Title: Empirically-driven Analysis for Model-driven Experimentation: From Lab to Sea and Back Again (Part 2)

Suggested Tracks:  
C2 Concepts and Organizations, C2 Modeling and Simulation, C2 Analysis

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Abstract

In this paper, we describe our recent efforts that bring together organizational design theory, effective organizational modeling, and observation of Navy operations to guide our near-term human-in-the-loop experimentation design. We summarize the findings from our team’s investigation of an Expeditionary Strike Group (ESG) and discuss how this empirical knowledge helped us modify and adjust both our models and our understanding of the key ESG organizational issues. The resulting Goal-Function Roadmap model supplies the “missing link” between the influence models of effects propagation and the optimization models for resource allocation and scheduling. We illustrate how we are using this knowledge: (1) to design the next round of human-in-the-loop experiments to provide answers that would yield practical benefits to the ESG and the U.S. Navy; and (b) to lay out possible avenues and the road-map for the next three-to-four years of research for the Office of Naval Research’s (ONR) Adaptive Architectures for Command and Control (A2C2) program.

1. Opportunity: Blending Science with Operations

The model-driven human-in-the-loop experimentation is the primary vehicle through which the Adaptive Architectures for Command and Control (A2C2) program of Office of Naval Research (ONR) strives to achieve its long-term objectives that include: (a) Optimizing the design of C2 structures and processes to meet modern mission challenges; (b) Advancing the U.S. Navy’s understanding of how to best take advantage of the optimized designs; (c) Facilitating adaptation of C2 structures and processes; and (d) Advancing the U.S. Navy’s understanding of design tradeoffs. Achieving these operationally-driven objectives requires the research that is: (i) operationally-relevant (i.e., addresses the “right” problems); (ii) effective (i.e., provides actionable answers); and (iii) cost-efficient.

The Expeditionary Strike Group (ESG) provides both the context and the opportunity for the A2C2 program to study how some of the critical organizational design and adaptation issues manifest in the real operational settings. The ESG is intended to be a very adaptive and fluid organization, able to address a variety of missions (Figure 1; example ESG missions are described in a companion paper [Weil2006]). The evolving organizational structure, integration of Joint resources, part-time inclusion of coalition assets, and competing demands for mission prioritization make the ESG an ideal subject of inquiry for the A2C2 program. To capitalize on this opportunity, the current focus of the A2C2 project team is to explore the ESG organizational concept through analysis and tool development.

Figure 1. A variety of ESG mission elements.
Based on several briefings and interactions with the ONR, the ESG command staff, the Tactical Training Group Pacific (TACTRAGRUPAC), and the Expeditionary Warfare Training Group Pacific (EWTGP), several key organizational challenges within the ESG were identified. These challenges were subsequently studied through the observations and focused interviews aboard the ESG flagship during their deployment. The findings and ideas that the A2C2 project team was able to amass while aboard will assist in structuring the next three to four years of research for the ONR A2C2 program.

2. In the Lab: Model-Based Diagnosis of ESG Organization

The ESG is a U.S. Navy task force that combines the amphibious capabilities of a traditional Amphibious Readiness Group/Marine Expeditionary Unit (Special Operations Capable) (ARG/MEU[SOC]) with the combatant firepower of Navy cruisers, destroyers, and frigates [Hutchins2005]. The ESG concept sports a highly mobile, self-sustaining force, capable of conducting expeditionary warfare operations to support a full range of theater contingencies [ESG2005]. Those missions could range from humanitarian and disaster relief to combat operations [Weil2006]. The addition of cruiser, destroyer and submarine assets make the ESG capable of deploying independently as well as part of a larger joint force. Robust offensive and defensive capabilities offered by the additional ships, like Tomahawk cruise missiles and the AEGIS combat system, not only provide for better support of troops ashore, but also enable the group to act autonomously.

A key advantage of the ESG is structural adaptability that permits the ESG to support a wide range of missions (from amphibious assault to disaster relief). The unique ESG command structure that integrates the Navy and Marine Corps forces is the key to this adaptability. An aspect of this adaptable structure entails activating alternate warfare commanders, who operate in supporting-supported roles depending on the mission, in order to distribute workload. Lateral collaboration is employed as an enabler of structural adaptability with a reliance on non-traditional communication and coordination.

