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Adapting C2 to the 21st Century

# Use of an Executable Workflow Model To Evaluate C2 Processes

Network-centric Metrics
C2 Modeling and Simulation
C2 Experimentation

**Draft**

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## Abstract

This paper presents interim results of a Johns Hopkins University Applied Physics Laboratory (JHU/APL) multi-year command and control (C2) evaluation project. The purpose of the project is to develop methods for evaluating whether or not the application of net-centric principles to command and control improves the effectiveness and efficiency of C2. This year's effort focuses on the development of a model to evaluate execution of a global strike process. The model characterizes the activities and associated capabilities of that process including activity completion times. It represents the sequencing relationships among the process elements in the form of a workflow. Execution of the model drives a visual representation of workflow completion status, which is used to synchronize the actual conduct of the global strike process by participants in response to a scenario-driven event. The model has the ability to record the amount of time required to complete the work of each workflow element and to compare those times against historic temporal execution information stored in its knowledgebase. It is postulated the executable workflow model will serve as an effective means for evaluating C2 processes.

# 1. INTRODUCTION

## 1.1 Background

This paper presents interim results of a Johns Hopkins University Applied Physics Laboratory (JHU/APL) multi-year, independent research and development (IR&D), command and control (C2) evaluation project. The purpose of the project is to develop methods, within the context of an evaluation framework referred to as the Multi-resolution Evaluation Framework (MRMEF) (References 1-2), for evaluating whether or not the application of net-centric principles to command and control improves the effectiveness and efficiency of C2. This year's effort focuses on the development of a model to evaluate execution of a global strike process. The model characterizes the activities and associated capabilities of that process including activity completion times. It represents the sequencing relationships among process elements in the form of a workflow. Execution of the model drives a visual representation of workflow execution status, which is used to synchronize the actual conduct of the global strike process by participants in response to a scenario-driven event. The model has the ability to record the amount of time required to complete the work of each workflow element and to compare those times against historic temporal execution information stored in the model's knowledgebase. It is postulated the executable workflow model will serve as an effective means for evaluating C2 processes.

## 1.2 Scope

The scope of this paper includes a brief description of the MRMEF, which is more fully described in the references cited above. It discusses the use and importance of process decomposition to the overall approach of evaluating C2 capabilities and presents a high-level example of decomposition as it applies to the global strike process. It further describes how a decomposed process can be translated into an operational workflow by applying sequencing relationships to process elements. When modeled, the executable form of that workflow can be used to drive and control the conduct of mission tasks, such as a global strike operation. The paper concludes with a description of why and how this executable workflow model approach adds value to the C2 evaluation process.

# 2. NET-CENTRIC C2 EVALUATION DESCRIPTION

This effort is focused on the development of several key elements, which are postulated to be significant enablers for the successful evaluation of net-centric C2. Those elements are listed below, graphically represented in Figure 1 and described in detail in the following paragraphs.

- Multi-resolution Modeling Evaluation Framework
- Process Decomposition and Assessment Capability
- Mission-specific Workflow Evaluation Capability
- Service-based Data Collection, Analysis, and Reporting Capability

