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The State of the Art and the State of the Practice

Paper title: "Computational Modeling and Analysis of Networked Organizational Planning in a Coalition Maritime Strike Environment"

Track: "C2 Concepts and Organizations"

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Abstract

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Suggested topics

Edge organizations; knowledge networks; mission planning.

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The *Edge* represents a fresh approach to organizational design, moving knowledge and power to the edges of organizations. But this raises issues in terms of comparative performance with respect to alternate organizational designs. The research described in this article extends our investigation into the design and efficacy of Edge organizations for current and future, military, mission-environmental contexts. We begin with field research at sea with a coalition expeditionary strike group, observing in particular the planning process associated with maritime tasking orders, and focusing in particular on the effects of networking, knowledge and power flows. Such field research is used to develop and validate a computational model of the current maritime component commander organization and planning process. Through computational experimentation, the nature of this organization and process are analyzed to assess the relative strengths and weaknesses of alternate communication capabilities, knowledge networks and power flows. New work described in this article reveals insightful dynamic patterns and differential performance capabilities of various C2 organizations. This work suggests immediate results amenable to practical application in the Military, and it suggests also an exciting agenda for continued research along the lines of this investigation.

Suggested topics

Edge organizations; knowledge networks; mission planning.

Introduction

The *Edge* [Alberts & Hayes 2003] represents a fresh approach to organizational design, which appears to be particularly appropriate in the context of modern military warfare. It proposes to capitalize upon fully connected, geographically distributed, organizational participants by moving knowledge and power to the edges of organizations. This highlights promising opportunities for enterprise efficacy. But it also raises issues in terms of comparative performance with respect to alternate organizational designs. Modern military organizations in general have adapted and evolved over many centuries and millennia, respectively. Hierarchical command and control (C2) organizations in particular have been refined longitudinally (e.g., through iterative combat, training and doctrinal development) to become very reliable and effective at the missions they were designed to accomplish. In contrast, the many putative benefits and comparative advantages proposed for Edge organizations are only just beginning to be formalized in terms of research hypotheses for empirical testing.

A major problem is, few research approaches exist at present to examine Edge propositions empirically (see [Nissen-Buettner 2004, Stanford POW-ER 2006]). For instance, it remains unclear even whether informative examples—much less exemplars—of Edge organizations in practice can be identified for study (cf. [Nissen 2005A]). And attempting to test large-scale military organizations in the laboratory suffers from severe problems with external validity [Campbell & Stanley 1973]. Likewise, modifying one or more operational military organizations in the field to take on Edge-like characteristics creates problems with internal validity [Cook & Campbell 1979].

Further, current conceptualizations of Edge organizations are limited largely to natural language descriptions (e.g., [Alberts & Hayes 2003, Gartska & Alberts 2004]) and static models (e.g., [Maxwell 2004]). Descriptions in natural language—even from the best writers—retain considerable ambiguity in terms of conceptual meaning and interrelations. Many people can use the same words and phrases to mean different things. And many different interrelations can be characterized to describe the same phenomena. Plus, static models are unable to represent the kinds of rich, dynamic, often emergent behaviors that are important for understanding complex organizations and environmental interactions such as observed in military C2.

Additionally, the organizational processes associated with contemporary military C2 do not remain static. Rather, they change continually, longitudinally as well as across different organizational instantiations. For instance, modern warfare in the U.S. has adapted over this past two decades to focus on joint warfighting [Joint Pub 1 1991], in which multiple services (e.g., Army, Navy, Air Force, and Marine Corps) operate together, as integrated units under a common commander. The Joint Task Force (JTF) organization represents a case in point, which created new pressure for changes in the corresponding C2. This JTF concept changed in turn recently to include joint forces from a coalition of international partners, called appropriately the Combined Joint Task Force (CJTF), with additional, attendant pressure for changes in the corresponding C2.

As the nature of modern warfare adapts to changes in mission-environmental contexts, changes to the corresponding C2 organizations, work processes and technologies change even faster and more radically. This represents a reflection of Ashby's *requisite variety* [Von Foerster and Zopf 1962]: viz, the variety of the controller must increase beyond that of the system to be controlled. For instance, even within the CTF organization, the nature of maritime-led C2 is shifting markedly, with the Joint Force *Maritime Component Command Tactical Memorandum (JFMCC Tacmemo)* emerging as a new, doctrinal aspect of joint and coalition warfare [Navy Tacmemo 3-32-03 2003]. Although some elements of the planning and execution process are adapted from the familiar air tasking order (ATO) process used for years in planning and controlling air operations, the nature of maritime operations differ qualitatively (e.g., maritime forces offer myriad, different strike and defensive capabilities) and quantitatively (e.g., maritime forces can remain on station for months instead of hours). Unfortunately, our understanding and informed design of maritime planning and operations lags behind our implementation of the associated organizations, processes and systems in the Military. This trial-and-error and adaptation-from-the-ATO approach is fraught with peril, and emphasizes the need for current research to inform military organization and practice.

The research described in this article represents the second stage of a multi-disciplinary, multi-year investigation into the design and efficacy of Edge organizations for current and future, military, mission-environmental contexts. Specifically, we build upon recent work (e.g., [Constantin et al. 2004, Nissen-Buettner 2004]) to employ methods and tools of computational experimentation and to model and analyze networked organizational planning in a coalition maritime strike environment. This study follows previous work to specify computational models of Hierarchy and Edge organizations in the C2 domain [Nissen 2005A, Stanford 2005 POW-ER], through which a commitment to semi-formal modeling and empirical testing pushed our understanding forward considerably in this domain. For instance, we understand now some of the fundamental theoretical and empirical aspects of Edge organizations, and we have learned to appreciate robust differences in mission-environmental fit (e.g., Industrial Age vs. 21st Century warfare, Cold War vs. Global Terror context) and performance (e.g., in terms of mission speed vs. risk) between Edge and Hierarchy organizations.

In this present article, we conduct field research at sea with a combined force maritime component command (CFMCC) and an expeditionary strike group (ESG), observing in particular the planning process associated with maritime tasking orders, and focusing in particular on the effects of networking, knowledge and power flows. New knowledge developed through such field research is used to develop a computational model of the current maritime component commander organization and planning process. Through computational experimentation, the nature of this organization and process are varied systematically to analyze the relative strengths and weaknesses of alternate organizational forms (e.g., Hierarchy, Edge, and Combined Force Maritime Component Commander), knowledge-network topologies and process architectures. New work described in this article reveals insightful dynamic patterns and differential performance capabilities of various C2 organizations. This work suggests immediate results amenable to practical application in the Military, and it suggests also an exciting agenda for continued research along the lines of this investigation.

Background

In this section, we build upon previous research (esp. [Nissen 2005B]) to summarize briefly how the Edge organization compares theoretically to other archetypes discussed in the literature, but we focus intensively upon key background pertaining to the Combined Force Maritime Component Command (CFMCC) planning process.

Edge Specification

Very briefly, Nissen [Nissen 2005B] employs Mintzberg's classification [Mintzberg 1979] rubric to specify Hierarchy and Edge organizational forms. These specifications are useful in their own right to ground current conceptualizations in organization theory and to indicate similarities and differences with other organizational forms through archetypal classification. Table 1 summarizes the classification of the Hierarchy and Edge organizations according to this scheme. The interested reader is referred to this prior work for detailed rationale and parameterization. But for our present purposes, it suffices to note that the two organizational forms are quite distinct. The Hierarchy column labels the organizational archetype that corresponds most closely with the kind of military C2 organization associated with a CJTF: *Machine Bureaucracy*. This classification is relatively clear and straight forward, and it corresponds with popular notions of the military as a bureaucratic organizational form.

Table 1 Classification of Hierarchy & Edge Organizations (adapted from [Nissen 2005B])

Design Factor	**Hierarchy**	**Edge**
Coordination	Work standards	Mutual adjustment (Adhocracy)
Specialization – H	High	Low (Simple Structure)
Specialization – V	High	Low (Professional Bureaucracy)
Training & indoc	High	High (Professional Bureaucracy)
Formalization	High	Low (Simple Structure, Professional Bureaucracy, Adhocracy)
Grouping	Function	Market & function (Adhocracy & Professional Bureaucracy)
Unit size	Large	Small (Adhocracy)
Planning & control	Action planning	Limited action planning (Adhocracy)
Liaison	Few	Many throughout (Adhocracy)
Decentralization	Centralized	Selective decentralization (Adhocracy)
Archetype	*Machine Bureaucracy*	*Professional Adhocracy*

Classification of the Edge organization is a bit more difficult, however. This is in part because the military does not organize currently for C2 in terms of *edge*, and in part because the properties of an Edge organization draw from multiple archetypes. Indeed, few examples of Edge organizations can be identified in practice (cf. university research, open-source software development, soccer teams; see [Nissen 2005A]). Further, there is some tension in classifying Edge organizations regarding the level at which *edgeness* applies. For instance, *edge* clearly does not apply to the Military as a whole. Yet several, very small military units today (e.g., SEAL and Special Forces teams) depict many *edge* characteristics. In terms of the classification rubric, the Edge organization reflects aspects of Adhocracy, Simple Structure and Professional Bureaucracy; hence it does not correspond as cleanly with any single archetype. Staying focused on our CFMCC unit of analysis, and looking to non-military examples of Edge organizations (e.g., university research, open-source software development, soccer teams), we consider the Adhocracy and Professional Bureaucracy to reflect this organizational form best. Hence we label it "Professional Adhocracy" in the table. Thus, we see that the Hierarchy and Edge represent qualitatively distinct organizational forms, but that both such forms can be grounded in theory via analytical application of this classification rubric.

C/JFMCC Planning Process

In early 2003, the Navy hosted a conference to discuss maritime C2 issues from a major U.S. joint warfighting experiment—the conference's focus was on the maritime component commander level. That experiment highlighted some problems related to maritime planning at the operational level. It was decided that the Navy should develop specific doctrine regarding how to organize and perform the functions required of a Joint Force Maritime Component Commander (JFMCC), especially addressing those areas related to operational-level planning. The doctrine was designed to be inclusive of planning in either a joint or combined (i.e., where forces of one or more other countries are participating) environment. The subsequently developed planning process should be viewed as an articulation of a shared way of thinking about how to plan and not a rigid directive, because in the Navy's view, doctrine is conceptual, and does not require relinquishing freedom of judgment. [Navy Doctrine Pub 1 1994]

There are three recognized levels of cognitive focus for military organization. First is the strategic level, where national-level policy, goals, and plans are developed to use national resources to achieve those goals. An example of that is where organizations such as the Joint Chiefs of Staff, Combatant Commands (e.g., U.S. Central Command and U.S. Pacific Command, and Military Service Headquarters) interface with other National Security Council-level organizations. Next is the operational level, where the unit of analysis for this paper is focused. Operational level organizations (e.g., Combined Joint Task Force commanders and their functional component staffs, such as maritime – numbered fleet staffs) are focused on developing plans for, conducting, and sustaining major military operations (e.g., humanitarian assistance and armed conflict involving major combat elements, to include divisions and separate brigades, Navy task forces, and others) that support achieving strategic-level goals. Finally there is the tactical level of war, where engagements are planned and executed. Activities at the tactical level focus on the ordered arrangement and maneuver of combat elements (e.g., ships, aircraft, battalions, companies) in relation to each other and to the enemy, or in the case of humanitarian relief operations, to the crisis situation, to achieve objectives.

At the operational level, the CFMCC organization is one of the principal divisions of a Combined Joint Task Force (CJTF) hierarchy—typically there are four functional divisions: CFMCC, CFACC (Combined Force Air Component Commander), CFLCC (Combined Force Land Component Commander) and CSOTF (Combined Special Operations Task Force). The major responsibilities of such organizations are: to make recommendations to the CJTF commander for employment of forces; and to plan and coordinate operations to accomplish missions assigned by the CJTF commander. Overarching military planning doctrine states that planning is a sequential process performed simultaneously at each level described above. [Joint Pub 5-0 1995] At the operational level, component commanders' planning activities must include deployment, employment, sustainment and redeployment of forces assigned. Due to the dynamic nature of military operations, planning is also an iterative process that supports development of branch and sequel plans: modifications, and new or significant changes to existing plans, respectively. Those requirements have led to the development of detailed planning processes.

The CFMCC planning process was designed to produce plans that would enable accomplishment of assigned missions, and integrate maritime capabilities where applicable into all aspects of the joint operation. To that end, the CFMCC planning process is characterized by a high level of synchronization with the CJTF's and other component commanders' planning processes. The CFMCC has a six step planning process that is focused on ensuring a thorough understanding of assigned missions, and promulgation of unambiguous tasking to assigned forces. It is a top-down process, where the CFMCC commander provides guidance and intent at the start of each step, and approval of products at the completion of each. [Navy Tacmemo 3-32-03 2003]

The first step of the planning process is Mission Analysis. In this step, a standard approach is taken to review and analyze orders, guidance, and the overall situation. This step is designed to promote common understanding among all members of the planning team. The step ends with the commander's approval of the mission analysis products that include items such as a restatement of the mission that is focused on essential tasks, and a list of all tasks that need to be accounted for in the plan. As the final approval is happening, elements of the planning team are preparing for the Course of Action (COA) Development step.

COA Development is the second step, which begins with the commander providing planning guidance, and drawing on his experience to articulate initial intent on how the missions should be accomplished. There are myriad ways to develop COAs. The two consistent requirements are that an outline of a plan be developed, and that it accomplishes the mission in consonance with the commander's guidance and intent. Typically, multiple COAs that meet the following characteristics are generated: suitable, distinguishable, feasible, acceptable, and complete. The commander usually reviews each COA during the development phase, and provides refinements and direction for which ones should proceed to completion. Once the COAs are fully developed, the commander reviews them, and stipulates which ones will proceed to the COA Analysis step. The commander also provides guidance on what types of things to analyze, and what criteria are to be assessed.

COA Analysis is the third step, in which the planning team has wide latitude on how to conduct the analysis, but this step has three goals: to provide the commander with an assessment of the strengths and weaknesses of each COA based on the evaluation criteria; to more fully develop the plan to promote synchronization; and to identify and mitigate risks. Typically, a wargame (i.e., a simulation, by whatever means, of a military operation involving two or more opposing forces using rules, data, and procedures designed to depict a situation [Joint Pub1-02 2001]) is conducted to provide a reliable basis for understanding and improving each COA. This step ends once the planning team can cogently report information regarding each of the evaluation criteria, the strengths and weaknesses of each COA, and recommend a COA to the commander.