As noted in [Weil2006], the ESG is an experimental organization. Newly established ESGs generate new command relationships [Mohs2003], many of which at present have not yet been standardized or doctrinally derived. ESGs are responsible for missions traditionally guided by both Composite Warfare Command (CWC) and Joint Amphibious Doctrines. The ESG Commander must contend with ambiguous doctrinal relationships, and define any unique relationships, roles, and responsibilities that he wishes to adopt to increase the efficacy of his/her command. As a result, the specifics of the decision-making roles and interactions of the organization should be carefully modeled to match the mission at hand.

Model Paradigm

The A2C2 research program produced the systems engineering approach to designing organizations that are “congruent” with their missions and hence exhibit superior performance. The concomitant quantitative methodology for designing superior organizations [Y. Levchuk2003] and its extensions to designing robust and adaptive organizations [G. Levchuk2004] have been validated by human-team-in-the-loop experimental research, conducted as part of the A2C2 program [Entin1999] [Diedrich2003] [Entin2003] [Entin2004] [Weil2005]. The A2C2 research team viewed the ESG C2 organizational design as the real-world application to examine the potential (for real-world analysis and design) of the organizational design methodology first developed in the lab.

We have used the associated modeling paradigm [G. Levchuk2003] of event-driven distributed mission task processing by a hierarchical C2 organization to develop the initial ESG model to guide our preliminary diagnosis of the ESG organizational issues. Our initial ESG model was based on interviews with ESG, TACTRAGRUPAC, and EWTGP, as well as on the analysis of the ESG documentation available through their private Collaboration at Sea website. We modeled the ESG mission as composed of the event-driven task chains (Figure 2) corresponding to high-level ESG tasks (such as, for example,
Conducting Amphibious Assault; Providing Operational Fires (Joint/Coalition); Conducting Airfield/Port Seizure; Providing Sea Lines of Communications Protection; and so on). See [Hutchins2005] for more comprehensive list of the ESG tasks.

Model Input: Mission Events and their Expectations

Figure 2. Event-driven task chain and event expectations (illustration).

Our model utilizes the mission expectations to assess the event-driven distributed task processing by a hierarchical C2 organization in a given scenario, in order to estimate the ensuing performance measures (e.g., see task accuracy and timeliness performance measures illustrated in Figure 3). The model can be used to optimize the design of a C2 organization to exhibit superior performance [Y.Levchuk2000][G.Levchuk2004].

Figure 3. Organizational performance measures for a given mission scenario (illustration).
We modeled the ESG organization as a hierarchical C2 network whose components exercise direct control over operational resources (Figure 4). The ESG mission areas of responsibility are allocated to the associated ESG components that could also be engaged in various dynamic supporting-supported relationships, as required by the mission and determined by the ESG commander. Our initial ESG model is described in detail in [G. Levchuk 2005].

More specifically, we applied our methodology to model the two ESG configurations: the “West Coast” ESG formation (of the first ESG deployment in 2003 from the West Coast as the maritime component for the Global War on Terrorism) and the “East Coast” ESG formation (of the second ESG deployment in 2004 from the East Coast). The West Coast ESG model has a Flag or General Officer (FO/GO) led staff, which provides the combatant commander with: (1) a subordinate staff capable of planning at the operational level; (2) the capability to task organize, which includes taking command of inorganic forces as required; and (3) a single source commander capable of providing maritime and land force [U.S. Fleet Forces Command 2002]. The East Coast ESG deployment has similar ship and aircraft composition but lack the FO/GO led staff of the West Coast formation [Deal 2004].

Critical ESG Issues Diagnosed andSelected

We used the model-based comparison between the two ESG formations described above to identify the ESG issues that our model predicted to be critical for the ESG performance and dynamics. For example, we highlighted the need to investigate the impact of multiple potentially non-commensurate doctrines (i.e., doctrines for the composite warfare command and for the joint amphibious operations) under which the Amphibious Squadron (PHIBRON) cell of the ESG must operate simultaneously as it is engaged in different supporting-supported relationships during the ESG mission.

Our preliminary recommendations [Weil 2006] were presented to the FO/GO of an ESG and to senior members of his staff for their comments and for prioritizing the subsequent A2C2 research efforts. The top three prioritized topics that emerged from this meeting and were found to merit an investigation are as follows:

1. **Examining the Structure and (Re)configurability of the PHIBRON cell** – Our model predicted that a relatively small staff such as the PHIBRON can become overloaded by the number of concurrent missions during high operational tempo conditions. For example, a PHIBRON cell in some West Coast ESG designs is simultaneously responsible both for the amphibious operations – from embarkation to transit to assault under combat conditions – and for the Sea Combat
Command (SCC) operations – including Surface Warfare, Undersea Warfare, Maritime Interdiction Operations, and Maritime Security Operations. The multiplicity of roles could cause stress in the organization, and result in lowered efficiency. A subtopic of this topic was the investigation of the impact of multiple doctrines on the PHIBRON operations and processes.

