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Model Path Analysis as a Basis for Evaluating Command and Control (C2) Workflow

Topic 6: Modeling and Simulation

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Abstract

This paper presents the results of a Johns Hopkins University Applied Physics Laboratory (JHU/APL) C2 evaluation project sponsored under Navy Sea Trial/Sea Strike. The project supports improved planning and execution at the Operational Level of War by modeling targeting processes used in the Maritime Operations Centers (MOCs) during joint operations. The modeling framework consists of the data, systems, and networks required for targeting, the role players, represented by organizational swim lanes that perform the work, and the Find, Fix, Track, Target, Engage, and Assess (F2T2EA) functional swim lanes representing the phases of the targeting process. Each model is decomposed into a series of processes linked by data flows, i.e. paths, representing a thread of work performed during prosecution of a dynamic or deliberate target. The time and resources needed to complete the work are captured for each process during the modeling effort. Model vetting and validation are achieved by analyzing each path. Once vetted and validated, each path is stored in a path library for later comparison and analysis. During experimentation, workflow paths are constructed dynamically and compared against paths in the library as a basis for evaluation targeting workflow performance.

1. INTRODUCTION

1.1 Background

The global Maritime Operations Center (MOC) initiative is the Navy's #1 priority for improving planning and execution at the Operational Level of War. MOC focuses on improving the Navy's operational level Command and Control capabilities through a series of globally networked MOCs including five full MOCs and four tailored MOCs. The Navy has also created two developmental MOCs (MOC-X and MOC-T) which focus on experimentation and training, respectively. Significant technical challenges exist in the development of MOCs in the area of Force Application (FA)/Fires due to the need for rapid responsiveness with joint integrated effects in the dynamic environment of many of the Navy's current and planned missions.

The MOC Concept of Operations (CONOPS) calls for the use of standardized processes and methods by all globally networked MOCs. The CONOPS focuses on providing common methods by which different Maritime Headquarter (MHQ) staffs may evolve toward standardized processes for assessing, planning, and executing actions at the operational level of war. By conforming to this CONOPS, operational-level staffs may achieve organizational flexibility to transition between various command roles and enhance global networking among Navy organizations.

As a step towards implementing the CONOPS, the US Fleet Forces Command's (USFF) Maritime Operations Center Project Team (MOCPT) located at Second Fleet is developing/augmenting a structured decomposition of its Force Application (FA)/Fires Command and Control (C2) planning, execution, and forecasting processes with the goal of representing those processes via a formalized model and simulation (M&S). That M&S will be used to support "what-if" analysis for process improvement and the translation of processes into executable workflow. The MOCPT plans to focus process and workflow development on three critical areas, which include: Dynamic Targeting, Deliberate Targeting, and Joint Target List development. It also plans to develop a prototype Maritime Collaborative Information Environment (CIE) to facilitate MOC-to-MOC collaboration and collaboration among MOCs with other joint Maritime partners. The workflow from each targeting area will be incorporated into the CIE.

This paper presents an approach proposed by the Johns Hopkins University Applied Physics Laboratory (JHU/APL) for evaluating C2 in a maritime domain via a project sponsored under Navy Sea Trial/Sea Strike. The project supports improved planning and execution at the Operational Level of War by modeling targeting processes used in the Maritime Operations Centers (MOCs) during joint operations. The modeling framework consists of the data, systems, and networks required for targeting, the role players, represented by organizational swim lanes that perform the work, and the Find, Fix, Track, Target, Engage, and Assess (F2T2EA) functional swim lanes representing the phases of the targeting process. Each model is decomposed into a series of processes linked by data flows, i.e. paths, representing a thread of work performed during prosecution of a dynamic or deliberate target. The time and resources needed to complete the work are captured for each process during the modeling effort. Model vetting and validation are achieved by analyzing each path. Once vetted and validated, each path is stored in a path library for later comparison and analysis. During future experimentation, workflow paths will be constructed dynamically and compared against paths stored in the library as a basis for evaluation targeting workflow performance.