The fourth step is COA Comparison and Decision, which can also vary widely in how it is conducted. Typically a side-by-side comparison of the COAs is conducted for the commander based on the evaluation criteria. The staff identifies advantages and disadvantages of each COA, and makes a COA recommendation. Where practicable, subordinate commanders will attend this step of the process, and provide their recommendation to the CFMCC commander. This step ends when the commander selects and approves one of the COAs, and provides any COA refinement directives.

The fifth step is Orders Development, which is initiated upon COA selection and delivery of commander's approved guidance and intent statements. At this point, the planning team reconciles any outstanding planning issues, and prepares an order in conjunction with other relevant staff entities as coordinated by the CFMCC Chief of Staff. That order should articulate the COA in a clear, useful format that is easily understood by those executing the order. As the parts of the order come together, the CFMCC staff conducts a detailed review of the entire order to ensure that it is complete and in agreement. Any discrepancies or gaps are then corrected as facilitated by the planning team. Upon completion of review, the order is compared with orders and plans from other components (e.g., CFACC, CFLCC, and CSOTF) to identify and resolve any discrepancies. Upon the CFMCC planning team's completion of those steps, the order is reviewed and approved by the CFMCC commander.

The final step of the process is Transition, where the planning team hands the order and relevant planning products to the CFMCC current operation center to issue the order and supervise execution of the plan. Transition can be conducted in a number of different ways, but typically a briefing is developed by the planning team. That transition briefing and its associated order are given to the CFMCC current operations (COPS) team in a venue that allows them to ask questions and seek clarification. With the completion of the transition briefing, the planning process for that plan is complete.

Research Design

In this section, we provide a brief overview of the tools used to model and assess the C/JFMCC organization and planning process. Much has been written elsewhere about the computational tools and their use for evaluating military C2 organization. The interested Reader is directed to the corresponding citations and references below for additional information. We also describe our qualitative field research at sea to understand the C/JFMCC organization and planning process.

Computational Tools

Here we draw from [Nissen-Levitt 2004], and build upon [Nissen 2005B] to describe briefly the computational methods and tools used for modeling the CFMCC organization and process. The Virtual Design Team (VDT) Research Program [VDT 2005] reflects the planned accumulation of collaborative research over two decades to develop rich, theory-based models of organizational processes. Using an agent-based representation [Cohen 1992, Kunz et al. 1998], micro-level organizational behaviors have been researched and formalized to reflect well-accepted organization theory Levitt et al. 1999]. Extensive empirical validation projects (e.g., [Christiansen 1993, Thomsen 1998]) have demonstrated representational fidelity and have shown how the qualitative and quantitative behaviors of VDT computational models correspond closely with a diversity of enterprise processes in practice. The interested reader is directed to the references for detailed discussion of these tools. Such reader may be interest also to learn that current VDT technological work and research vectors are described in parallel with this present study [Ramsey-Levitt 2005].

The POW-ER application used in this present research (V1.1.3) is in beta test, hence it does not possess all of its intended capabilities, and it suffers still from a number of known and unknown bugs. As such, there is some risk in using the application now, for some of the computational results reported below may reflect hidden errors, which may affect our corresponding findings and conclusions. However, the basic performance and outputs of POW-ER have been verified, and several key behavioral and performance results (esp. planning duration) have been validated through our fieldwork on the CFMCC process. Hence we have considerable basis for confidence in the thrust of the results we report. Additionally, all of the comparisons that we make below are relative to one another, and control for the same underlying variables and behaviors. Hence any bugs or errors inherent in POW-ER are controlled and applied consistently across all models. Thus, although one or more of the absolute results reported may be in some error, the relative results reported—which comprise the essence of our experimental study—are reported on a consistent basis.

Table 2 summarizes POW-ER parameterization of both the Hierarchy and Edge organizations from above. This provides an important linkage between our theoretical grounding above of these contrasting organizational forms and our computational modeling via POW-ER. Hence our POW-ER models can be used to help specify theory, and theory can be used to help explain our POW-ER models. This provides us with a bidirectional *Rosetta Stone* for understanding organizational models, and it facilitates our present task of modeling the CFMCC organization and process computationally.

Table 2 Representations of Hierarchy & Edge Organizations

Structural Factor	Hierarchy	Edge
Organization Structure	- High *centralization* - High *formalization* - Low *matrix strength* - 3-level hierarchy - Command (PM): 3 FTE - Coordination (SL): 200 FTE - Operations (ST): 40,000 FTE - 4, large units - Med *skill level*	- Low *centralization* - Low *formalization* - High *matrix strength* - 1-level meritocracy - Command (PM): 0 FTE - Coordination (SL): 0 FTE - Operations (ST): 40,000 FTE - 16, smaller units - Med *skill level*
Communication Structure	- Vertical channels - "Wheel" structure - Few communication links - *Information exchange* (0.1) - Push communications - Low *application experience* - Meetings (2 hr/day, 10%)	- Horizontal network - "Circle" structure - Many communication links - *Information exchange* (0.9) - Post & smart pull - Med *application experience* - P2P communications
Work Structure	- 4 operational tasks - Sequential execution (2-Ph) - Sequential interdependence - *FEP* (0.1) - *PEP* (0.1) - Leader demands extra - *Work duration* (3 months) - Loose coupling - *Rework strength* (0.3) - Command & staff rework	- 16 operational subtasks - Concurrent execution - Reciprocal interdependence - *FEP* (0.2) - *PEP* (0.2) - Leader demands emergent - *Work duration* (0) - Tight coupling - *Rework strength* (0.1) - No Command or staff

CFMCC Field Research Design

To understand the details of the CFMCC process *as it is practiced* (i.e., perhaps differently than laid out on paper), we designed a qualitative study in the field, through which we immersed ourselves in the organization, processes, people and technology through the 2005 Trident Warrior experiment at sea [Woods 2005]. Results of this fieldwork are informative in their own right, as well as serving to validate our POW-ER models.

The setting for this study covered a ten-day military field experiment, during which we conducted direct observations and multiple interviews, and administered surveys. The setting provided a high level of fidelity to observe the CFMCC planning process directly. One of the authors is a Navy Commander, with substantial experience in this domain, which provided both insight and access to the organization and its people and processes. The CFMCC organization included the Deputy Commander of the NATO Striking Fleet Atlantic in command of the maritime component. He was supported by a significant portion of the Striking Fleet Staff, which included 16 dedicated planning team officers. That portion of the staff was sufficient to perform CFMCC planning and execution functions for a small scale coalition military operation. The setting included staff operations from traditional Navy command centers, both afloat and ashore. The remaining portion of the staff and the commander of NATO's Striking Fleet performed support duties by acting as the CJTF commander and staff, and other associated headquarters and organizations. The CFMCC had fully participating subordinate commands (i.e., Expeditionary Strike Group (ESG) and a Marine Expeditionary Unit (MEU) staff that started as a response cell, but grew midway through the experiment to provide a high level of fidelity for planning functions) that operated from traditional afloat command centers as well. The CFMCC staff and ESG were augmented by coalition staff officers and both real and virtually represented ships.

During the experiment, we were allowed unfettered access to observe all planning events. Additionally, we conducted seven extensive interviews with key planning process leaders and executives; four of those interviews were tape recorded and transcribed. An interview protocol was developed for two different levels of participants. One protocol was focused on CFMCC executives to elicit evaluative comments about the process. The other protocol was focused on getting an accurate description of the process from its leaders. We also administered multiple qualitative surveys to the entire planning team, and supplemented our observations with dozens of informal conversations with them. Those survey instruments were designed to capture a description of the process, and knowledge inventories. Other sources of data included archival data regarding details of the planning process. All of this data collection was performed in an effort to corroborate what had been observed directly, as well as provide additional insights and perspectives on the planning process.

Results

In this section, we describe results of our field research, and we elaborate the computational model developed to represent and emulate the behavior of the CFMCC process. We also include some preliminary experimental results, and discuss the associated insights.

After assembling all of the data (field notes, interview transcripts, surveys and written organization and process documents) a coding processes was started on the interview transcripts, notes, and surveys. Categories based on related properties found in the transcripts began to emerge. As the coding process continued and new categories were identified, all of the data were reread to see if there were any corroborating examples previously unnoticed. There were at least four complete iterations through the data. The data also provided a useful way to glean the various perspectives on the organizational structure, knowledge network and knowledge flows in play at the unit of analysis, CFMCC level. The direct observations, augmented by an understanding of the relevant CFMCC organizational documentation, provided a sound way to capture the steps of the processes and interactions that took place. We used those details as a balance to some of the subjective views of the participants who seemed to find the interviews and observations to be more of an assessment of their knowledge of how planning should be done vice a collection of the description of the planning system in use.

CFMCC Field Research

This section summarizes key results from our CFMCC field research. We organize such results into three areas: 1) CFMCC Organization and Planning Process, 2) CFMCC Knowledge Network, and 3) CFMCC Organizational Behavior. Each set of results is presented in turn.

CFMCC Organization and Planning Process

The CFMCC commander's staff was re-organized within the last six months, and additional modifications were recently made to investigate newly developed procedures that support the targeting and scheduling work required between the planners and the personnel in COPS. Figure 1 depicts the basic staff structure; this is not a complete view: instead it only captures the relevant staff sections discussed in this paper. The commander was a British Navy Commodore (one star flag officer) with operations and planning experience. There was a section of special assistants comprised of both senior (e.g., Captains, Colonels, and Commanders) and junior personnel (e.g., Navy Lieutenants) from various specialties, including, but not limited to Law, Special Warfare, Public Affairs and Medical. The CFMCC staff had three major staff sections employed for this experiment. The Operational Net Assessment (ONA) section was responsible for three areas: 1) intelligence functions including planning intelligence, surveillance and reconnaissance (ISR), 2) intelligence analysis, and 3) operations assessment. The Communications and Information Systems (CIS) section was responsible for information management (IM) and communications support. Again, these descriptions are broad and not meant to be inclusive of all the functions. Of note, there were two primary networks used during this experiment. The secure internet protocol

(SIPRnet) for U.S. personnel only, and the Coalition Naval Force network (CNFnet), which was supposed to be a mirror image of the SIPRnet; unfortunately, there was a time delay for getting data from one network to the other—that was also compounded by occasional inaccuracies in data transfer, which exacerbated the time delay as data accuracy needed to be confirmed. The paucity of CNFnet terminals was an additional hindrance to the effective flow of communications.

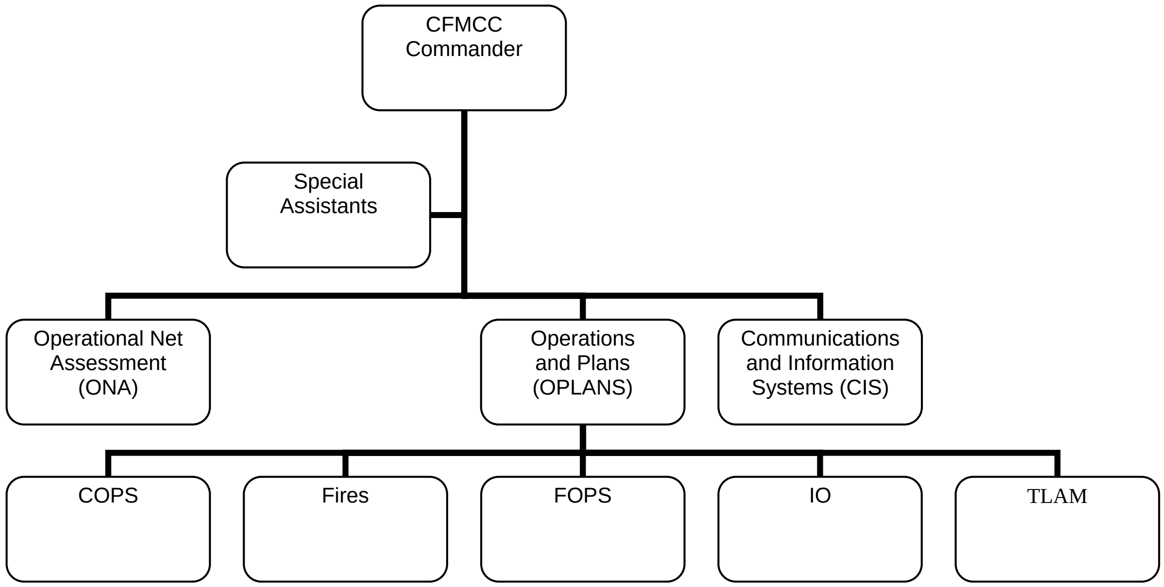

Figure 1 CFMCC Organization Diagram

The Operations and Plans (OPLANS) section was divided into five recognizable subsections. Current Operations (COPS) is responsible for managing current day activities and ensuring that orders are issued and executed. Those orders are generated based on approved plans or necessary modifications to plans based on the realities of the current situation. COPS focused on events happening within the next 24 hours. This was the first time that the OPLANS section used a distinct Fires subsection in conjunction with a targeting process. This subsection handled the details of prioritizing maritime capabilities (e.g., aircraft and missiles), especially those that require targeting support and coordination with the CFACC and its asset scheduling and airspace control procedures. Fires was a static organization: each officer had a narrowly defined role in producing formatted products (e.g., Master Maritime Target List and Master Maritime Attack Plan). It was bounded to support the 24 to 96 hour time frame from the current day's activities.

The Information Operations (IO) subsection supported the CFMCC's plans development requirements by planning in parallel and in close coordination with FOPS. This subsection appeared to be a separate planning section due to their frequent work with highly classified information. Typically, an IO planner was physically present when OPT work was in progress. The Tomahawk Land Attack Missile (TLAM) subsection was not an active player in this experiment; however, it is mentioned here because the leader of that subsection was assigned the collateral duty of being the Knowledge Management Officer (KMO) for the CFMCC staff. That officer had a daily meeting with all of the CFMCC's collateral duty knowledge managers (KM) to discuss information management procedures and issues. Of note, the FOPS subsection's collateral duty KM was never able to participate in an OPT's function due to the amount of work involved insuring that information was being properly posted to web portals and being accurately transferred from SIPRnet to CNFnet.

The Future Operations (FOPS) subsection, where the majority of the focus of this research was conducted, is comprised of a diverse group of personnel who are responsible for developing plans for the CFMCC commander. Led by a Marine Corps Lieutenant Colonel, the

Future Operations Officer, this subsection had two Army Majors and a Lieutenant Colonel, nine Navy staff officers (two Commanders, four Lieutenant Commanders, three Lieutenants, and one Navy Chief Petty Officer), and two Air Force Officers, a Lieutenant Colonel and a Major. Those officers brought the following functional area expertise to this subsection: Aviation (both fixed and rotary wing), Naval Special Operations, Infantry, Artillery, Military Intelligence, Surface and Submarine Warfare. There were three coalition officers, all three were surface warfare Lieutenant Commanders—the totality of the surface warfare expertise in FOPS.

