Title: **Applying A2C2 Framework to C2 Challenges of Maritime Headquarters with Maritime Operation Center**

Suggested Topics: **Modeling and Simulation**

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Abstract

The *Maritime Headquarters with Maritime Operations Centers* (MHQ with MOC) is *an Enabling Concept for Maritime Command and Control* and the associated CONOPS. A *Maritime Headquarters* (MHQ) will perform both operational-level warfighting and fleet management/Title X activities supported by a *Maritime Operations Center* (MOC). The MHQ with MOC architecture development effort is currently under way for the Commander, SECOND Fleet (C2F), to specify the MHQ with MOC organizational relationships and operational nodes, activities/processes, information exchange requirements and associated systems, interfaces and communications links for a maritime headquarters with a maritime operations center within the FYDP, targeting full capability during the 2015 - 2020 timeframe. The initial phase of the architecture development is focusing on the maritime headquarters' operational-level warfighting responsibilities. A follow on effort will expand the scope of the MHQ with MOC architecture to incorporate fleet management activities/requirements and address the maritime headquarters fulfilling the role of a Joint Task Force (JTF) Commander.

This paper proposes a dynamic MHQ with MOC model to examine flexible Navy MHQs as an option for how the US Navy can better meet the needs of the national military command structure at the operational level of war. This paper addresses the issues of:

- Identifying the key design and performance challenges of the MHQ with MOC:
  - Delineating the interplay among the key MHQ with MOC dimensions and its internal and external variables;
  - Identifying the MHQ with MOC information and decision aid/support requirements and implications of alternative implementations;
  - Pinpointing (current and future) bottlenecks, tracing gaps, suggesting mitigation solutions.
- Designing reconfigurable integrated model of the MHQ with MOC:
  - Modeling MHQ with MOC organizational structure, allocation of resources, flow of information and control, technology enhancement;
  - Implementing simulation-ready optimization-capable inter-operable executable models of the MHQ with MOC processes.

Motivation

"The demands for naval forces are up. The forces that will be needed in the future will be expeditionary, rotational, engaged, whether it's in Africa, South America, the Gulf, the Western Pacific, or other parts of the world."

(Commander, U.S. Fleet Forces Command Change of Command, 18 May 2007)

The **U.S. Navy** is currently undergoing a rapid transformation across several key dimensions:

1. **Strategy**: The U.S. Navy is developing *new maritime strategies* to guide its transformation efforts to ensure the security of the global maritime commons in the new network-centric era, and to fit the challenges of the 21st century— from deterring a potential blue-water "peer competitors" to conducting small, near-shore expeditionary ventures to provide cover fire against insurgents and/or to aid the post-9/11 global war on terrorism.
2. **Command Structure**: The U.S. Navy is reorganizing its *maritime headquarters* (MHQs) and standardizing its *maritime operations center* (MOC) processes to better meet the needs of the national military command structure at the operational level of war, including integration efforts to promote international maritime security objectives.
3. **Training**: The U.S. Navy is streamlining and institutionalizing its *training programs* and procedures to provide qualified personnel to efficiently meet future challenges as operations intensify in scale and complexity.
4. **Tools and Technologies:** The U.S. Navy is building new tools that capitalize on emerging information age technologies to enable the Net Centric Warfare (NCW), which identifies new sources of power (information sharing, information access, speed). The high tempo and increased complexity of modern warfare requires agile forces capable of rapidly turning the information advantage into a military advantage.
5. **Networking, Interoperability, and Collaboration:** The U.S. Navy is working to better connect Naval Command and Control (C2) elements with other organizations and commercial entities, together forming a *decentralized global network* – that would imbed the Navy organizing principles such as **FORCEnet** – and would enable consistent coordination and knowledge sharing to support maritime security and other operations. Also, as one of the key potential elements of the Joint, Interagency, Multi-organizational, Multi-national (JIMM) environment, the U.S. Navy will need to effectively deal with cultural and socio-political aspects that accompany JIMM organizations.

The *Adaptive Architectures for Command and Control (A2C2)* program of the Office of Naval Research (ONR) is ideally positioned with theories, methods, findings, and tools that can directly support the above transformation efforts by the U.S. Navy. As a program to develop *adaptable* organizational structures and processes, the A2C2 is now in a unique position to apply its theoretical advances and its unique team repository of research expertise to the upcoming U.S. Naval challenges, and to help advance the Navy’s understanding of how to combine strategic alternatives and take advantage of available technologies and network connectivity to organize and conduct modern and future operations.

Theoretical modeling approaches and tools have already been developed under the A2C2 program for designing mission-tailored organizations and processes optimized for superior performance, and for model-driven assessment of proposed designs to determine the performance envelop, robustness to unpredicted developments, and process bottlenecks and critical areas; e.g., (Y.Levchuk et al., 2007) (Meirina et al., 2008) (Sager et al., 2007) (Y.Levchuk et al., 2006) (G.Levchuk et al., 2004) (Tu et al., 2004) (Y.Levchuk 2003). This modeling approach has not yet been operationally applied, however. This paper presents the application of the A2C2 modeling approach to challenges associated with designing, integrating, and staffing flexible maritime headquarters (MHQs) and concomitant maritime operations centers (MOC) consisting of component commands, numbered fleets and Navy principal headquarters to perform normal and routine daily operations, and when designated, to function as the Navy component to a joint force, a functional maritime component or a joint task force headquarters. It presents a dynamic model of the MHQ with MOC that instantiates computational methods for testing and refining the MHQ with MOC architecture. Our approach converts the static MHQ with MOC architecture into a dynamic model, and uses the resultant dynamic model to test the capacity limits of the MHQ with MOC staffing plan, and to analyze the flow of information products between processes. It allows for a systematic and broad analysis that can be used to support accreditation, training, and refinement of MHQ with MOC structure and processes.

