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"C2 for Complex Endeavors"

Large-Scale Collaboration for Ill-Structured Problems

Topic 9: Collaborative Technologies for Network-Centric Operations
Topic 8: C2 Architectures
Topic 5: Organizational Issues

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Abstract

Traditionally, military forces have relied on deconfliction to drive down complexity and situation awareness burdens. Network-Centric Operations (NCO), however. depend on thoughtful orchestration through improved situation awareness and self-synchronization. Commanders are expected to understand the situation, their superior's intent and anticipate the actions of those around them in a complex and volatile environment. To successfully meet these rigorous requirements, the net-centric organization must facilitate much higher levels of ad hoc, time-sensitive collaboration. Commanders and staffs need to quickly build and dissolve sophisticated links with many operational partners as they contend with ill-structured problems in a complex battlespace. Current collaboration tools are limited in that they force a tradeoff between the complexity of the collaborative engagement and the number of participants. Tools that can handle large numbers of active users only support simple collaboration (e.g., chat), while those that support complex interactions (e.g., whiteboard) are quite limited in the number of parallel users they can realistically support. In this paper, we propose a new model that can integrate large numbers of users in complex collaboration. This effort leverages the proven Group Support Systems pattern while addressing the problems that have kept such systems from moving into the mainstream.

1. Introduction

The move to Network-Centric Operations (NCO) is a sea change for the Department of Defense. The precision and lethality of our modern arsenal is unquestionable, but its effective employment is dependent upon accurate and timely information. Moreover, military success is becoming less and less dependent on kinetics and warfare, and more dependent on integrated efforts across the spectrum of response to include stabilization, humanitarian assistance and disaster relief operations. Net-centric, self-synchronizing warfighters have to constantly make sense of a complex and dynamic environment – often times an impossible task for any single person. By tapping into the collective "wisdom of crowds", however, we may be able to realize the full potential of NCO and build a self-supporting network of sensemaking operators.

Currently, we have a host of collaborative tools available and embedded within our processes. Almost without exception, these tools are simply analogous extensions of our manual collaborative efforts. As such, they break down barriers to geographic distribution and provide some efficiencies, but they can't escape the issues associated with process bottlenecks and scalability.

Instead of relying on collaborative tools that mimic the physical world, we need to develop a class of tools and supporting processes that can effectively and efficiently aggregate and synthesize the efforts of many more active participants. By doing so, we can expand the scope and effectiveness of collaboration. We anticipate that such capabilities would also lower the barriers to incremental participation by people who might not otherwise contribute. In many situations, there is a core group of dedicated, active participants. There are, however, a far larger number of people who could provide value but remain passive, or do not participate at all. By leveraging this "long tail" of previously passive participants, we would hope to find value in the incremental contributions of all team members.

By removing the process bottlenecks that afflict current collaborative systems we could investigate new ways to build composable processes that effectively scale. Additionally, we

would harness the judgments of the participants to improve the quality of collaborative engagements.

2. Network-Centric Operations

Network-Centric Operations has proven to be a major departure from legacy doctrine for the American military. The chain of logic behind it is that given high quality and timely information, people throughout the organization can act independently and interdependently to achieve commander's intent. Moreover, the decentralized, network-centric organization can reach these ends more effectively and efficiently than a hierarchical, centralized organization can ever hope.

2.1 Self-Synchronization

The holy grail of NCO is self-synchronization (Alberts, 2003). It rests firmly upon the proposition that subordinates have superior local knowledge, and if they understand the goals (commander's intent), principles (rules of engagement), and plans (orders) of an operation, they can produce results superior to the centrally controlled organization. If we accept the wisdom of this core precept, it follows that an enhanced collaborative capability will aid subordinates and improve our force agility and ultimate effectiveness.

2.2 Agility

Ultimately, the competitive advantage provided by NCO is agility. Through C2 and force agility, commands can rapidly adapt to meet a full range of contingencies. During the cold war, we had an appropriate focus on large-scale general war with the Eastern Block. As a result, we built weapons and measures that served us well in large-scale conventional conflict, as displayed in Desert Storm.

