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MEASURES OF EFFECTIVENESS UNDER DIFFERENT COMMAND AND CONTROL ORGANIZATIONAL ARCHITECTURES*

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Abstract

Today's military faces enormous pressure to downsize and restructure. In addition, operations-other-than-war, such as humanitarian assistance and peace-keeping, differ significantly from traditional combat missions. The unique characteristics of peace-keeping missions involve inherently more complex command arrangements. Moreover, the increased political sensitivity associated with these missions further exacerbates the stress on command and control (C2) arrangements. Thus, Joint and Coalition doctrine is more complex and reliant on the synchronized employment of combined arms. The process of organizing for Joint and Coalition operations must be driven by the disparate missions and the requisite tasks involved. Depending on the specific mission, the diverse range of future anticipated operations can require a wide variety of Service capabilities under a Joint Force Coalition. It follows that the C2 organization should be flexible in order to allow commanders to meet the many and diverse operations that are expected to continue to be undertaken. This paper reports on the use of measurement instruments developed for the initial experiment conducted under the Adaptive Architectures for Command and Control (A2C2) program. The goal of the A2C2 research effort is to provide insights based on exploring innovative thinking and empirical research on organizational design that can assist in positioning the Joint community to face the diverse challenges and dynamic changes that are projected for the future.

1. INTRODUCTION

Changes in military doctrine, as well as in operational and organizational concepts, will fundamentally alter the character and conduct of future military operations. One of these changes involves the concept that the Navy's command and control (C2) processes should be capable of transitioning smoothly and effectively into Joint (i.e., multi-service) or Coalition (i.e., multinational) operations: a basic premise is that naval doctrine must be seamless in its support of joint doctrine and joint operations. While certain current underlying principles, such as centralized planning with decentralized execution and flexible control procedures, are inherently conducive to a smooth transition to joint operations, several areas that impact doctrinal decisions have been identified as shortfalls and in need of additional study [1]. One specific area is how to align naval C2 architecture to transition to a Joint and Coalition C2 architecture.

Another major reason for examining novel ways of organizing US military forces is that new military missions are considerably more difficult and complex than traditional missions in terms of C2 arrangements in several ways. The Institute for National Strategic Studies describes these differences, which include: (1) the compression of strategic, operational, and tactical decisions and processes; (2) the ad hoc nature of command, force, and sustainment arrangements: (3) the lack of unity of command or even purpose; and (4) the addition of a civil-military dimension [2].

To obtain insights as to how some of these current doctrinal objectives can best be accomplished, analysts are studying how to achieve C2 flexibility. For example, how might a carrier battle group (CVBG) and an amphibious ready group (ARG) operate either as a combined unit or separately when required, as might be done during crises or routine deployment. Another fundamental change affecting our military organizations is the notion that tomorrow's force must be effective while requiring fewer personnel. One aspect of accomplishing future missions with fewer personnel is that a flattening of the organization may also be necessary to reduce hierarchical overhead.

In this vein the Joint Warfighting Center [3] is examining the transitional period that US military forces are currently experiencing and have identified several key issues. Some of the challenges posed by changes in military doctrine and operational and organizational concepts include:

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- What alternate force structures (or architectures) might make best use of new ideas currently under consideration?
- How might organizations restructure to take advantage of the new visions?
- What are the advantages and pitfalls?
- What might the "military after the next" look like?

Adaptive Architectures for Command and Control

The Adaptive Architectures for Command and Control (A2C2) research program, sponsored by the Office of Naval Research, is a multi-year, multi-disciplinary effort being conducted to gain insights into the questions enumerated above. A guiding principle of the A2C2 program is that a precursor to the design of flexible organizations is a practical knowledge of the interactions among three key dimensions, all driven by the mission: task structure, organizational structure, and coordination requirements. Research indicates performance is higher when there is a "match" between the task environment and the organizational design or architecture. One of the guiding principles of the A2C2 research program is that the architecture of an organization must correctly match the task structure to achieve superior performance [4]. The A2C2 program has adopted a multifaceted approach, employing a variety of methodological perspectives—including field surveys, empirical research, simulations and analytical modeling tools—to gain insights into the issues of (*i*) how to select the best architecture for an organization, (*ii*) when to adapt to another organizational structure, (*iii*) the diagnostic variables that indicate when an organization is about to/or should change, and (*iv*) what factors enable, mediate, or effect adaptability without an unacceptable degradation in performance.