Outline of MHQ with MOC Dynamic Model and its Analysis Capabilities

In this paper, we present the results of applying the dynamic model of the MHQ with MOC, being developed by Aptima, Inc. for the U.S. Second Fleet. Aptima’s mission for the Second Fleet is to develop, demonstrate, and recommend computational methods of testing and refining the MHQ with MOC architecture. During the first phase of this mission, which was executed in approximately eight weeks (October and November, 2007), Aptima converted the static MHQ with MOC architecture into a dynamic model, then used this initial model to test the capacity limits of the MHQ with MOC staffing plan, and to analyze the flow of information products between processes. Aptima has also developed recommendations for future dynamic modeling in support of accreditation, training, and refinement of MHQ with MOC structure and processes.

Model Layers, Scope, and Resolution.

Our proposed integrated MHQ with MOC dynamic model represent the existing blueprint of the MHQ with MOC architecture, but is reconfigurable to easily account for possible future changes. It represents the key dimensions of the MHQ with MOC architecture, while providing the drill-down capabilities to navigate between the MHQ with MOC architectural layers, in order to appropriately focus the model scope and resolution, tailor its structural composition, review external interactions, trace input-output process and information flows, examine goal-driven and event-driven courses of action (COA), and map various scenarios onto the process-driven lifecycle. The model focuses on several aspects of the MHQ with MOC:

(i) Mission expectations; (ii) Likely determinants of mission success (performance shaping mechanisms); (iii) Strategy; (iv) Structure; (v) Information flow lifecycles and tangible MHQ with MOC products; (vi) Available technologies and their effects; (vii) Personnel and training requirements.

The MHQ with MOC model explicitly represents the top-down MHQ with MOC organizational behavior drivers – e.g., strategic objectives in the theater – that drive strategy development, goals selection, and are translated into the strategic and than into the tactical tasking. The model explicates the multi-resolution mission planning process, whereas outputs from the higher levels of command serve as inputs to the lower level planning that also account for the specific context and detail (not known at the higher C2 levels or during the time of higher-level planning). The model quantifies how at each level the operational plans are adopted to account for the detailed information available, and how the feedback loop with the higher elements of the headquarters is used to adjust the strategic objectives and plans. The model also addresses the MHQ with MOC requirements for inter-service coordination and interoperability (between Navy and Air Force, Army, Special Ops etc.). Finally, the model explicitly represents the bottom-up MHQ with MOC organizational behavior drivers, such as expectations for events and environmental conditions, own force availability versus enemy posture, neutrals and their various objectives, needs, and impact, etc..

Our proposed integrated MHQ with MOC dynamic model quantifies the three types of behaviors characteristic of the MHQ with MOC:

1. Process-driven (i.e., periodic, routine) behaviors and processes (e.g., Maritime Tasking Order development cycle) → Lifecycle rhythm.
2. Goal-driven (i.e., pre-planned, synchronized for effect, linked to mission objectives and predecessor requirements) → Performance expectations and assessment (e.g., % achieved).
3. Event-driven (i.e., reactive, contingency-avoidance and opportunistic) behaviors and processes (e.g., time-critical targeting) → Critical events and typical event-driven COA.

To appropriately model the MHQ with MOC mission, we integrate several modeling approaches previously developed under the A2C2 program, such as: (1) Goal-driven Mission modeling (Meirina et al., 2008); (2) Event-driven Mission modeling (Tu et al., 2004) (Y.Levchuk 2003); and (3) Process-driven Mission modeling (G.Levchuk et al., 2004). For example, we employ the Goal-Function Roadmap (GFR; Figures 1) that supplies the “missing link” between influence models of effects propagation and optimization models for resource allocation and scheduling. GFR encodes the (intended or actual) evolution of the environment from applying “functions” (COA) directed at achieving organizational goals, and encodes organizational strategies and COA. It emphasizes *functional control* of the battlespace over its physical occupation to help generate effective combat power synchronized at the proper time and place. We will utilize the GFR model to quantify how MHQ with MOC translates the information inputs into the strategies it develops.