2. **Introducing a single ISR commander/coordinator**–Our model indicated that the ESG may have insufficient access to the ISR-dedicated assets which could lead to possible “stovepiping” of the ISR requests and to inefficient use of scarce (low number, high-demand) assets to cover a large area of ESG mission responsibility. The position of ISR commander/coordinator (ISR-C) can help prioritize asset utilization for ISR to make effective use of the inherent ISR capabilities of all assets (including ESG, theater, and national level) and to maximize multi-capable ISR platforms (e.g., UAV, E2C, P3) including external ISR support and reachback.

3. **Hybrid Supporting-Supported Structures**–Although supporting-supported (S-S) relationships represent very flexible arrangement, there are instances in which ambiguity could arise. For example, a Commander A can be supporting a Commander B for one mission, while simultaneously Commander B is supporting Commander A in a second mission. This situation may potentially introduce the conflict of authority (e.g., when determining the use of resources that can benefit both missions) and could challenge Unity of Command, which indicates that all forces operate under a single commander with the requisite authority to direct all forces. As one of the objectives for the A2C2 ESG research, we suggested identifying challenges in implementing the S-S relationships and devising mechanisms to resolve conflicts that may arise when a commander is engaged in multiple concurrent missions.

**4. Out at Sea: Findings While On-board an ESG Flagship**

Three members of the A2C2 team visited the flagship of an ESG just prior to their deployment in and around theater and while the ESG participated in a coalition land/sea training exercise. The embarked A2C2 team interviewed both senior and junior staff members of the ESG, PHIBRON, and MEU(SOC), observed senior level briefings, reviewed information sources, and monitored the Joint Operations Center (JOC). See a companion paper [Weil2006] for details regarding the data-collection efforts and methods used by the A2C2 team.

Although the data collection methods used were flexible to take advantage of the emergent events, interviews, and observations, particular emphasis was placed on the three topic areas identified by the CESG as being of high criticality: (i) Structure and (re)configurability of the PHIBRON cell; (ii) Introduction of the ISR commander/coordinator; and (iii) Use of Hybrid Supporting-Supported Structures. Regarding the impact of multiple doctrines employed by the PHIBRON for its different missions (the composite warfare doctrine for the SCC and the Joint Amphibious Doctrine for the amphibious operations), the members of the PHIBRON reported that they experienced this more as a conflict of two different missions—the SCC and the amphibious operations—rather than a conflict between two doctrines. The PHIBRON commander indicated acting like a single warfare commander executing two missions. However, to manage artificially high workload conditions during their pre-deployment training, the PHIBRON staff reported naturally creating two sub-groups, one responsible for planning SCC and the other for planning amphibious operations. The PHIBRON commander, in turn, could oversee both types of operations and ensure coordination.

The ESG investigated had designated the intelligence officer (N2) of the ESG staff to serve as the ISR Coordinator (ISR/C) to maintain battlespace awareness. The ISR/C responsibility in this arena was to ensure that (1) the use of scarce resources was consistent in supporting the commander’s intent, and (2) that the intelligence gathered was processed and integrated to be acted upon when necessary. By aligning the use of all the ESG intelligence assets with the commander’s intent, the ESG was able to handle...
several geographically dispersed areas simultaneously, and both the ESG Current Operations and Future Operations staffs were happy with the intelligence support they were receiving.

At the time of the A2C2 observation of the ESG, there had been relatively few situations in which supporting-supported (S-S) relationships had to be specified, and those had been straightforward to the relevant commanders. However, if an ESG is envisioned to engage in activities in which there are multiple, reciprocal, simultaneous S-S relationships among commands, greater specification may be required. The A2C2 team will be exploring the ESG S-S relationships further during follow-up ESG visits.