The rest of the world took notice of the rout and came to the conclusion that asymmetric warfare was the best hope for taking on the United States. Even while we face down terrorists and asymmetric threats around the globe, we must still be prepared for general war. Complicating the mix, our forces have also inherited the challenging role of first responder to international humanitarian crises.

Agility is the means by which our forces can rapidly adapt to meet any or all of these challenges. As we have witnessed in Iraq, our adversaries are complex. We cannot treat these sophisticated and dynamic threats as a static problem to be solved. We must be constantly innovating and improving our methods faster than they can adapt. Only by taking and jealously holding the initiative can we fight on our terms rather than our enemies'.

2.3 Complexity

Much of the perceived need for hierarchical control arises from the sheer complicatedness and complexity of our environment and systems. Modern campaigns are a vast symphony of logistics, intelligence, and operations. From an industrial age viewpoint, the way to orchestrate these innumerable activities is through strong, centralized control.

However, as one ties more and more operational entities, sensors and databases together in the quest for speed and effectiveness, not only does the level of complication increase, but the effects of uncontrollable factors multiply. Though there are many definitions of complexity and complicatedness, a useful way to distinguish the two is through the effects of random or uncontrollable events on the system. For the purposes of this paper, we discriminate between the complicated and the complex based on the criteria outlined in Figure 1.

Complicated = not simple, but ultimately knowable

- **Deterministic**
- **Can be modeled accurately**

Complex = not simple and <u>never fully knowable</u>

- **Probabilistic**
- **Models always subject to random or pseudorandom events**

Figure 1 – Complicated vs. Complex

A future NCO campaign with heightened operational tempo, interdependent joint actions and myriad sensors and shooters is not merely complicated, it is complex. It is far from simple and will never be fully knowable. Collaborative systems must provide sufficient agility such that users can successfully adapt processes to such a truly complex environment.

2.4 The Control Spectrum

Centralized control is an indispensable tool in the commander's toolbox. We should, nevertheless, seek to make our forces as agile as possible. By giving commanders new options for command and control we improve our ability to exceed any future threats.

In the book *Power to the Edge*, Alberts and Hayes outline a continuum of successful C2 approaches (Alberts, 2003). At the most centralized end of the spectrum are *Cyclic* controls based on a specific timeline. The most decentralized approach is termed *Control Free*, whereby commanders issue objectives to subordinates and leave them to accomplish the mission. In between is a range of approaches ordered by degree of centralization as illustrated in Figure 2.

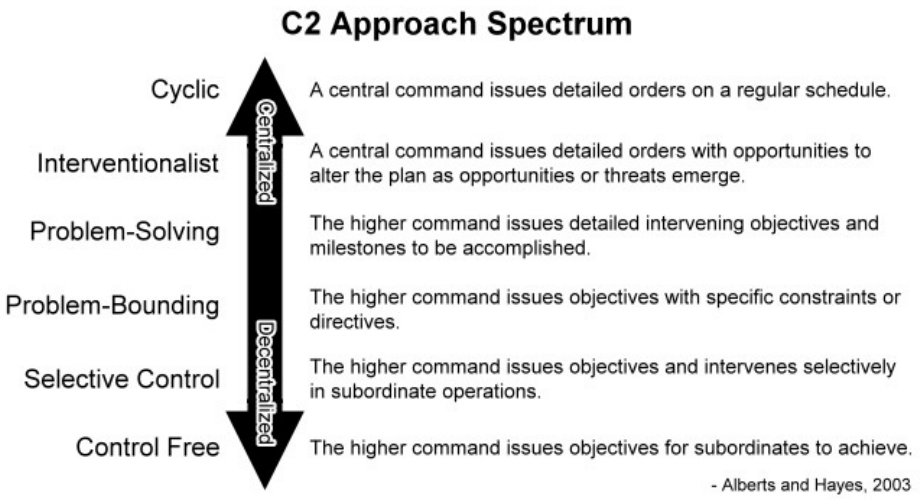

Figure 2 – Command and Control Spectrum

The more centralized approaches fit well into the industrial age schema. Communication channels were lean and crowded, and sensors were limited. As a result, the limited situation awareness of subordinate commanders would not allow them to understand the greater operation and orchestrate their actions accordingly. In addition, there were only limited networks and computing resources to drive rapid collaboration and coordination. The obvious way to direct such poorly informed sources is through centralized control while allowing some tactical latitude.