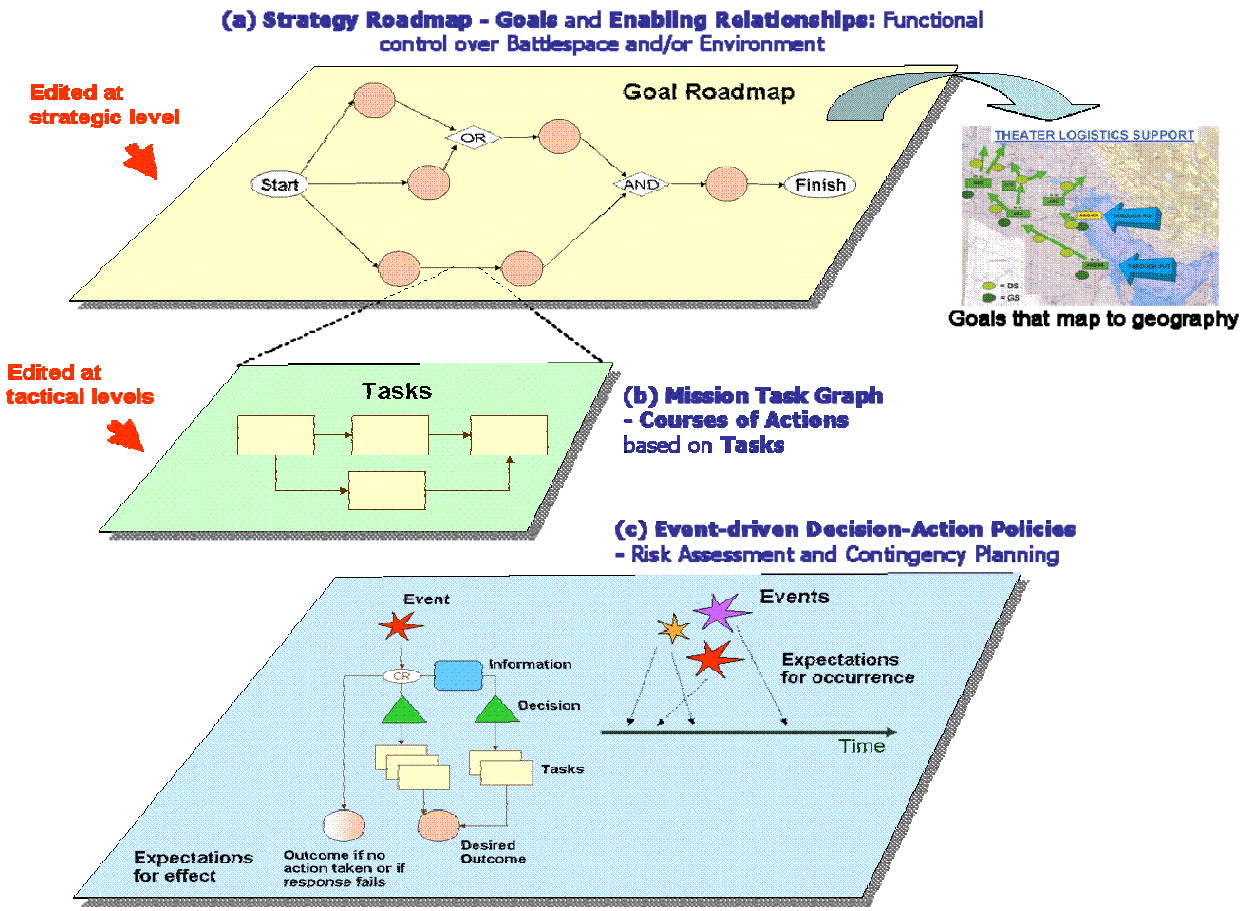

Figure 1. Mission structure in a Goal-Task model.

Our MHQ with MOC dynamic model explicitly identifies and formalize the MHQ with MOC dynamic workflow processes (including communication, command, resource control, information propagation, fusion and execution) and constraints of the organizational structure and strategy (as notionally illustrated in Figures 2 through 4 below).

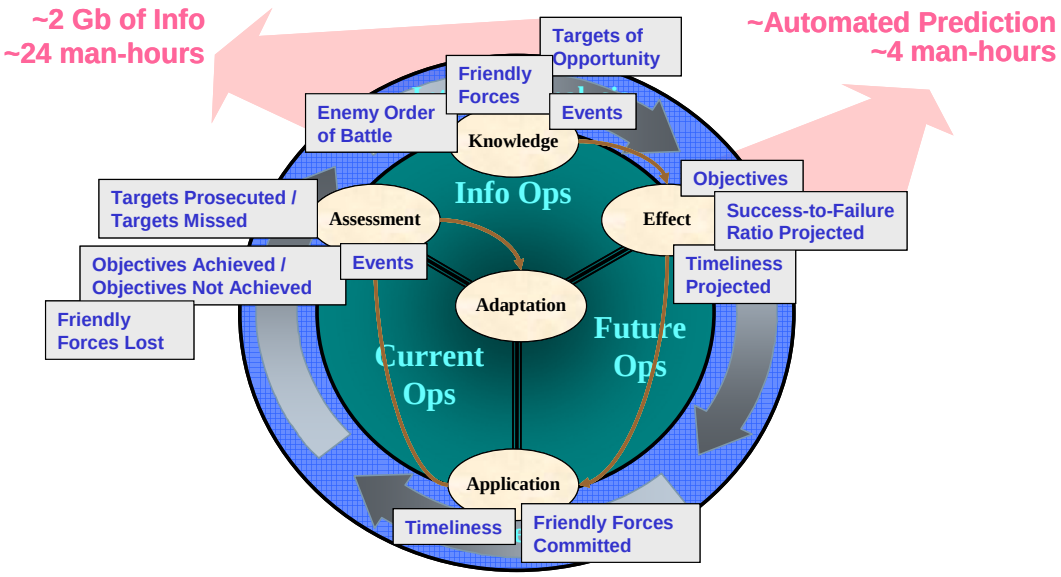

Figure 2. MHQ with MOC processes, products, and requirements - Illustration.