The observation of ESG activities and senior staff meetings increased our understanding of information flow and decision making techniques in hybrid organizations like the ESG. One of the empirical findings was the tendency for goal-driven decoupling among the three internal organizational dynamics rhythms – for MEU, PHIBRON, and ESG. Given the observed empirical cues (e.g., competing tension between roles of amphibious operations and SCC; competing command for assets; etc.), we predict that the interaction between the corresponding three rhythms (including their synchronization, information flow, and dynamic shift of the corresponding supporting-supported relationships) represents one of the key processes that would affect the performance of the ESG battle group under different scenarios.

Additional data collected during ESG data collection included the examples of: (a) event-driven action-reaction sequences of operational activities of ESG; (b) rank-ordered ESG mission requirements (beginning with example objectives for several typical situations and drilling down to the goal-sub-goal chains); (c) observations of existing ESG C2 arrangements (examples highlighting how C2 structures really work in practice); (d) ESG measures of performance and performance tradeoffs; (e) areas of responsibility of ESG commanders and the key ESG “management decisions” and critical events that spawn these decisions; (f) multi-capable ISR platforms (UAV, E2C, P3, etc.) and their assimilated use; (g) information flows in network-enabled ESG C2 systems (for several typical situations) and flow elements (e.g., observations, call for information, decisions, orders, etc.).

5. In the Lab Again: Organization-Mission Rhythm Model

As the result of analyzing the empirical ESG data (which included both the observations and interviews collected by the A2C2 team during its ESG visit, as well as document & doctrine reviews), our organizational model was modified as follows.

Goal Roadmap Dimension of the Mission Definition

Rather than referencing a non-commensurate nature of the two doctrines (for the composite warfare command and for the joint amphibious operations), as was hypothesized by our original model, the ESG staff and the members of the PHIBRON reported that they experienced a conflict of two different missions—the Sea Combat Command and the Amphibious Operations. Moreover, some of the interviewees reported the apparent incongruence between the MEU expectations for its mission and the PHIBRON and ESG expectations/requirements for the MEU mission. To model these idiosyncrasies, we have augmented our original model (of event-driven distributed task processing) with the Goal-Function Roadmap dimension (Figure 5).
The Goal-Function Roadmap (GFR) model, appropriately integrated with our original model for event-driven distributed mission task processing by a hierarchical C2 organization (as illustrated in Figures 5 and 6), will supply the “missing link” between the influence models of effects propagation and the optimization models for resource allocation and scheduling. The GFR visualizes the evolution of the environment (potential or actual, depending on the context) toward achieving organizational objectives (goals) as a result of applying “functions”. Functions denote controlled changes to the environment (contrasting that with events that represent uncontrolled changes to the environment). A function implies both the intent to change the environment and a concomitant course of actions (COA) to enable the change (or a set of alternative COA). Nodes of the GFR correspond to organizational goals and arcs of the GFR correspond to functions (and to concomitant COA). Using the auxiliary “AND” and “OR” nodes facilitates the roadmap interpretation, allowing one to distinguish strategic alternatives from combined functional requirements (Figures 5 and 6).
Figure 6. Elements of the mission structure in a modified model.

The GFR (Figure 6) can have several representation levels, with the higher representation levels corresponding to the strategic levels of operations (i.e., choosing objectives and defining high-level COA) and the lower levels corresponding to the tactical levels of operations (i.e., event and situation-driven resource-specific COA selection, adaptation). The GFR emphasizes functional control of the battlespace over its physical occupation to help generate effective combat power synchronized at the proper time and place.

**Organization-Mission Rhythm Model**

Based on the empirical findings gathered, we concluded that one of the key processes that determines how the ESG battle group would perform under different scenarios is the interaction between the three relatively-decoupled internal organizational dynamics rhythms – for MEU, PHIBRON, and ESG-staff cell. This interaction includes the synchronization among the three processes, the concomitant information flow, and the dynamic shift of the corresponding supporting-supported relationships.

Consequently, we have modified our original model to include the **process models** for MEU, PHIBRON, and ESG-staff cell. The corresponding process models simulate the integrated Processing of Information and the generation of plans by the three elements (i.e., MEU, PHIBRON, and ESG-staff cell) of the ESG C2 Organization. Every Process generates **Information Outputs** based on the **Information Inputs**. The Process Model (illustrated in Figure 7) is generalized to include the mission execution and the effects propagation, fed back into the organization through observations that become **information inputs**. The
organizational plans are assessed for completeness, correctness, and clarity, which impact the likelihood of successful mission execution and other performance measures (Figure 7).

