Service-Oriented Architectures, Network-Centric Warfare, and Agile, Self-Synchronized C2: Impacts to Data Fusion Process Design

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ABSTRACT

One of the primary if not the central motivating rationale for Network-Centric Warfare (NCW) is that NCW provides an enabling mechanism for information sharing and shared understanding and awareness of military situations of interest, that in turn allows the realization of entirely new concepts of C2 that are advertised as providing greatly increased agility, speed of command, and synchronization in C2. In turn, the underlying enabling "IT" mechanism for NCW is the Service-Oriented Architecture (SOA) concept, within which all functional services, to include Data Fusion Services, will presumably operate. These attractive but as-yet-not-fully-defined concepts represent a challenge to the Data Fusion community in terms of understanding the implications of the evolving NCW, SOA, and new C2 concepts on the design of Data Fusion Services. Key to this understanding in particular is the need for a close dialog with the C2 research community on exactly what the information needs of new C2 concepts will be and how those needs can best be met by appropriately-designed Data Fusion Services. This talk will address each of these issues and argue for the need for both: (1) a multi-community approach to the architecting of effective and efficient SOA's, and (2) for new initiatives in distributed Data Fusion to address the specific technical challenges of NCW-specific Data Fusion Service design and implementation. (It should be noted that this paper is drawn largely from US literature and so presents a US-based viewpoint developed by the author; the paper does not represent any official US governmental views.) This brief paper is intended to sketch the topical areas that will be addressed in the associated Keynote speech.

Llinas, J. (2006) Service-Oriented Architectures, Network-Centric Warfare, and Agile, Self-Synchronized C2: Impacts to Data Fusion Process Design. In *Information Fusion for Command Support* (pp. KN2-1 – KN2-6). Meeting Proceedings RTO-MP-IST-055, Keynote 2. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

Motivation: Network-Centric Warfare (NCW)

In Ref 1, the tenets of Network Centric Warfare are described diagrammatically as follows:

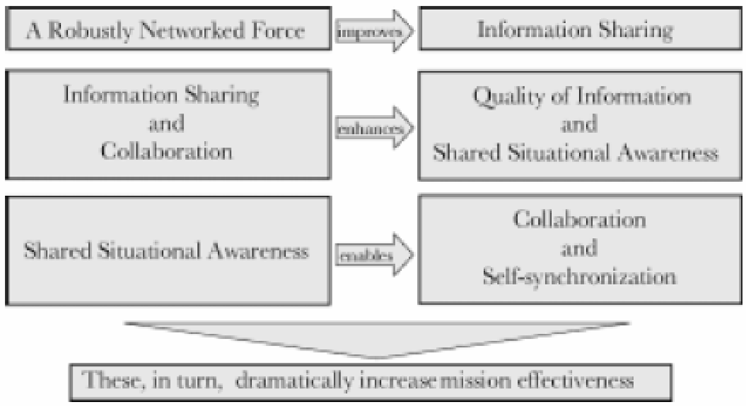

Fig. 1 Tenets of Network Centric Warfare (from Fig 12 of Ref 1)

Or, in words, that a force structure that has an enabling capability for information sharing will realize the benefits of improved quality of information and also of improved situational awareness (ie individual or what could be called "nodal" awareness when considering the force as a networked system), and that the netted environment in turn allows for collaboration, self-synchronization, and shared situational awareness---and that these informational benefits ultimately lead to "dramatically improved mission effectiveness". Implicit in these tenets is that the people involved will be empowered to act based on the above informational benefits and an awareness of the commander's intent for the mission/tasks at hand. Most warfare tasks will require collaboration among people from different operational groups (often called "communities of practice" [1]); these interacting communities of practice in turn form a "community of interest" or COI [2]. The COI's are characterized as "evolving" and form dynamically to address the changing needs of the battlespace; ie they are self-organizing and emergent. It is this quality that, in conjunction with the other features above, gives rise to the asserted agility in responsiveness seen in the NCW literature.

