Designing Optimal Organizational Structures for Combat Information Centers in the Next Generation of Navy Ships

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Abstract

The need exists for a comprehensive methodology for synthesizing *adaptive* decision making organizations to complete complex missions. Over the years, research in organizational decision making has demonstrated that a strong functional dependency exists between the specific structure of a task environment and the resulting optimal organizational structure and its decision strategy. What is needed is an application of a scientific model of organizational design, used to optimize organizational performance within specific mission parameters and constraints. This model predicts which organizational alternatives would be most likely to result in optimized staffing within the domain of safe and effective command and control operations. This paper describes the application of our team modeling approach to the design of a reduced-manning notional combat information center for future Navy surface ships, using knowledge of future missions, resources available, information networks, and doctrinal rules.

1. Introduction

Combat Information Centers (CIC) are the nerve centers of today's AEGIS-equipped Navy cruisers and destroyers. In the current CIC, a large number of watchstanders are needed to effectively conduct combat operations. As the Navy focuses on developing the next generation of surface combatants, there is considerable feeling that the introduction of new technology, combined with a more effective organization of the CIC, could reduce these manpower requirements (Bush, Bost, Hamburger, and Malone, 1998).

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The increasingly important role played by coordinated teams in a variety of settings, like the members of a CIC, is widely recognized, and there has been extensive work in recent years on methods for the measurement of team performance (see Brannick, Salas, and Prince, 1997) and for the effective training of teams (see Swezey and Salas, 1992). There has been little work, however, on methods for *designing* teams and the effective organizations mentioned above. Team structures and individual roles for team members typically evolve, based on previous structures and roles, through an ad hoc process of trial, error, and adjustment. Human factors practitioners have, in the past, been limited in what they could offer to the design process when new, radically different, system designs require the creation of new team structures and new roles for team members. In recent projects sponsored by the Navy, Aptima has pioneered the development and use of a breakthrough team design method—a systematic, formal, quantitative approach to designing the team that best fits the tasks to be accomplished.

One of these projects, the Navy's Manning Affordability Initiative, seeks to develop and use human performance models to derive optimal system designs for tomorrow's Navy ships, including optimal design of the command and control organizations, including the CIC, onboard those ships (Cannon-Bowers, Bost, Hamburger, Crisp, Osga, and Perry, 1997). Under the sponsorship of the Manning Affordability Initiative, Aptima is applying a comprehensive, systematic, quantitative methodology (Levchuk, Pattipati, & Kleinman, 1998) to design an organization optimized for a prototypical mission for the Navy's next generation of surface combatants. This methodology, based on algorithms and methods developed for the Adaptive Architectures for Command and Control (A2C2) program (Serfaty, 1996), uses knowledge of future Naval missions, resources available, information networks, and doctrinal rules to design an optimized organization for the shipboard command center. It provides a formal, quantitative method for designing an optimal organization for a mission, moving organizational design from a *heuristic* based procedure to a *scientifically* based process.

2. Approach

The Team Integrated Design Environment (TIDE) organizational design methodology is mission-driven. That is, the model uses a detailed scenario that specifies the tasks required to accomplish a mission and the resources available to accomplish those tasks, and uses algorithms to optimally allocate these tasks and resources to team members to create an organizational structure. To capture the tactical and operational elements in a scenario, we rely on expert insight from the warfighter and subject-matter experts who develop scenarios. The interaction between operational experts and modeling specialists at this stage is essential for the design process.

At the core of TIDE is a systems engineering approach that describes organizational performance criteria as a multi-variable objective function to be optimized (See Levchuk et al., 1999 for a more detailed description of these modeling methods). This objective function is expressly related to a specified mission structure which results in organizations that are mission specific. To apply the TIDE methodology, one needs to know the sequence in which tasks are performed, the resources that are used to perform each task, and the interdependencies among tasks. Given this information for a specific mission scenario, our modeling techniques can suggest ways that tasks should be grouped together (i.e., handled by the same person or the same group of people) in that scenario in order to both satisfy organizational constraints and optimize performance according to different possible criteria (e.g., maximizing mission success, minimizing likelihood of error, minimizing inter-node communication, or equalizing workload across people). For our initial effort, we defined the primary design objective as reducing staffing levels in the CIC by fifty percent without exceeding feasible workload.

2.1. *Three Part Allocation Model*

The TIDE approach is based on a *three part allocation model*, presented in Figure 1, that considers: 1) mission tasks; 2) system resources, and 3) human decision makers (the warfighting team). The organizational design process is, in simplest terms, an algorithm-based allocation between these three parts. The allocation is intended to optimize an organization based on a priori defined dimensions of organizational performance. In TIDE, organizational performance is assumed to be a function of a variety of design parameters, including individual workload, distribution of responsibility, communication between decision makers, coordination of resources, information processing efficiency, and information transfer efficiency.