**Information Processing Model generalized to include mission execution and effects (illustration)**

This new modification of our ESG model is intended to capture the key phenomena that characterize the existing ESG two line commanding organization. We integrate our original model for event-driven distributed mission task processing by a hierarchical C2 organization with the distributed information processing model generalized to include the mission execution and the effects propagation, to obtain the **Organization-Mission Rhythm Model** (Figure 8). Note that we can use our Organization-Mission Rhythm Model to represent the battle rhythms of the ESG and its internal elements (MEU and PHIBRON).
The TOD methodology referenced in Figure 8 denotes the Team Optimal Design methodology [Y. Levchuk2002] applied under the A2C2 program to design organizations that are congruent with their missions and thus exhibit superior performance [Entin1999] [G. Levchuk2002a&b]. The PAT methodology referenced in Figure 8 denotes the Process Assessment Tool [Y. Levchuk2004] and its methodology for measuring with confidence how various process modifications (e.g., insertions of different technologies) affect the capability of a C2 organization to successfully fulfill its mission and achieve superior performance.

The Organization-Mission Rhythm model combines the process-based and event-based approaches (Figures 8 and 9). While we specifically model (at the macro-level) the structure of the various processes (such as logistics, intelligence gathering, operations/mission planning and execution, day-to-day ship activities) and the input-output relationships between organizational elements (such as Ship line, MEU,
PHIBRON, ESG-staff cell, Navy) designated to carry out these processes, we also model (at the micro level) the concomitant event-driven decision and information flow cycles and decision points (Figure 9). In this way, we model the key events of interest (e.g., peak interactions, resolving competing demands, friction/discontent events, etc.) to guide our experimentation efforts.

For the ESG, our Organization-Mission Rhythm model can be used to quantify how relatively-decoupled (i.e., abstracted as separate) MEU, PHIBRON, and ESG-staff cell internal organizational dynamics rhythms coexist and dynamically interact with each other. For example, we model how the supporting-supported relationships between MEU and PHIBRON shift as they manage the competing demand for assets (such as helicopters, UAVs, etc.). We also model how FO/GO arbitrates priority between PHIBRON and MEU – as had been observed several times by the A2C2 team during its visit. The detailed arbitration decision model (partially illustrated in Figure 9) helps us identify the potential friction points among interacting command staffs to address how to best resolve the corresponding events.

The ESG-contextualized Organization-Mission Rhythm model (abbreviated and summarized) specifies:

- Processes (Normal Ship Operations; Mission Operations Planning; Intelligence Gathering/Processing; etc.)
- Timeline/schedule/cycle/rhythm
- Input-output requirements/enabling relationships and information sources
- Priorities/precedence
- Organization (Ship line; MEU; PHIBRON; ESG-staff cell; etc.)
- Enabling-enabled relationships (and their event-driven dynamics)
- Input-output dependencies
- Control over resources
- Schedule (e.g., meetings, etc.)
6. Designing Near-term Human-in-the-loop A2C2 Experiments

In this section, we summarize the design of one candidate (near-term) A2C2 experiment based on the integrated Organization-Mission Rhythm model. While this design is based in part on data collected by the A2C2 team, the key concepts have been abstracted for maximum generalizability to other similarly modular organizations. The long-term opportunities that result from the concomitant modeling efforts will be delineated in the following section.

As the near-term experimental goal, we set to explore practical ways to improve the performance of “joint” organizations (of which the ESG is one example) that combine organizational components which previously operated independently. We will study the potential for adjusting the (mis)alignment of missions for different organizational components to improve organizational performance (e.g., to increase effectiveness and efficiency). A key hypothesis for a prospective A2C2 experiment is that, when the mission objectives for disparate organizational components are better aligned (i.e., more congruent and/or closely-coupled [Diedrich2003]), the result is improved collaboration among organizational components and superior performance of the organization as a whole (Figure 10). In the context of an ESG, the PHIBRON and MEU are the two sub-groups that (1) interact frequently, (2) are quasi-independent, and (3) have historically been autonomous (Figure 10). We will focus our experimental objectives on exploring ways to optimize the interaction between the rhythms of organizational sub-groups, inspired by the modular construction of the ESG.