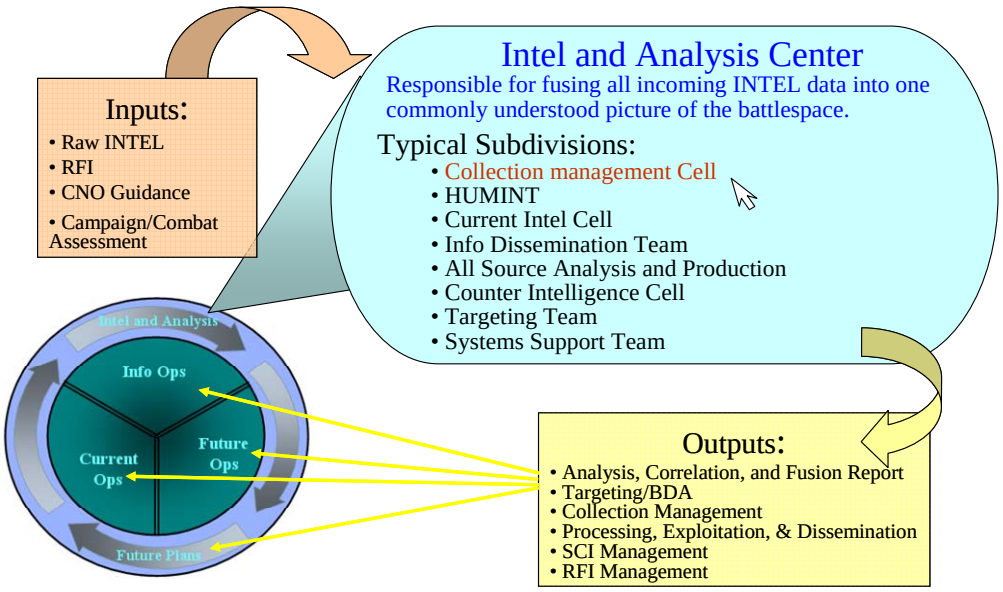

Figure 3. Information and Control Flow to/from Intel and Analysis Center of the MHQ with MOC (a fragment).

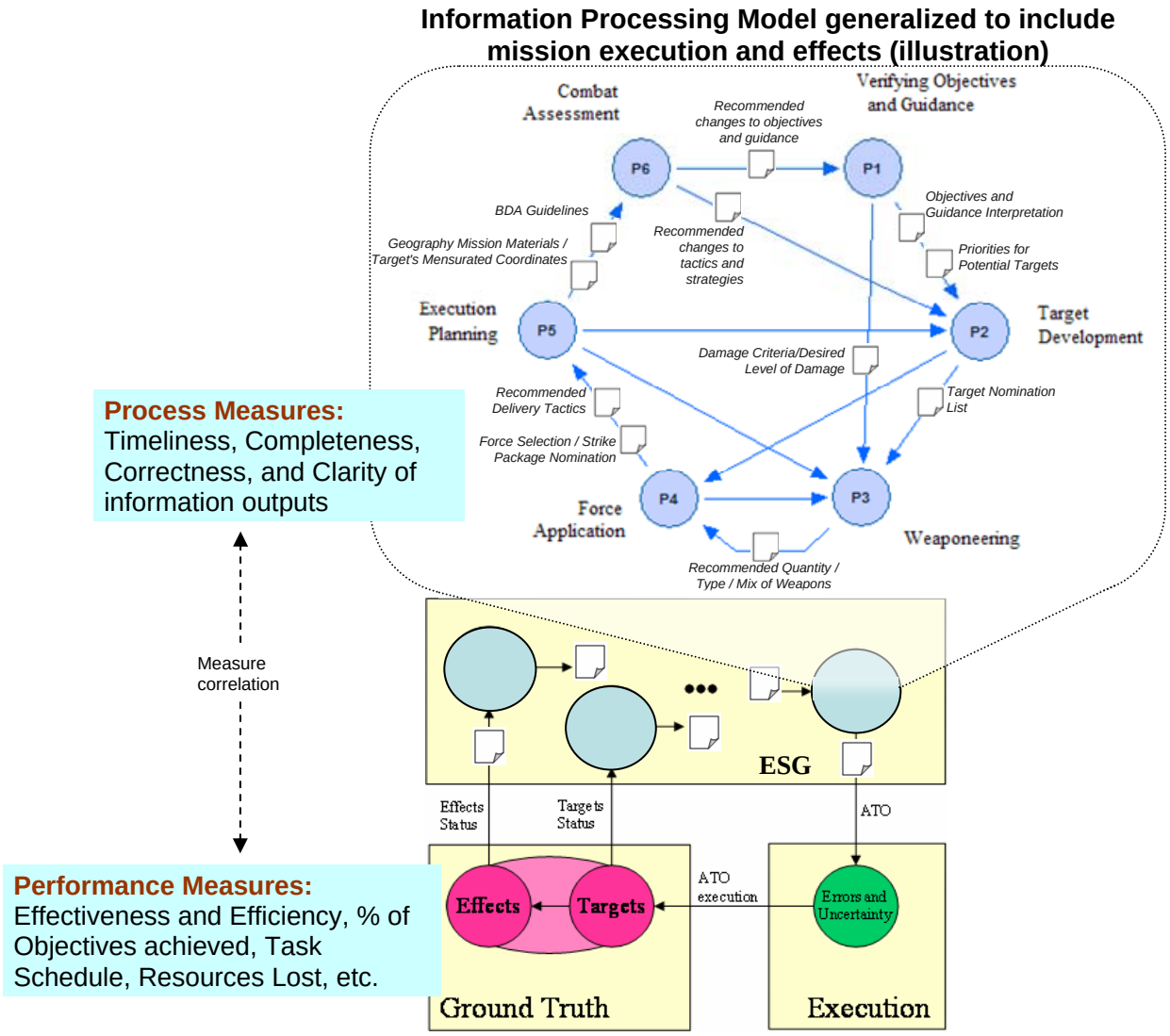

Figure 4. Organizational Process Model (a portion of) - Illustration.

