<u>**Cover Sheet**</u>

Supporting Organizational Change in Command and Control: Approaches and Metrics

Paper: 79

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Abstract

Network-centered Command and Control (C2) has great potential to increase military effectiveness, in some measure due to enhanced information sharing and dissemination techniques. However, for these technologies to be maximally effective, C2 organizations need to have the flexibility to tailor their organizational structures in response to changing mission conditions.

In the experiment reported here, a model-based approach to supporting organizational adaptation was assessed. The purpose of this experiment was to explore ways in which obstacles to adaptation could be overcome. Teams of Naval Officers participated in three simulations of a joint forces mission on the Distributed Dynamic Decision-making (DDD) simulator (Serfaty & Kleinman, 1985; Kleinman & Serfaty, 1989). The match between organizational structure and mission task requirements was manipulated within-participants, resulting in differences in coordination requirements. Between the second and third simulated missions, participant teams were given the opportunity to select an organizational structure from a list of model-based, predefined organizational designs, to better accommodate the changing mission requirements. To support organizational change, model-based prospective information was provided to the teams. This support led to the adoption of better matched congruent organizations in each of the participant teams. Several measurement techniques were designed to evaluate both the degree of adaptation and its effect on mission performance.

Introduction

The emerging network-centered military promises an unprecedented degree of operational flexibility, in part due to improved information sharing and dissemination. Initiatives such as FORCEnet require that information from warfighters at all echelons of command, sensors attached to unmanned automated vehicles, and automated analyses be integrated and delivered to the appropriate decision makers in a manner that significantly improves operational tempo, situational awareness, and mission effectiveness. Yet, to take maximum advantage of these emerging technologies, military organizations need to have the flexibility to quickly adjust their organizational structures (e.g., team member roles and responsibilities, information flow patterns, allocation of resource control) in response to changing conditions so as to respond to emerging threats as quickly and effectively as possible. Recent exercises (Diedrich et al., 2003; Entin et al., 2003) have demonstrated that mission performance is higher when Command and Control (C2) organizational structures are aligned – or *congruent* – with mission tasks to be performed. Conversely, when organizations are *incongruent* with mission tasks, mission performance is degraded. Congruence is defined as the extent to which resource allocation and information flow is optimized to the mission at hand. Because mission effectiveness is of such high criticality, it is imperative that organizations recognize the degree of congruence between their structure and the battlefield requirements, and exercise the ability to modify their structures if appropriate. This has led to the experiment reported in this report, which addresses ways to support organizational adaptation and the development of model-based measures of organizational congruence to facilitate adaptation.

Entin & Serfaty (1999) found that high-performing organizations demonstrate improved coordination when they recognize high degrees of incongruence. Behaviors and communication patterns change strategically in response to changing environmental conditions, improving mission performance. However, teams are less likely to alter their *organizational structure* to increase organizational/environmental congruence (Hollenbeck et al., 1999). Here, organizational structure refers to the allocation of assets and reporting structures. Several reasons have been noted for their reluctance:

- **Lack of Authorization**: Military organizations do not have a history of rapid, on-line structural adaptation. Without this precedence for self-induced change, organizations may feel that they lack the authority to make alterations to their structures.
- **Lack of Training**: The structure of organizations cannot be designed arbitrarily; many parameters need to be carefully considered and balanced. Organizations may lack the training to make organizational changes effectively, and will therefore be reluctant to change.
- **Lack of Sensitivity**: When organizations sense incongruence, they may have difficulty gauging the nature or severity of the disparity. As a consequence, they may resist organizational change even when it is indicated.
- **Lack of Familiarity**: Organizations may feel uncomfortable switching from established structures to those that are less well known. They may feel that imperfect existing structures are more desirable than structures that are better suited but unproven.

As a consequence of these obstacles to change, organizations may choose to remain in inefficient structures, neglecting opportunities for improved performance. However, the potential benefits of alternative organizations may warrant their consideration even in the face of these obstacles.

Therefore, it is essential to understand how an organization can be persuaded to adapt. The primary purpose of the exploratory study reported in this paper is to address this question.

A secondary purpose of this study was to identify and refine measures of adaptation. Entin et al (2003) found that several behaviors consistently occurred with high organizational incongruence, including higher self-reported operator workload, larger communications volume, and certain performance measures intrinsic to the simulation environment (i.e., tasks processed and their accuracy). These factors could be used when diagnosing organizational health and the need for structural change early in a mission, when organizational change may still be a viable course of action. It should be recognized that measuring the indicators that underscore the *need* for structural adaptation differs from measuring the *occurrence* of change or the *effects* of change in subsequent performance. Entin et al. (2004) investigated inducements toward adaptation where the mechanism that allowed structural change was open ended; teams of Naval officers were able to reallocate control of resources in response to changed mission conditions. In the Entin et al. study, measuring the occurrence and degree of change was as straightforward as counting the number and types of resource allocation exchanges; the fewer the number of exchanges, the smaller the degree of change. However, while this may be an indication of organizational change, organizational *adaptation* implies that the changes made improve mission performance. As a consequence, measures must be developed that are sensitive to the effects of adaptation, even in simulations where overall performance is obscured by limited training opportunities. In the current study, two such measures were employed, one based on statistical mission performance analysis, the other based on modeled team performance.

The findings presented in this report continue a long line of research (e.g., Entin et al., 2003; Kleinman et al., 2003; Diedrich et al., 2003; Entin et al, 2004) that has explored aspects of incongruence between organizations and their mission tasks. In several experiments (see Diedrich et al., 2003), variations of the following scenario were presented. Two organizational designs were utilized:

- A *divisional* organization in which each participant had complete control of a single multifunctional platform, and was therefore able to independently process a variety of tasks (e.g., air interdiction, surface warfare, search and rescue, air superiority) in a bounded geographic area.
- A *functional* organization in which each participant had complete control of a single mission essential function (e.g., strike, search and rescue, special operations) throughout the battlespace, independent of the platform on which those assets resided.