In the FOPS subsection, the FOPS leader was predominately focused on interfacing with the OPLANS officer and the CFMCC commander—receiving planning guidance and delivering planning products. The development task was accomplished by assigning an Operational Planning Team (OPT) leader who assembled a team of staff officers from within FOPS based on their knowledge and expertise. The OPT leader also sought to pull in other desired expertise, mostly from within the CFMCC staff, but also from subordinates. Outside agency expertise would also have been requested if desired, and if an appropriate venue and communications capability were available. An officer assigned to FOPS might work on more that one OPT concurrently, but that did not happen during this experiment. As designed, the FOPS subsection supports planning beyond the current day's activities. There was one condition within FOPS that bears mentioning; trained and experienced coalition planners, although assigned to FOPS like any U.S. staff officer, became a separate sub-subsection within FOPS—they were located in a different office with other U.S. personnel that were also augmenting FOPS, but those U.S. personnel were the most junior, and had no planning training or process experience. Those details were noted by both the survey data and direct observation.

During the experiment, the CFMCC was required to develop branch plans to fulfill assigned missions that were received from the CJTF commander. There were two distinct branch plans developed. The first branch plan, for a raid operation, was completed and handed over to the COPS division before planning for the second mission was assigned. The Future Operations division of the OPLANS staff section was responsible for developing those branch plans. Upon receipt of the CFMCC mission, the OPLANS officer sought planning guidance from the CFMCC commander and subsequently delivered the planning task and guidance to FOPS. Key to delivering the planning task was both the commander's and the OPLANS officer's years of experience and education in operational planning: it allowed them to impart specific focus areas and clarifying assumptions that they determined were needed for the planners to be efficient during planning process steps.

Upon receipt of the planning task, the FOPS leader quickly gathered the "core" planners (i.e., four of the sixteen person FOPS subsection) and assigned one as the OPT leader. This group of core planners, made up of only U.S. officers, accounted for 66 percent of the total relevant experience for planners—they had 30 of the 45 total years of experience. Relevant experience was determined by survey data that indicated previous experience as an operations or plans officer for a senior (i.e., Commander/Lieutenant Colonel or above unit commander). Furthermore, the core accounted for 40 percent of the officers that had been educated in an operational-level planning process via an official military course. After a brief meeting, each planner in this group worked independently on different portions of the mission analysis step, filled in the required output products, and brought the resulting products to a FOPS subsection meeting to review the mission analysis in preparation for briefing it to the commander. This FOPS meeting took place in a theater-like room inside the command ship. The "core" planners, who happened to account for three quarters of the highest ranking planners, were located in the front of the room and dominated the majority of the discussions that occurred during this mission analysis review. This type of plans development was repeated for the COA development and CONOPS development steps.

From a knowledge management perspective, those steps of the process were significantly focused on work flows: producing mission analysis products without incorporating much opportunity for knowledge flows among the subsection, especially coalition officers' inputs—where coalition officers could inject a non-U.S. perspective and their surface warfare expertise. It was noted by multiple U.S. and coalition personnel that the coalition planners were "under utilized," mostly "providing [solicited] advice on coalition capabilities"—information that could be found by looking in readily available unclassified publications—vice providing coalition input to the planning process. An assessment of the planning products by a key participant revealed that those products required breaking the U.S. process and focus in order to incorporate coalition perspectives, all of the good ideas, and what-if questions that should have been present in the products. Additionally, it was recognized by U.S. officers within FOPS that there was no surface warfare planning expertise. "I really don't have a true surface warfare officer…and that is one thing that I need…." And, "The ESG was our primary input for that [surface ship planning expertise]. We had one Lieutenant, Junior Grade and one Lieutenant, but they were not always available. I'd say that we had about a 60% show time from those guys." Those statements stand in stark contrast to the three coalition surface warfare officers—educated and experienced in planning and surface warfare operations—assigned as co-equal staff officers within FOPS. In short, there was little utilization of some of the *key* knowledge inventory available—even though a process existed to provide the opportunity for knowledge flows. A full-time KM, employing knowledge management principles and tools (e.g., conducting knowledge inventories and knowledge flow analyses of process steps) and mentored by the KMO, could enhance knowledge creation and utilization while not jeopardizing work flows. Clearly in this event, planners had ample time to work the process steps, yet did not incorporate tacit knowledge flows, both coalition perspective and surface warfare expertise.

CFMCC Knowledge Network

Table 3 represents the network of knowledge sources that were *available* within the FOPS subsection to support Raid planning, and it summarizes which sources were *used* for such planning.[1] Hence it elucidates a comparison between potential and manifest knowledge sources pertaining to Raid planning. Across the top are the column headings for expertise that was most relevant to the Raid planning. Due to the limited nature of scenario for this experiment, some seemingly important functional areas (e.g., Undersea Warfare, Amphibious Surface Operations and Operational Law) were not represented. For instance from the table, expertise in the areas of operational planning (labeled "Op'l Plans"), Raid operations (labeled "Raid Ops"), and the others was both available and relevant to the mission planning process. In other words, this represents *what* knowledge in terms of expertise was available.[2] The row headings indicate the nationality and branch of service of the FOPS staff personnel. These headings summarize all of the major cultures that were expected to be active participants in the planning process, but exclude the CFMCC Commander's, who participated principally in the role of decision maker. For instance from the table, active participation from the Australian, New Zealand and US Navies, as well as other US service planners was expected. In other words, this represents *who* brings knowledge in terms of expertise to support the planning process.

Cells within the table indicate the intersection of these two sets: who brings what expertise to the planning process. Further, within each cell of the table, the symbol "B" or "b" represents a participant with the rank of Commander or Lieutenant Commander (i.e., O5 or O4 grade officers) or other service equivalents, while a "C" is for a Lieutenant (i.e., O3) or below. In other words, this represents the *level* of participation in terms of rank, which serves as a proxy for multiple variables (esp. experience). Although some Navy Captain (i.e., O6) and above participated in some aspects of the process, their participation was peripheral (e.g., supervision, decision making), hence they are excluded from the table. Moreover, *italicized* lettering represents a person that has formal classroom instruction in an operational planning process, and **bold** lettering represents a person that has experience as an operational planner. Small lettering indicates a person neither schooled nor experienced in operational planning. The outlined column helps draw attention to the entire FOPS subsection used for operational planning.[3] This represents a proxy for the knowledge inventory associated with each participant. Hence one can

[1] Planning participant from outside the OPLANS subsection level (e.g., Special Assistants such as Staff Judge Advocate, and subordinate commands such as ESG and MEU) are not reflected as that goes beyond the scope of the data collection effort.

[2] The column marked Support is only listed to allow completion of the accounting of expertise of all the personnel assigned to the FOPS subsection.

[3] Of note, only 15 of the 16 member FOPS subsection are shown because the submarine officer was assigned duties other than planning during the experiment.

see readily both the network and inventory levels of knowledge available to support Raid planning. Again, this can be viewed in terms of the *potential* knowledge network (i.e., available for support).

In contrast, not all of such potential knowledge network became *manifest* during the observed Raid planning process. Specifically, only those whose knowledge was *used* to support Raid planning are highlighted with underlined letters (e.g., ***B***, ***C***). Because the table is a bit busy with the various letters and different kinds of highlighting, we indicate those cells in which at least one element of available expertise was utilized by a yellow (light) background color (shade); that is, where at least one letter in a cell is underlined, we highlight such cell for vivid contrast with those where none is underlined. Notice, for instance, that nearly every cell in the five rows representing the (joint) US Services is highlighted as such. Indeed, only one candidate cell in these five rows (i.e., labeled "Support") is not highlighted. This reveals that the US Services were engaged actively and jointly in the Raid planning.

Alternatively, notice that one of the cells in the two rows representing the available and applicable Coalition partners (i.e., the Australian and New Zealand Navies) is highlighted. This reveals that the US planners practically excluded their Coalition partners from the planning process, despite the latter bringing valuable expertise. For instance, both the Australian and New Zealand Navies made relatively high-level officers (e.g., O5s and O4s) available, and such officers possessed a combination of both education and experience in the planning domain. As another instance, both of these Coalition partners possessed critical expertise in the area of surface combat, *which was not available elsewhere in the knowledge network*. These cells are highlighted in red (dark) color (shade) for emphasis. Such contrast between the potential and manifest knowledge network offers excellent diagnostic potential, and should be indicative of performance problems likely to afflict the planning process. Additionally, notice that *none* of the participating Coalition partners or US Services brought expertise in terms of amphibious operations. The corresponding blank column in the table offers diagnostic potential also, revealing how even the potential knowledge network was deficient in terms of this area of expertise. For contrast, we highlight this column in red also.

Table 3 Knowledge Network for Raid Planning

Expertise / Culture	Op'l Plans	Raid Ops	Aviation	Surface Combat	Info Ops	ISR	Spec Ops	Support
Australian Navy	***B***			***B***				
New Zealand Navy	*B* b			*B* b				
US Navy	***B B*** c c c		***B B*** c c					c
US Marine Corps	***B***							
US Air Force	***B B***		***B***		***B***	***B***		
US Army	***B B*** **B**	***B B*** **B**				***B***		
US Special Operations	***C***	***C***			***C***	***C***	***C***	

Table 4 represents the same knowledge network, and uses the same labeling and shading conventions to distinguish potential from manifest. However, this latter table pertains to the second branch planning process for a Maritime Interception Operation (MIO), which included its own separate raid operation as a contingency. Here one can observe how the knowledge network changes across different missions to be planned. Hence the topology of a knowledge network is contingent upon the associated mission task. This makes intuitive sense, because different areas of knowledge and process participants would be expected for different kinds of missions. Diagramming the knowledge network makes such topological differences explicit. Notice that the column headings here are slightly different than those in the table above. Again, different areas of expertise are required for different kinds of missions. Further, in this instance of planning, the time available for each step was significantly reduced from five days down to one. Hence the CFMCC planning process was subjected to considerably greater levels of stress in this second mission scenario. We note also that planners received direction to promote more input from Coalition partners in this second mission.

Table 4 Knowledge Network for Maritime Interdiction Operation (MIO) Planning

Expertise / Culture	Op'l Plans	MIO OPS	Aviation	Surface Combat	Info Ops	ISR	Spec Ops	Support
Australian Navy	**B**	**B**		**B**				
New Zealand Navy	*B* b	*B* b		*B* b				
US Navy	***B B*** c c c		***B B*** c c					c
US Marine Corps	***B***							
US Air Force	***B B***		***B***	***B***	***B***			
US Army	***B B*** **B**	**B**				***B***		
US Special Operations	***C***	***C***					***C***	

Comparing knowledge networks between the two missions, several noteworthy points become apparent. First the reader can see clearly from Table 4 that there was significantly greater diversity of inputs obtained in this latter mission planning process than in the former one. The planning meetings took place in the same theater-like room, but in the case of this MIO planning process, the products were developed collaboratively with inputs from a majority of the personnel in the FOPS subsection. This provides a stark contrast to the Raid planning described and delineated above. Notice also that no column in Table 4 is empty. This reveals how the CFMCC organization learned to improve its use of knowledge inventory over time. Hence comparing knowledge network topologies such as these can elucidate trends in organizational learning as well as highlighting different knowledge networks and inventory levels.

CFMCC Organizational Behavior

From the data coding work, the dominant categories that emerged reflected the static nature of the command and control process for military planning, and its required rework to deal with anomaly conditions vice in process adaptation. In other words, if something changes or appears ambiguous, then planners go back to the beginning and seek clarification from superiors in the chain of command. The process was often compared to a marching along or going down a road, and that deviations or lack of focus on the end of the road would "lead you down a primrose path" or "What happens is…kind of flailing, the road is much more painful and twisting..." when the planning team is not led through the process.

Additional categories related to planning were Knowledge Stores and Creativity Task. Specifically, primacy was placed on knowledge held by people that had actually performed the tasks at hand. Planning teams would have sought to "pull in" additional expertise, especially if the scenario, players and communications venue had been available. The next most important knowledge store was proficiency in the steps of the planning process. High proficiency in the planning steps allows a significant contribution to the dialog that goes into creating the plan. Many of the steps of plan creation involve "sitting down and talking" to "come up with" everything that needs to go into it. Planning is precisely not a “mind numbing process,” but rather one that is enhanced by sharing the best ideas from a diverse set of personnel including the minority. In this case the minority referred to the coalition planners that were assigned as members of the CFMCC staff.

Upon conducting analysis of the available data in combination with the coding information, the CFMCC organization was determined to most closely align with the Hierarchy organizational archetype. This determination is made by comparing the Coordination Mechanism’s Design Factors against the data available. Regarding Work Standards in the planning functional area, there were many standards in place with specified process sequences that led to publishing formal planning documents and orders that directed operations of the CFMCC organization and its subordinate commands and coordinated requirement. The JFMCC Tacmemo and Information Management Plan (IMP) were thorough governing documents that codified procedures and products.

Remaining true to tradition, the CFMCC organization is very closely aligned with the hierarchy. Horizontal and vertical specializations are both high. Subordinate commands are given well defined functional (e.g., Air Warfare, Maritime Interception Operations) responsibilities. Of note, within the Operation Plans (OPLANS) primary staff section of the CFMCC, the planning directorate does include staff officers from other primary staff sections (e.g., Operational Net Assessment (ONA) that is responsible for intelligence functions and mission assessment) for the purpose of making up cross-functional work teams to augment the generalist planners that are responsible for leading the develop of broad operational-level plans. Those plans are intended to sequence major action in time and space, and they should not provide restrictive details on how a tactical commander is to conduct an operation. From a planning perspective, the sequential nature of top down planning with required back-briefings up the chain of command highlights the high vertical specialization that remains in tact.

Training and Indoctrination remains high, which do not, on the surface, distinguish the Hierarchy from the Edge type organization. Observations indicate that at the subordinate units, the Hierarchy is the dominant type, but within the CFMCC staff, there are fewer barriers to entry as evident by more non-naval service officers filling key roles with very little formal Navy or CFMCC education and training programs being required. The CFMCC staff relies on those officers’ professional competence and general knowledge to contribute to planning from their first days in the organization.