3. Collaboration

In order to move towards decentralized command and control participants up and down the chain of command must have a greater understanding and situation awareness than under centralized schemes. Moreover, since relationships and operations are not being mandated from on high, NCO participants must have mechanisms to better collaborate and act in concert with all partners, whether they are habitual, new or even unanticipated.

Research by Nunamaker et al posits that there are three levels of group work: individual, coordination, and group dynamics (J. Nunamaker, Dennis, Valacich, Vogel, & George, 1991). Individual is compared to a group of sprinters, each exerting effort but in an uncoordinated, individual manner. Coordination is a level of collaboration where the work is coordinated but done independently. This level of group work is synonymous with the "divide and conquer" approach to group tasks. Nunamaker et al compare this level of group work to a relay team at a track event. The members of the team each work together to an extent for the good of the team but each member is still working on an individual basis. The highest level of collaborative group work is the group dynamics level. This is collaboration where the members of the group work in a concerted effort toward the group's goal. To achieve this level of collaboration, significant levels of communication and coordination are required.

3.1 Collaborative Bottlenecks

Collaborative work in an NCO environment can easily achieve the lower level of individual group work and can, with significant effort, achieve the second level of coordination. Groups can assign tasks, compile results, and move forward by compiling the individual results. Unfortunately, the collaborative systems and processes we currently have do not easily facilitate coordination and completely fail to support group dynamics on a large scale because they mimic real-world face-to-face (FtF) collaboration.

For example, whiteboard is akin to a digital chalkboard. Like a physical chalkboard, though a lot of people can passively watch, only a limited number of people can actively draw before the effort falls into chaos. Even the massive Kmart chat room in Operation Enduring Freedom had to limit the number of people allowed to contribute. While the number of readers was left largely ungoverned, too many active contributors had pushed the collaboration into dysfunction. Figure 3 illustrates how the effectiveness of collaboration drops precipitously as the number of *active*

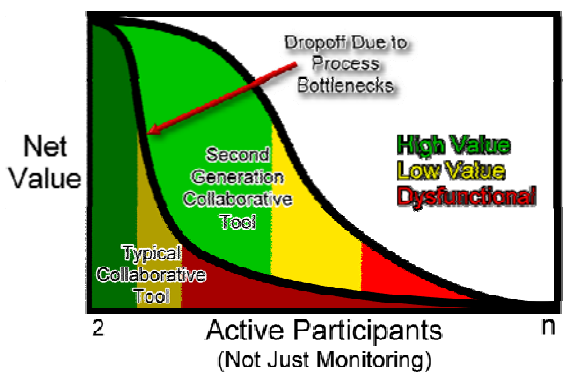

Figure 3 – Scalability of Collaborative Tools

participants increases.

Additionally, virtual collaboration misses the rich nonverbal and environmental signals that drive FtF collaboration. Each step in the process must be made explicit to the participants – workflow must be built-in to move to higher levels of coordination and group dynamics. Unfortunately, most defense-related tools that include workflow lack any real agility. They are custom built for specific workflows and cannot be re-tasked for new contexts. As such, the general trend among collaboration systems is reflected in Figure 4. The available tools simply can't support large numbers of participants in more complicated collaborative efforts.

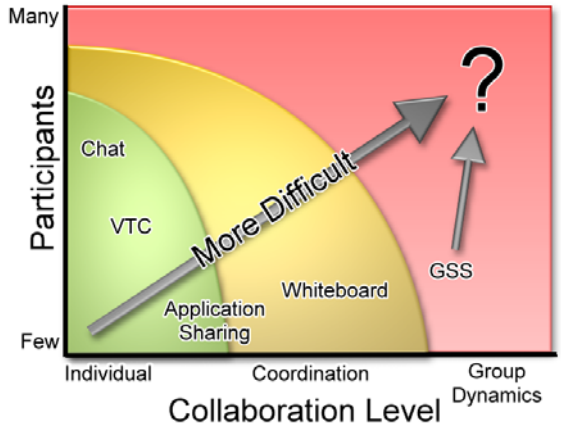

Figure 4 – Collaboration Levels and Participation

Though it is not currently able to support large numbers of participants, one type of collaborative tool that supports Group Dynamics are Group Support Systems (GSS). GSS are systems that use composable modules to move groups through complicated collaborative work.