The enabling mechanism for information sharing is the Global Information Grid or GIG, that has its roots in the US in the Clinger-Cohen Act (Ref 4) that was a law designating that the US defense establishment should have a "single, end-to-end information system capability that includes a secure network environment, allowing DoD users to access shared data and applications, regardless of location and supported by a robust network/information-centric infrastructure". Building on this authorization, the technical communities in the DoD developed the GIG concept, one central part of

[1] "communities of practice" are (Ref 2) groups of people linked together by "commitment and identification with the expertise that forms the basis of their practice"—ie they are a group of experts in a domain or task area

[2] "communities of interest" are *collaborative* groups of users who must exchange information in pursuit of their shared goals, interests, missions, or business processes. (Ref 3)—ie they are multidisciplinary in nature.

which is the Network Centric Enterprise Services (NCES)" capability; NCES is a collection of fundamental services that allow informational and functional interactions and sharing. As the name implies, NCES is grounded on a "Service-Oriented Architecture" or SOA design concept. There is a considerable literature on SOA's that describe their features and benefits; the SOA concept is the latest preferred architectural approach that has evolved from the computer science/software engineering communities after some four decades of evolution of such design concepts. In this approach, functional capabilities are made available to users as "services" that interact through the use of the core enterprise services that include security control, messaging, and "discovery" services that allow users to become aware of available services. In this milieu, any Data Fusion (DF) capability will also be provided as, and designed as, a service. This, one fundamental impact of operating in the NCW context is that a functional capability such as DF will have to be designed to operate in the SOA environment. While accomplishing this for any specific application context will not be trivial, it seems that the computer science/software engineering communities have been addressing these design questions with considerable energy, and that much guidance will be available to enable such service-based designs to be realized.

There are nevertheless some SOA-based design questions that still loom important for any functional capability, including DF. One of these is the notion of "dynamic composability", in which, in an SOA architecture, a user can construct a tailored version of a service capability suited to the specific needs of the moment. To achieve this would seem to require that the "granularity", ie the specificity of the structure of DF service components, be designed so that the user can thread together only those components needed for the task at hand. To do so will require that the DF Service designer understand and anticipate a range of user needs across some application domain, eg a mission or task-set domain so that the developed design can provide the necessary capabilities in such a "problem space". This type of design challenge is one motivation for the DF community to work toward understanding how COI's will function in NCW and what their informational needs will be. Additionally, in spite of the apparent flexibility of an SOA, in most military-application cases not all enterprise services will be available all the time to respond (in real-time) to all functional-service demands. This means that in general any functional service will have to understand how such cases will arise and develop contingency-processing strategies to handle these conditions. For example, for a DF Service, it may be possible that at some point communication (via NCES services) to a Sensor Service is not available; the DF Service will require some strategy to handle such delays etc.

Communities of Interest

The COI concept for NCW and the GIG/NCES characterizes COI's as having four types of structure, depending on how they operate and what they do; these types are shown in the figure below, from Ref 5.

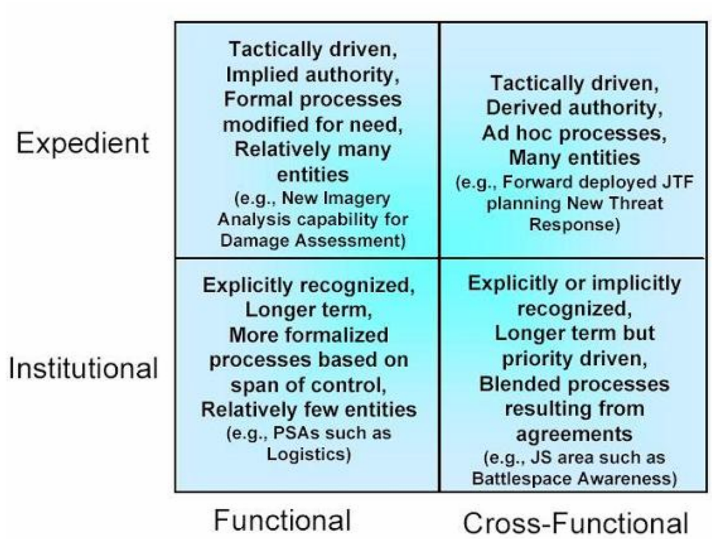

Fig 2. Types of COI's (from Ref 5)

It can be seen that COI's will have a range of operational and functional characteristics; importantly, this means that their informational needs will be diverse in accordance with these differing characteristics, meaning that the DF Services supplying information to these COI's may need to be designed differently so that certain types of qualities are achieved for each COI type.

COI Information Needs

At least one key COI that will be serviced by DF is the Command and Control (C2) COI. The information needs of a C2 COI will be specified at least to some degree in what are called "Mission Capability Packages (MCP)" (Ref 6). Developing an MCP begins with a clearly defined mission or set of missions and seeks to define a) what is required to meet the mission(s) successfully and b) how those requirements may differ from the current force structure, command and control arrangements, organizations, doctrine, and technologies. This process is evolutionary and initial MCP concepts are developed in the concept development phase based on prior research, lessons learned, and expert judgment. The evolutionary MCP approach calls for exposing the MCP concept to review and critique by the operational community and domain experts early and often in order to refine and improve the concept. This review may take the form of demonstrations, experiments, exercises, simulations, modeling, or expert criticism. Consequently, it seems quite appropriate that DF Service designers become involved with or at least aware of how any MCP's are being developed that would have informational requirements dependent on DF capabilities; this is another effect of NCW on the DF Service design process.