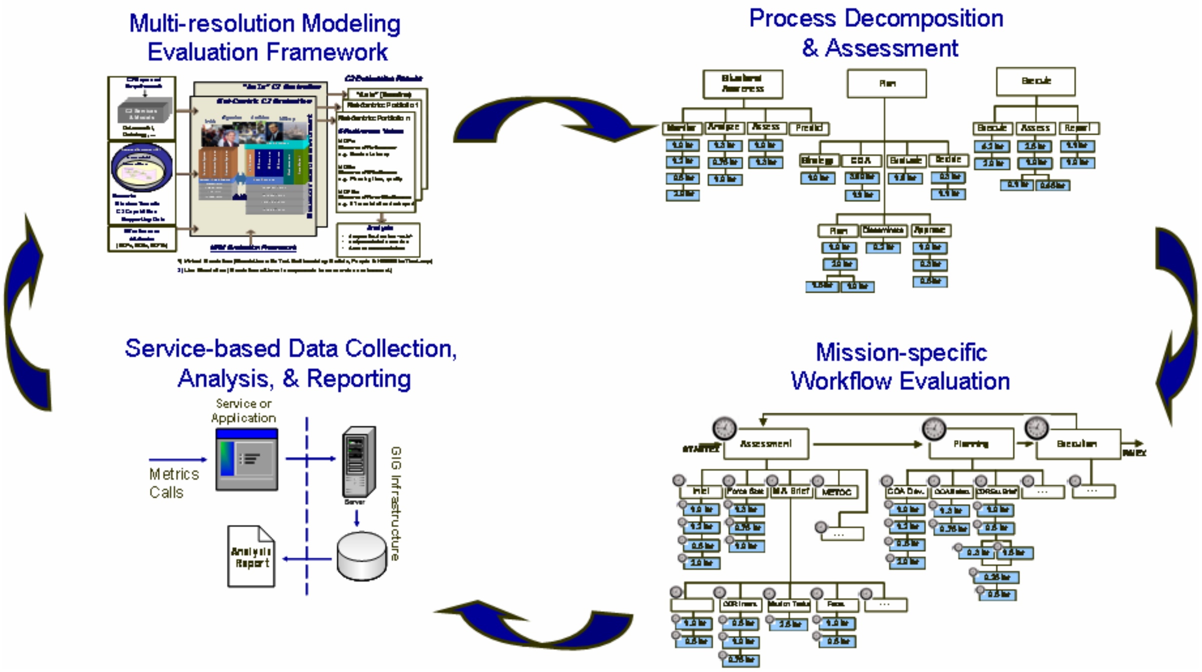


Figure 1. Key Elements for the Evaluation of Net-centric C2

## 2.1 Multi-resolution Modeling Evaluation Framework (MRMEF)

The MRMEF was developed to serve as the 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 2. A brief summary of the MRMEF is provided in Appendix A. The other key elements for evaluating net-centric C2, shown in Figure 1, are considered components of the MRMEF.

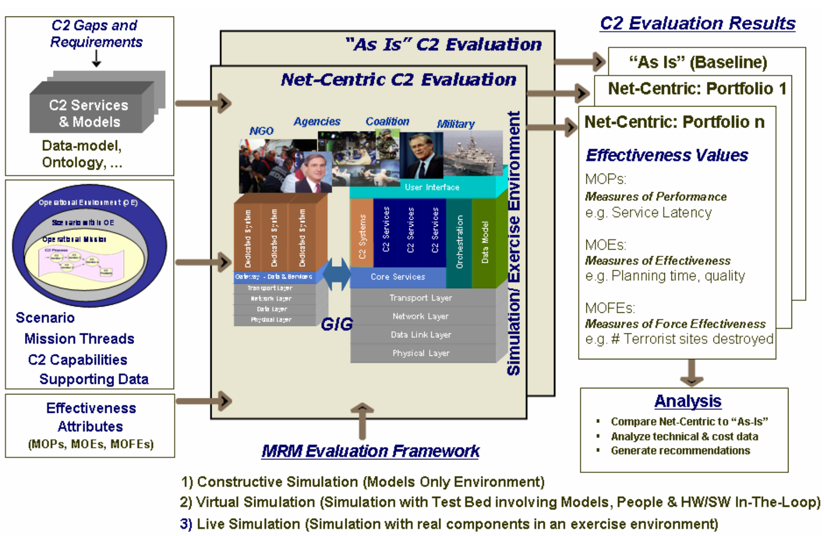


Figure 2. Multi-resolution Modeling (MRM) Evaluation Framework

## 2.2 Process Decomposition and Assessment

One of the requisite enablers for the successful analysis and evaluation of C2 is the ability to decompose C2 processes in the context of a mission domain. Our research this year is focusing on C2 as it applies to global strike, one of the mission areas for which USSTRATCOM has responsibility. The relationship of that and other USSTRATCOM mission areas and their associated cross-cutting functional capabilities, of which C2 is apart, is depicted in Figure 3.