1.2 Scope

The scope of this paper includes a brief description of the modeling approach used for this project referred to as the Multi-resolution Modeling Evaluation Framework (MRMEF), which is more fully described in the references (1, 2). It discusses workflow modeling regarding one portion of the targeting process that we addressed so far in this year's research, which has focused on the dynamic targeting process. Finally, the paper presents an approach for how we plan to use the workflow pathways within the model to evaluate targeting timing and workflow performance.

1.3 Net-centric C2 Evaluation Description

Several key elements, listed below, are considered to be significant enablers for the successful evaluation of net-centric C2. Those elements are described in detail in the following paragraphs.

- Multi-resolution Modeling Evaluation Framework (MRMEF)
- Workflow Modeling
- Workflow Evaluation

1.3.1 Multi-resolution Modeling Evaluation Framework (MRMEF)

The MRMEF was developed to serve as our foundational basis for evaluating net-centric C2. It utilizes constructive, virtual, and live simulations and hardware-, software-, and humans-in-the-loop, where appropriate, to support that evaluation. Multi-resolution Modeling (MRM) has many advantages over more traditional approaches for analyzing C2. It has been successful because it has the characteristics needed to solve difficult analysis problems by integrating information achieved with high-fidelity models and generalizing the results and implications via a low-resolution model (Reference 3). An overview of the MRMEF is shown in Figure 1. A brief summary of the MRMEF is provided in Appendix A.

1.3.2 Workflow Modeling

One of the requisite enablers for the successful analysis and evaluation of C2 and a key element of the MRMEF is the ability to decompose C2 processes in the context of a mission domain. Our research this year has focused on C2 as it applies to dynamic targeting in a maritime domain. With the assistance of subject matter experts from the Naval Warfare Development Command (NWDC), we decomposed maritime dynamic targeting into a high-level set of processes that were distributed among a two dimensional model structure in which the F2T2EA kill chain elements were deployed along the x-axis of the model and the organizational elements involved with dynamic targeting, including Subordinate Tactical Commands, The MOC's Current Operations Cell (COPS) and TLAM Fires element, Other Components, e.g. Air Force components, and the Joint Force Commander (JFC), were deployed along the y-axis. We augmented the process model by including sequential relationships among the process elements to generate a dynamic target workflow model (Figure 2).