Two mission scenarios were created, based on model-based organizational design principles (Kleinman, et al, 2003), which were designed to be incongruent to one of the organizational structures while providing a good fit (i.e., congruent) to the other. This was accomplished by including tasks that required the coordination of multiple assets that were controlled by either a single individual (predicted to be congruent, regardless of organizational structure) or multiple individuals (predicted to be incongruent, regardless of organizational structure). Using these organizations, Diedrich et al (2003) found that performance was significantly worse in the incongruent conditions as compared to the congruent conditions, based on a variety of mission performance and behavioral measures. These results underscored the need for organizational adaptation to improve mission performance, and for future experimentation, established an appropriate stimulus for change (empirically validated, model-based degradations in performance).

However, encouraging adaptation is a difficult task, given the multiple obstacles to organizational change. Entin et al (2004), using the scenarios and organizations described above, designed a study to motivate adaptation by providing palpable incentives to change. Performance deficiencies were noted and presented to the participants with the express purpose of motivating adaptive changes. This provided opportunities for facilitated discussions regarding the effects of organizational change. Despite these actions, structural change was infrequent, and often limited to a few modifications of resource allocation.

Hence, the objectives of the current study were two-fold. The first and primary purpose was to explore the mechanisms that can help decision makers identify the need for adaptation and enable them to make adaptive structural changes. In particular, the methods employed were designed to overcome the obstacles to adaptation:

- **Overcoming a perceived lack of authorization**: Targeted instruction about the benefits of organizational change was presented to overcome reluctance to adjustment (i.e., overcoming organizational inertia).
- **Overcoming the lack of training in organizational design**: Rather than giving participants the ability to create alternative organizational designs from scratch, several fully formed organizational designs were presented to participants, accompanied by a rationale for their creation.
- **Overcoming the lack of sensitivity**: A suite of feedback measures, based on proven performance and behavioral indicators of congruence, was presented to participants at critical times. The display design and timing of their presentation was intended to emphasize the criticality of organizational adaptation.
- **Overcoming the lack of familiarity**: Prospective performance measures, based on proven modeling techniques, were presented to accompany unpracticed organizational design, in large part to lower participant anxiety about the utility of novel organizational structure.

A secondary purpose of this experiment was to identify measures of structural change and their efficacy in the context of both simulated and actual mission conditions. Given the logistical constraints on participant training, these measures needed to be robust in the face of relatively impoverished mission performance. Two approaches to measurement were developed toward this end:

- The measurement of simulated mission performance for several experimentally inspired organizational structures.
- The measurement of participant mission performance for the subset of tasks that required collaboration.

These methods are designed to facilitate structural change by supplying the knowledge and tools necessary for successful adaptation, and to measure the degree of adaptation in meaningful ways. It was hoped that these actions would foster observable adaptive behaviors.

Method

Participants

Twenty-Five officers and non-commissioned officers served as participants for this exercise (see Table 1). Of these, 18 were Naval Reservists and 6 students at the Naval War College in Newport, RI. Participants were organized into four teams of six individuals.

Table 1: Participant profile.

Rank	#
Captain	2
Commander	10
Lieutenant Commander	7
Lieutenant	3
Chief Petty Officer	1
Petty Officer 2nd Class	1

Simulation Environment

The Distributed Dynamic Decision-making (DDD) environment was used to simulate several mission scenarios for use in this study. The DDD is a distributed client/server simulator that allows extensive mission customization in order to investigate individual and team performance in an operationally rich, experimentally valid environment. In general, DDD simulations involve individual and team decision-making about complex situations based on information and resources provided by both the simulation and other team members (Serfaty & Kleinman, 1985; Kleinman & Serfaty, 1989). The simulation enables the manipulation of variables such as organizational structure and mission scenario tasking. A variety of performance measures can be recorded within the DDD (i.e., tasks processed, latencies, and accuracies) to assess performance.

Procedure

Each team was assigned to one of two organizational structures characterized by the types of assets within each team member's control (see Diedrich et al., 2003). In the Divisional organizational structure (D), each team member had responsibility of functionally diverse assets in a single, defined geographic area; they were given control of all assets within that area. In contrast, participants in teams assigned to the Functional organizational structure (F) were given control of functionally similar assets dispersed throughout the mission battle space; for example, they might be given all ISR or Strike capabilities available within the simulated environment. In this investigation, participants were assigned randomly to two D teams and two F teams.

Participants were briefed as to the general purpose of the study. Training began with two hours of DDD "buttonology" in which participants were shown how to use the DDD user interface, the capabilities of the assets and platforms available within the DDD environment, and basic strategies for accomplishing common tasks. This was followed by a second, two-hour training session in which participants completed short mission scenarios. This session exposed participants to the general mission expectations, which involved following a mission task plan, reacting to unexpected time critical events, balancing defensive and offensive roles, and coordinating with other team members for task completion. The training scenarios were designed to instruct without imposing bias for any particular organizational structure. This was accomplished by creating hybrid task conditions that employed aspects of both divisional and functional favoring tasks. The participants performed these scenarios in both the D and F organizations, in a counterbalanced fashion.

Following the second training session, the data-collection phase of the study began. The two scenarios used were developed to be congruent to either the Divisional organizational structure (D) or to the Functional organizational structure (F) (Diedrich et al., 2003). A mission was considered to be *congruent* if the team's organizational structure (D or F) was matched with its associated scenario (i.e., a D team in a d scenario or an F team in an f scenario; Table 2). In contrast, a session in which the team and scenario structures are mismatched was considered *incongruent* (D with f, F with d). Congruence was achieved by defining task requirements within a scenario that matched the asset capabilities controlled by individuals within an organizational structure, thus reducing need for coordination between players and minimizing communication and coordination overhead.

