific aspects: shared requirements, shared devices, shared mechanisms, and shared processes (Bolstad & Endsley, 2000). Shared SA requirements refer to the degree to which team members understand information that other team members need to successfully achieve their objective. Shared SA devices include shared communications, shared displays, and shared environments. Shared SA mechanisms are shared cognitive models among team members. The final aspect, shared processes, represents effective team processes for sharing information (Bolstad & Endsley, 2000).

Nofi (2001) suggests that "SSA degraders" can be found within each aspect of SSA development. A commonly discussed SAA degrader discussed by researchers is poor personal communication. Shared communication devices may offer team members too much information or unreliable information. Also, remote locations between team members may hinder the ability to effectively reciprocate information, especially when team members are required to use computer mediated communication (CMC) devices (Whitworth, Gallupe, & McQueen, 2001). Therefore, creating, enhancing, and maintaining SSA depends on the ability to mitigate these "degraders" and facilitate effective communication among team members (Millward, 2005).

3.3.2 Shared Situation Awareness (Mental Models/Cognition)

Recent work by Wallenstein, et al. (2006) shows the challenge of building human behavior models in complex and cognitive domains. Effective distributed learning requires team members to acquire a common knowledge of the task at hand. As noted in previous studies, team performance relies on the extent to which team members hold similar expectations (Cannon-Bowers & Salas 1990; Klimoski & Mohammed, 1994). Cannon-Bowers and Salas (1990) introduced the concept of shared mental models to describe the fluid, implicit interaction often observed in successful teams. Teams must predict and cope with task difficulty and change by altering their strategies. Shared mental models are the mechanisms that help teams make sense of situations and facilitate coordinated team performance and decision making (Cannon-Bowers, Salas, & Converse, 1993).

Team members typically do not share a single mental model. Rather, there are likely multiple mental models co-existing among team members (e.g. Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994). Shared mental models are characterized by a variety of factors including the characteristics of the team, the nature of the task, the type of equipment, and the interaction among the team members (Cannon-Bowers et al., 1993). However, these factors are generally categorized as either task work or teamwork mental models. Task work mental models include the understanding of activities and action sequences of the task, whereas teamwork mental models refer to the understanding of communication needs, compensatory behaviors, performance monitoring, and internal coordination strategies of the team (Webber et al., 2000).

Recent research has shown that task work and teamwork shared mental models relate positively to team processes, such as communication and decision making, as well as performance (Mathieu, et al., 2000). Furthermore, team processes were found to fully mediate the relationship between shared mental models and performance (Mathieu et al., 2000). Although empirical support is limited, emerging findings suggest that appropriate team mental models have positive effects on team processes and effectiveness (Mathieu et al., 2000). Such findings suggest that the development of shared mental models is a promising leverage point for distributed learning techniques aimed improving team effectiveness.

3.3.3 Adaptive Thinking

Adaptive thinking refers to effective response to changing circumstances (Hansberger, Gaskins, Cuper, Spain, Harris, Ishom, 2006). This idea presupposes that the circumstances will be novel and will require flexible decision-making that does not detract or stray from the end-goal. A cognitive skill such as this would be unusually suited to the training benefits of a gaming mode of instruction given its inherent need for the presentation of novel situations. While direct experience is always a preferred way to learn, sometimes it is not possible for a person to experience all possibilities before an adaptive skill is needed. The presentation of multiple scenarios in a serious gaming type of training environment can better equip one to deal with a variety of situations that could occur in the future, rather than just those that mimic earlier experiences. Individual and shared mental models indicative of adaptive thinking can be built through the use of any number of commercial and public software packages (Gaskins, et. al., 2006).

3.3.4 Communication

As suggested by the above discussion, one of the most critical aspects of distributed learning environments is the role of information transfer between team members. As noted by researchers such as Guzzo (1986), a hallmark of functional teams is the notion of team member interdependence. In other words, teamwork requires team members to rely on each other to complete tasks. In most cases, such interdependence is manifested in the transfer of information.