Formalization remains high especially when dealing with the superior-subordinate units within the CFMCC; however, within the CFMCC staff organization there is an emergence of more frequent—and expected—informal sharing of planning details, particularly among personnel with similar professional specialties. One planning team leader said, “…collaboration is required so that you are not popping it [plan details] on the JOC and it is not a surprise to these guys….” Additionally, he said, “…give a guy a piece of the puzzle…I expect him to [take it] back to the IO [Information Operations] Cell…and get with 8, 9 or 10 IO guys [that] have real good functional knowledge of the area and…discuss it and come back with a real good effort.” The planning directorate leader (Future Operations Officer (FOPSO)) indicated that they were hoping to have more informal interaction with the CFMCC commander regarding planning issues, but because the majority of that discussion happened in a video teleconference meeting forum, that interchange was markedly formal.

Grouping remains largely based on functional areas both vertically throughout the CFMCC organization as well as internally. There is a trend within this CFMCC to rely less on functional organizations, but there remain clear similarities to the traditional Napoleonic functional areas. This CFMCC staff did not organize exactly along the lines of the JFMCC TACMEMO. In fact, all operations, except Intelligence, Surveillance and Reconnaissance (ISR) planning are conducted in the OPLANS major staff section. Within the OPLANS section, however, current operations (COPS), Fires, FOPS and Information Operations remain separate entities. The Fires directorate can be thought of as a bridge between the COPS and the Information Operations and FOPS planning sections. COPS monitors execution activities and makes minor adjustments, as required, to daily activities.

Unit Size remains large within the observed CFMCC organization. The Navy has realigned the traditional Carrier Battle Group, making it smaller and less capable, while concomitantly increasing the size and capability of the Amphibious Ready Group into an Expeditionary Strike Group (ESG). Planning and Control of those forces clearly remains a hierarchy with action planning accomplished in a sequential manner from the organizational apex down. Regarding the Decentralization design factor, there is strong evidence that it remains a Hierarchy. This CFMCC required pre-execution back briefings and was responsible for any external coordination with horizontally aligned headquarters.

The Liaison design factor is perhaps the first factor that is showing signs of moving more towards Adhocracy. At the CFMCC level, the planning leadership recognizes the benefits of temporarily creating diverse teams from multiple staff directorates, outside organizations, and subordinate organizations; however, changing to a more ad-hoc planning center for coordination between organizational units remains a slow process that is complicated by physical separation due to shipboard environments and information systems limitations (e.g., bandwidth and reliability of throughput), and limited manning, both in personnel numbers and requisite experience.

CFMCC Computational Model

Here we describe the computational model developed through our research to understand the CFMCC organization and process. We first outline briefly the specification of this computational model, after which we report simulated performance results for the baseline model. To promote continuity and insight, the discussion here in the main body of the paper is kept purposefully at a relatively high, summary level. However, more detailed discussion is included in Appendix A for the Reader interested in model details.

Model Specifications

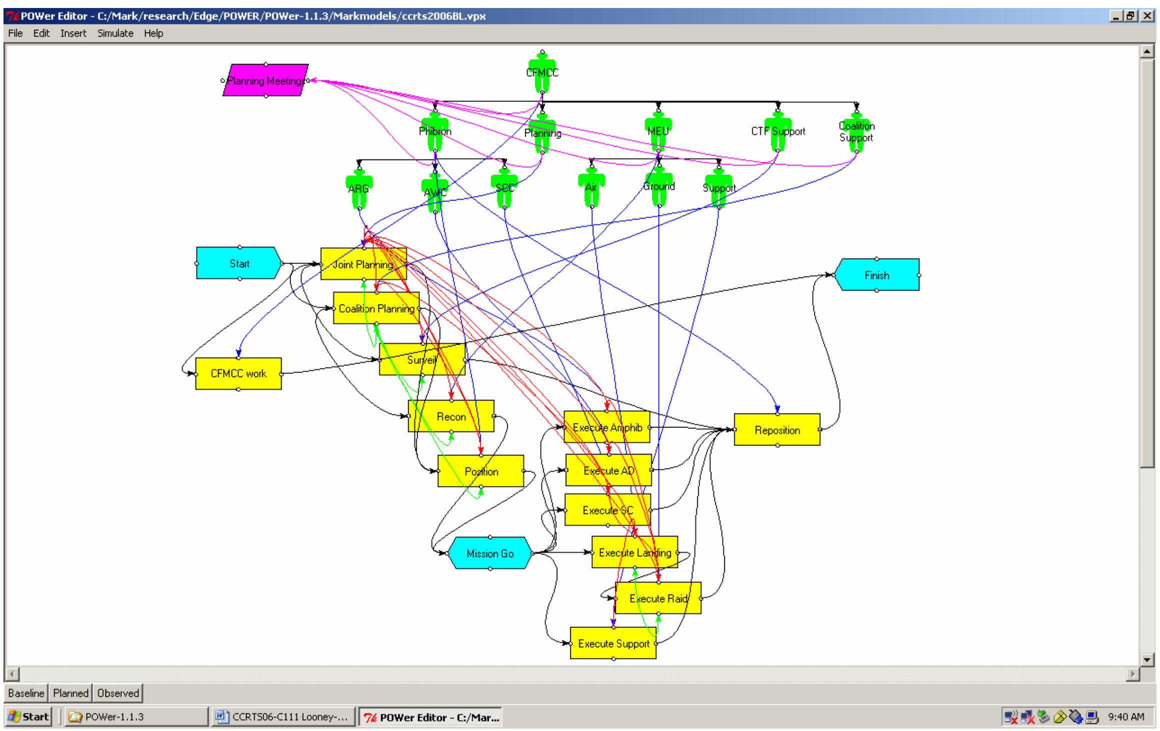

Figure 2 POW-ER CFMCC Model Baseline

Figure 2 depicts a POW-ER screenshot for the CFMCC organization that was observed and studied in the field. As noted above, the coalition mission involves a raid operation by maritime forces to capture and detain some terrorist leaders while attending a meeting on a foreign, coastal country. Details associated with this figure and the corresponding computational model used to represent the baseline CFMCC organization and process structures are included in Appendix A. Behind each object in the figure lies a number of model parameters that are set to represent and guide the behavior of the agent-based model. We set most of these parameters at empirically determined "normal" levels, which reflect organizations in general (see [Jin and Levitt 1996, Levitt et al. 1999, Nissen and Levitt 2004]). But based on our prior work (e.g., [Nissen 2005B]), military doctrine (e.g., [Joint Pub 5-0, Naval Tacmemo 3-32-03]), and the field research described above, many aspects of the military organization are quite unique, and the CFMCC organization in particular exhibits several idiosyncratic characteristics, which are represented discretely in the computational model. Table 5 summarizes the key model parameterization for the CFMCC organization and processes. To preserve continuity for the non-modeler, the discussion here skips directly to experimental manipulations and performance results. Again, we include Appendix A to elaborate such parameterization in greater detail and more comprehensively, and to describe the baseline model performance in considerable detail. This baseline model, which reflects the CFMCC organization and processes observed in the field, has been validated and calibrated through our field research, and is used as a basis for comparison with the other computational models.

Table 5 Summary CFMCC Helo Raid Model Parameterization

Parameter	Baseline
Centralization	High
Formalization	High
Matrix strength	Low
Communication pr	0.30
Noise pr	0.30
FE pr	0.05
PE pr	0.10
Rework strength	0.30
"ST" role	ST
Team experience	Low
Planning skill	Medium
Coalition skill	Low
Coalition inclusion	Low
Meetings	2 hours/day
Coalition planning lag	1 day
Application experience	Low
CJTF levels	3

Experimental Manipulations

We use the baseline model described above, to which we refer as the Observed Model, as the basis for experimental manipulation to develop four alternate models for comparison via POW-ER. Three of these four models are inspired both by theory and fieldwork, and the fourth represents a thoughtful combination of the three to form something of a "best of breed" alternative to the observed CFMCC organization and processes. As above, to promote continuity and insight, the discussion here in the main body of the paper is kept purposefully at a relatively high, summary level. As above, more detailed discussion is included in Appendix B for the reader interested in model details.

The first manipulation addresses the communication structure, systems and processes that support the CFMCC organization and processes. This Communications Model has fundamentally the same structure as shown above for the baseline in Figure 2. Within this structure, however, we identify considerable differences in terms of communication capabilities (see Appendix B for details). The second manipulation addresses the knowledge network and distribution of expertise through the CFMCC organization. This Knowledge Network Model has fundamentally the same structure as shown above for the baseline in Figure 2 also. Within this structure, however, we identify considerable differences in terms of knowledge flows (again, see Appendix B for details). The third manipulation addresses the structure and behavior of the

CFMCC, with express interest in decreasing the level of bureaucracy, and in pushing power (e.g., for decisions and actions) out toward the edges of the CFMCC organization. Unlike the two manipulations and corresponding models above, this Power Flow Model has a fundamentally different structure than shown above for the baseline in Figure 2. Figure 3 delineates this different structure. Notice immediately how the three-level hierarchy depicted above has been reduced in this model to a one-level meritocracy, and that several areas of staff responsibility (e.g., Phibron, MEU, coalition) have been consolidated into an integrated planning organization. In the model, this is expected to reduce friction between the various units, and to improve coordination (see Appendix B).

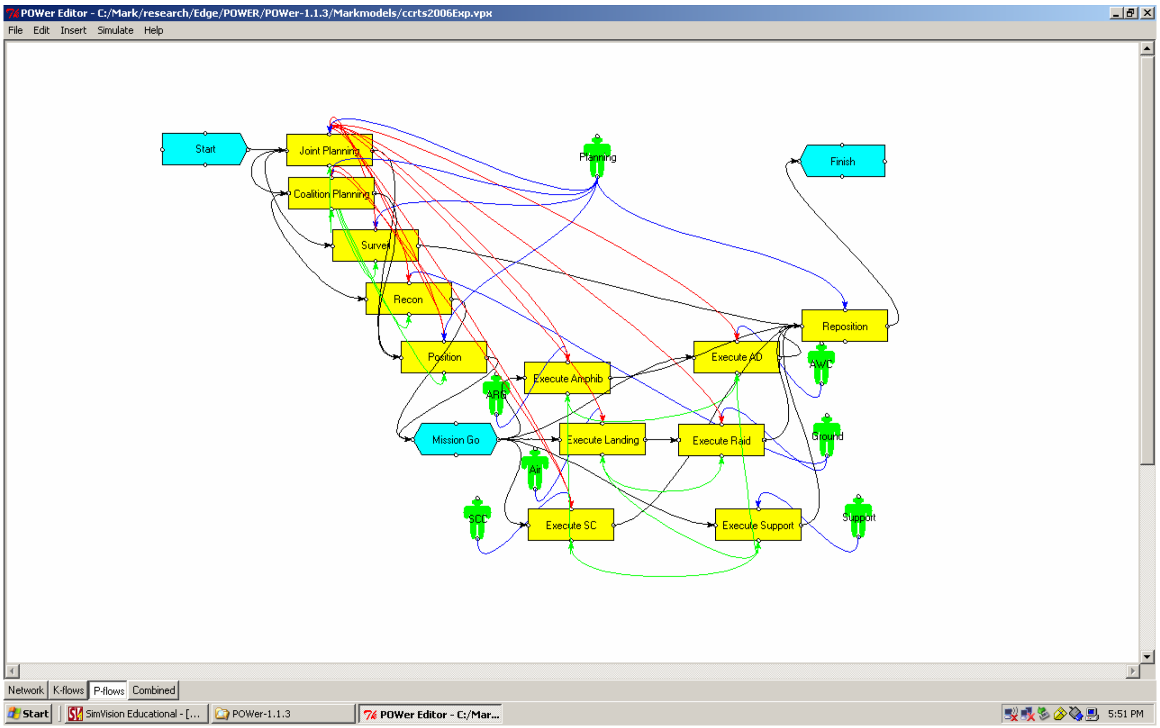

Figure 3 CFMCC Power Flow Model

The final manipulation combines the best aspects of each manipulated counterpart. For instance: it draws upon the enhanced network structure from the Communications Model (e.g., with the attendant reduction in noise, high degree of coalition inclusion, elimination of daily meetings, obviation of the coalition planning lag); it draws upon the enhanced knowledge structure of the Knowledge Network Model (e.g., with the attendant increases in both team and application experience, and in both planning and coalition knowledge); and it draws upon the Power Flow Model (e.g., with the attendant changes in organizational structure, error probabilities, rework strength, and hierarchical levels). It remains unclear whether such changes from the other three models will be complementary or conflicting in this Combined Model, but it represents an intriguing alternative for experimentation.

Experimental Results

Experimental results are reported in Table 6 below. Results for the Observed Model should be used for comparison. To facilitate such comparison, we highlight in bold font the most noteworthy results in the table. As above, we highlight only the most significant results here, using Appendix B for elaboration and detail. Look first at performance results for the Communications Model ("Comms" in the table). In general, one can notice reductions in all of the duration measures (i.e., *sim duration:* simulation duration for the mission as a whole; *joint plan dur:* joint planning time; *coal plan dur:* coalition planning time; *mission go*: time from mission planning to execution). This indicates *greater speed* in the Communications Model than in the Observed Model. But notice that all three of the other models examined through this experiment—the Knowledge Network Model ("K-Net"), the Power Flow Model, and the Combined Model—have greater speed still. Hence the kinds of network and communication advances enabled via the Communications Model help to improve the speed of the CFMCC organization and processes, but not as much as do those enabled by enhanced knowledge flows of the Knowledge Network Model or increased power flows of the Power Flow Model. Clearly the Combined Model, by blending features from each of these models, reflects the greatest speed—a very important attribute of operations in the military domain.