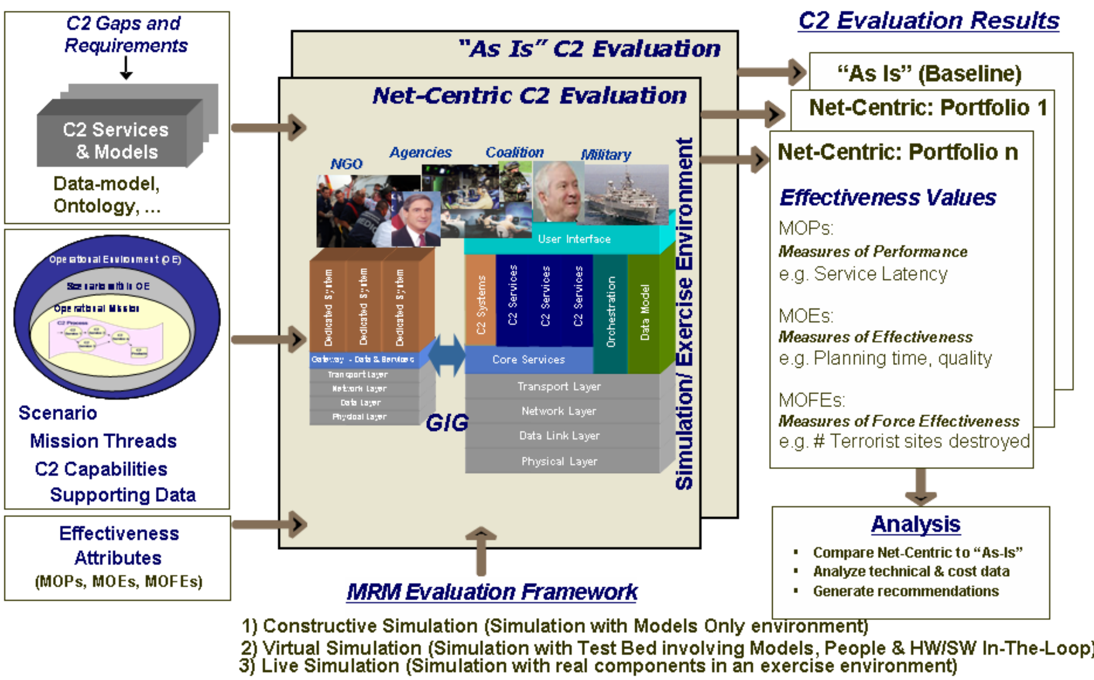

Figure 1. Multi-resolution Modeling (MRM) Evaluation Framework (MRMEF)

We are in the process of developing a simulation of the model using the Telelogic ProcessModel ™ tool, to demonstrate the flow of three types of dynamic targets through the model: Time Sensitive Targets (TST), Maritime Dynamic Targets (MDT), and Critical Component Targets (CCT). The simulation allows us to estimate the amount of work and time required by MOC staff to monitor and coordinate dynamic targeting at the operational level of war during maritime only and joint operations. The simulation supports "what-if" analysis, which allows us to change the workflow in a structured, repeatable manner by adding increased parallelism, automation, etc. to determine if those changes increase temporal and/or workload efficiency.