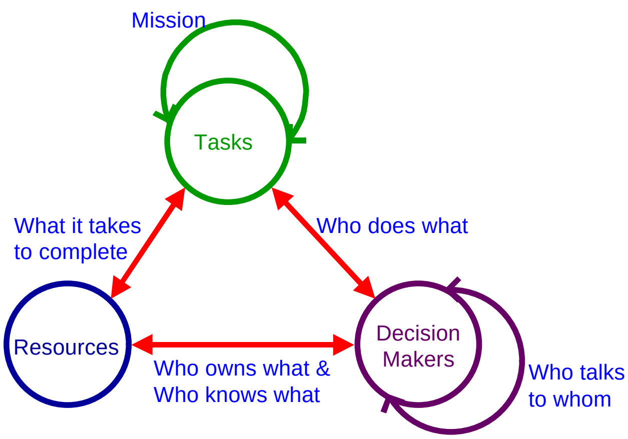

Figure 1. TIDE Three Part Allocation Model

2.2. Three Stage Iterative Allocation Process

The organization is designed as a result of an allocation process that is completed in a series of three iterative stages:

<u>Stage I</u> of the modeling process determines the task-to-resource allocation that optimizes completion of mission objectives and answers the question “What does it take to complete the mission?” This optimization is based on task precedence, resource requirements, and geographical constraints.

<u>Stage II</u> of the process employs an algorithm that clusters the resources into unique groups, each of which will be assigned to an individual member of the organization. We refer to this stage as the resource-to-decision maker stage, but in reality the entire decision maker-task-resource allocation schedule is defined because tasks and resources are paired in Stage I. The second phase answers the questions of “Who owns what resource, who knows what information, and who does what task?”

<u>Stage III</u> completes the organizational structure by specifying the command and communication networks and answers the question “Who talks to and works with whom?” The objective is to use the algorithms to optimize the distribution of task responsibilities to the team members and

the transfer of information between them. At the same time, the workload of the individual members is considered to ensure that proposed loads correspond with assumed expertise and capabilities. This provides a preliminary evaluation of the organization and this feedback is used to iteratively modify the task-resource and decision maker-resource allocations, if necessary.

3. Manning Affordability Example

3.1. *Mission Scenario*

As stated, TIDE is a mission driven design process which requires a detailed scenario as a primary input to the modeling process. For our prototype effort, we created a prototypical mission that future Navy ships may be asked to perform. This mission included aspects of an air dominance scenario being developed for the Manning Affordability Initiative by Naval Surface Warfare Center in Dahlgren, VA. In addition to the air dominance responsibilities, our scenario also included aspects of Naval surface fire support (NSFS) for an amphibious attack, theater ballistic missile defense (TBMD), and a search and rescue mission for a downed fighter pilot. In addition to this mission information, we specified the resources available to accomplish the identified tasks. The resources include ownship and four DDG-65 under ownship command, with associated sensors, radars, links, weapons systems, and airborne assets.

3.2. *Mission Decomposition*

An essential question that underlies all organizational design processes is “Who does what?” This requires that a mission be described in terms of its tasks (the “what” independent of the “who”). A process of multi-dimensional mission decomposition is used to identify mission elements. As the name suggests, we conducted several types of decomposition (i.e., goal, domain, action) in which we break down a mission to a representative level for the team we are modeling. An accurate representation of the mission is critical to the development of optimized organizations. Because the optimization process is driven by designating who should do which part of the mission, errors in the mission structure will propagate into the final team design. To ensure quality inputs, the identification of mission tasks and their attributes is derived from subject matter experts’ descriptions of the mission.

The objective of the mission decomposition is to identify the fundamental mission elements which serve as the basis for building an analytical model of the mission. For example, as shown in Figure 2, we identified four main mission domains which are further decomposed to the action level. While Figure 2 shows a number of actions, including data analysis and target tracking, in practice this decomposition is conducted at a greater level of detail to break down a mission to a representative level for the team we are modeling.