Table 2: Congruence of Structure and Scenario Requirements

		Organizational Structure	
		Divisional (D)	Functional (F)
Scenario Structure	d	Congruent	Incongruent
	f	Incongruent	Congruent

Each mission scenario was presented in operational terms that were familiar to the participants. They involved a Joint Forces mission in which teams were required to use a variety of sea, land, and air assets to destroy or capture an enemy command center, two naval bases, two air bases, and a seaport. Concurrent to these primary mission tasks, the teams had both offensive and defensive responsibilities that were time critical and distracted them from the main mission objectives (e.g., destroy Exocet missiles and coastal defense launchers, perform search and rescue operations, engage targets of opportunity, etc.). For additional complexity, the area of operations also contained neutral parties and peripherally hostile assets which were either to be ignored or to be of low priority. Missions lasted approximately 35 minutes or until the final mission task was completed, whichever came first.

Each team participated in three data-collection sessions (see Table 3). In the first data-collection session, each team participated in a scenario congruent with their organizational structure. In the second data-collection session, each team participated in a scenario which was incongruent with their organization. To justify the change in mission task requirements associated with incongruence, teams were informed that their adversary was changing their defenses to impede the team's mission progress. However, participants were not given the opportunity to change their structure in response; they had to participate in the session in a sub-optimal incongruent structure.

Table 3: Experimental Design

Time →	***Session #***	***Session***	***Description***	***Team Structure***
	1	Congruent	Team structure and mission task requirements in alignment	Divisional or Functional
	2	Incongruent 1	Team structure and mission task requirements in discord	Divisional or Functional
	Planning Session: Opportunity to Change Structure in Response to Incongruence			
	3	"Incongruent" 2	Congruence between Team Structure and Mission Task Requirements dependent on Chosen Team Structure	One of 5 alternative organizations (D, D2, R2, F2, or F)

After each data-collection session, participants were given feedback on several aspects of their performance via a computer generated "Congru-o-meter." The Congru-o-meter included measures of overall performance, performance on major offensive and defensive responsibilities, participant workload, and gain (a composite measure of task accuracy and proportion of tasks completed). These measures were presented in comparison to high performing (congruent) groups described in Diedrich et al (2003). The criticality of organizational change was underscored in the presentation of these feedback measures.

Following the second data-collection session, participants were given the opportunity to change their organizational structure. Teams were given explicit guidance on the merits of organizational change and its expected performance gains. During a 45 minute facilitated planning session, five fully-formed alternative organizational structures (see Table 4) were presented to the participants, purported to be from the Joint Task Force Commander (CJTF). After making their organizational choice, a third data collection session commenced in which the mission tasks and requirements were identical to those of the second data-collection session (i.e., incongruent with the team's original structure) but with the organizational structure chosen during the facilitated planning session.

Organizational Structures

In a previous study (Entin et al., 2004), teams of Naval officers were asked to create organizational structures adaptively, in response to changing degrees of congruence. In a facilitated planning session lasting approximately one hour, these teams had to acknowledge the incongruence, weigh the appropriate factors, and come to a consensus as to the best organizational design. In the face of the obstacles described in the introduction, teams are reluctant to make organizational changes, even when presented with convincing evidence of the benefits of doing so. As a result teams made few major changes; adaptation was modest.

In the current study, further efforts were made to encourage adaptation. Rather than requiring teams to create organizational structures from the bottom up, fully formed alternative organizations were presented. During the planning session, descriptions of alternative organizations were accompanied by several supporting documents, including a description of the roles and responsibilities of each team member within that structure and a detailed account of the asset allocation. During the planning session, participants had to discuss the relative merit of each alternative, and then arrive at a consensus regarding their preference.

Table 4: Organizational Design Choices

Organizational Structure	***Description***
Divisional (D)	Each participant controls a single platform with multiple functional areas
Divisional/Functional Hybrid (D2)	Four participants control a single platform each; two players control functional assets across the theater (ISR, BMD)
Regional (R2)	Theater is divided into two geographic regions. Groups of three participants divide the assets functionally (ISR/SAR/SuWC, STRIKE/AWC, MINES/BMD) within those two regions.
Functional/Divisional Hybrid (F2)	Four participants control functional assets (STRIKE, SOF/SAR, BMD, ISR) across the theater; two players control a single platform each with multiple functional areas.
Functional (F)	Each participant controls a single function across the theater

These alternative organizations were created by holding the number of assets within the game constant (e.g., number of ships, number of missiles) while changing the asset control allocation. The original D and F structures constituted two of the available organizations. Design of the remaining three organizations was constrained by several factors. First, each structure needed to have an operational justification – it needed to be a plausible alternative for the participants, who had extensive Naval expertise. Second, the offered organizations had to represent distinct alternatives to the D and F structures discussed above. Participants had to be able to recognize the advantages and disadvantages of each. Finally, the new organizational structures needed to be evaluated with regards to the divisional and functional scenarios, and the degree of congruence determined. Thus, the task requirements of each scenario had to be considered when designing the organizational structure.

Three new organizational structures were created with these constraints in place. They were, in part, inspired by the comments made by operational participants in a previous study (Entin et al., 2004). The first structure is a Divisional/Functional Hybrid (D2), in which the majority of team members control assets in a manner similar to the Divisional structure (i.e., control of all assets on one platform), but where two participants are given more extensive control of a single asset type (i.e., all UAVs or anti-ballistic missiles). A second alternative organization is a variation on the Functional organization. In the Functional/Divisional Hybrid (F2) organization, four team members retained essentially Functional roles; they controlled a single asset type distributed among the platforms simulated. The two remaining participants played a Divisional role, each controlling all assets on a single platform. The third structure, the Regional (R2) structure, divided participants into two sub-groups each responsible for half of the battlespace. Within each of the halves, participants had defined Functional roles. In each of the three alternative organizations, the dispersion of resources among the team members fell in between the Divisional and Functional organizations (see Figure 1).