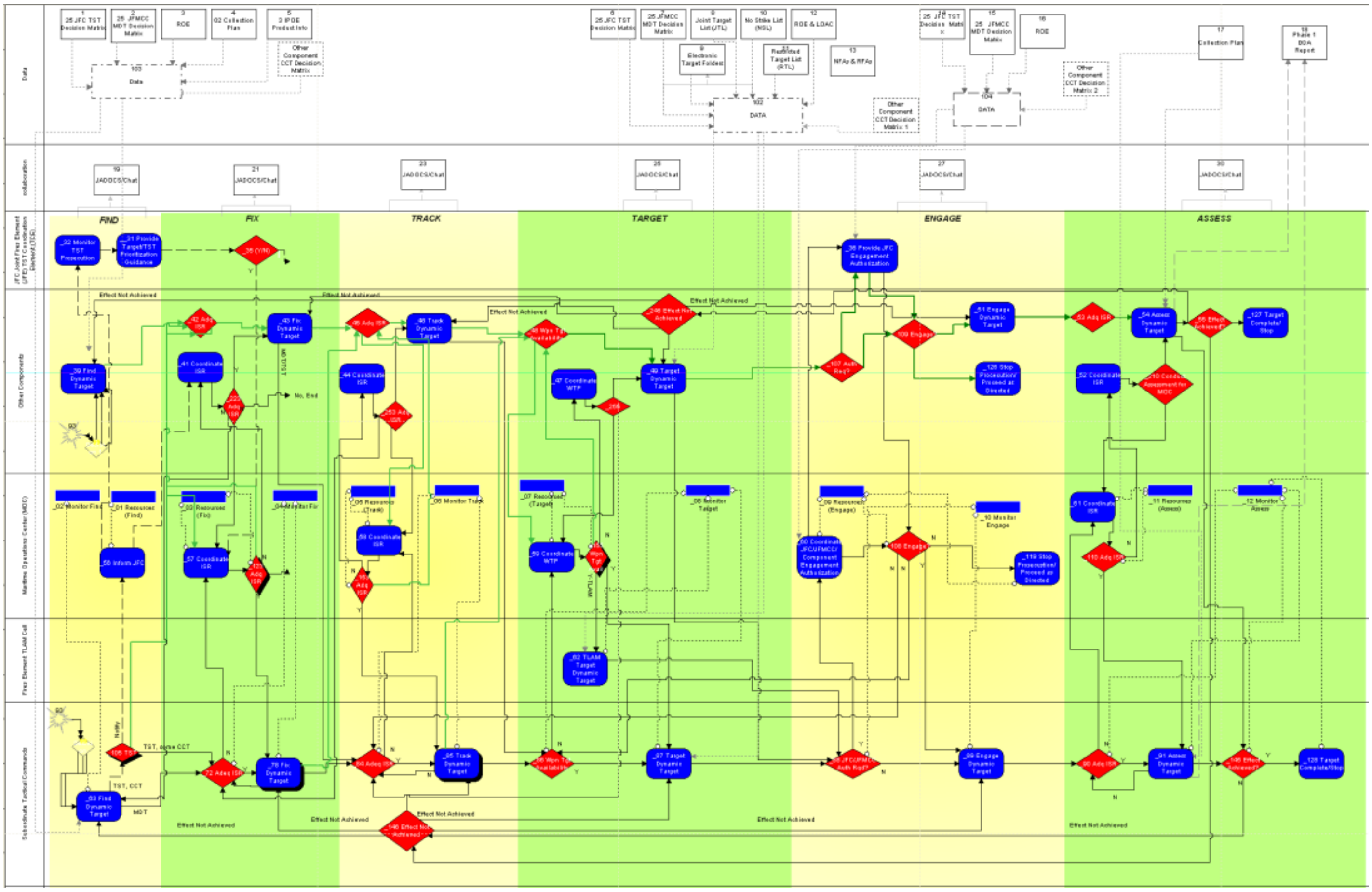

Figure 2. Dynamic Targeting Workflow Model

1.3.3 Workflow Evaluation Approach

The dynamic targeting workflow model was divided into a data area, which delivers data to and consumes data from the model, and a set of organizational and F2T2EA functional swim lanes, as described above. An initial set of workflow pathways, which represent the work of dynamic targeting for each type of dynamic target were defined in the model. Each pathway was analyzed for accuracy, timing, and resource utilization. In Figure 3, Path 1 is an iconic representation of a Maritime Dynamic Target (MDT) that is being prosecuted by a Subordinate Tactical Command (STC) with assistance by the MOC. Path 2 is a similar representation of a Time Sensitive Target (TST) that is being prosecuted by a Subordinate Tactical Command with assistance from the MOC and one of the Other Component (OC) commands. The intent is to develop a set of paths that represent the most likely 80% of the possible workflow paths that could be exercised during dynamic targeting operations. Those paths with timing and resource utilization (staff workload) estimates are then stored in a Path Pattern Library for future reference and comparison (Figure 3).