Model Capabilities

The MHQ with MOC dynamic model can be used to conduct:

- **Assessment:** Qualitative analysis and assessment of the MHQ with MOC architecture, along with a diagnosis of problematic areas and suggestions for potential organizational remedies.
- **Comparison:** Comparative modeling of MHQ with MOC architectural alternatives in order to provide a quantitative assessment of performance pay-offs.
- **Optimization:** Optimization-based design and simulation of alternative C2 architectures and quantitative assessment of performance pay-offs.

The model can be also used to identify the bottlenecks while suggesting methods to dynamically enhance 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.

In sections below, we illustrate the following capabilities of the proposed dynamic MHQ with MOC model:

1. Consistency Analysis of MHQ with MOC Architecture: We will illustrate a methodology to analyze the DoDAF MHQ with MOC simplified core process model for logical inconsistencies such as the use of products before their generation, generation of products not used, and use of products not generated by MHQ with MOC. This will improve correctness of the MHQ with MOC model, and thus enhance its credibility for fleet review activities, such as tabletop exercises.
2. Manpower Analysis: We will illustrate a methodology to amend the MHQ with MOC model data with first order estimates of manning requirements for a given level of throughput (e.g., a Normal Operations use case or scenario). Thus, we will present the implementation and application of a dynamic MHQ with MOC model to assess potential MHQ with MOC manning requirements.

Other model capabilities potentially beneficial to the MHQ with MOC architecture development effort are as follows:

3. Warfighter Review Support (for MHQ with MOC tabletop exercise): One can apply a dynamic MHQ with MOC model to systematically reviewing processes and structures related to maritime security and other activities, in order to enhance the quality and timeliness of warfighter feedback and related reports, and to potentially enhance coordination of Navy efforts concerning MHQ with MOC and MDA.
4. Timing Analysis: One can apply a dynamic MHQ with MOC model generate the estimates of MHQ with MOC activity durations (i.e., for assessing the potential duration of processes individually and on aggregate; assessing bottlenecks; and time vs. quality tradeoffs). This will potentially accelerate and support the MHQ with MOC accreditation activity by developing and refining accreditation standards and measures.
5. Modeling and Support of Accreditation and Training: One can apply a dynamic MHQ with MOC model to provide MHQ with MOC with the capability to enhance accreditation and training using a dynamic model of MHQ with MOC information flow given mission requirements and capacity constraints. The MHQ with MOC accreditation team can apply the dynamic MHQ with MOC model to (1) specify critical metrics; (2) assess MHQ with MOC organizations on those metrics; (3) identify deficiencies in those organizations; (4) provide design/architecture recommendations to ameliorate or remove deficiencies; and (5) generate model-based training support materials to remediate those deficiencies. This will improve the efficiency and effectiveness of accreditation and training by delivering (1) an assessment report for one or more accreditation events, (2) the dynamic assessment model, (3) training products, (4) the dynamic model, draft user documentation, and a sample data set.
6. Modeling and Support of MHQ with MOC Refinement: One can apply a dynamic MHQ with MOC model to provide MHQ with MOC with the long-term capability to refine the MHQ with MOC and to provide a concise knowledge repository for warehousing lessons learned and other critical information. This capability will take the form of a dynamic model capable of predicting the effects of modifying the MHQ with MOC processes, manning, training, equipment, and organization and capable of linking and storing the empirical dynamic MHQ with MOC process and performance data in a simulation-like format for future review at varied user-defined levels of granularity. This will support continuous refinement and experimentation on MHQ with MOC by delivering (1) a reconfigurable, dynamic MHQ with MOC model, user documentation, and data sets; (2) design, execution, and analysis of a small scale experiment demonstrating the utility of this model to the Navy, validating its output, and assessing its usability; (3) application of this model for one or more extant MHQ with MOCs.

Application 1: Consistency Analysis of MHQ with MOC Architecture

We applied our dynamic MHQ with MOC model (illustrated in Figure 5) to conduct consistency analysis of the DoDAF simplified core process model for the Maritime Headquarters with Maritime Operation Centers. The analysis has focused on the tangible information products, identified as Data Objects in the DoDAF MHQ with MOC core process architecture. The Aptima team has analyzed the DoDAF MHQ with MOC model for logical inconsistencies such as the use of information products before their generation, generation of products not used, and use of products not generated by MHQ with MOC.