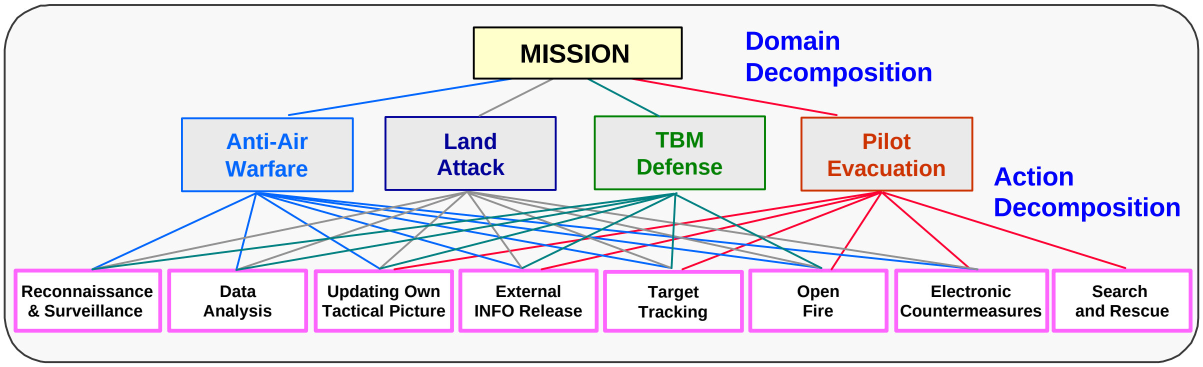

Figure 2. Domain and Action Mission Decomposition

These mission decompositions are used to define parallelism, sequence, and structure for the mission tasks. These task interdependencies are used to create a hierarchical structure among mission tasks which is represented by a mission task dependency graph. An example of one such graph is shown in Figure 3. This task graph provides a high-level hierarchical representation of our selected mission. Likewise, Figure 4 presents the task structure for the anti-air warfare domain, based on a more detailed level of decomposition. This output, the quantitative mission structures, is presented to subject matter experts for final review before the organizational design process proceeds.