4. Group Support Systems

Group collaboration for decision making can produce great results. A meta-analysis of over fifty field studies found that in 86.5 percent of the studies, the users of Group Support Systems experienced performance improvements (Fjermestad & Hiltz, 2000). Additionally, GSS research also shows significant savings in person-hours and calendar time (deVreede, Vogel, Kolfschoten, & Wien, 2003). Collaborative efforts can leverage the knowledge and experience of the team members, develop innovative ideas, and increase participant buy-in for decisions (Adkins M, Burgoon M, & Nunamaker J. F). Additionally, diverse groups outperform homogeneous groups by increasing the breadth of decision options even when the homogeneous groups have better individual performers (Page, 2007).

Typically, collaborative decision support processes can be broken into five core activities as outlined in Table 1. Of the five core activities, three are overt and indispensable: diverge, converge and evaluate. The other two are necessary, but can be accomplished through the three primary processes.

Pattern	Description
Diverge	Move from having fewer concepts to having more concepts
Converge	Move from having many concepts to focusing on a few concepts deemed worthy of further attention
Evaluate	Move from less understanding of the value of concepts for achieving a goal to more understanding of the value of concepts for achieving a goal.
Organize	Move from less understanding to more understanding of the relationships among concepts
Build Consensus	Move from having less agreement among stakeholders to having more agreement among stakeholders.

Table 1 – Collaborative Activities (Briggs, de Vreede , & Nunamaker, 2003)

Divergence can be achieved through parallel brainstorming. This activity increases the cognitive bandwidth of a meeting by allowing users to simultaneously develop and surface new ideas for the group. Evaluation is also a rather simple and well-understood process. As with a market or vote, we simply allow participants to show their support for different options or ideas.

The challenge to collaborative decision support lies in convergence processes. Humans are born to synthesize ideas into rich threads. This is, however, difficult to do in a group where opinions and ideas have to be balanced and lean communications channels limit shared understanding. Typically, to overcome this obstacle, groups will either employ a facilitator to move them through the convergence process, or they will simply hand the assignment to an individual or subgroup (revert to coordinated work). In either case, the process becomes less collaborative and more serial in nature.

Facilitated methods of group course of action (COA) development were proven effective during a five-year DARPA sponsored research project on collaboration. Throughout the effort, researchers from the University of Arizona embedded with the U.S. Navy's Third Fleet staff, often facilitating group meetings and decisions. For example, during RIMPAC '98 (Rim of the Pacific), the largest naval exercise in the world, Arizona researchers successfully facilitated officers from seven coalition nations in building COAs for dealing with a real-world hurricane that was approaching the Hawaiian operations area. In twelve hours the group went from assignment to the development of seven courses of action for the commander of Third Fleet. Though effective, the overhead of the facilitator and the cumbersome convergence process limited its widespread transition possibilities. It is not viable to train and assign human facilitators throughout a force.

We believe that systems can be created that will attack the problems associated with collaborative convergence and the facilitator. The core idea behind this is that by aggregating the small judgments of the participants, a prototype system can mimic the efforts of a human facilitator and overcome the collaborative bottlenecks that may suppress innovation and effectiveness. As in Figure 5 (Helquist, Kruse, & M. Adkins, 2008), the system will periodically move participants between tasks (roles), asking questions about which ideas belong together, what idea threads should be named, which ideas are redundant, et cetera. By engaging all of the participants simultaneously, the prototype will significantly speed the collaborative interaction while increasing participation. We also expect users to find greater net value as currently the GSS convergence process is difficult and unsatisfying for participants (Briggs, Vreede, & Jay F. Nunamaker, 2003; Chen, Hsu, Orwig, Hoopes, & J. F. , 1994).