Table 6 CFMCC Performance Results – Experimentation

Measure	Observed	Comms	K-Net	Power Flow	Combined
Sim duration	9.5 days	**8.8 days**	**6.9 days**	**8.6 days**	**5.3 days**
Joint plan dur	3.5 days	3.3 days	**1.5 days**	3.4 days	**1.6 days**
Coal plan dur	4.5 days	**3.6 days**	**1.6 days**	**3.6 days**	**1.5 days**
Mission Go	6 days	**5 days**	**4 days**	**4 days**	**4 days**
Direct work	2694 P-days	2694 P-days	2694 P-days	2726 P-days	2726 P-days
Rework	126 P-days	96 P-days	52 P-days	**411 P-days**	**60 P-days**
Coordination	136 P-days	48 P-days	114 P-days	**668 P-days**	**407 P-days**
Wait time	16 P-days	**19 P-days**	**8 P-days**	**0 P-days**	**0 P-days**
Meetings	42	**0**	**31**	**0**	**0**
FRI	0.23	0.27	0.26	**0.38**	**0.42**
PRI	0.26	**0.35**	**0.20**	**0.32**	**0.32**
Max backlog	2.0 days	**1.4 days**	**1.6 days**	**1.8 days**	**1.3 days**

The next set of measurements reflects different magnitudes and distributions of *work volume*. The direct work is the same or comparable across all models, but notice that rework varies considerably. Interpretation of rework has two sides to it. The more errors that are made during the process (e.g., resulting from poor planning), the greater the rework required. Alternatively, particularly when organizations are inexperienced and/or working rapidly, many errors may not get corrected—or may not get corrected completely—which can result in *less* measured rework. Hence, one needs to look also at *FRI* and *PRI—the* two risk measures that quantify the additional effort that would be required to fix functional and project-level errors, respectively, that *were not corrected via rework*—for a clear picture of the situation. For instance in the Communications Model, measured rework is down, but risk (esp. reflected via PRI) is up, suggesting some equivocality in terms of performance. By contrast in the Knowledge Network Model, both rework and risk (i.e., reflected via PRI) are down, which is unequivocally superior to performance along these dimensions in the Observed Model. By further contrast in the Power Flow Model, both rework and risk are up, which reflects unequivocally inferior performance.

Coordination and wait time measurements reflect radically different kinds of organizations, with concomitantly different modes of information processing and behavior. Notice, for instance, the reduced coordination load associated with the Communications Model, and the huge increase in such load required via the Power Flow Model. Notice, as another instance, how wait time actually increases with the Communications Model, but decreased dramatically with the Knowledge Network Model, and *goes to zero* via the Power Flows Model. The number of required meetings measured across the different models tells a related but unique story: meetings have both positive (e.g., improve communication) and negative (e.g., consume time) aspects to them. From these data, it would be difficult to correlate meetings with organizational efficacy (e.g., in terms of speed or risk). But the data suggest that the nature of meetings does have an effect on performance. Notice finally, as a third instance, how every alternate model reflects lower backlog levels than the Observed Model does. This reflects actors in the organization getting less far behind on their work tasks through the course of the mission.

To summarize, one cannot say unequivocally that the performance of any one modeled organization is *dominant* over that of another. Some organizations perform better along certain performance dimensions than others do. The net assessment depends upon the relative prioritization of the different performance dimensions, particularly the apparent tension between mission speed (e.g., as measured by *duration, mission go*) and risk (e.g., as measured by *FRI, PRI*). Interestingly, such tension between speed and risk has been reported previously (e.g., see [Nissen 2005B]). The fact that we have grounded these models in behaviors of an operational CFMCC organization at sea provides considerable confidence in the fidelity of this phenomenon. Alternatively, one can say unequivocally that the behaviors of the various modeled organizations differ qualitatively. The various manners in which both direct and indirect (e.g., coordination) work are accomplished across the alternate CFMCC organizational models are noticeably distinct. Moreover, the nature of such distinctions provides insight to the military leader and policy maker; by elucidating the effects of alternate organizational forms and processual-technological configurations, the trained eye can discern readily the kinds of organizational changes that would be most appropriate for a variety of different mission-environmental contexts, network infrastructures, knowledge distributions, and power topologies. This adds considerable substance to Contingency Theory, and it enables informed evaluation and decision making regarding the CFMCC organization and process. It also showcases an exciting, new approach to understanding military organizations—those yet to be envisioned, as well as those that exist in practice today.

Conclusion

The *Edge* represents a fresh approach to organizational design, moving knowledge and power to the edges of organizations. But this raises issues in terms of comparative performance with respect to alternate organizational designs. The research described in this article extends our investigation into the design and efficacy of Edge organizations for current and future, military, mission-environmental contexts. We began with field research at sea with a coalition expeditionary strike group, observing in particular the planning process associated with maritime tasking orders, and focusing in particular on the effects of networking, knowledge and power flows. Immersive research revealed variations in the topologies of knowledge networks, as the nature of the mission changed, and as the CFMCC organization matured. This suggests that mission planning participants need to understand the knowledge network that they have available to them, and that some incentivization may be required to encourage such participants to utilize such network to its full potential. This suggests also a line of future research associated with understanding the varying knowledge network topologies that emerge in practice, identifying which topologies fit best the diverse personnel characteristics and mission contexts encountered by CFMCC organizations and processes, and assessing alternate organizational, processual and technological interventions that offer promise to improve knowledge and power flows in this maritime domain.

Our field research was also used to develop and validate a computational model of the current CFMCC organization and planning process. This serves to extend prior research that linked archetypal organizational forms from theory quite generally to contrasting, “ideal type” military C2 organizations such as Hierarchy and Edge. In such prior research, our computational models remained necessarily quite general, and could be validated (i.e., to ensure that organizational structures and behaviors in the models were representative qualitatively of those in the operational organizations being represented) at only a relatively high level. Here we were able to elaborate and validate our model in considerably greater detail. Additionally, our prior models could be validated, but could not be calibrated (i.e., to demonstrate that models reflected quantitative performance of operational organizations). Here we were able to calibrate the performance of computational models with respect to their operational counterparts at sea. This provides an unprecedented level of model fidelity in the CFMCC domain, and it establishes a solid basis for computational experimentation. Because we have good confidence in the validated and calibrated baseline model results, we can maintain good confidence in the model manipulations (e.g., Communications Model, Knowledge Network Model, and Power Flows Model) also. This serves to inform the leader and manager about relative advantages and disadvantages associated with the kinds of alternate organizational forms examined in this study, and can equip such leader and manager with understanding of how varying organizational form can have a direct impact on CFMCC organizational performance. This serves also to illuminate a promising research trajectory that involves elaborating the planning process in increasing detail, and examining systematically a broader range of alternate communication, knowledge and power manipulations.

Thus, the effects realized by networked environments on military planning, and consequently operations, are governed by multiple items, but especially organizational design, knowledge flows, and work processes. This research illuminates a promising way to investigate the potential benefits of organizational design changes, technological improvements, process changes and combinations of other adaptations for military operations. The main contribution of this study involves the comparison, based on computational experimentation, of a traditional military hierarchical organizational structure against alternate instantiated organizations with some Edge-like properties. This takes us another step closer to establishing operationalized contingency theory for military organizations, and to articulating systematically the relative advantages and disadvantages of Edge organizations *in specific mission-environmental contexts*. This represents an essential aspect of science as applied to Edge organizations.

An additional contribution comes from highlighting the mission planning processes as a knowledge creation task and not just a work task. Discussion and contemplation are key components that are required to be balanced with work tasks such as developing planning products. Although hampered often by the challenges of operating from sea-based headquarters, the networked environment and information technology tools that enhance the timeliness and level of richness in communicating explicit and tacit knowledge pose considerable potential to increase the requisite variety available to operational planning sections. Before that can happen, however, the available knowledge networks and inventories must be made explicit, and process participants must be incentivized to utilize them productively. Moreover, leaders and managers must learn to balance the exploration associated with knowledge creation against the exploitation involved with knowledge work (see [Nissen 2006]). Knowledge management research along these lines can provide ways to assess the tradeoffs between learning and working, and assist leaders and managers in striking such balance.

The battlespace coordination improvements that accompanied the installation of radios in tanks and airplanes some 65 years ago have been touted by some as a revolutionary change in military operations. Although today's digital exchange of targeting information, coupled with the increased speed, range, accuracy and lethality of ordnance can be viewed as a similar level of improvement, comparable gains in operational level planning are required to deal with the complex hostilities and postwar situations. While speed of operations is a critical factor for both operational tempo and flexibility, improvements in knowledge creation tasks may prove beneficial in mitigating some of the risks associated with rapid operations. This appears to be the case in particular as we contemplate transformation of coalition maritime forces to become ever more Edge-like. However, the cognitive capabilities of process participants (i.e., people) are not advancing as rapidly as the technology and understanding of organizational forms is. Bounded rationality is as present and restrictive today as it has ever been, and insights from this study suggest that such bounded rationality may represent a troublesome constraint on our ability to organize and operate in Edge configurations. Further research needs to be undertaken to determine how the negative effects of such bounded rationality can be ameliorated, especially where radical organizational forms such as elaborated via the Power Flow and Combined models is concerned.

Finally, the relative effects of different kinds of knowledge flows need to be understood better. When military planners and others utilize their knowledge networks, it will likely become important to understand the circumstances in which the associated knowledge takes tacit versus explicit form, and the extent to which knowledge form affects organizational performance. The organization faces the option of trying to make knowledge explicit (e.g., in sea-based websites such as K-Web, networked systems such as CAS) or whether to leave it in tacit form (e.g., in the experience of individuals, routines of organizations). Now that we have validated and calibrated a relatively good fidelity model of the CFMCC organization, we can begin a campaign of systematic study to address the high-impact set of research questions along these lines.

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Appendix A – Model Parameterization

Here we elaborate our model parameterization in greater detail. We first outline the specification of this computational model, after which we report simulated performance results for the baseline model.

Model Specifications

Figure 4 depicts a POW-ER screenshot for the CFMCC organization that was observed and studied in the field. The coalition mission involves a raid operation by maritime forces to capture and detain some terrorist leaders while attending a meeting on a foreign, coastal country. The mission tasks are represented in this figure by (yellow) rectangular boxes, and divided into two phases: a) future operations and b) current operations. Future operations center on mission planning, whereas current operations focus on mission execution. The five tasks comprising the future operations phase include: 1) joint planning, 2) coalition planning, 3) surveillance, 4) reconnaissance, and 5) positioning. The seven tasks comprising the current operations phase include execution of: 1) amphibious operations, 2) air defense operations, 3) surface and subsurface combat operations, 4) helicopter infiltration and landing operations, 5) expeditionary raid operations, 6) air-ground support operations, and 7) repositioning. A related task for CFMCC work is included also to depict demands upon the staff (e.g., daily briefs, intelligence gathering, and CJTF interface) beyond this particular mission. Dark (purple) trapezoid shapes depict standing meetings in the figure.

Joint planning extends from mission analysis to writing maritime tasking orders of the CFMCC, and involves participants from all US Military services (i.e., Army, Navy, Marines, Air Force). A separate process for coalition planning operates in near parallel, but lags the joint planning due to its conduct on a separate computer network infrastructure. The CFMCC Future Operations joint and coalition planning staffs have primary responsibilities for these tasks, but lower-level (e.g., Amphibious Squadron ("Phibron"), Marine Expeditionary Unit ("MEU")) and higher-level staffs (esp. CJTF) have involvement as well. Light (blue) links in the figure depict task assignments for the various organizational participants. Surveillance pertains principally to aerial assets (e.g., Predator, JSTARS, AWACS) that monitor the area continually, throughout mission planning and execution. Such assets are provided via CJTF or CFACC support for use by the CFMCC organization. Reconnaissance refers here to Marines ashore, infiltrating the area to ensure that the mission target is in sight before executing the remaining mission steps. The MEU is responsible for this mission task. Positioning refers to the movement of ships (e.g., from the Amphibious Ready Group ("ARG"), Air Warfare ("AW") and Sea Combat ("SCC") Commands) into designated positions around the target in advance of mission execution. The Phibron staff has primary responsibility for positioning. When all of these future operations tasks have been completed, and the mission is ready to go, the CFMCC Commander makes the decision, and issues the corresponding order to conduct the raid.

The time horizon for future operations is on the order of days. The nature of these tasks makes their conduct largely sequential. Dark (black) links in the figure depict task sequencing. But their tight interdependencies (esp. between joint and coalition planning, surveillance and reconnaissance) allow for considerable overlap and concurrency. Light (green) links in the figure depict reciprocal interdependencies. In contrast, execution tasks issued and monitored by current operations center personnel take place concurrently, in a matter of hours. Although the future and current operations phases are depicted separately, and performed largely by different organizational units, they are not independent, and the levels of performance on some tasks affect the levels of performance on others. For instance, the quality of planning affects directly the performance of all mission execution tasks, and problems encountered with nearly any mission tasks will cause replanning to occur. Medium (red) links in the figure depict rework dependencies of this nature.

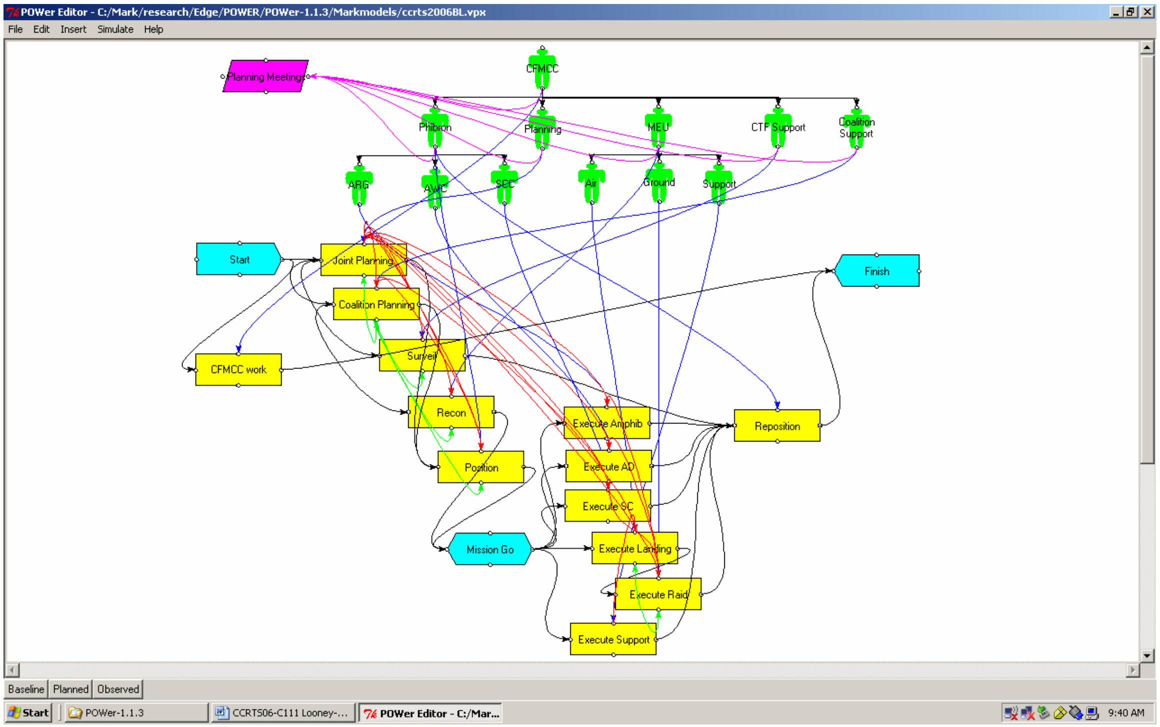


Figure 4 POW-ER CFMCC Model Baseline

Notice further that the organization is represented here in three hierarchical levels, all of which operate subordinate to the CJTF Commander. Organizations are depicted in the figure as medium (green) person icons, and the dark (black) supervision links reflect lines of both authority and formal communication in the organization. Hence, whereas the precedence links reveal the task structure of the CFMCC processes for this mission, the supervision links reflect both lines of authority and formal communication. The light (blue) task assignment links tie together the task structure of the model with the organization and formal communication structure. This provides a rich and robust, integrated view of the CFMCC organization and mission processes, and this view has been validated through our fieldwork at sea.