The similarity of the alternative organizations to the true Functional and Divisional organizations was determined by measuring the *degree of asset control dispersion* (Figure 1). This was determined based on the resource capabilities of the assets controlled by each team member, or decision-maker (DM), in the organization. A high score indicates an organization in which decision-makers control resources of distinct functions and operational capabilities. This organization corresponds to a Functional resource allocation. A low score indicates that decision-makers control assets with similar resource capabilities. This indicates an organization with Divisional resource distribution. Formally, this metric is defined as follows.

For each asset m in the organization of M decision-makers ($m = 1,...,L$, where L is the number of assets), the resource capability vector is defined as $r_j^m; j = 1,...,K$, where K is the number of resource types (functions). The total number of resources for a type j is therefore equal to $\hat{R}_j = \sum_{m=1}^{L} r_j^m; j = 1,...,K$.

The asset control is defined via DM-asset assignment variables $a_{i,m}; i = 1,...,M; m = 1,...,L$, where $a_{i,m} = 1$ if decision-maker *i* controls asset *m*, and $a_{i,m} = 0$ otherwise. Then, decision-maker *i*'s control of resource type/function *j*, equal to the amount of corresponding resources controlled via ownership of its assets, is found as $R_j^i = \sum_{m=1}^{L} r_j^m a_{i,m}$. The average number of resource of type *j* at any decision-maker is $\frac{\hat{R}_j}{M} = \frac{\sum_{m=1}^{L} r_j^m}{M}$. This defines "averagely capable" decision-maker, and is the goal of *Divisional* asset distribution. However, the feasibility of asset assignment might prevent such an allocation. The error function is defined as $\varepsilon_j = \sqrt{\frac{1}{M}\sum_{i=1}^{M}\left(\sum_{m=1}^{L} r_j^m a_{i,m} - \frac{\hat{R}_j}{M}\right)^2}$, which is a root-mean square error for distribution of resources of type *j* in the organization and identifies the dispersion of resource of type *j* among decision-makers. This value is 0 for divisional resource distribution (when all decision-makers have the same amount of resources of this type, thus achieving maximum overlap in resource *j*), and equal to $(M-1)\left(\frac{\hat{R}_j}{M}\right)^2$ for functional resource distribution (when only a single decision-maker controls all resources of type *j*, thus achieving no resource overlap in resource *j*).

As the result, the degree of asset control dispersion is defined as the normalized mean square error function $\varepsilon = \frac{\sum_{i=1}^{M}(\varepsilon_i)^2}{(M-1)\sum_{j=1}^{K}\left(\frac{\hat{R}_j}{M}\right)^2} = \frac{\sum_{j=1}^{K}\sum_{i=1}^{M}\left(\sum_{m=1}^{L} r_j^m a_{i,m} - \frac{\hat{R}_j}{M}\right)^2}{M(M-1)\sum_{j=1}^{K}\left(\frac{\hat{R}_j}{M}\right)^2}$. This measure is equal to 0 when there is a maximum overlap of resource capabilities among decision-makers (Divisional case), and equal to 1 when there is no overlap in resources (Functional case).

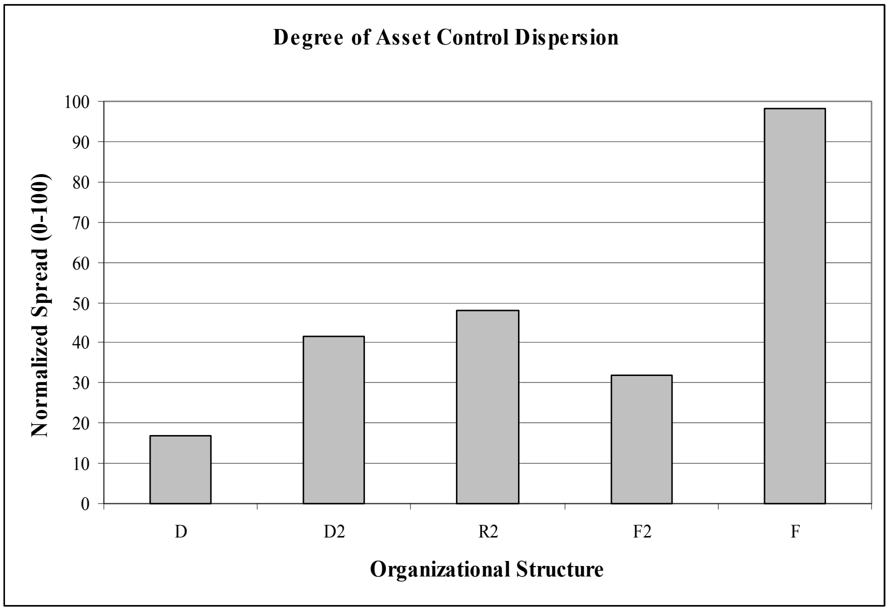

Figure 1: Degree of Asset Control Dispersion.

A high score indicates a highly Functional organization in which team members control a single asset type across the simulation; a low score indicates more consolidated control.

Applying this metric to the original and hybrid organizations, the Functional organization displayed the most dispersed asset control; control of each asset type was given solely to a single individual. Similarly, the Divisional organization displays the least disparity between DMs, because each member controls a limited number of all assets. The D2, R2, and F2 organizational structures demonstrated a degree of dispersion or spread that was intermediate between the D and F organizations. Note that although the F2 organization was based on the F organization, the degree of spread was mitigated by the shared responsibility of some assets between all DMs. As a consequence, its spread was lower than that of the D2 and R2 organizations.