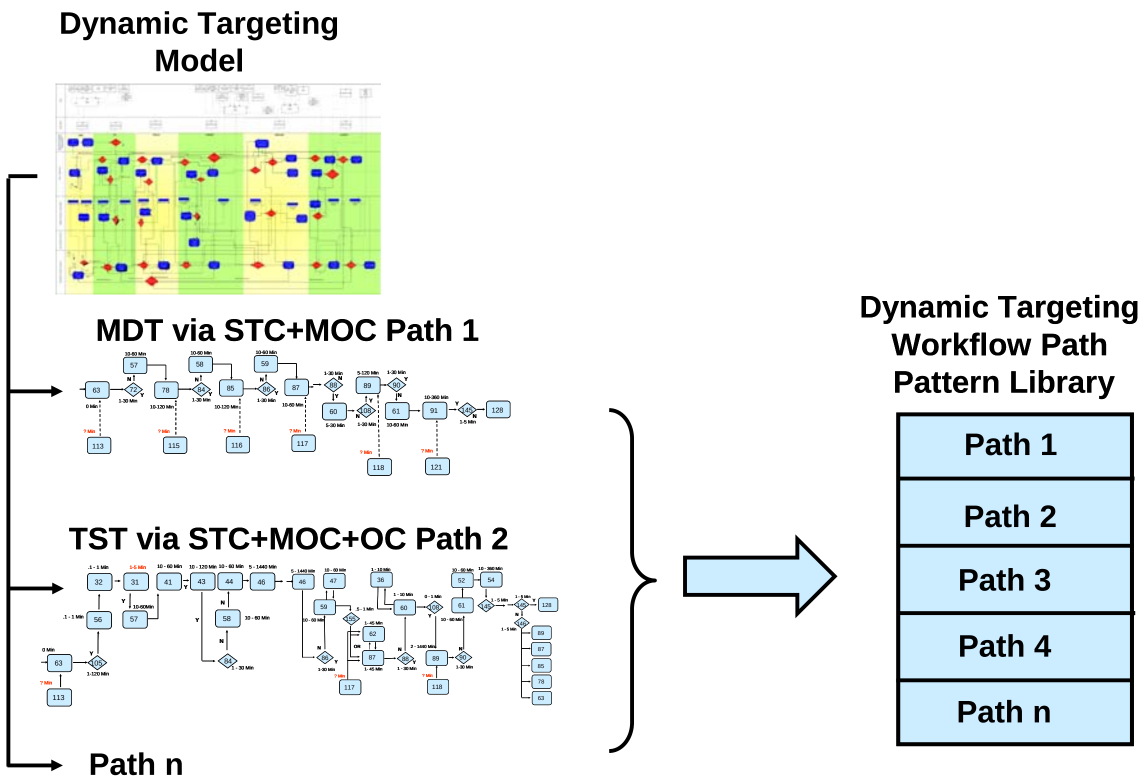

Figure 3. Dynamic Targeting Workflow Path Pattern Library

To evaluate dynamic targeting performance, we intend to construct a workflow path for each target as it is being managed in the MOC during mission execution. The sequences of processes that are being executed to manage a given target are the basis for constructing a workflow path for that target. The data that processes consume and/or produce along a given path are directly associated with the systems that support dynamic targeting. A workflow path for a given target can be constructed dynamically by monitoring those systems for process data products and the sequence in which they are generated (Figure 4).

For this approach to be valid, the following assumptions must be true:

- the processes specified in the model consume products and expose products for consumption during targeting operations, which can be monitored via systems that support those operations
- workflow products are meta-tagged with target identification and resource information, e.g. role identification of a person or a system performing the work
- during targeting operations, supporting systems can be monitored for each target being prosecuted
- a workflow path can be constructed via the use of a software agent, i.e. a Target and System Tracking Agent (TSTA) in Figure 4, for each target being prosecuted based on the products being consumed and exposed for consumption

- the TSTA has the ability to identify the path, the amount of time spent at each process node in the path, and the resource utilization, i.e. number of staff, performing the work at each node
- the TSTA also has the ability to track the status and performance of the supporting systems