Revolution in Military Affairs

The novel concepts, technologies and innovations that are currently being studied for integration into today's military are referred to collectively as the Revolution in Military Affairs. The underlying concept is that advances in technology will lead to dramatic changes in how military forces are organized, trained, and equipped for future operations. "The key to understanding the concept is to make the necessary force changes to let the true value of the new technologies emerge" [5].

The US military is currently evolving in ways that parallel the changes currently underway in the business sector. The classic business model of the past was based on the company as the source of power and wealth, and the military model on the "platform"—ship, plane, or tank—as the source of power. Now, networks that combine information gathering, command and execution are the keys to both business and military success. The Navy is transitioning away from its advantage of large ships to dominate the seas to coordinated, multiservice networks that combine information gathering, command and control, and firepower [6]. Another advantage is that the focus is now on the emergent behavior from within the organization rather than what occurs in the board room or the flag staff offices. "Network-centric warfare" reflects this fundamental change in thinking in terms of notions involving such new ideas as self-synchronized versus command-synchronized forces [6].

Using this business metaphor, the Joint Task Force (JTF) command staff seeks to understand which nodes add value to the JTF's command process, thus contributing to improved speed of command, and which nodes add no value or possibly detract from the process. An ongoing research effort (albeit involving a different approach from the A2C2 work) to provide answers to this question involved identifying the decision requirements in a Marine Corps Regimental Combat Operations Center (COC). Based on a decision requirements analysis, that is, what the key decisions were and how they were being made, researchers recommended improvements in the organization of the COC [7]. The research team concluded that four to five Marines could operate the command post efficiently, a substantial reduction from the original 20-plus personnel; certain nodes in the organization were considered unnecessary (i.e., impediments) to decision making and were removed. A similar study is currently underway for the First Marine Expeditionary Force to determine decision requirements and barriers to effective decision making for a larger organizational structure.

A unique attribute of coalitions is their ad hoc nature, since their initial form lacks an organizational structure representative of any single organization. Negotiating the traditional elements of structure (e.g., mission, roles, authority relations, control and coordination mechanisms) is part of forming a Joint or Coalition organization [8]. This emergent need to create integrated organizations that will produce optimal performance outcomes is critical to the private business sector as well as to joint service and multi-national coalitions. "We must find the most effective methods for integrating and improving interoperability with allied and coalition partners" [8].

The remainder of this paper will briefly describe some of the tasks examined in the initial A2C2 experiment, some of the performance metrics used and results obtained with these measurement instruments.

2. DECISIONMAKING TASKS

One of the major assumptions behind the "flattening" concept discussed earlier is the existence of a common operational picture. All commanders at all levels must have a common view of the battlespace—they must see the same threats, at the same time, and possess the same understanding of the overall situation as well as certain specific aspects of the evolving situation. Since our

purpose was to test organizational structures in a future environment of shared, global information, a common operational picture was provided. When one decision-maker (DM) in the organization saw a threat or task, it was seen by all others at the same time. The idea was that this common view might reduce parochialism in certain circumstances, through fostering a shared mental model among team members.

The emerging concepts described above are enabled by what is referred to as information superiority, or increased sustained situation awareness (SA). This paper reports on a measurement instrument designed to capture the SA of the team members who served as subjects in this experiment. Other process and performance measurement instruments were used for this experiment and are reported elsewhere. Several outcome measures, that are not discussed in this paper, were collected automatically by the computer simulator.

Coordination of Effort

The types of situations embodied in the scenarios used for the A2C2 initial experiment emphasized coordination of effort across team members (organizational nodes). This was operationalized in terms of synchronizing performance of mission subtasks and cooperation in terms of sharing access to limited assets.

Maintaining Situation Awareness

The ability to maintain SA has always been difficult (c.f., the "fog of war"). Several factors associated with Joint and Coalition operations exacerbate this challenge, such as maneuver tactics that emphasize high tempo operations on a nonlinear (constantly changing) battlefield. In general, SA refers to the DM's moment-by-moment ability to monitor and understand the state of the complex system and its environment [9]. Developing SA includes understanding many factors including the commander's intent, mission, enemy, terrain and weather, troops and fire support available, and time. Generally speaking, the concept of SA refers to the mental process of knowing what is going on at any point and time in the surrounding environment. SA is important in military decisionmaking for several reasons. It provides the foundation for subsequent decisionmaking and action selection in complex, dynamic environments. When emergencies arise, the completeness and accuracy of the DM's SA are critical to the ability to make decisions, revise plans, and manage the system. Moreover, loss of SA and lack of positive target identification are found to be the two variables that account for most fratricides in warfare [10]. (A separate, yet related point, is that developing an effective C2 architecture is noted as one of the most critical steps within the Joint arena that can impact future fratricide rates [10]. With the growing emphasis on multinational operations the process of distinguishing friends from foes becomes increasingly difficult.) Finally, maintaining accurate SA is critical for conducting coordinated operations involving shared resources.