We hypothesize that, if interacting organizational sub-groups (such as a hypothetical PHIBRON and MEU in an ESG-like organization) pursue goals that are (or are viewed by each party as) decoupled from those of the other party or the aggregate organization, the tension between those cells will persist over time, and their combined efficiency may suffer as a result. The FO/GO leading the superordinate organization must arbitrate to resolve conflict (such as competing demands for scarce assets), but cannot fully alleviate the tension between the sub-groups. We further hypothesize that, if/when a MEU and PHIBRON view their goals as closely-coupled with (or congruent to) each other, the tension subsides, they synchronize their activities better, and their combined performance excels. Thus, one possible way to resolve potential tension and improve performance is to select/structure the missions in which goals of sub-groups are closely-coupled with (or congruent to) each other.

We further hypothesize that, after the MEU and PHIBRON have accumulated enough exposure to “mutually closely-coupled” missions, the tension between them will decrease, regardless of what missions they will face. We will study to which degree the missions can be structured so that the goals of the sub-groups will be viewed by each of them as sufficiently closely-coupled with (or congruent to) each other and with (to) the integrated organization (e.g., the full ESG). We also hypothesize that joint training on the “right” missions can enhance viewing of the MEU and PHIBRON’s goals by each party as mutually coupled (or congruent).
We define the design objectives for a prospective A2C2 experiment as follows:

- Examine C2 in the ESG (including employment of supporting/supported relationships, Unity of Command, etc);
- Study hypothesized causes of divergence of opinion between sub-components of the ESG (e.g., MEU and PHIBRON);
- Suggest and validate ways to reduce tension and synchronize performance;
- Examine the role of the FO/GO under each setting;
- Extend the “congruency” concept (i.e., that organizations congruent with their missions exhibit superior performance) to include the alignment (or congruency) of objectives concept (i.e., that organizational components whose sub-missions are aligned or congruent exhibit superior performance).

The hypotheses to be tested in the prospective A2C2 experiment are as follows:

- Goal incongruence (misalignment) between MEU and PHIBRON can result in tension and decreased operational efficiency …
- …thus resulting in asynchronous internal organizational rhythm cycles, more stringent competing demands for assets, less synchronization.
- Congruence (alignment) between MEU and PHIBRON’s goals decreases tension and results in superior performance…
- …thus resulting in synchronous internal organizational rhythm cycles, less stringent competing demands for assets, better synchronization.
- After the sub-groups have enough exposure to “mutually aligned (or congruent)” missions, the tension between them will decrease, regardless of what missions they will face.
- Joint training on the “right” missions can improve alignment of goals.

To achieve our design objectives, we utilize our Organization-Mission Rhythm model (and its Goal Roadmap and Information Process dimensions) to devise the two baseline missions for the prospective A2C2 Experiment with different degrees of goal coupling between the MEU and PHIBRON elements of the ESG. We devise the two scenarios (see Figure 11): one in which the MEU and PHIBRON’s goals are decoupled (Scenario 1) and a second in which the goals are aligned (Scenario 2).
Figure 11 illustrates the ESG mission for Scenario 1 (we use the metrics of graph connectivity to measure the degree of decoupling between the MEU and PHIBRON’s sub-missions). The Scenario 1 is designed so that MEU has its own “independent” objectives in sight, while PHIBRON also has its own “loosely dependent” objectives. Note that some relatively-small degree of coupling between the MEU and PHIBRON’s Goal Graphs will be preserved for Scenario 1, because we want to measure the ensuing interaction between the MEU and PHIBRON, and compare it to the corresponding interaction for the Scenario 2 (described in Figure 11), for which the concomitant coupling will be very strong.

The **performance and process measures** for the prospective A2C2 Experiment are as follows:

- C2 in ESG (including employment of supporting/supported relationships, Unity of Command, etc);
- Degree of Coupling/Alignment between Goal Graphs;
- Alignment/Synchronization of ESG/MEU/PHIBRON’s internal organizational rhythms;
- In-simulation performance accuracy/effectiveness and efficiency;
- Communication types and their correlation to information requirements.

The ESG-contextualized Organization-Mission Rhythm model allows us to assess the corresponding measures and generate predictions, to be compared with the empirical results in order to validate our model.

The **model predictions** for the prospective A2C2 Experiment are as follows:

1. Scenario 1 will result in asynchronous internal organizational rhythm cycles among ESG-staff cell, MEU, and PHIBRON.
2. Scenario 1 will result in tension between MEU and PHIBRON and will produce stringent competing demands for assets with less than adequate synchronization.
3. Scenario 2 will result in synchronized internal organizational rhythm cycles of ESG-staff cell, MEU, and PHIBRON.
4. Scenario 2 will result in lesser tension between MEU and PHIBRON and will produce lesser competing demands for assets due to adequate synchronization.
7. A2C2 Program Benefits and Long-term Roadmap

The modeling enhancements presented in this paper include the Goal-Function Roadmap Model and the organizational Information Process Model. These modeling efforts offer several key benefits, which can be further enhanced by their integrated use (e.g., as in the ESG-contextualized Organization-Mission Rhythm Model presented earlier).