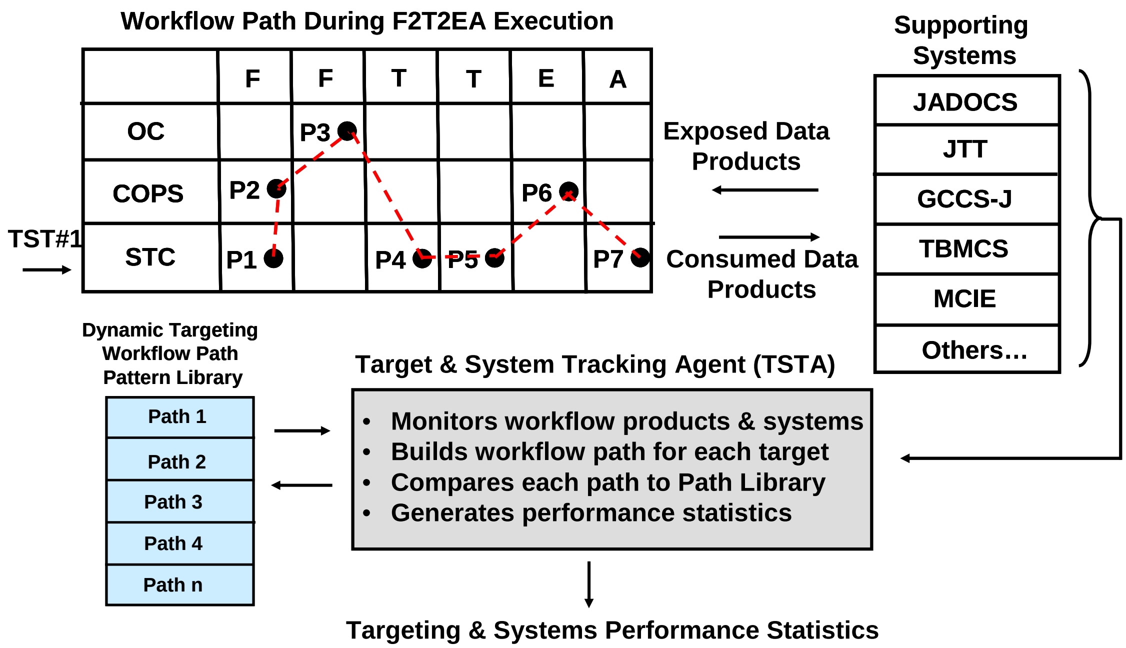

Figure 4. Dynamic Targeting Workflow Path Construction and Analysis

Once these conditional assumptions are confirmed true, the target path and its corresponding metrics are then compared against the same or a similar path in the Path Pattern Library to determine differences between the current path and the vetted historical library path regarding timing and resource utilization for each process node in the path as well as the end-to-end path for a given target. The intent is to "roll-up" the results of this analysis into an operational level of war (OLW) dashboard (Figure 5) to be used by the MOC to assess whether targeting operations for a given mission are proceeding as planned with an expected level of workload performance.

2. CONCLUSIONS

This research represents a work in progress. We are currently interacting with Fleet organizational elements responsible for MOC operations to vet these concepts. Over the next several months, we plan to develop a conceptual prototype of an OLW dashboard that provides MOC decision makers with an operational and, if required, a detailed "drilldown" view of a mission's dynamic targeting operations.