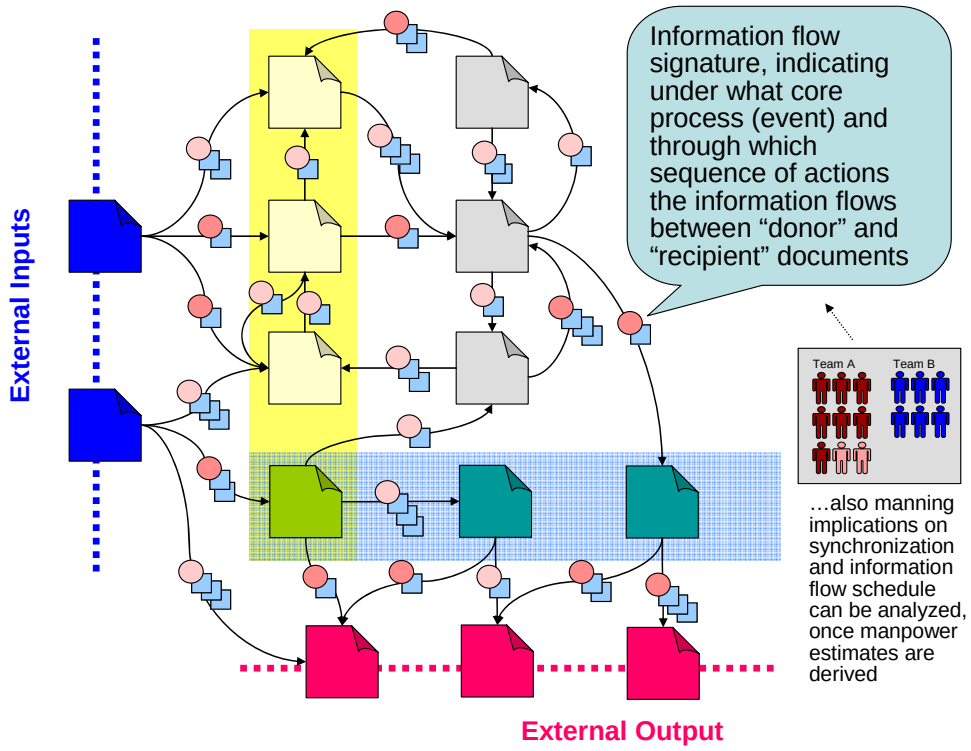

Figure 5. Information flow among data objects - illustration.

In addition to examining the Information Products within the DoDAF MHQ with MOC architecture, we also examined the MHQ with MOC core processes for whether they are linked to the tangible Information Products that capture the outputs that these core processes are tasked to generate. Explicitly identifying within the DoDAF MHQ with MOC architecture the organizational elements (potentially external to MHQ with MOC) that use the corresponding documents helps clarify the DoDAF MHQ with MOC core process model and limit potential inconsistencies.

Finally, the timing estimates about core process activities were further analyzed (via using Aptima’s dynamic MHQ with MOC model) for consistency/feasibility of resulting synchronization constraints, for

potential bottlenecks, and for potential process modifications to streamline the production of the MHQ with MOC products.

Specifically, we applied computational methods to classify the 181 data products in the 22 October 2007 version of the MHQ with MOC architecture into (1) 37 products generated and consumed by the MHQ with MOC, (2) 53 products generated by MHQ with MOC but not consumed by it, and (3) 91 products required by MHQ with MOC but not generated by it.

The analysis produced the following insights:

- Information products in categories (2) and (3) above represent (a) dependencies between the MHQ with MOC and other contributors to the Collaborative Information Environment where those products reside, or (b) errors in the MHQ with MOC model. ***We recommended that dependencies be documented in future iterations of the model. Errors should be corrected, of course.***

The list of suspect information products (1 & 2) is documented in Aptima’s report of 5 December 2007 and is available on request. This analysis can be rapidly updated with more current data as required.

Application 2: Preliminary Manpower Analysis

We applied our dynamic MHQ with MOC model to analyze the operational capacity of the MHQ with MOC in normal and routine operations, given MHQ with MOC processes, manning estimates per process, and process duration estimates (derived from the interviews with several Navy Commanders).

Data import: To accomplish this, Aptima dynamic MHQ with MOC model has automatically imported the DoDAF data (processes, activities, data objects, organizational units, pools, and events from the DoDAF dataset of 22 October 2007), output diagrams of user-specified subsets of these data (see Figure 6), and input data into a dynamic model of MHQ with MOC processes. These data were supplemented with the duration and manning estimates obtained from interviews with Subject matter Experts (Navy Commanders). New versions of the architecture can be imported automatically using this same process in the future.