Researchers have studied the communication process for many years, and have constructed models to depict that process. Shannon and Weaver (1949) proposed one of the earliest models of the communication process, drawing from work with telephone communication. They specified a five-element communication process that emphasized the transmission process. It began with the information source or message transmitter, who passes the message through some medium channel (electronic or other). The message receiver then gathers and decodes the information for eventual use by the destination. Shannon and Weaver (1949) emphasized that failure can occur at any stage of the communication process. Specifically, at the information encoding stage, the source may encode the information improperly, leaving out crucial details or emphasizing certain other details. Transmitting the message may occur in an incomplete or incorrect manner. Similarly, receiving the message is fraught with potential problems, due to the biases and expectations of the receiver.

A critical component of the model is noise, which may serve to confound the message. Noise may consist of any unwanted stimulus that renders the message less comprehensible. For example, on the modern battlefield, noise may occur because of conflicting information, irrelevant information, or competing sources of information.

Since Shannon and Weaver's early work, other models of the communication process have been proposed, addressing the weaknesses of the five-step process. Some of these models reflected the increasingly complex nature of team communication. For example, the "Sawtooth Model" proposed by Watzlawick, Beavin, and Jackson (1967) captured the dynamic and interaction aspects of communication, focusing on incoming and outgoing messages. As time went on, network models of communication emerged, further increasing the complexity (and therefore the model validity) of representations of the human communication process.

Since the early 1900s, there have been a variety of training techniques developed to enhance military performance (Adams, 1987). Many of these have involved simulation, so that critical aspects of the target task might be rehearsed in a safe, cost efficient manner. Only since the early 1990s, however, have trainers focused on collaborative performance in distributed contexts (Alluisi, 1991). Because of the prevalence of such activities on the modern battlefield, it is imperative that simulators address communication and cooperation needs.

3.3.5 Other Human Factors Considerations

The major issues that relate to human factors and cognitive modeling for human Behavior Representation with the GIG have been covered here. There are many others that are important for future consideration that will complement these basic and broad issues, including

- Workload and Complexity[1] (Billings, 1997)
- Human Supervisory Control (Sheridan, 1992)
- Supervisory monitoring of operators (Mitchell, 2004)
- Human Information Processing (Sheridan, 2002)
- Information processing stages (Parasuraman, 2000, Miller & Parasuraman, 2003)
- Information Overload (Mitchell, 2004)
- Critical Information Requirements (Bjorkman, 2002)
- Seven Stage Cognitive Model (Norman)
- Goal Operator Method (Card, 1983)
- Data/Frame Theory (Klein, 2001)
- Complexity measures (Mitchell 2004)
- Decision Making (Febrache 2004), OODA Loop (Boyd, 1996)
- Data Fusion (Leedom, 2004) (Pew and Mavor, 2003)
- Remote Leadership (Kelloway, 2004)

[1] The GIG is designed to minimize the cognitive demands from workload associated with the complexity and disparity of information. Yerkes-Dodson Law indicates too little or too much work will lead to poor performance with the optimal level in this inverted-U relation being maintained at relatively mid levels of workload.

- Adaptive Automation, Appropriate levels of Automation (Mitchell, 2004)
- Collaborative Mission Planning and Decision Biases (Mitchell, 2004)
- Human Computer Interaction (Card, 1983)
- Display and Web Site Usability (Dumass, 2004)
- Feedback, Training (Salas, 2001)
- Virtual Environments (Staney, 1998)

Research is being conducted in all of these areas. The main challenge will be to align these research results and make Human Factors results available in time for technical experts to apply them to technical specifications.

4 SUMMARY

The Global Information Grid becomes a reality. It will be based on rigid and accepted technical solutions. However, the challenges that arise from these new possibilities must be analyzed and evaluated not only by technicians, but also – and maybe in particular – by Human Factors experts. The cultural changes and leadership challenges that will arise from these new technical capabilities will be huge. The challenges on the human and organizational levels cannot be solved on a technical level. As Alberts and Hayes point out,

> *Power to the edge is about changing the way individuals, organizations, and systems relate to one another and work. Power to the edge involves the empowerment of individuals at the edge of an organization (where the organization interacts with its operating environment to have an impact or effect on that environment) or, in the case of systems, edge devices. Empowerment involves expanding access to information and the elimination of unnecessary constraints.*

The Global Information Grid is the technical enabler to reach this vision. Human Factors must contribute as the psychological enabler in order to make it a reality.

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Acknowledgement: The authors like to thank Taryn T. Cuper for the support in finalizing the paper.