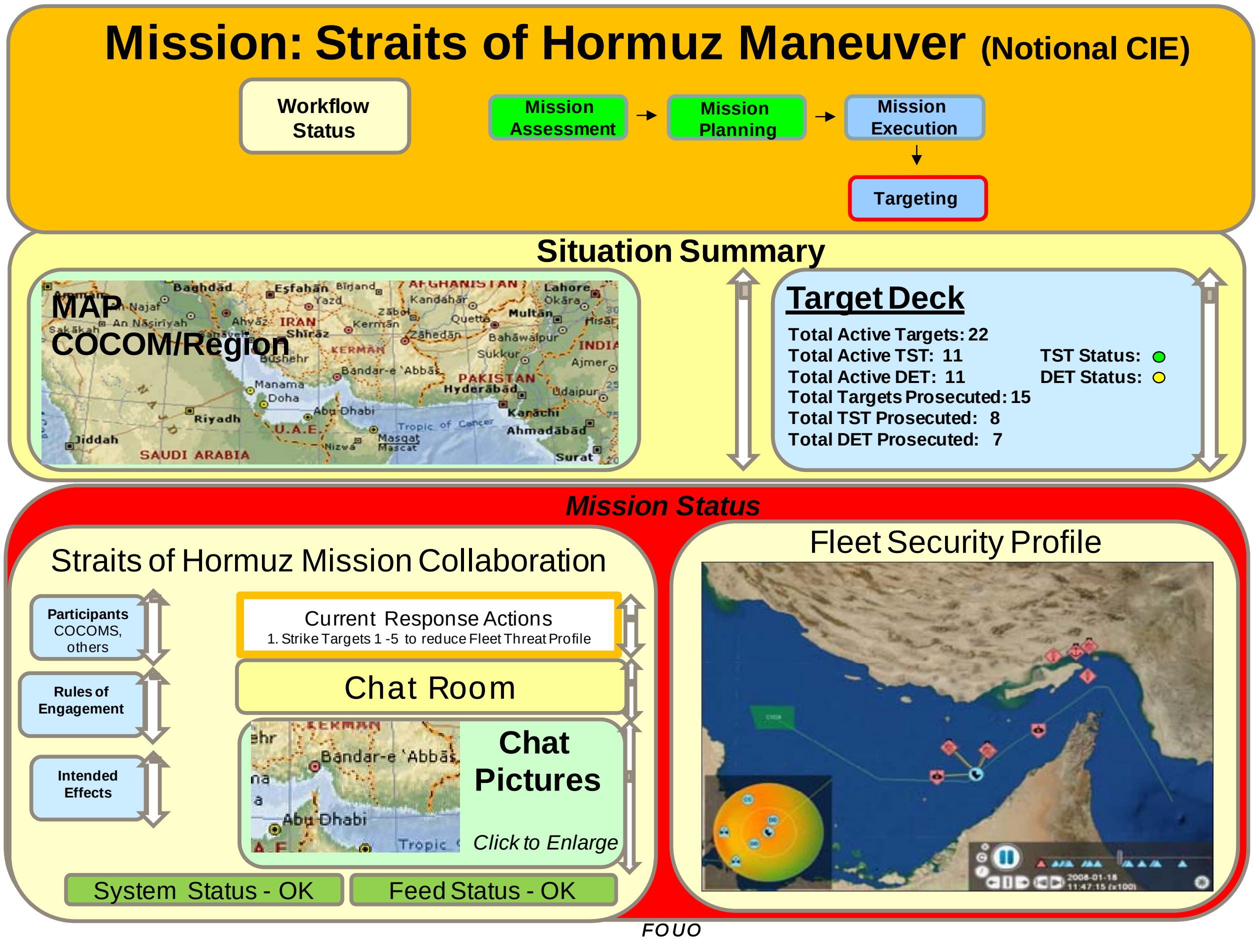

Figure 5. Notional OLW Dashboard Providing Targeting Status Information

3. REFERENCES

1. Forsythe, S.L., North, P.D., and Barnes, V.B, "Evaluation of Net-centric Command and Control via a Multi-resolution Modeling Evaluation Framework," in *10th Int. Command and Control Research and Technology Proc.*, June 2005

2. North, P.D., Forsythe, S.L., "Evaluating Net-centric Command and Control via a Multi-resolution Modeling Evaluation Framework: a FY05 IR&D Project" in *11th Int. Command and Control Research and Technology Proc.*, June 2006

3. Smith, Roger D., *Essential Techniques for Military Modeling & Simulation*, Winter Simulation Conference, 1998.

Appendix A. Multi-resolution Modeling Evaluation Framework

A significant challenge to evaluating net-centric C2 is to develop an approach that facilitates evaluation of C2 capabilities in a complex hybrid architecture environment. Our approach, referred to as the Multi-resolution Modeling Evaluation Framework (MRMEF), uses constructive, virtual, and live simulations and hardware-, software-, and humans-in-the-loop where appropriate. Multi-resolution Modeling (MRM) has many advantages that are needed to analyze C2. MRM has been successful because it has the characteristics needed to solve difficult analysis problems by integrating information achieved with high-fidelity models and generalizing the results and implications via a low-resolution model (Reference 3). An overview of the MRMEF is shown in Figure A-1.