A strong case can be made that it is highly desirable for the commander at each node of the organization to be aware of both the current top priority task/s and the future top priority task for each node within the organization. However, many factors can degrade an individual's SA (e.g., information ambiguity, cognitive overload, human error, loss of communications or other information sources, time delay in information receipt) and a considerable amount of attention is required to construct a prioritized and accurate mental model of the environment. DMs must perceive, synthesize and determine the relevance of a continual stream of incoming information, often pertaining to several concurrent contacts or tasks, while projecting future anticipated events and making decisions regarding actions to be taken [11]. DMs must assess, compare, and resolve conflicting information, while making difficult judgments. They must remember the status of critical contacts and their associated tasks along with the contact's response to actions taken by the team. These decisionmaking tasks are interleaved with other required tasks, such as keeping other team members informed (both above and below the DM's node).

3. A2C2 INITIAL EXPERIMENT

The goal of the initial A2C2 experiment was to investigate the general hypothesis that there is an interaction between task structure and organizational structure. The context was a JTF, in a six-node hierarchy, including or not including a common functional commander (analogous to the middle-level commander within the organization). The JTF was conducting a multi-faceted amphibious operation, involving maritime, ground, and air assets. The situations in which common functional commanders were expected to add value formed the basis for the two specific hypotheses tested in this experiment:

- An organization with a common functional commander is better for tasks that require coordination between units in this functional area for the use of assets owned by one of them.
- An organization without a common functional commander is better for tasks that require coordinated use between units in this functional area for assets not owned by either of them.

Two different organizational hierarchies (2-tier and 3-tier) and two variants of the scenario (different task structures) were used to examine the relationship between the levels of hierarchy in an organization and different types of coordination requirements (competition for internal and external assets) in a 2x2 design.

Subjects

Twenty-four military officer students from the joint C4I Systems curriculum at the Naval Postgraduate School in Monterey, CA, served as subjects. The subjects were organized into four six-person teams. Teams were formed by the experimenters with participants distributed according to military occupational/ warfighting specialty and branch of service, to the extent possible given the demographics of the sample.

Procedure

To gain insights as to how C2 architectures comprising different organizational hierarchies can impact mission performance we systematically observed the behavior of six-person teams performing mission tasks under distinctly different architectures. Task structure was also manipulated in terms of asset coordination. One condition required coordination of organic assets (assets that are owned by one of the service components), while the other required coordination of non-organic assets (assets owned outside the service component, e.g., by the CJTF). Competition events were inserted into each mission scenario to stress the organization's ability to coordinate assets. Thus a major premise of the A2C2 program, is that the (re)structuring of an organization should be driven by the characteristics (and structure) of the task or mission the organization faces.

Command Structure. Two levels of organizational structure were used: a 3-tiered structure, with a common functional commander, either a ground component commander (GCC) or a maritime component commander (MCC), supervising the two lowest-level units (either Marine Expeditionary Units 1 & 2 (MEU1 and MEU2) under the GCC or the CVBG and ARG under the MCC); and a 2-tiered, with the two lowest-level units reporting directly to the CJTF. Although the 2-tiered and 3-tiered structures were separated for analysis, the two JTF organizations that were used for the experiment each had an intermediate commander supervising one component and none supervising the other. Thus, in half the runs there was a GCC, while in the other half there was an MCC. This was done in order to keep the number of subjects constant across all trials, and avoid task-load-per-individual problems that would have arisen had the two structures been comprised of a different number of subjects. The two organizational structures are shown in Figures 1 and 2.

Distributed Dynamic Decisionmaking (DDD-III) Simulator. Data were collected in the Distributed Dynamic Decisionmaking (DDD-III) Simulator, a six-station test-bed environment that simulates decision-making nodes within a Joint Task Force organization. (For a detailed description of the DDD-III see [12].) After approximately 4 hours of training in the use of the computer consoles the subjects engaged in four scenarios. The scenarios were each about 45 minutes in length and contained between 3 and 4 tasks per scenario in addition to numerous defensive tasks.