Behind each object in the figure lies a number of model parameters that are set to represent and guide the behavior of the agent-based model. We set most of these parameters at empirically determined "normal" levels, which reflect organizations in general (see [Jin and Levitt 1996, Levitt et al. 1999, Nissen and Levitt 2004]). But based on our prior work (e.g., [Nissen 2005B]), military doctrine (e.g., [Joint Pub 5-0, Navy Tacmemo 3-32-03]), and the field research described above, many aspects of the military organization are quite unique, and the CFMCC organization in particular exhibits several idiosyncratic characteristics, which are represented discretely in the computational model. Table 7 summarizes the key model parameterization for the CFMCC organization and processes. To preserve continuity for the non-modeler, the discussion in the body of the article above remains at a relatively high level. We include discussion here in Appendix A to elaborate such parameterization in greater detail and more comprehensively. These parameter settings reflect our CFMCC field observations, and are used to specify the Observed Model, which we use for comparison with others in the experimentation section below.

Briefly, the first three parameters reflect organization design specifications. *Centralization* describes the degree to which information flows and decision making are hierarchical in nature; *formalization* describes the degree to which work processes and routines reflect documented, standardized procedures; and *matrix strength* depicts the degree to which personnel look to one another to coordinate actions, as opposed to being supervised closely by managers. The parameter settings included in the table reflect both theory [Nissen 2005B] and observation of the

CFMCC. *ST role* pertains to the behavior of “subteams”—those actors at the edges of the organization, which accomplish direct work, and interact directly with the environment. Generally subteams are less concerned about reworking exceptions to the same degree that subteam leaders (SL) or project managers (PM) are. Probabilities for *communication, noise, functional exceptions (FE)* and *project exceptions (PE)* represent, respectively, the intensity of communications, frequency of interruptions, and likelihood of errors at both the functional-unit and cross-project levels. *Rework strength* represents the extent to which errors made at one stage of the mission affect the performance at other, sequentially dependent stages. For instance, and in particular, errors made upstream in the planning stages can induce considerable problems in mission execution downstream.

Table 7 Summary CFMCC Helo Raid Model Parameterization

Parameter	Baseline
Centralization	High
Formalization	High
Matrix strength	Low
Communication pr	0.30
Noise pr	0.30
FE pr	0.05
PE pr	0.10
Rework strength	0.30
“ST” role	ST
Team experience	Low
Planning skill	Medium
Coalition skill	Low
Coalition inclusion	Low
Meetings	2 hours/day
Coalition planning lag	1 day
Application experience	Low
CTF levels	3

The next three parameters reflect specifications of separate knowledge levels within the CFMCC organization. *Team experience* describes the degree to which the same people have learned to work together over time. The CFMCC is noted as balanced between treating people as fungible units (i.e., transferring them frequently between different units and jobs) and emphasizing teamwork through training (e.g., unit training, group training, task force exercises). The people we observed had not worked together *substantially*—although they had clearly worked together before the mission began—before this raid mission commenced, hence the “low” specification. *Planning skill* refers to the competency of joint planning in the organization, which we specify as “medium” to reflect adequate planning knowledge of joint operations. Alternatively, *coalition skill* refers to the competency for such planning to include coalition partners. Notice we specify this latter competency as “low” in the Observed Model. Although considerable coalition expertise *was present* in the CFMCC organization (e.g., multiple coalition ships with well-staffed and experienced personnel), most such expertise *was not used* when planning the raid mission; therefore, the level of skill *applied* was relatively low. Similarly, coalition personnel were excluded largely from several of the key planning sessions, as indicated by the “low” parameter setting for *coalition inclusion*.

Meetings pertain to the daily briefing and decision-making meetings conducted throughout the future operations phase of the mission. *Coalition planning lag* specifies the length of time required to analyze and port key planning and like mission information from the network that was employed by US units over to the network that was used by coalition partners. *Application experience* settings stem from [Nissen 2005B] also, and reflects the push, broadcast style information dissemination (e.g., via CAS and Knowledge Web) that is characteristic of the Hierarchy in general and CFMCC organization in particular. Such communication complicates the information-processing tasks associated with searching for and learning important knowledge (e.g., learning what is necessary, when it is needed). Finally, the three levels shown in the last row of the table correspond to the three levels of hierarchy that are subordinate to the CJTF commander.

Clearly judgment is involved with modeling such as this. The beauty of semi-formal model representation through our computational approach is that one can be very precise about how a model is specified, and another can understand exactly what modeling assumptions it entails. This provides a substantial contrast to models described solely through natural language, which is ambiguous, and through which the same terms (e.g., *centralized, end user*) can be used to mean very different things. Further, our in-depth fieldwork serves to validate these parameter settings well.

Baseline CFMCC Performance Results

We use the POW-ER system to emulate the behavior and performance of the CFMCC organization and mission processes. At this point in our research, we have validated the CFMCC Observed Model described above against the structure, behavior and performance of its operational counterpart at sea, which provide us with a solid basis for computational experimentation; that is, because our baseline computational model corresponds well to its operational counterpart at sea, we have good confidence that the behavior and performance of our other computational models, which we use for experimentation, are representative of operational CFMCC organizations and processes as well. Such confidence enables considerable power in terms of description, explanation and prediction of organizational behavior and performance, and represents a hallmark of our research along these lines.

Table 8 summarizes simulated performance for the Observed Model and four experimental manipulations. Beginning with the Observed Model results reported in the second column, the first measure *sim duration* (9.5 days) denotes the simulated calendar time for the emulated mission tasks to be accomplished. This duration measure corresponds to the entire mission task structure, from Start to Finish, delineated in the figures above (i.e., beginning with Joint Planning, and ending with Reposition). Unlike measurement along the critical path, this measurement takes into account indirect work (e.g., rework, coordination, decision wait time), and does not assume that all actors are available full time to accomplish their assigned tasks. Simulated duration (i.e., *sim duration*) reflects our Maximum Likelihood Estimator, and is indicative of the performance to be expected from organizations in practice.

Table 8 CFMCC Performance Results – Baseline

Measure	Observed
Sim duration	9.5 days
Joint plan dur	3.5 days
Coal plan dur	4.5 days
Mission Go	6 days
Direct work	2694 P-days
Rework	126 P-days
Coordination	136 P-days
Wait time	16 P-days
Meetings	42
FRI	0.23
PRI	0.26
Max backlog	2.0 days
Actor (day)	CFMCC (3)

The subsequent three measures detail organizational performance on selected subparts of this mission task graph. For instance, *Joint plan dur* measures the elapsed (i.e., calendar) time required for joint planning. At 3.5 days, this corresponds well with our observations onboard ship.

Likewise, *Coal plan dur* (4.5 days) measures the elapsed time required for coalition planning to conclude. Coalition planning lags behind joint planning by one day—due largely to the use of different networks for planning and communication—and is reflective of our observations also. These results are comparable to the nominal three days' elapsed time outlined for the planning process. Hence the planning process that we observed required roughly one day longer to perform than planned. This is due in part to the mission taking place as the CFMCC organization was in its formative stage, and in part due to the very deliberate pace at which the planning activities took place. As the organization matures, and as necessity mandates more rapid planning, the process would likely accelerate somewhat. Indeed, our follow-up study confirmed this acceleration effect. Finally, and perhaps the most important duration measure, *mission go* measures the elapsed time from the beginning of mission planning until the Commander's decision to execute the raid. At roughly 6 days, this reflects a CFMCC organization that took just less than one week to: plan the raid; conduct adequate surveillance; get a reconnaissance team ashore and in place to observe the meeting; get all of the ships into position around the target; and ready the landing and expeditionary raid teams.

The next four measures reflect *work volume* for four kinds of work effort. *Direct work* accounts directly for the work effort that is planned to be accomplished. Most simulation models include only direct work, but this misses some important aspects of reality in the workplace. In addition to such direct work, for instance, most projects in practice encounter errors and exceptions, which require *rework* effort. Additionally, projects must be managed, and actors can expend considerable time and energy on information processing through *coordination*. Finally, *wait time* accounts for the time spent by organizational actors while waiting for decisions to be made and for necessary information to be provided. Our model accounts for these latter effects. The units for each of these work volume measures is *person-days* (P-days), which differ fundamentally from the elapsed time measures above. For instance, if ten people work for one day on a task, the elapsed or calendar time will be 1 day, whereas the work volume in person-days will be 10 P-days (i.e., 10 people x 1 day = 10 P-days). Results in P-days for the Observed Model reveal 2694 direct work, 128 rework, 136 coordination, and 16 wait time.

Because the units (*work volume* in P-days) are the same, these measurements can be compared directly, and it is insightful to do so in percentage terms. For instance, relative to 2694 P-days' direct work, roughly 5% (i.e., 126 P-days) rework is required. Thought of differently, roughly 5% *additional* work effort was required to correct errors made during the accomplishment of direct work. As a related instance, relative to this same 2694 P-days direct work, roughly 5% (i.e., 136 P-days) coordination is required. Thought of differently, roughly 5% *additional* work effort was required to coordinate the accomplishment of direct work. As a third instance, less than 1% (i.e., 16 P-days) wait time is required. Thought of differently, the equivalent of less than 1% *additional* work effort was wasted with people waiting for necessary decisions to be made and information to be provided. Although the effects of these rework, coordination and wait-time activities are relatively small in the present case, their inclusion increases the fidelity of the model, and such measures can provide vivid contrasts between different organizational designs (e.g., see [Nissen 2005B]).

Meetings measures the number of people expected to participate in the daily meetings across the time span between the start of mission planning and the mission-go decision. The measured value indicates 42 people-meetings were required; that is the number of participants times the number of meetings. With meetings scheduled for two hours in the Observed Model, that equates to over 80 person-hours or nearly 2 person-weeks spent in meetings. Meetings have a two-sided effect. One the one hand, people who attend meetings communicate well, and keep one another apprised well of status, problems and accomplishments. Such factors contribute toward effective work progress, coordination and quality, particularly on cross-functional work performed by functional specialists in different organizations. On the other hand, meetings consume time of the people who attend them, which reduces their productivity on direct work. Also, not all actors are able generally to participate in every meeting to which they are invited. When participants miss meetings, the productive effects of the corresponding meetings are reduced in the model via POW-ER behavioral emulation.

The final four performance measures reflect *functional risk (FRI), project risk (PRI), maximum backlog*, and *actor*, respectively. *FRI* and *PRI* both quantify the amount of work volume (i.e., with respect to direct work) that would have to be expended—in addition to those reported above for direct work, rework, coordination and wait time—to correct all errors that were not reworked completely, or not reworked at all, during task performance. Clearly not every error made while accomplishing every task must necessarily be reworked completely, but the more such errors that are not corrected, or are not correctly completely, the greater the risk of encountering problems during mission performance. FRI pertains specifically to risk stemming from errors encountered in the performance of functional work (i.e., within the work units of functional actors such as joint planning, coalition planning and surveillance), whereas PRI pertains instead to risk stemming from errors encountered in the coordination of such functional tasks. *Backlog* quantifies the number of days' workload that a particular organizational actor is behind in its progress of task work, and the maximum value of such backlogged work is reported—for the actor with the highest backlog—in the table. *Actor* reports which actor had the highest backlog during model emulation, and the day on which the backlog reached such maximum is reported (in parentheses). This measure can be insightful in terms of identifying critically constrained resources and the associated bottlenecks. The value of 2 days reported for the Observed Model reflects backlog of the CFMCC staff (on Day 3), and results directly from the hierarchical information flows and centralized decision-making processes endemic in the CFMCC organization and processes.

Appendix B – Experimental Manipulations and Results

Here we elaborate our experimental manipulations and results in greater detail. We begin with a summary of the baseline CFMCC performance results, which reflect the Observed Model. We then detail the basis and parameterization of our experimental manipulations, and summarize in turn the experimental results.

Experimental Manipulations

We use the Observed Model described above as the basis for experimental manipulation to develop four alternate models for comparison via POW-ER. Three of these four models are inspired both by theory and fieldwork, and the fourth represents a thoughtful combination of the three to form something of a "best of breed" alternative to the observed CFMCC organization and processes. To help focus attention, we show in Table 9 only those parameters that are manipulated experimentally. The Observed Model parameter values shown in Column 2 are repeated from the table above for reference and comparison.

The first manipulation is summarized in Column 3 ("Comms"). It addresses the communication structure, systems and processes that support the CFMCC organization and processes. This Communications Model has fundamentally the same structure as shown above for the baseline in Figure 4. Within this structure, however, we identify considerable differences in terms of communication capabilities. Some of these are explained in [Nissen 2005B] for the Edge Organization. For instance, post-and-smart-pull communication is characteristic of the Edge, and well-connected, high-bandwidth networking that represents the promise of the Global Information Grid. These facilitate the information-processing tasks associated with searching for and learning important knowledge (e.g., learning what is necessary, when it is needed). We represent this with a reduction in the parameter *noise* (0.10). Additionally, we integrate the coalition partners directly into the planning process—both processually by incorporating the associated people into the work processes, and technologically by using a single, common network for all planning and operations work—which makes their corresponding coalition expertise more readily available. We represent this effect with an increase in the parameter for *coalition skill level* (medium), and show the corresponding *coalition inclusion* parameter (high) in the table. Further, we capitalize upon the advantages inherent within this communications structure to eliminate the daily planning and decision meetings, and by integrating the coalition partners directly into the planning process, we obviate the coalition planning lag. All other Communications Model parameters remain constant at the same levels reported above for the Observed Model.