The two original scenarios (f & d) were designed to emphasize disparities in congruence between the two original structures (F & D). Similarly, the congruence of the three new structures needed to be evaluated with regard to the two scenarios. Two aspects of congruence were modeled: coordination and overall performance. As expected, the fully Functional and fully Divisional organizational structures were modeled to exhibit the lowest workload (Figure 2) and highest performance (Gain Area; refer to Figure 3) in the functional and divisional scenarios respectively. The other three organizations were modeled to lead to a coordination requirement and performance in between these two endpoint organizational structures. These prospective, model-based data were shown to the participants as they made decisions regarding potential change.

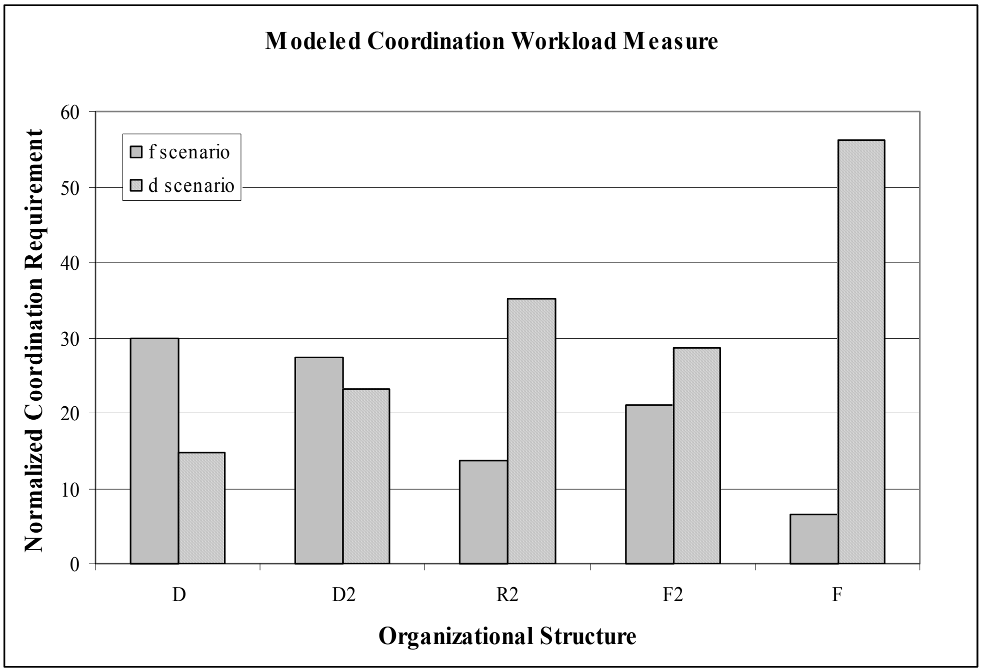

Figure 2: Modeled Coordination Workload Measure. Lower values indicate lower overhead, and are therefore lower predicted workload.

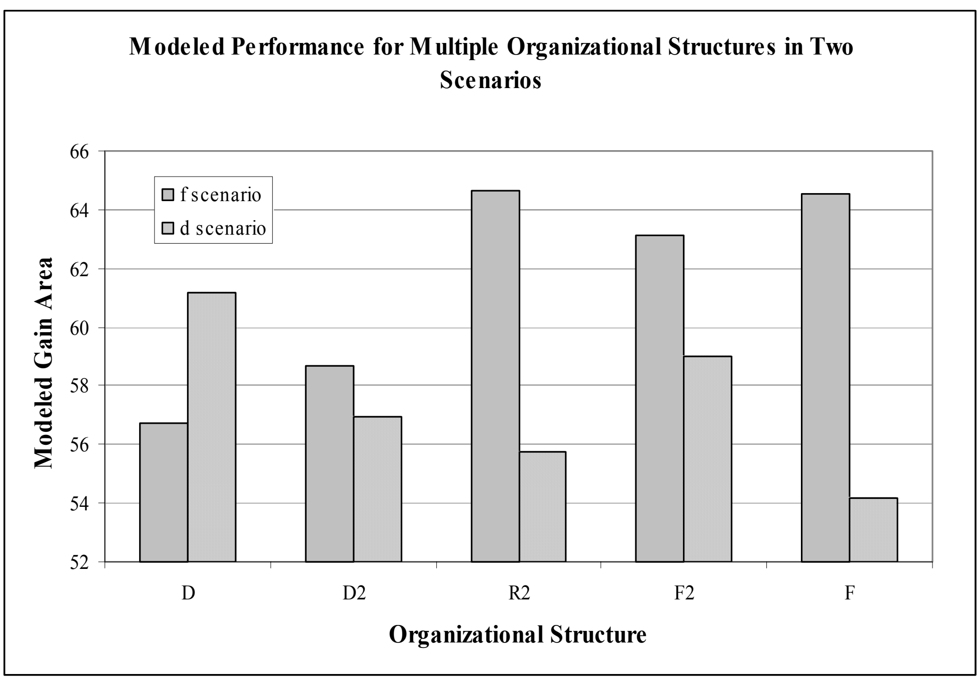

Figure 3: Modeled performance measure. Higher values indicate higher expected performance.