Complex Adaptive Systems

The above characteristics of COI's (Fig 2) show that they will generally have emergent, self-organizing properties, be quite adaptive, be controlled locally, and exhibit possibly non-linear interactions. These types of properties are among the properties of complex adaptive systems (CAS), suggesting that COI's should be viewed in this context. More specifically, it can be argued that to realize the asserted C2 benefits and tenets of NCW for modern warfare, considered more complex and dynamic than traditional warfare (see Ref 7 for example), a correspondingly-complex type of control paradigm must be invoked. The so-called "Law of Requisite Variety" in cybernetics (Ref 8) can be invoked in this argument, that says that to properly control such a system, the variety of the controller function (the number of accessible states which it can occupy) must match the variety of the combat system itself. In other words, the control system itself, here the C2 COI organization, has to be complex, with great agility. This has then another impact on DF Service design: to understand how CAS's work and what their informational needs are to function effectively.

Dynamics in NCW

Achieving the benefits of C2 and military operations in general of operating in an NCW context is strongly dependent on, and seems to begin with, the notion of information sharing among people. Sharing in turn implies interaction, minimally to send messages but this can also mean sharing beliefs, mental models, interpretations, preferences, and choices for deciding and acting. We see two interacting and important dynamic loops in these interactions: people-to-people, and people-to-automated systems, to include DF processes. Operating within a context of commander's intent, these dynamic processes intersect and together yield (hopefully)the emergent, agile properties of time-critical effective action-taking and effects-producing operations that the NCW vision allows. An additional impact foreseen in order to realize these benefits as regards the people-to-automated systems interaction is that that interaction needs to be of a mixed-initiative type, allowing human intelligence to not only control a passive/responsive type automated capability but to modify the operating knowledge of that automated capability. Such advances in the design of DF Services are seen as not only desirable but necessary to achieve the type of agility envisioned for the NCW environment.

Research and Development

From our reviews of available literature to date, it seems that there has been a limited degree of holistic type research and development on the COI/CAS-side of the NCW paradigm. Of course, a concept like NCW will take some considerable time to be realized in the full operational sense, but we would argue that the realization of that vision is more dependent on the people-side of NCW than on the GIG/NCES side. Moreover, if the CAS argument is accepted then there is a need to develop the design knowledge that will allow CAS capabilities to be developed that have predictable or at least bounded behaviors (since CAS's can also exhibit pathological/chaotic behaviors). Most of the R&D in this area to date has been with the aid of agent-based techniques, which is of course helpful and insightful, and also cost-effective, but there is a lack of validation and R&D on human-based equivalents, using real people in experimental settings to learn the design knowledge to construct

COI's that indeed achieve the desired "NCW-like" performance. Further, recent literature has shown that if formal, statistically-validated experimentation and results-analysis is desired as a framework to study these processes and behaviors, serious thinking ahs to be applied to develop cost-effective test and evaluation strategies that also yield statistically-valid results.

References

1. Alberts, D.S. and Hayes, R.E., " Power to the Edge: Command and Control in the Information Age", Command and Control Research Program Publications at http://www.dodccrp.org

2. Communities of Practice Home Page at http://home.att.net/~discon/KM/CoPs.htm

3. Dept of Defense, "Net-Centric Environment Joint Functional Concept", Version 1.0, 7 April 2005, http://www.dtic.mil/futurejointwarfare/concepts/netcentric_jfc.pdf

4. Anon., "Clinger Cohen Act of 1996 Clinger Cohen Act of 1996 and Related Documents", presentation at http://www.defenselink.mil/nii/org/cio/doc/CCA-Book-Final.pdf

5. Dept of Defense, "Communities of Interest in the Net-Centric DoD Frequently Asked Questions (FAQ)", May 19, 2004, Version 1.0

6. Alberts, D.S., " Mission Capability Packages", . National Defense University, Strategic Forum, Institute for National Strategic Studies, Number 14. 1995, at http://www.ndu.edu/ndu/inss/strforum/z1405.html

7. Moffat, J., "Complexity Theory and Network Centric Warfare", DODCCRP Publications, 2003

8. Anon., "The Law of Requisite Variety" at http://pespmc1.vub.ac.be/REQVAR.html