Table 9 CFMCC Parameter Manipulations

Parameter	Observed	Comms	K-Net	Power Flow	Combined
Centralization	High	High	High	**Low**	**Low**
Formalization	High	High	High	**Medium**	**Medium**
Matrix strength	Low	Low	Low	**High**	**High**
Communication pr	0.30	0.30	0.30	**0.90**	**0.90**
Noise pr	0.30	**0.10**	0.30	0.30	**0.10**
FE pr	0.05	0.05	0.05	**0.20**	**0.20**
PE pr	0.10	0.10	0.10	**0.20**	**0.20**
Rework strength	0.30	0.30	0.30	**0.10**	**0.10**
“ST” role	ST	ST	ST	**SL**	**SL**
Team experience	Low	Low	**Medium**	Low	**Medium**
Planning skill	Medium	Medium	**High**	Medium	**High**
Coalition skill	Low	**Medium**	**High**	**Medium**	**High**
Coalition inclusion	Low	**High**	Low	**High**	**High**
Meetings	2 hours/day	**none**	2 hours/day	**none**	**none**
Coalition planning lag	1 day	**none**	1 day	**none**	**none**
Application experience	Low	Low	**Medium**	Low	**Medium**
CFMCC levels	3	3	3	**1**	**1**

The second manipulation is summarized in Column 4 (“K-Net”). It addresses the knowledge network and distribution of expertise through the CFMCC organization. This Knowledge Network Model has fundamentally the same structure as shown above for the baseline in Figure 4 also. Within this structure, however, we identify considerable differences in terms of knowledge flows. Some of these are explained in [Nissen 2005B] for the Edge Organization. For instance, we identify frequent personnel rotation as problematic in terms of knowledge flows and the associated professional competence. Instead of maintaining the relatively high turnover endemic in the observed CFMCC organization, this manipulation keeps people in jobs for longer periods of time—or sending people to specialized training courses, or possibly even creating a planning subspecialty in the Navy to emphasize and develop the associated expertise—and maintains corresponding work teams and groups for longer periods as well. One result is an increase in *team experience* (medium). This manipulation also identifies the most knowledgeable people in the organization (e.g., via knowledge maps, more attention to transactive memory), and includes them—even through reachback to shore organizations, in the US and in coalition nations—in the planning process as *mentors* as well as direct participants. This provides the CFMCC planning process with access to much greater expertise than is available organically. We represent this knowledge-network effect by increasing the parameters for *planning skill* (high) and *coalition skill* (high), and by increasing *application experience* by one level (medium) as well. As above, all other Knowledge Network Model parameters remain constant at the same levels reported above for the Observed Model.

The third manipulation is summarized in Column 5 (“Power Flow”). It addresses the structure and behavior of the CFMCC, with express interest in decreasing the level of bureaucracy, and in pushing power (e.g., for decisions and actions) out toward the edges of the CFMCC organization. Unlike the two manipulations and corresponding models above, this Power Flow Model has fundamentally different structure than shown above for the baseline in Figure 4. Figure 5 delineates this different structure. Notice immediately how the three-level hierarchy depicted above has been reduced in this model to a one-level meritocracy, and that several areas of staff responsibility (e.g., Phibron, MEU, coalition) have been consolidated into an integrated planning organization. In the model, this is expected to reduce friction between the various units, and to improve coordination. Notice also the addition of many light (green) links to represent reciprocal interdependencies between the various units participating in the current operations phase of the mission. Following [Nissen 2005B] in part to represent aspects of Edge Organizations here, real-time, peer-to-peer coordination replaces the hierarchical flows of information and decision-making represented in the Observed Model. Notice further that the daily meetings are gone, as is the CFMCC staffwork from the other models. Although much of such work remains within the larger CTF organization, it does not burden this "CFMCC" organization accordingly. We use quotations around the term *CFMCC* here, because this one-level meritocracy has no express role for a CFMCC Commander and staff; that is, the position *CFMCC Commander* does not exist in this Power Flow Model.

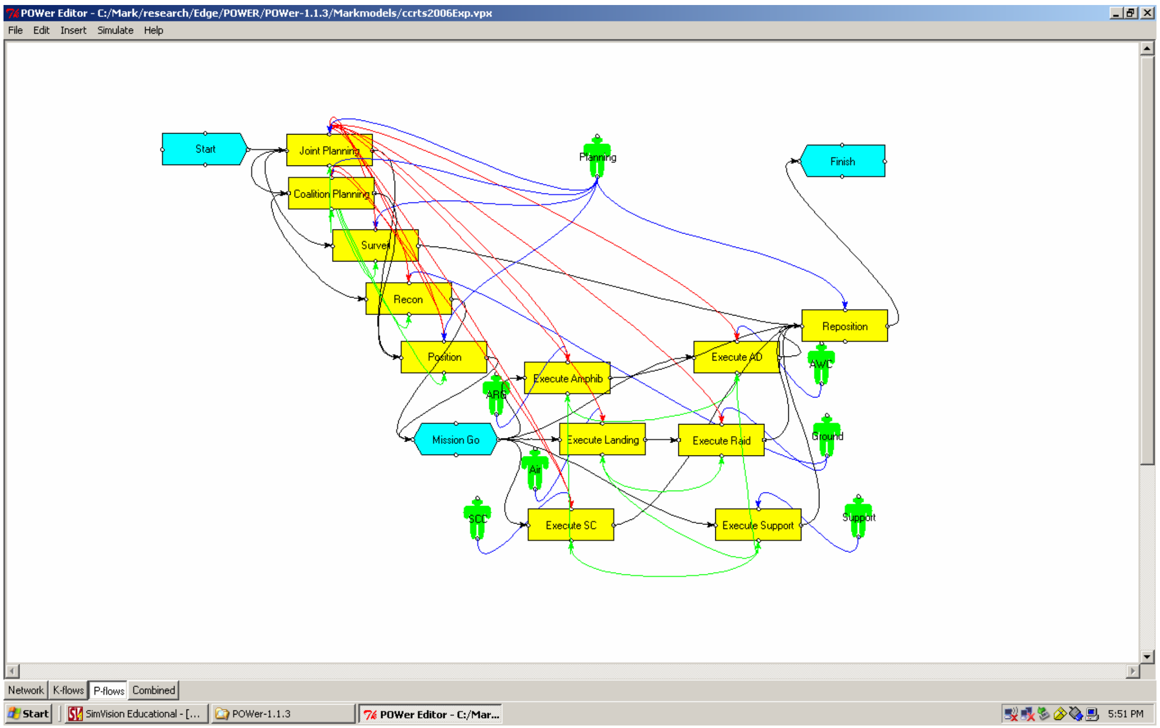


Figure 5 CFMCC Power Flow Model

Within this different structure, we also identify considerable differences in terms of power flows. Some of these are explained in [Nissen 2005B] for the Edge Organization. For instance, notice the parameter settings for *centralization* (low), *formalization* (medium) and *matrix strength* (high) differ dramatically from those in the observed CFMCC organization. These represent a less bureaucratic organizational structure. As another instance, *communication probability* (0.90) is much higher than the parameter settings for all of the other models. This reflects the huge increase in communication intensity required to coordinate an organization that lacks hierarchical levels, and that reflects tightly coupled, reciprocally interdependent tasks. Accordingly, however, the probabilities of making errors at both the functional (0.20) and project (0.20) levels are at least double those set for the other models. Without the same degrees of centralization, formalization, supervision and hierarchical information flows, opportunities for errors can be expected to grow accordingly. Alternatively, *rework* (0.10) is reduced in this parameter setting, because the increased task interdependence should substitute the cycle *work then rework* (i.e., characteristic of sequential interdependence) with *work until right* (i.e., characteristic of reciprocal interdependence). Clearly the increase in coordination load will covary with this effect. Notice the parameter *"ST" role* is set to "SL" in this model. This reflects a great degree of delegation to the working level (i.e., edges) of the organization, as each actor in the meritocracy behaves with considerable authority and autonomy, yet the actors collectively remain linked closely via reciprocal task interdependence and intensive communication. Although we do not assume the same kind of network structure available in the Communications Model, we do integrate the coalition partners directly into the process, and hence have access to the associated *coalition skill* (medium), which similarly obviates the coalition planning lag, as shown in the table. And as with its communications model counterpart, our Power Flow Model eliminates the daily meetings as shown in the table. Finally, the last table entry for this model indicates that our three-level hierarchy is replaced by a one-level meritocracy. As above, all other Power Flow Model parameters remain constant at the same levels reported above for the Observed Model.

The final manipulation is summarized in the last column. Consistent with its label, this Combined Model combines the best aspects of each manipulated counterpart. For instance, it draws upon the enhanced network structure from the Communications Model, with the attendant reduction in noise (0.10), high degree of coalition inclusion, elimination of daily meetings, and obviation of the coalition planning lag. As a related instance, it draws upon the enhanced knowledge structure of the Knowledge Network Model, with the attendant increases in both team and application experience, and in both planning and coalition knowledge. Further, it draws upon the Power Flow Model as well, with the attendant changes in organizational structure (e.g., lower centralization, formalization and supervision; greater delegation and autonomy), error probabilities, rework strength, and hierarchical levels. It remains unclear whether such changes from the other three models will be complementary or conflicting in this Combined Model, but it represents an intriguing alternative for experimentation.

Experimental Results

Experimental results are reported in Table 10 below. We repeat the results for the Observed Model from above for reference. Look first at performance results for the Communications Model ("Comms" in the table). Notice there is a small reduction in total simulation duration (8.8 days) for the mission as a whole and for the joint planning process (3.3 days), but coalition planning time is reduced to 3.6 days. This is a direct result of weaving the coalition partners directly into the planning and coordination processes, and of using a common network infrastructure for all. This result also translates directly to one day less to be ready for mission execution (i.e., "Mission Go"), which represents one of the most important measures for the CFMCC. In this model, rework (96 P-days) is down by about one fourth, and coordination (48 P-days) is less than half the effort required for the Observed Model, but wait time (19 P-days) reveals a modest increase. Some of these results can be explained by the absence of daily meetings, which has both positive and negative effects, but the two risk measures—FRI (0.27) and PRI (0.35)—reflect some increase in risk of the Communications Model over the Observed Model, particularly in terms of project work. The maximum backlog (1.4 days) reveals some improvement, as the CFMCC and others get less further behind in this communications structure (i.e., Communications Model) than in the one employed at sea (i.e., Observed Model). As with all performance comparisons such as this, one cannot say that one organization's performance is *dominant* over the others: some performance measures (e.g., durations, backlog) reflect clear improvement, whereas others (e.g., risk, wait time) reveal performance degradation. The net assessment depends upon the relative prioritization of the different performance dimensions. The same holds true across all of these models.

Results for the Knowledge-Network Model are summarized in the fourth column. Notice all four of the duration measurements are dramatically lower than those reported for the Observed Model. Mission duration (6.9 days) is nearly three days' less, and both joint and coalition planning spans (1.5 and 1.6 days, respectively) are half or less of those required for the observed CFMCC organization. Time to Mission Go (4 days) is down too, accelerating the future operations part of the process by one third. Further, rework (52 P-days) and coordination (114 P-days) volumes are lower too, and wait time (8 P-days) is half that observed at sea. The number of meetings (31) is down too, but FRI (0.26) reflects a slight increase in functional risk than the observed CFMCC process was exposed to. Alternatively, PRI (0.20) reflects a reduction in risk at the project level, and as above, reduced project backlog (1.6 days) reveals some improvement, as the CFMCC and others get less far behind. Notice that the maximum backlog for the CFMCC takes place on Day 2 in this Knowledge Network Model. This reflects the accelerated pace of the knowledge-enhanced process. As above, one cannot say that one organization's performance is *dominant* over the others. But the reduced mission planning and execution times hint at superior performance along the dimension *speed* in particular.

Table 10 CFMCC Performance Results – Experimentation

Measure	Observed	Comms	K-Net	Power Flow	Combined
Sim duration	9.5 days	**8.8 days**	**6.9 days**	**8.6 days**	**5.3 days**
Joint plan dur	3.5 days	3.3 days	**1.5 days**	3.4 days	**1.6 days**
Coal plan dur	4.5 days	**3.6 days**	**1.6 days**	**3.6 days**	**1.5 days**
Mission Go	6 days	**5 days**	**4 days**	**4 days**	**4 days**
Direct work	2694 P-days	2694 P-days	2694 P-days	2726 P-days	2726 P-days
Rework	126 P-days	96 P-days	52 P-days	**411 P-days**	**60 P-days**
Coordination	136 P-days	48 P-days	114 P-days	**668 P-days**	**407 P-days**
Wait time	16 P-days	**19 P-days**	**8 P-days**	**0 P-days**	**0 P-days**
Meetings	42	**0**	**31**	**0**	**0**
FRI	0.23	0.27	0.26	**0.38**	**0.42**
PRI	0.26	**0.35**	**0.20**	**0.32**	**0.32**
Max backlog	2.0 days	**1.4 days**	**1.6 days**	**1.8 days**	**1.3 days**
Actor (day)	CFMCC (3)	CFMCC (3)	CFMCC (**2**)	**Support (7)**	**Support (5)**

Results for the Power Flow Model are summarized in the fifth column. Notice all of the duration measurements are lower than those reported for the Observed Model. Mission duration (8.6 days) and coalition planning (3.6 days) both show substantial improvement, with joint planning (3.4 days) only slightly less than the baseline, and time to Mission Go (4 days) is down by one third. However, notice both the rework (411 P-days) and coordination (668 P-days) reflect dramatically different work performance than reported above for the other models. With respect to the Observed Model, more than three times the number of errors are being committed and fixed, and coordination time reflects nearly a quintupling. Further, notice that *wait time is zero*: here organizational actors are not waiting around for information to be provided or for decisions to be made; instead, they are acting on the best information they can obtain for themselves, and making the best decisions that they can with such information and with their knowledge and levels. The FRI (0.38) and PRI (0.32) are both considerably higher here than reported for the observed CFMCC model, reflecting increased risk at both the functional and project levels. The effect of working actors behaving as subteam leaders (SL) as opposed to subteams (ST) has a large effect here. With less than 2 days' backlog reported, actors do not get any farther behind schedule in this model than in the others. This is despite the fact that the Power Flow Model *has only a single-level meritocracy*. Notice the maximum backlog affects in the Support organization, not the CFMCC, and occurs on the seventh day. Hence the greatest backlog is shifted from the future operations phase (i.e., as reported on all three models above) to the current operations phase (i.e., as reported here on the Power Flow Model). Again as above, one cannot say that one organization's performance is *dominant* over the others. Particularly in this case where durations are down, but risks are up, the net assessment depends upon the relative prioritization of the different performance dimensions. The same holds true across all of these models.