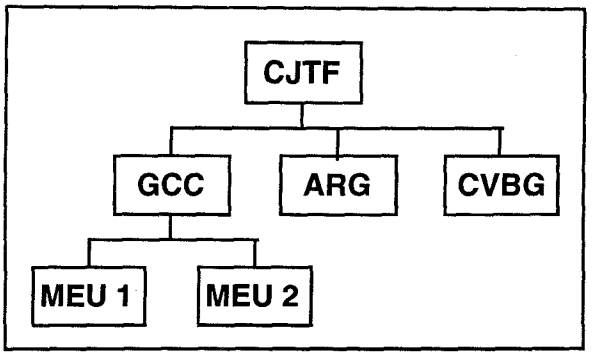

Figure 1. 3-Tier Ground Hierarchy 2-Tier Maritime Hierarchy

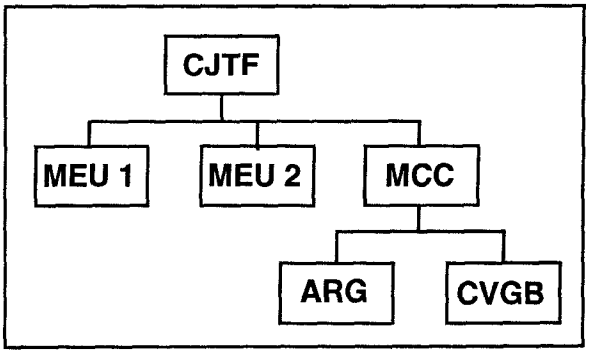

Figure 2. 2-Tier Ground Hierarchy 3-Tier Maritime Hierarchy

Treatment of Data

SA was assessed using a self-report questionnaire and was designed to assess Endsley's [9] three levels of situational awareness: perception of environmental elements, comprehension of the current situation, and projection of future status. We argue that if team members possess good situational awareness, in terms of good perception and comprehension of the current situation, they will be able to state with some accuracy what mission tasks are critical both for themselves and for team members at other nodes in the organization. To assess SA in an on-line manner the simulation was stopped (paused) at two times that were considered to be pivotal, and a questionnaire was administered. The questionnaire required each team member to respond to a matrix-formatted form by selecting his/her two most critical tasks at that point in time from a list of mission tasks. Team members were also required to indicate what they thought were the two most critical tasks confronting each of the other five team member at that time.

SA Accuracy Score. Subject matter experts rated responses in terms of four levels of accuracy. A "4" was assigned to the most accurate responses, "3" was assigned to an acceptable response, "2" was assigned to an incorrect response, and a "1" was assigned to missing data.

Mean SA accuracy scores were compared to assess the effectiveness of 2-tier vs 3-tier organizations in terms of their ability to foster accurate SA. Of particular interest is the awareness of the DMs who are actually accomplishing the mission tasks. Hence, the SA accuracy ratings for the two low-level DMs (either MEU1 and MEU2 or CVBG and ARG) were combined, and the means were compared when they were operating under the two different architectures.

SA accuracy scores were also compared for the commanders, to determine both their own SA and their awareness of the most important tasks confronting the low level DMs in their chain of command. Hence, these comparisons were designed to view both local SA (the DM's own perspective), and the global perspective (what the DM believes the critical tasks are for other team members).

Concordance Measure. A measure of concordance was devised to assess this aspect of the team members' SA. That is, we compared what each team member said were the critical tasks for each other team member with what the other team member actually recorded were critical. If there were no matches a score of 0 was given, if there was one match a score of 1 was given, and if there were two matches a score of 2 was given.

4. RESULTS

Concordance

Our first analysis was on team wide SA using the concordance scores. Only one marginally reliable result emerged from this analysis. In the second assessment period, teams appeared to exhibit better SA in terms of higher concordance scores under the 2-tier as compared to the 3-tier organizational structure (Means .55 and .40, respectively, $p<.085$). This result would imply that flattening the organization may improve SA.

The next analyses examined the SA of each team member. There were no reliable effects for the CJTF position. The MCC/GCC position yielded a significant organizational structure main effect showing higher SA in the 2-tier as opposed to the 3-tier condition, and this was true in both time periods ($p<.05$). The same pattern of results were observed for the MEU1 position in time period one ($p<.02$) and for the ARG position in time period two ($p<.05$). These results add further credence to the idea that a flatter organization may improve SA.