The *coordination workload* (Figure 2) was modeled to predict the amount of communication among decision-makers required to synchronize their assets to execute tasks. This synchronization is needed when multiple assets owned by different decision-makers must execute the same task. The normalized coordination workload between decision-makers n and m was defined as

$\boldsymbol{D}(m,n) = \dfrac{\sum_{i=1}^{N} u_{mi} u_{ni} t_i}{\text{mission duration}}$, where N is the number of tasks, t_i is the duration of task i and

$u_{mi} = \begin{cases} 1, \text{if DM } m \text{ is assigned to task } i \\ 0, \text{otherwise} \end{cases} = \begin{cases} 1, \text{if } \exists \text{ asset } j \text{ such that } a_{mj} = 1 \text{ and this asset executes task } i \\ 0, \text{otherwise} \end{cases}$ It can be seen that $\boldsymbol{D}(m,n)$ is equal to the average number of synchronized task executions between decision-makers n and m per unit of time. The coordination workload of decision-maker m is defined as $\boldsymbol{E}(m) = \sum_{n=1, n\neq m}^{M} \boldsymbol{D}(m,n)$, and the *coordination workload* measure of an organization as the root-mean-square of coordination workloads of DMs in this organization: $\Theta = \sqrt{\frac{1}{M}\sum_{m=1}^{M} \boldsymbol{CW}^2(m)}$. This metric accounts for both the mean and the variance of coordination workload among decision-makers, and, consequently, provides a measure of balance of coordination among DMs.

In the presence of time-critical tasks, an organization may trade-off task accuracy for timeliness. For an organization that is incongruent with its mission, such engagement practices may result in the same levels of task timeliness as for a congruent organization. However, this timeliness is achieved at the cost of lower accuracy. Therefore, a measure that reflects the task accuracy and timeliness tradeoff can be combined into a single measure, called the *task gain*. The task gain of a task i is defined as the accuracy multiplied by its value: $g_i = \alpha_i \cdot \omega_i$, where α_i is task accuracy and ω_i is task value. Task accuracy is based on satisfaction of task resource requirements by the assets assigned to execute this task. When all resources required by task i are met, that is $\sum_{m=1}^{L} y_{im} \cdot r_j^m \geq \hat{r}_{i,j}$ (where $y_{im} = \begin{cases} 1, \text{ if asset } m \text{ is assigned to task } i \\ 0, \text{ otherwise} \end{cases}$ and $\hat{r}_{i,j}$ is requirement of resource type j for task i), then the accuracy of task completion is equal to 100%. However, in realistic applications where the resources are scarce, an organization may wish to reduce the task execution accuracy in order to achieve better timeliness. In order to accommodate timeliness-accuracy trade-off, a model of accuracy has been defined within the DDD simulator for scoring the DMs as a square of the average of ratios of the resource used to the resource required over all resource types:

$$\alpha_i = \left(\frac{1}{\hat{K}} \sum_{j=1}^{K} \frac{\min\left\{ \hat{r}_{i,j}, \sum_{m=1}^{L} y_{im} \cdot r_j^m \right\}}{\hat{r}_{i,j}} \right)^2$$

, where $\hat{K}$ is the number of non-zero resource requirement types of task i: $\hat{K} = |\{ j : \hat{r}_{i,j} \neq 0 \}|$. The ratio of the resource used to the resource required identifies the percentage of satisfied resource for the corresponding resource type. The squaring of the average of these ratios for required resources penalizes significant resource allocation mismatches.

Applying these measures to the organizational structures used in this study, the F and D organizations were determined to have the highest congruence with the scenarios used. The F organization in the f scenario and the D organization in the d scenario were modeled to have the highest gain and lowest coordination workload given the alternatives. The D2, F2, and R2 were by and large intermediate between these endpoints, showing gain and workload requirements that were not optimal but were preferable to the fully incongruent organizations. The exception to this was the fit between the R2 organization and the f scenario, which was modeled to have gain that was comparable to the congruent F organization. However, it was also expected to require a larger degree of coordination, which could ultimately lower performance.

Operational justifications were created for the scenarios, based on their relationship to the F or D scenarios already familiar to the participants. The relative merits of each organization were described in terms of specific roles and responsibilities associated with each team member in each organization. These measures indicate that the new organizational structures (D2, F2, & R2) have levels of congruence intermediate between F and D in each of the scenarios used in this study. Therefore, these intermediate organizations met all of the criteria for viable alternatives.

Results & Discussion

While the DDD is capable of capturing many aspects of mission performance (e.g., accuracy, task completion latency, mission success, subjective workload), the focus of this discussion is on structural adaptation to change. We concentrated on two major components to the assessment of adaptation:

1) **Did adaptation occur?** During the facilitated planning sessions, teams could have chosen to remain in their original organizations. The range of alternative organizations presented varied in terms of congruence to the anticipated mission scenario. It was therefore critical to capture the choices of each team, and note the congruence of the chosen organizations.

2) **Did adaptation improve performance?** Change is ultimately adaptive only if performance improves as a result or if it is held constant in the face of increasing stress. However, given logistical constraints, standard performance measures (i.e., overall mission progress, accuracy, and latency) were not ideal. Alternative measures of adaptation were explored as a consequence.

Noting the Occurrence of Adaptation

During the facilitated practice session, each of the four teams chose one of the alternative organizations (see Table 5). Both of the teams originally assigned to the Divisional structure chose the Functional organization. This change demonstrated maximum adaptation because the Functional structure was modeled to have the highest congruence with the scenario they were to engage.

Table 5: Planning Session

Team	***Original Organizational Structure***	***Chosen Organizational Structure***	***Comments***
Team 1	Functional	D2	Nearly congruent
Team 2	Divisional	Functional	Fully congruent
Team 3	Divisional	Functional	Fully congruent
Team 4	Functional	D2	Nearly congruent

Similarly, the teams originally assigned to the Functional structure chose the D2 organization. The D2 structure was more congruent to the subsequent scenario than the original Functional organization, and it was modeled to lead to more efficient coordination and higher performance than the majority of the alternative organizations. While there were not enough teams to make a definitive conclusion, it is possible that the Functional teams were reluctant to adopt the fully congruent Divisional organization because each team member would have been required to learn a larger variety of tasks. In the Functional organization, each team member has only one or two responsibilities, and thus only needs to learn a few series of actions to interact with the simulator. In the fully Divisional organization, each team member is responsible for a larger variety of tasks (~6-8). The task/organization mapping for the D2 organization required most team members to perform 4-5 different tasks, while two team members were responsible for a single task each. Participants may have been compromising between the modeled gain and workload information presented and the anticipated re-learning required for the transition to the Divisional organization.