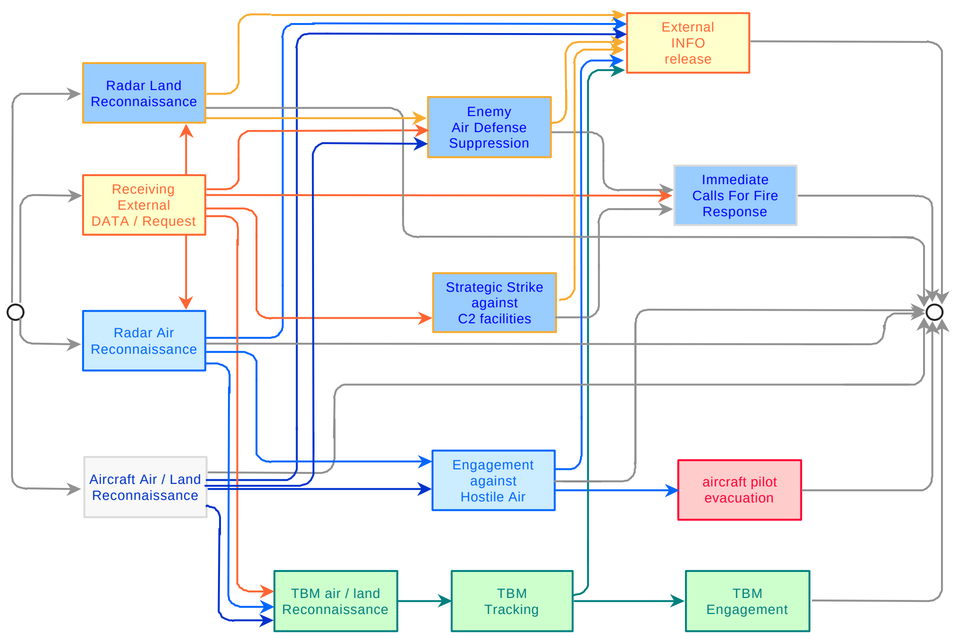

Figure 3. Top-level Task Dependency Graph

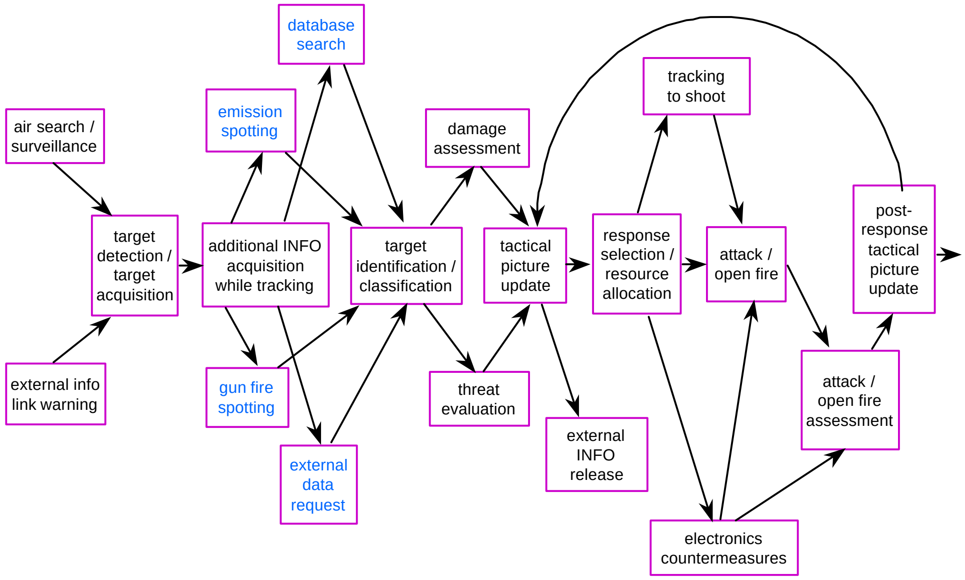

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Figure 4. Quantitative Mission Structure using Detailed Action Decomposition

3.3 *Results*

As a proof of concept for the Manning Affordability Initiative, we developed two different CIC organizational structures for the above mission scenario. Our first organization was based on a "representative" CIC, organized in much the same way as a current AEGIS CIC, although with new tasks added for the future-based scenario. This CIC design has 10 positions, corresponding roughly to positions that currently exist in the CIC. We then developed an "optimized" CIC design, based on the mission, the tasks, and the resources. The primary objective of the optimization was to reduce team size, but we also tried to equalize workload distribution across team members. We allocated resources to tasks and tasks to decision makers. The final product was the five-person organization (50% manning reduction) shown in Figure 5, with new positions that do not correspond exactly to any existing CIC positions: a tactical action coordinator; an air dominance coordinator; a long range weapons coordinator; a short range weapons coordinator; and an information management coordinator. The next step will be an expansion of the effort to consider other, different missions for future Navy ships, and empirical testing of team performance under these innovative organizational designs.

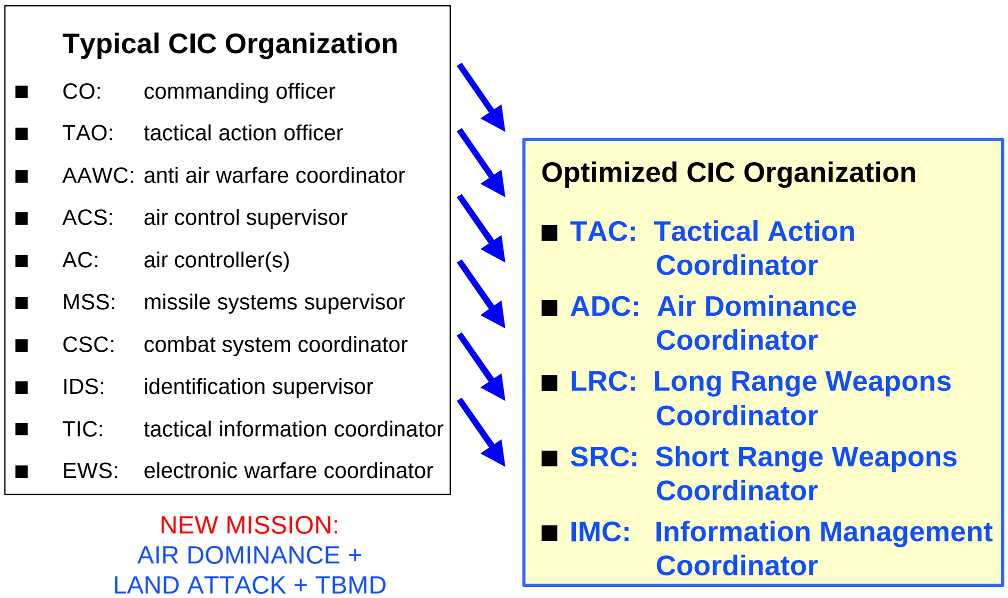

Figure 5. Example: New Roles of Optimized Command Team

4. Summary

Using TIDE, A novel, formal, and quantitative way to model teams and organizations, we created a new, reduced-staff organizational structure for a CIC of the future. For each member of this team, we specified the resources under their control, including information access structures. The modeling process describes the command, tactical, and information hierarchy within the team. This proof-of-concept organization was designed with one specific scenario in mind. Additional, more complete scenarios that take many other issues into consideration are necessary before coming up with a final CIC configuration. However, this tool does provide a good starting place, and a means for iteratively testing and refining design ideas. A key attribute is that it is a generative tool - it produces team designs, it doesn't just test them after someone else has thought them up.

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