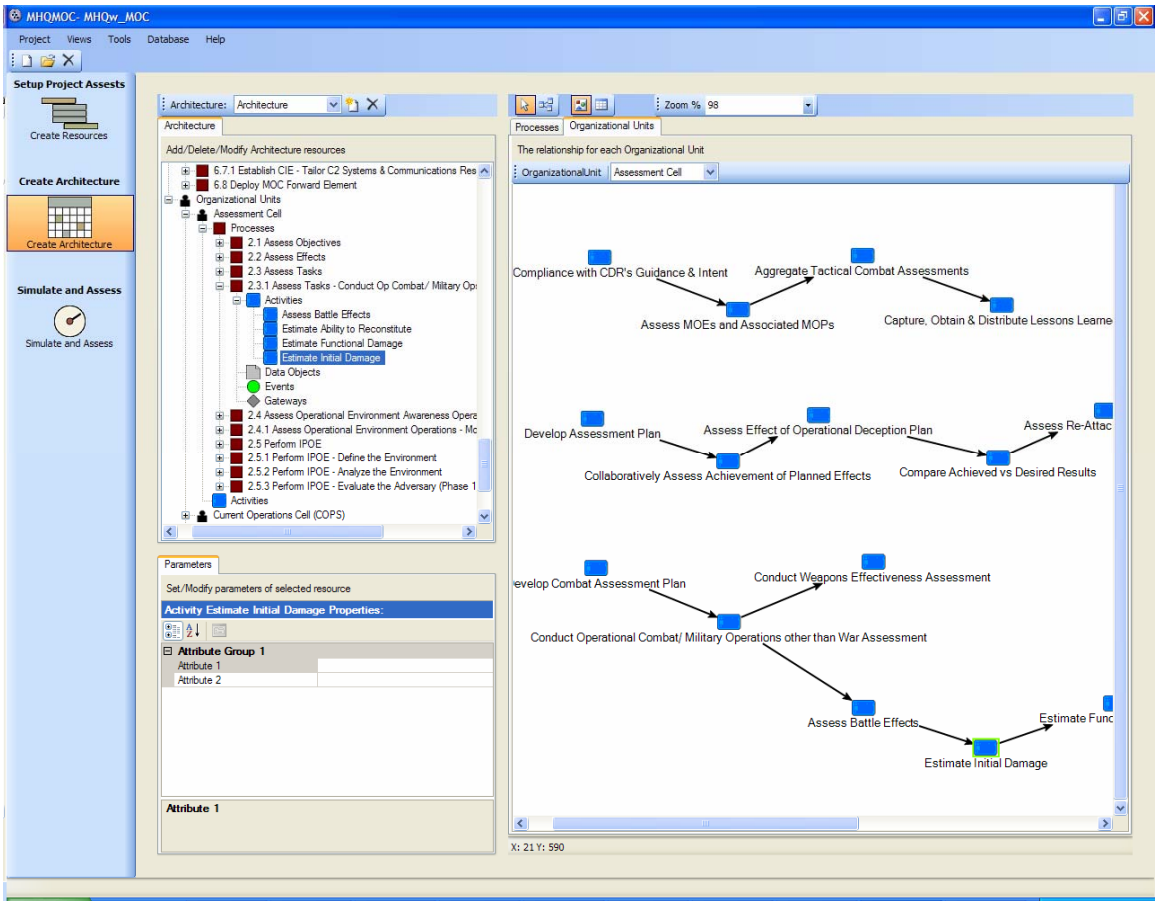

Figure 6: MHQ with MOC architecture user-specified views of the processes and the subordinate activities of each organizational unit. Here, we display only the Assessment Cell’s processes and subordinate activities 2.1 through 2.5.3.

Dynamic modeling: Aptima’s dynamic model (see Figure 7) simulates the execution of processes across MHQ with MOC. It presents the user with these features:

- A line graph (upper left) presents the manning required against the manning available to be utilized over all processes;
- A GANTT chart (lower left) represents the stress imposed on each process over time due to conflicts between requirements for manning and the availability of personnel to fulfill them. The stress states are
    - *Low stress* (blue): Required manpower is < 80% of available manpower)
    - *Medium stress* (yellow): Required manpower is 80-120% of available manpower)
    - *High stress* (red): Required manpower is >120% of available manpower)
- A control (upper right) enables users to select among three analyses of potential manning shortages. These analyses concern: (1) static manning requirements, (2) demands imposed by concurrent execution of multiple processes, and (3) the propagation of performance problems as inaccurate or stale information percolates through MHQ with MOC processes.

- A line graph and GANTT chart (middle right, yellow area) represents the performance of a user-specified organizational unit of interest at a user-specified manning level. The line graph contrasts the manning requirements with manning availability from the unit. The GANTT chart represents the timing of processes executed by the unit.
- A line graph (lower right) represents the proportion of MHQ with MOC staff who are idle, or who are in units experiencing low, medium, or high stress due to process manning requirements that exceed available manning.