Measuring the Effects of Adaptation

Each team made organizational changes when they had the opportunity, and the changes made were predicted to be adaptive, based on modeled performance. However, organizational change is only adaptive if it leads to improved performance. Expert performance in the DDD simulation requires substantial targeted training in a single organizational structure. Because the purpose of this study was to investigate organizational flexibility, training was divided between both D and F. This reduced bias towards particular organizational designs, but also precluded us from training participants in all organizational structures to the degree necessary for true mastery, leading to wide performance difference among teams and generally sub-optimal simulation performance. Therefore, overall simulation performance is not an accurate measure of adaptation.

The DDD simulation is composed of a moderately high number of events (~130 per session) that team members must engage, either individually or in conjunction with other team members. Engagement consists of placing the correct asset(s) within a proscribed range from the target, selecting the target, and prosecuting the target via a series of menu choices – all while avoiding enemy attack. Coordination with other team members requires communicating the intended actions, and timing the attacks to ensure that they all occur within a thirty second window of time. Approximately 50% of events required a single team member to engage successfully with a single asset, while the remaining 50% require multiple assets to engage accurately.

Recall that the modeled performance of the organizational choices was dependent on the coordination requirements dictated by control of resources. Tasks requiring a single asset are not associated with high degrees of coordination – an individual team member can engage the task easily. However, that subset of tasks requiring multiple assets for engagement are associated with a high degrees of coordination. In a highly incongruent environment, these tasks require multiple team members to coordinate resources within a small window of time, increasing overhead and potentially decreasing performance accuracy. In a congruent environment, these tasks require single individuals to use multiple assets within their own control. The predicted result is higher accuracy.

This leads to predictions about performance in the sub-set of tasks that require coordination. The scenarios used in sessions 2 and 3 were identical; for the teams that began in the Functional structure, the same divisional scenario was used, while teams which began in the Divisional structure participated in the functional scenario. The major difference between session 2 and 3 was the organizational structure of the teams. Both Divisional teams choose new Functional structures, while the Functional teams chose the sub-optimal, but adaptive D2 organization. This leads to several predictions about performance. Regardless of overall performance, teams should engage a larger number of tasks that require coordination between sessions 2 and 3. The accuracy of these engagements should improve as well. These improvements should be greater for the Divisional teams (Teams 2 and 3) because their choice of organization was more congruent to the scenario.

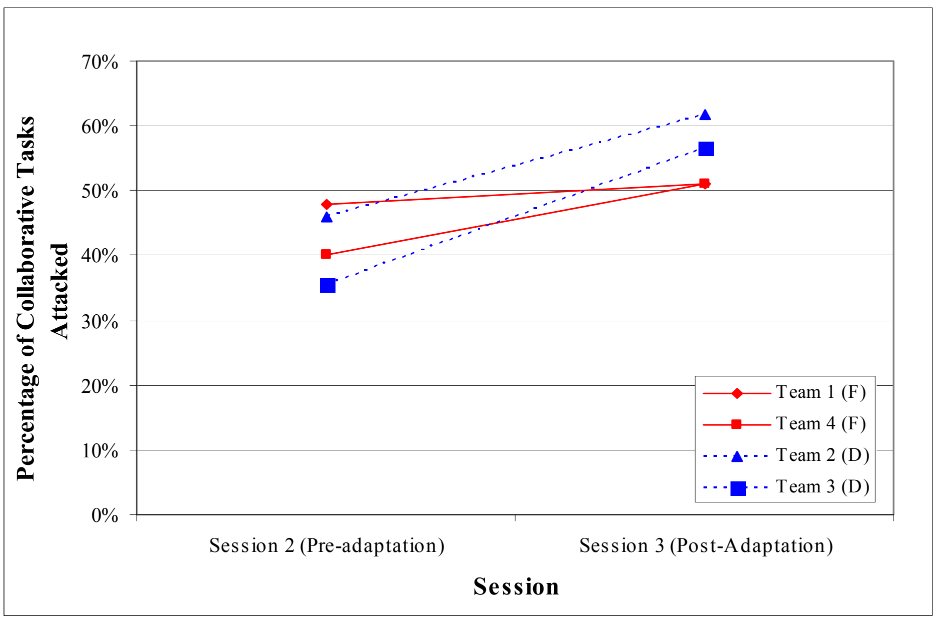

Figure 4: Percentage of Collaborative Tasks Attacked in Sessions 2 & 3

Between sessions 2 and 3, the percentage of tasks that required collaboration (that were engaged) increased for all teams (see Figure 4). This includes tasks that were engaged with fewer than the required assets (i.e., the task required both special forces [SOF] and STRIKE assets [e.g., F18s fighters], but only SOF assets were used). The percentage of collaborative tasks engaged increased on average by 12.75% (7% for Functional teams, 13.4% for Divisional teams). The organizational choices of each team increased the structure/scenario congruence, which decreased the coordination overhead. This allowed teams to engage more targets. This effect was greater for the teams originally assigned to the Divisional organizations, because their organizational choice (i.e., Functional) had a higher degree of congruence with the scenario than did the teams originally assigned to the Functional organizations (i.e., because they chose the sub-optimal D2 organization).