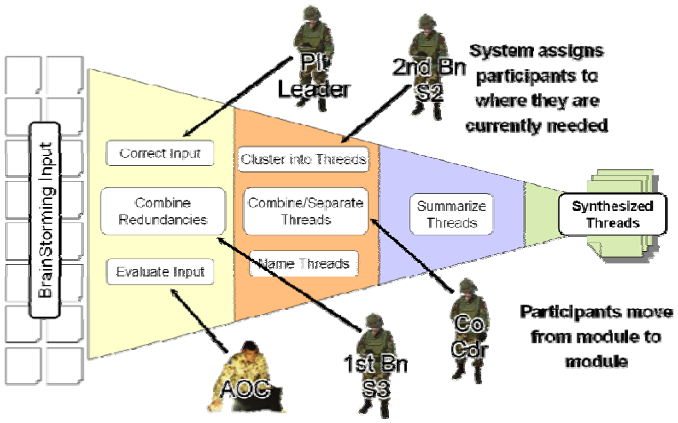

Figure 5 – Collaborative Process

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Prototype Efforts

Building a collaborative architecture is not trivial. Fortunately, much of the technical infrastructure already exists for a prototype. Previously, researchers at the Center for the

Management of Information at the University of Arizona, and later Brigham Young University built an improved brainstorming module for large groups on a free and open-source collaborative architecture known as Koncero.

The focus of Koncero system development will be on the three primary collaborative activities: *divergence, convergence and evaluation*. The three modules are composable and can be organized dynamically to lead collaborative participants through any number of complicated, ill-structured decisions. Convergence is the most difficult phase and is comprised of a number of subtasks or role modules. Although the exact form of the prototype is bound to change as we learn more about collaborative convergence. Table 2 lays out the specific convergence modules we intend to create for the prototype and experimentation.

Module	Description
Correct Input	Participants correct simple errors and/or restate ideas to improve correctness, clarity, etc.
Combine Redundancies	Participants find and combine redundant entries.
Evaluate Input	Participants rate entries in terms of important criteria (effectiveness, creativity, efficiency, etc).
Cluster into Threads	Participants sort ideas into categories.
Combine/Separate Threads	Participants break up or combine threads as the collaboration matures and evolves.
Name Threads	Participants give threads meaningful names.
Summarize Threads	Participants construct abstract paragraphs to describe each COA thread.

Table 2 – Koncero Convergence Modules

As users log into the system through a web browser they will be assigned, depending on the current process requirements, one of the tasks from Table 2. For example, a user might be first asked to identify and combine redundant ideas for several minutes. Then he is moved to a new task and is shown a subset of several ideas and asked to evaluate them by assigning scores on a Likert scale. After completing that task, the participant might then be asked to cluster a different set of ideas by setting up “idea buckets” and dragging and dropping the ideas into them. Participants spend only a few minutes on each task, but the system derives value from even the shortest sessions. By constantly maintaining parallel effort where it is needed, the prototype will quickly and effectively move the group through all of the steps that a human facilitator would accomplish over a much greater time. Ultimately, the aggregation of the participants’ judgments will yield a set of work products that could not be created currently by a networked group with such ease or speed.

5. Conclusion

Groups often reach better decisions than individuals because the collective knowledge and skill of the group is typically greater than an individual’s knowledge or skill (N. Maier, 1967; N. Maier & R. Maier, 1957; Wright & Rohrbaugh, 1999). Furthermore, when employed properly, collaboration creates value in the sense of better and more innovative decisions (Aakhus, M. Adkins, & Glynn, 1997; J. F. Nunamaker, 2002).

For the most part, collaboration is straightforward when the groups are small, tasks are uncomplicated, and group members are located in the same place. As missions become more global and dynamic, and group size increases, collaboration becomes much more complicated. Defense-related collaboration is made even more difficult by the increasingly ad hoc nature of the engagements. Often teams come together quickly for a specific mission or “pop-up” task that

cannot be rehearsed or anticipated. Collaborative systems must do a better job of facilitating complicated work than is currently possible.

The participant-driven convergence approach advocated in this paper has the potential to significantly improve complicated collaboration among large and shifting groups of participants. In spite of the success and demonstrated efficacy of facilitated collaboration, there are considerable barriers to the use of a facilitator, even in collocated and synchronous groups. The participant-driven approach seeks to further empower the participants to conduct the critical convergence activities through parallel, anonymous work in order to arrive at effective and efficient collaborative outcomes.

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