For time period one, an organizational structure by task structure interaction occurred for the ARG position ($p<.065$). Higher scores occurred in the 2-tier condition when competition was for non-organic assets, however, when competition was for organic assets higher scores occurred in the 3-tier condition. Interestingly an organizational structure by task structure interaction ($p<.085$) was also found for the MEU1 position in time period two showing exactly the opposite pattern. If we modify our above argument slightly we can account for the ARG's results. Flatter organizations should in general improve SA and particularly when interest is for assets at a higher echelon. However, there may be instances in hierarchical organizations where a middle echelon may provide information that enhances awareness of the situation. These arguments do not fit the pattern of results observed for the MEU1 position. Perhaps, time period somehow made a difference or SA of team positions are affected differently by their position in the organization. Our hypothesis is that the difference observed between the two organizational structure means when competition is for non-organic assets is not reliable. The difference is only .047, whereas the difference between the means for the two organizational structures when competition is for organic assets is over three time larger. If we can discount the organizational structure results when competition is for non-organic assets then we are left with a main effect that supports the argument that flatter organizations improve SA.

Situation Awareness

Comparisons were made between the mean SA accuracy scores for the mid-level commanders and the CJTF to answer the question of whether there was an added value from having the mid-level commander present. Mean SA accuracy scores for the MCC and GCC were compared with those for the CJTF regarding their perception of the top priority tasks for the two DMs in the organizational nodes below him/her. Comparison of the SA scores of both the MCC and the GCC with the CJTF indicated no difference. Since the SA held by the two commanders operating within the 2-tier architecture is equivalent with that held by the commander in the 3-tier architecture these findings are interpreted as indicating there is no additional value from having the mid-level commander present.

Additional support for this interpretation was found in that the CJTF tended to have higher SA for the two nodes directly under him/her for both the maritime and ground forces (in the 2-tier organization) than the mid-level commander had for these two nodes. Comparison of SA accuracy scores for the GCC and the CJTF indicated increased SA for the CJTF for the two low-level ground units (MEU1 and MEU2) in both conditions, i.e., in (1) the 2-tier organization where he/she had direct interaction with the two lowest nodes in the organization and (2) in the 3-tier organization.

Another way to answer the question of whether SA is improved or hindered by having the mid-level commander present in the hierarchy is to examine the SA scores of the people performing in the two lowest-level nodes under the two organizational conditions. Mean SA accuracy scores of subjects performing the roles of the two low-level ground components and the two low-level maritime components were compared for the two architectures. Comparison of the mean SA accuracy scores for the two ground units and the two

maritime units each revealed no difference between performing under the 2-tier or the 3-tier conditions. However, one unanticipated difference was revealed: The two ground units had better SA than the two maritime units under both the 2-tier and 3-tier organizations.

The most striking result was found when comparisons were made within each trial between the two low-level units in the 2-tier organization with the two low-level units in the 3-tier organization. Recall that for each trial one service component (either ground or maritime) was operating in a 2-tier organization while the other service component operated in a 3-tier organization for that trial. Of the eight trials with the ground units in a 2-tier organization and maritime units in 3-tier, the ground units exhibited higher SA than the maritime units in five of the eight trials, and the SA scores were exactly the same in the other three trials. This indicates significantly better SA by the ground forces ($p<.02$) in this architecture. In contrast, when the maritime units were in the 2-tier organization, their SA did not differ significantly from the ground forces (four numerical ties, two trials with ground forces superior, and two trials with maritime forces superior). Hence, while the ground forces had achieved equivalent SA in both organizations, the maritime units (which were less directly involved in accomplishing the mission tasks) had higher SA in the 2-tier than the 3-tier organization, relative to their associated ground components.

5. DISCUSSION

These performance metrics seem promising and with further refinement should be useful performance measurement instruments. A future challenge is to develop measures that are indicators (predictors) of structural adaption.

The purpose of the initial A2C2 experiment was to collect exploratory data to aid in formulating hypotheses about the ways organizational structures impact decision making performance for different task structures. Developing performance and process measures for teams, organizational units, or for the organization as a whole, is a challenge. The SA concepts discussed in this paper can be extended to *team* SA wherein team members (who share goals) attempt to understand what their fellow team members are trying to do, how they are doing it, and why they have arrived at particular conclusions. This need for understanding applies both at a general level, and at the level of a particular decision. Overall team SA is the degree to which every team member possesses the SA required for his/her responsibilities.

6. CONCLUSIONS

Coalition operations are among the most complex and demanding of all military actives. As coalitions are ad hoc arrangements, they are often susceptible to disjointed command relationships, poor cooperative planning, and misgivings about sharing information and state-of-the-art technologies[4]. Developing an effective C2 architecture is one of the most important steps a commander can take to ensure successful completion of the mission.

Future work will involve an enhanced interdisciplinary approach in terms of integrating a model-based approach (i.e., optimization, modeling, and simulation-based research) with the psychology-based experimental efforts. Future efforts will entail experiments driven by models of organizations and adaptation in C2 architectures. In addition, increased emphasis on adaptation will be the focus of future experiments.

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