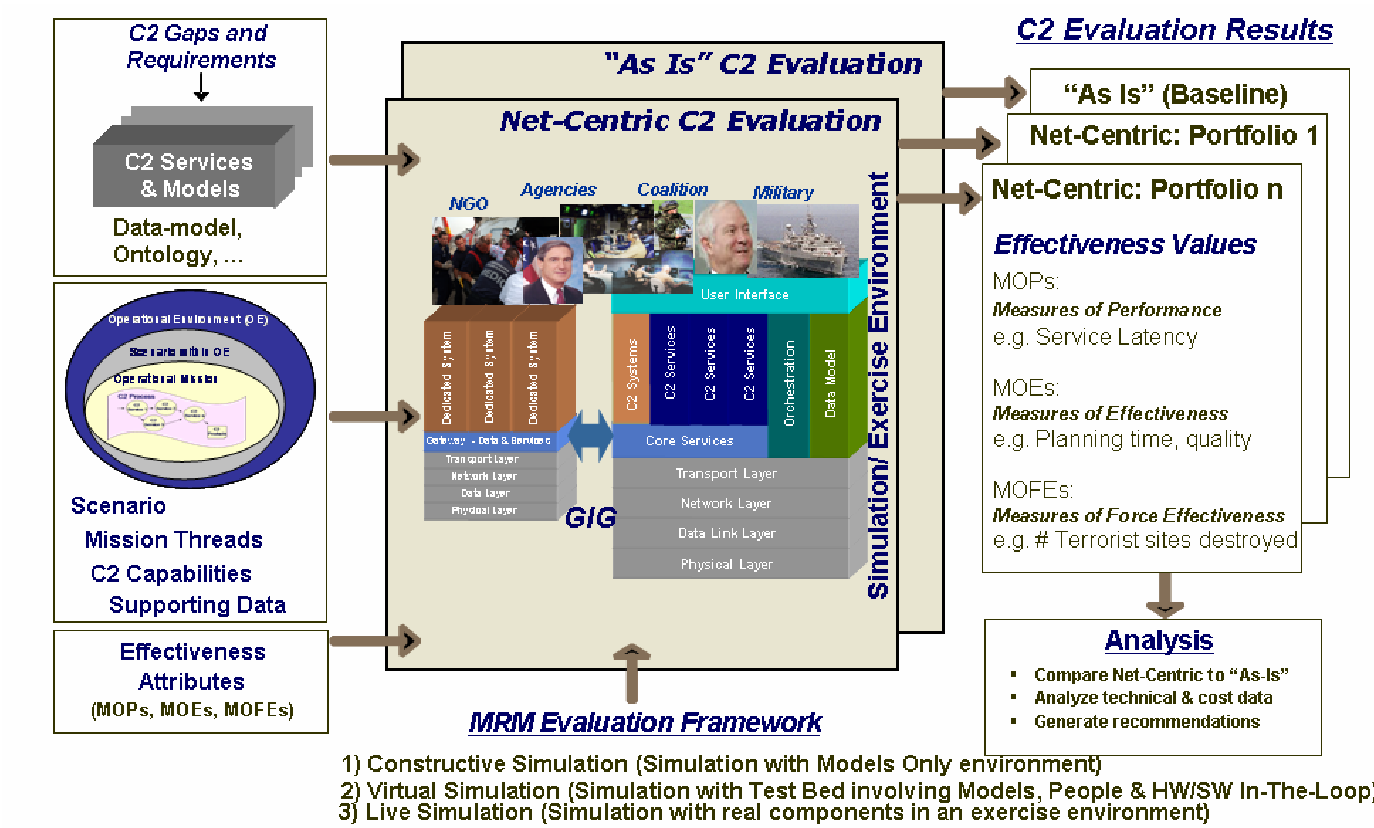

Figure A-1. Multi-resolution Modeling Evaluation Framework

The simulation/exercise environment of the MRMEF contains the entire hardware and software infrastructure needed to support the constructive, virtual, and live simulations of the framework.

The "cube" portion of the diagram represents real or modeled C2 or C2-related components. Inputs to the framework consist of a set of C2 services to be evaluated; the services were derived from C2 gap analysis, C2 requirements definition, data modeling, and so forth. A scenario defines the operational mission, i.e., the problem to be solved, and serves as the contextual basis for the evaluation. Measures to assess performance and effectiveness are defined based on the context of the scenario. Evaluation of C2 capabilities is accomplished by executing the "cube" components, (real, simulated, or a combination of real and simulated) in the context of the appropriate MRMEF simulation/exercise environment. C2 evaluation results are generated as a result of executing the scenario.

An "as-is" evaluation is accomplished by developing a scenario-based model of the "as-is" process to be evaluated and executing that model as a constructive simulation within the framework. A second model is developed representing the net-centric equivalent of that process. The net-centric process, which may involve a hybrid of legacy and net-centric components, both real and simulated, is executed within the framework as a virtual simulation. When real components are used, they are interfaced with the simulation via a separate test bed, which allows the real components to interact as necessary with modeled components. The resulting simulation executes at a higher level of fidelity or resolution overall. The framework also encompasses a very high-fidelity live simulation executed outside the laboratory environment with real players and components.

Analysis consists of comparing the "net-centric" with the "as-is" results and analyzing the differences to determine, both qualitatively and quantitatively, whether the application of net-centric principles and components to an existing process has enhanced or degraded engineering, command and control, or mission-level performance as measured via MoPs, MoEs, and MoFEs, respectively. If cost information about deploying and maintaining net-centric C2 capabilities is available or estimated, those data can be combined with the technical evaluation results to help guide future architecture, acquisition, and deployment decisions.