A smaller proportion of tasks requiring multiple assets were engaged with 100% accuracy (see Figure 5). A clear distinction can be seen between the Functional and Divisional teams. Overall, the coordination accuracy of the Divisional teams increased by 7.65%, while the accuracy of the two Functional teams remained flat. This pattern is consistent with our predictions; with higher congruence, the Divisional teams increased their accuracy. The Functional teams chose a structure that was less congruent with the scenario (the D2 structure in the d scenario). As in Figure 3, the modeled gain measures – an indication of performance – suggested that D2 structure would lead to only modest performance gains. The baseline performance differences between groups were likely a product of variable computer experience among participants.

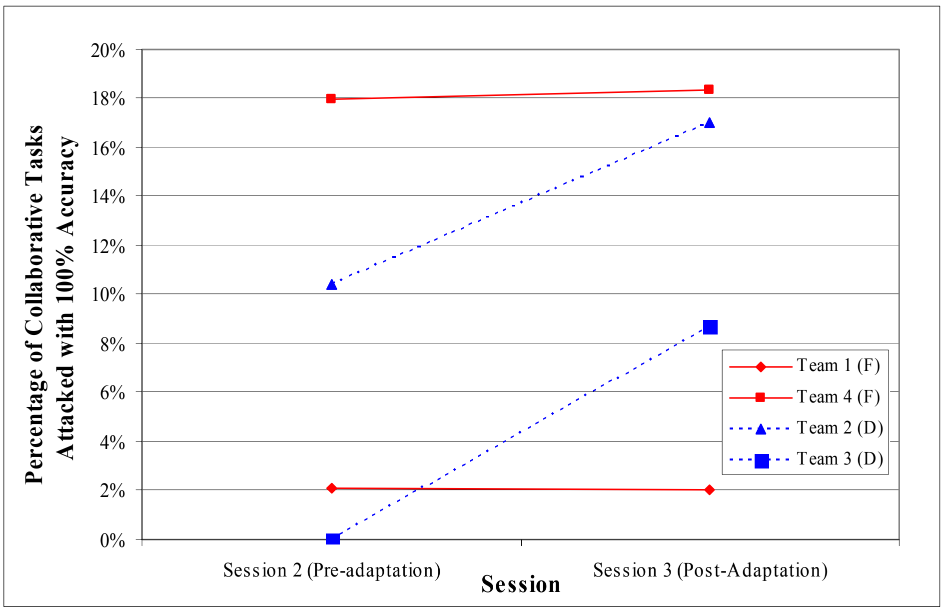

Figure 5: Percentage of Collaborative Tasks Attacked with 100% accuracy in Sessions 2 & 3

While the small number of teams and the high degree of variability precludes meaningful inferential statistics, the overall trends in the data are clear. When teams choose organizational structures that have a higher degree of congruence with their missions, engagements on tasks requiring multiple assets increases, as does accuracy on those tasks. In future studies, the longer term benefits of organizational change should be targeted, so temporary decrements in performance are not confused with mismatches between organizations and scenarios.

Conclusions

The transition to network-centered warfighting brings with it the possibility of flexibly altering organizational structures and resource control, creating organizations that are agile, responsive, and more effective. However, before this promise can be reached, a deeper understanding of the implications of organizational adaptation must be attained. The current study is part of a series addressing this issue, and represents a substantial step forward. Using a mix of experimentation and model-based simulations, the impact of organizational change on performance was assessed. In the current study, indications of adaptive structural changes were found. Four teams of Naval officers chose alternative organizations that were more congruent to the scenarios when given the proper tools, experience, and rationale.

In a similar study (Entin et al 2004), similar teams were reluctant to make organizational changes. Four types of obstacles were identified that made change difficult, all of which were addressed in the current study. These barriers to change were addresses in the following manner:

- **Overcoming a perceived lack of authorization**: Specific instructions were given regarding the criticality of organizational change, and explicit authorization
- **Overcoming the lack of training in organizational design**: Presenting teams with model-based alternative organizations that were already balanced allowed participants to concentrate their efforts on the strategic merits of each, rather than details about low-level resource allocation. This resulted in more productive discussions.
- **Overcoming the lack of sensitivity**: The use of the congru-o-meter allowed participants to easily recognize the need for organizational change, and contextualized their performance. Model-based measures of structure/scenario congruence provided a baseline that was robust to local variability in performance, and therefore afforded direct comparison of various organizational alternatives.
- **Overcoming the lack of familiarity**: Barring increased opportunities to practice in alternative organizations, model-based prospective information about novel organizational design allowed participants to make rapid assessments of the likely efficacy of alternative organizations.

Identifying change in this experimental design is simple; if teams chose alternative organizations, the change is obvious. However, measuring the impact of that change is more difficult. Adaptive changes in organizational structures should lead to improved team performance. However, limited practice in the simulator environment, inexperience in multiple organizational structures, and variability in participant computer experience lead to highly variable results. As a result, alternative measures need to be employed to evaluate adaptation.

The modeled performance measures used to evaluate the alternative organizational structures provide an efficient way to evaluate the efficacy of alternative organizations. Entin et al (2004) required participants to create new organizational designs without explicit guidance from trained organizational scientists. Subsequent DDD performance in these organizations was hampered by limited practice, which made evaluation of the utility of the organizations themselves difficult. However, calculating modeled performance measures is not subject to these difficulties. Model-based measures of performance and workload provide an alternative evaluative technique when human performance is affected by other factors.

In the current design, the organizational structures were presented to participants fully formed, and the modeled performance was already known. While performance was still highly variable, concentrating analyses on the subset of data specifically sensitive to coordination proved to be a valuable analysis. Although performance was low, the change in performance between pre- and post-adaptation sessions reflected the benefits of congruence. In future studies, these measures will be refined further, allowing analysis of the numbers of tasks requiring intra- and inter-person coordination while investigating the shorter-term costs and longer-term benefits of organizational adaptation.

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