On the one hand, the Goal-Function Roadmap (GFR) emphasizes functional control of the battlespace over its physical occupation to help generate effective combat power synchronized at the proper time and place. By explicitly defining the information and synchronization prerequisites to objectives and COA, it achieves close coupling of intelligence, operations, and logistics to help achieve precise effects and gain temporal advantage with dispersed forces. Also, the GFR improves the quality of higher-level analysis by facilitating the development of the “right” high-level models for a given purpose. The GFR format provides a much improved shared awareness of the situation and can enable more rapid and effective decision making at all levels of military operations (and thereby allow for the increased speed of execution).

At the strategic level, the GFR can be used to formalize the process of setting goals (objectives, outcomes); synchronizing goals in time for effects; abandoning goals that have been achieved or are no longer relevant;
identifying and resolving conflicts between goals; and prioritizing goals consistently for optimal collaboration and effective operation. At the tactical level, the GFR can be used to formalize the process of choosing COA to achieve goals; allocating resources to perform COA based on goals’ priorities; scheduling and self-synchronizing own COA; and assessing the status of each COA (whether or not it is being performed satisfactorily and on time).

On the other hand, the presented Organizational Information Process Model can be used for measuring how various organizational design modifications (e.g., the insertion of different technologies and/or processes) affects the capability of the C2 Organization to successfully fulfill its mission and to achieve superior performance. This model can be used to evaluate the degree to which various architectural and process modifications can be successfully applied within the C2 Organization to boost its performance. Also, the corresponding model can be used to identify the bottlenecks (Figure 13) while dynamically enhancing service of and control over the critical processes. Predicting when the organizational processes would become bottlenecks is one of the prerequisites to facilitating the timely organizational adaptation, which is the main subject of the A2C2 program.

The A2C2 modeling efforts open many opportunities to enhance the design and understanding of the Adaptive C2 Organizations. We design our human-in-the-loop experiments to foster our long-term program objectives, which include: (a) Optimizing the design of C2 structures and processes to meet the mission challenges; (b) Advancing the U.S. Navy’s understanding of how to take advantage of optimized design; (c) Facilitating adaptation of command and control structures and processes; and (d) Advancing the U.S. Navy’s understanding of design tradeoffs. We use our modeling methodology to optimize the experimental design to maximize the effectiveness of concomitant research and its use of resources. Our analytic-empirical efforts explore ways to optimize organizational performance, robustness, and adaptability.

One of the key distinctions between how we have conducted the experiments in the past and how we will conduct them in the future is in that we are now prepared, in addition to using the teams of humans, to also be using the synthetic agents. This is necessary because many important organizational phenomena can only be observed in the large-enough organizational settings, for which running the human-only
Our strategy is to test the scenario settings using a team that would combine the human decision-makers and synthetic agents, where human decision-makers will play the key organizational roles that we will be monitoring. In order to devise the synthetic agents that resemble the humans, we have to explicitly model the key human decision processes both at the individual and at the team levels. Such modeling enhances our understanding of the phenomena that facilitate organizational adaptation and enhance performance. Several avenues for the A2C2 program roadmap that capitalize on the modeling efforts presented in this paper are depicted in Figure 14.

8. Summary

In this paper, we have shown how real-world empirical data were used to develop the generic Organization-Mission Rhythm model that integrates three executable components - the Goal-Function (and COA) Roadmap, the Event-driven Distributed Task Processing, and the Organizational Information Processing models. The Organization-Mission Rhythm model offers several key benefits, from synchronizing objectives and forces (to achieve desired effects) to identifying the process bottlenecks to optimizing organizational design and adaptability (to achieve superior performance). The concomitant Goal-Function Roadmap model supplies the “missing link” between the influence models of effects propagation and the optimization models for resource allocation and scheduling. The model has been applied to designing the human-in-the-loop experiments targeted at providing answers that would yield practical benefits to the ESG and the U.S. Navy. We concluded the paper by summarizing the associated benefits and laying out research opportunities captured in the road-map for the Office of Naval Research’s Adaptive Architectures for Command and Control program.