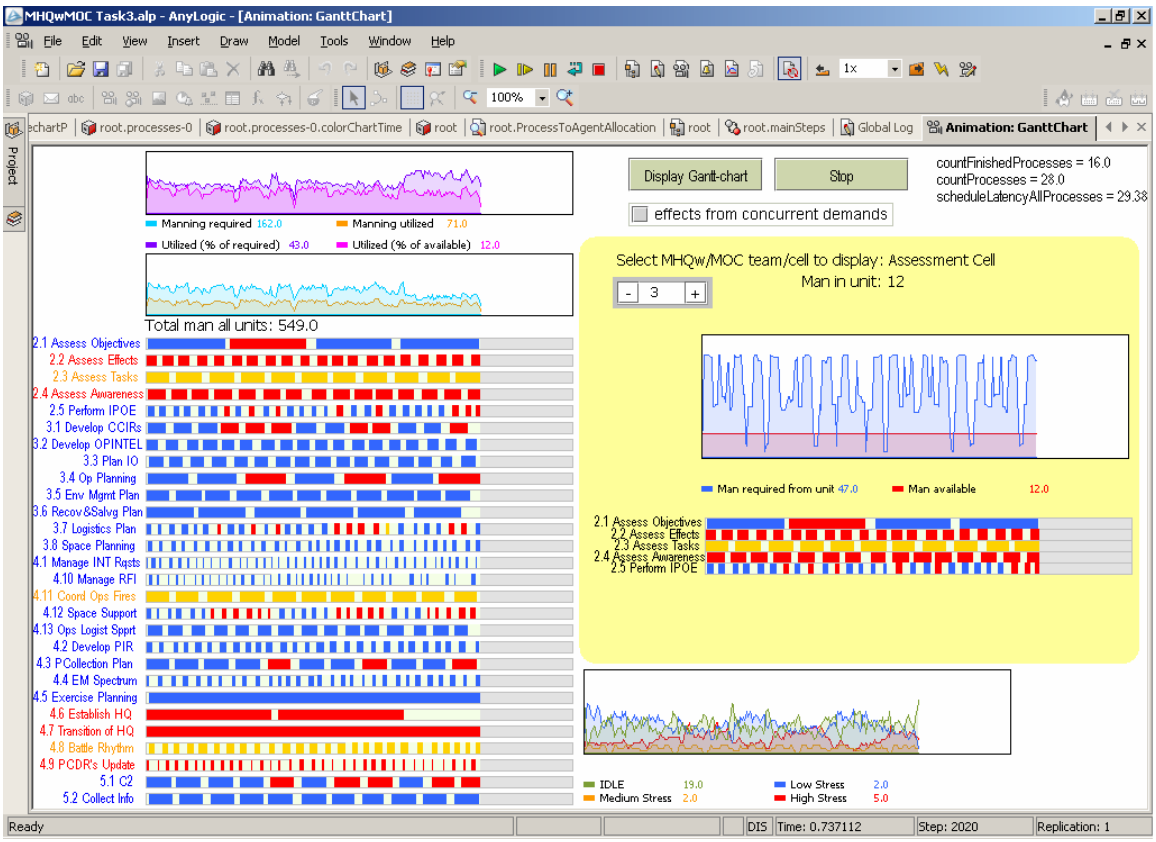

Figure 7: Dynamic model of MHQ with MOC displays manning requirements and utilization for all units over a two week time period (left), and a test of manning for a specific unit (right). Red, yellow, and blue bars in the GANTT charts represent the amount of stress (high, medium, or low, respectively) due to manning shortages.

Analyses conducted using this model can help the design team to identify processes that require more manning than is available, diagnose the conditions that trigger manning deficiencies (see findings below), and test new manning solutions.

Such analyses are important for two reasons. First, inadequate manning may drive the MHQ with MOC to apply several undesirable coping strategies. The MHQ with MOC teams can (a) delay some of the processes/activities; (b) base their analysis on partial, inaccurate, or stale information; or (c) circumvent some of the (less critical) information processing steps. These three strategies propagate time pressure and/or inaccuracy to other MHQ with MOC processes, activities, and their information products. Second,

these analyses can identify instances in which staff may be idle and those in which staff may be over-tasked; these are potential cases of inefficiency and ineffectiveness, respectively.

Our analysis of this data set produced the following insights. (We emphasize that analysis of more recent data sets may show that some of these issues are resolved.)

- *Manning requirements often exceed available manning for certain units*: Two units and MHQ Commander are highly vulnerable to overload, typically because timely execution of processes for which they are responsible requires more staff than these units have available. These MHQ w/ MOC entities are: MHQ Commander, MHQ Command Element, and the Assessment Cell. ***We recommended that the design team focus on these units as they design plans and policies for supplementing units from shared support staff, other units with similar expertise, or idle MOCs[1]. In addition, we recommended that the design team define operational metrics of efficiency and effectiveness that indicate when MHQ with MOC should implement backup policies.***
- *Specific processes are prone to high stress:* 5 processes are frequently prone to high stress (manning requirements are more than 120% of available manning). These processes are: 2.2 Assess Effects, 2.4 Assess Awareness, 4.6 Establish HQ, 4.7 Transition of HQ, and 4.9 PCDR's Update. Seven more processes are occasionally prone to high stress because of simultaneous execution of other processes by their responsible units. These processes are: 2.5 Perform IPOE, 3.1 Develop CCIRs, 3.4 Op Planning, 3.7 Logistics Planning, 4.12 Space Support, 4.3 P Collection Plan, and 5.1 Command and Control. The number of stressed processes can increase as the initial impact of process delays or inaccurate execution propagates through the MHQ with MOC. ***We recommended that the design team examine these processes – particularly those that a single team must execute simultaneously – with an eye towards streamlining the activities within them and the allocation of activities. We recommended that the design team focus operational assessment and training on those processes and their activities.***
- *Inaccuracy propagation*: We have assessed how staffing shortfalls delay or degrade information products, and how these effects propagate through the Collaborative Information Environment. Twenty-four information products are particularly sensitive in this respect. They are: Assessment Plans, Assigned Effects, COP, Desired Effects, Effects Assessment, Feedback, Mission, MOEs-Indicators/MOPs, Updated IPOE Product Info, Approved Collection Plan, Battlespace Awareness Operational Assessment, Fullfilled RFI/ CR, ISR Collection Plan, JFC RFI, Joint PIRs, MOEs-Indicators/MOPs, Posted CCIRs, Approved Mission Statement, Approved Planning Guidance, Commander's Intent, Draft Planning Guidance, Posted Planning Guidance, Priority of Effort, and Shaped Guidance. ***We recommended that the design team define methods of rapidly assessing the quality of these (and other) information products in the Collaborative Information Environment. Information product assessment can be heavily automated by applying business rules (concerning the completeness and timeliness of products, for example) and statistical language analysis technologies that identify coverage of topics or issues.***

These findings should be updated using the most recent MHQ with MOC data sets. Additional analyses can be performed.

[1] Three issues to consider in designing manning backup plans are the capability of backup staff (their knowledge of the mission at hand, skills, and technologies), availability (competition from current workload), and accessibility (the ease of coordinating with them).

Conclusions

This paper describes a dynamic MHQ with MOC model to examine flexible Navy MHQs as an option for how the US Navy can better meet the needs of the national military command structure at the operational level of war. The proposed model offers several key capabilities potentially beneficial to the MHQ with MOC architecture development effort, as it automates: (a) Consistency Analysis of MHQ with MOC Architecture; (b) Manpower and Timing Analysis; (c) Support for MHQ with MOC tabletop exercise; (d) Modeling and Support of Accreditation and Training; and (e) Modeling and Support of MHQ with MOC Refinement.

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