Finally, results for the Combined Model are summarized in the last column. Notice all of the duration measurements are lower than those reported for the Observed Model. Mission duration (5.3 days), joint planning (1.6 days), coalition planning (1.5 days), and time to Mission Go (4 days) all equal (nearly) or exceed performance levels of the best of the other models. This reflects the combined nature of this model, and in terms of duration measurements, the benefits of each model appear to be complementary. Rework (60 P-days) is lower here than in any of the other models—except for the Knowledge Network Model—driven largely by the knowledge-network effect. Coordination (407 P-days) reflects an intermediate value with respect to the other models—but it appears to be driven primarily from the Power Flow Model—and it reveals substantial growth over corresponding performance measured for the Observed Model. As with the Power Flow Model described above, wait time is zero here also, and no meetings are conducted. But FRI (0.42) is higher here than in any other model, and PRI (0.32) exceeds that of the observed CFMCC organization. With just over 1 days' backlog reported, actors do not get as far behind schedule in this model as in any of the other models, and such maximum backlog shifts to the Support organization, in the current operations phase of the mission. Again as above, one cannot say that one organization's performance is *dominant* over the others. The net assessment depends upon the relative prioritization of the different performance dimensions, particularly the apparent tension between mission speed (e.g., as measured by *duration, mission go*) and risk (e.g., as measured by *FRI, PRI*). Interestingly, such tension between speed and risk has been reported previously (e.g., see [Nissen 2005B]). The fact that we have grounded these models in behaviors of an operational CFMCC organization at sea provides considerable confidence in the fidelity of this phenomenon.

Appendix C – Model Parameter Definitions

In this appendix, we both paraphrase and quote from [SV online help] to include definitions of the model elements and parameters that are discussed above and applicable to the computational experimentation reported in this study.

Activity-See Task.

Actor-See Position.

Application experience-A measure of how familiar the position or person is with similar projects.

Behavior file-A file that specifies the simulator's default behavior, such as how much rework to add to tasks with exceptions.

Centralization-A measure of how centralized the decision-making is in a project. For example, high centralization indicates that most decisions are made and exceptions handled by top managerial positions such as the Project Manager. Low centralization means decisions are made by individual responsible positions.

Communication-The passing of information between positions about tasks.

Communications link-A dashed green link that links two tasks, indicating that the position responsible for the first task must communicate with the other position during or at the completion of the first task.

Coordination-A combination of the information exchange generated by communication and meetings.

Coordination Volume-The predicted time during a project or program that all positions spend at meetings and processing information requests from other positions.

Critical path-The set of tasks in a project that determine the total project duration. Lengthening any of the tasks on the critical path lengthens the project duration.

Decision wait time-The time a position waits for a response from the supervisor about how to handle an exception, plus any time the position waits for exception resolution before making the decision by default. See also Wait Volume.

Exception-A situation detected by the simulator where part of a task requires additional information or a decision, or generates an error that may need correcting.

Exception handling-Involves positions reporting exceptions to supervisors and supervisors making decisions on how to deal with the exceptions.

Failure dependency link-See Rework link.

Formalization-A measure of the formality of communication in an organization. For example, high formalization indicates that most communication occurs in formal meetings.

FRI (Functional Risk Index)-A measure of the likelihood that components produced by a project have defects. Also called CQI, or Component Quality Index.

Full-time equivalent (FTE)-A measure of position or person availability to perform a task. For example, a position with an FTE value of 3 has the equivalent of 3 full-time employees to perform tasks.

Functional exception-An error that causes rework in a task but does not affect any dependent tasks.

Links-A set of color-coded arrows that represent the relationships between shapes.

Matrix Strength-A measure of the level of supervision in a project or program, and a reflection of the structure of the organization. Low matrix strength means that positions are located in skill-based functional departments and supervised directly by functional managers. High matrix strength means positions are co-located with other skill specialists in dedicated project teams and have project supervision from a Project Manager.

Meeting-A gathering of positions to communicate about the project and project tasks.

Meeting Participant link-A dashed grey line that links a position to a meeting, indicating that the position must attend the meeting.

Milestone-A point in a project or program where a major business objective is completed.

Model-A visual representation of a program and its projects.

Noise-The probability that a position is distracted from assigned tasks.

Organization-A group of departments that staff a program or project.

Organization Assignment link-A solid pink line that links an organization to a project within a program.

PM-Project Manager, the position that assumes overall responsibility for a project.

Position-An abstract group representing one or more FTEs (full-time equivalents) that performs work and processes information. In a staffed project, positions represent a person or a group of persons.

PRI (Project Risk Index)-A measure of the likelihood that components produced by a project will not be integrated at the end of the project, or that the integration will have defects. PRI is thus a measure of the success of system integration.

Primary Assignment link-A solid blue line that links a position to a primary task, which is a task that takes priority over any secondary assignments.

Program-A set of related projects that share dependencies and together achieve the client's business objectives. A program also includes the associated responsible organizations, milestones, and relationships between projects.

Project-A project represents work an organization must perform to achieve a major business milestone. The work is represented by tasks, milestones, the positions that perform tasks, meetings, and the dependencies between all these elements. While a model may contain numerous projects, it need only contain one. Each project in a model supports the goal of the program to which the project belongs.

Project exceptions-Errors that might cause rework in a driver task and all its dependent tasks.

Project Exception Rate-The probability that a subtask will fail and generate rework for failure dependent tasks. This probability is generally in the range 0.01 (low) to 0.10 (significant, but common). If the Project Exception Rate is greater than about 0.20, so much rework can be generated that the project may never finish.

Project Successor link-A solid black line that links a project to another project or to a project milestone.

Rework-Redoing all or part of a task. Compare with direct work.

Rework Cost-The predicted cost of rework, or rework volume weighted by average cost per FTE of positions that do rework.

Rework link-A dashed red line that links a task to a dependent task that will need rework if the driver task fails.

Rework Volume-The predicted time needed for all positions on a project to do the required rework.

Scenario-See Case.

Secondary Assignment link-A dashed blue line that links a position to a secondary task, which is a task that can be worked whenever the position is not working on a primary task.

Simulator-Software that simulates the work done by positions as they perform individual project tasks, including both planned direct work and coordination and rework.

Simulation charts-Charts that summarize and provide details of the simulated performance of the program and the individual modeled projects.

Successor link-A solid black line that links milestones and tasks.

Supervision link-A solid black line that links a supervisory position to its supervised position.

Task-Any work that consumes time, can generate communications or exceptions, and is required for project completion.

VFP (Verification Failure Probability)-The probability that an exception will be generated for a task. The VFP is calculated during simulation based on a number of factors, including noise, communication rates, and team experience.

Wait Volume-A measure of the cumulative time spent by positions waiting for decisions to be made in a project.

Work volume-The predicted time that all positions on a project spend doing direct work.

Computational Modeling & Analysis of Coalition Maritime Planning

CCRTS 2006 - C2 Concepts & Organizations

CDR John Looney & Dr. Mark E. Nissen

Naval Postgraduate School

Sponsored in part by OASD-NII, through its CCRP.
Research coordinated through the Center for Edge Power.

Motivation

- Edge organization is fresh approach
- Question comparative & contingent performance
- Research problems with methods & ambiguity
- Computational experimentation as bridge method
- Center for Edge Power: MY, MD, MU R program
- This study:
  - Phase 1 – model specification & exp design
  - Phase 2 – field research to model CFMCC process

Prior Research
Archetypal Classification

Classification* of Hierarchy & Edge Organizations

Design Factor	**Hierarchy**	**Edge**
Coordination	Work standards	Mutual adjustment (Adhocracy)
Specialization – H	High	Low (Simple Structure)
Specialization – V	High	Low (Professional Bureaucracy)
Training & indoc	High	High (Professional Bureaucracy)
Formalization	High	Low (Simple Structure, Professional Bureaucracy, Adhocracy)
Grouping	Function	Market & function (Adhocracy & Professional Bureaucracy)
Unit size	Large	Small (Adhocracy)
Planning & control	Action planning	Limited action planning (Adhocracy)
Liaison	Few	Many throughout (Adhocracy)
Decentralization	Centralized	Selective decentralization (Adhocracy)
Archetype	*Machine Bureaucracy*	*Professional Adhocracy*

* See Mintzberg (1979)

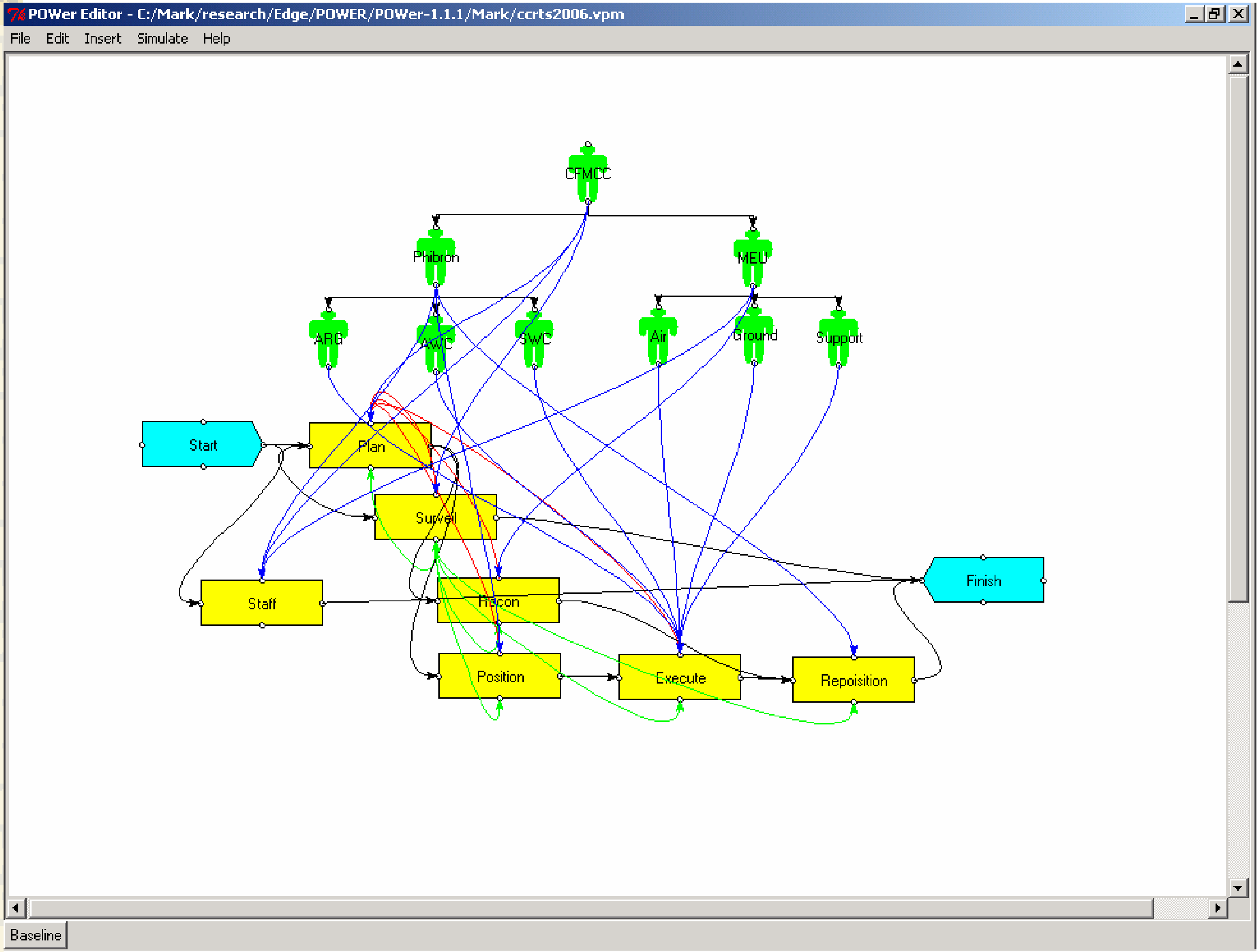
Research Design

- Computational tools – POWer
- CFMCC field research
- Integration, synthesis & CFMCC analysis

Field Research Results

- Observations confirmed CFMCC as a Hierarchy
  - High degree of work standards, horizontal and vertical specialization, formal information flow information, action planning and control, and centralization
  - Functional grouping, unit size and liaison are not clearly hierarchical
- Observations used to:
  - Refine the C2 model's baseline parameters
  - Validate and calibrate model performance – "Observed" column

CFMCC Computational Model
"Observed"



Alternative CFMCC Models

- Communications – same structure and skill levels
  - Common planning network, improved information processing
- Knowledge Network – same structure and network
  - Better educated, experienced, and trained planners
- Power Flow – same skill levels
  - 1-level meritocracy with interdependent tasks
- Combined – best aspects from each of the three models

Computational Results

Measure	Observed	Communications	Knowledge-Net	Power Flow	Combined
Simulation Duration	9.5 days	**8.8 days**	**6.9 days**	**8.6 days**	**5.3 days**
Joint Planning Duration	3.5 days	3.3 days	**1.5 days**	3.4 days	**1.6 days**
Coalition Planning Duration	4.5 days	**3.6 days**	**1.6 days**	**3.6 days**	**1.5 days**
Mission Go	6 days	**5 days**	**4 days**	**4 days**	**4 days**
Direct work	2694 P-days	2694 P-days	2694 P-days	2726 P-days	2726 P-days
Rework	126 P-days	96 P-days	52 P-days	**411 P-days**	**60 P-days**
Coordination	136 P-days	48 P-days	114 P-days	**668 P-days**	**407 P-days**
Wait time	16 P-days	**19 P-days**	**8 P-days**	**0 P-days**	**0 P-days**
Meetings	42	**0**	**31**	**0**	**0**
Functional Risk Indicator	0.23	0.27	0.26	**0.38**	**0.42**
Project Risk Indicator	0.26	**0.35**	**0.20**	**0.32**	**0.32**
Maximum Backlog	2.0 days	**1.4 days**	**1.6 days**	**1.8 days**	**1.3 days**

Contributions

- Calibration of POWer C2 model provides confidence in computational experimentation outputs
  - Highlights advantage & disadvantages of alternate organizational forms, process changes, and technological improvements
- Topologies of knowledge networks vary per task
  - Make K-net explicit, incentivize its use, and monitor the balance between exploration (creation tasks) and exploitation (work tasks)

Limitations & Future Research

- Limitations
  - Bridge research method, interpretation & judgment
  - C2 is relatively new domain for VDT; POWer in development
  - CFMCC studied in experimental vs. operational mode
- Future research
  - Campaign of experiments – compare CFMCC to other forms
  - Complementary studies ongoing & planned
  - Center for Edge Power welcomes input