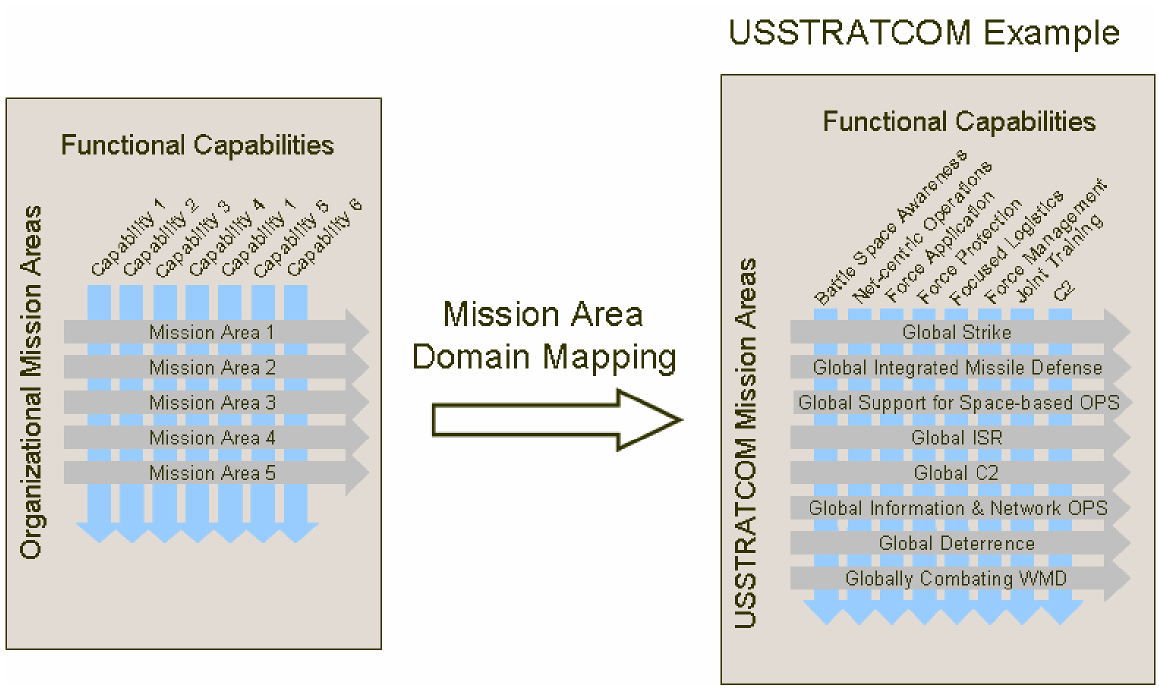


Figure 3. Mission Area/Cross-cutting Functional Capability Mapping

In 2005, USSTRATCOM initiated an effort to decompose its global strike and associated C2 processes. That decomposition resulted in the establishment of three top level process elements, which consisted of adaptive planning, crisis action planning, and execution. From those elements, a detailed global strike/C2 activity model was derived. That model established relationships among the process elements and also provided a limited characterization of process activity times based on the qualitative input of subject matter experts. An unclassified representation of that decomposition is shown in Figure 4. Since that time, the application of net-centric principles to global strike has resulted in a modification to the manner in which global strike is currently conducted and managed. Global strike processes are now represented in the form of a process workflow contained within a web-based, portal environment referred to as the Global Operations Center Collaborative Environment (GOC-CE). The GOC-CE is used to coordinate and facilitate joint collaboration during the conduct of global strike operations.

## 2.3 Mission-Specific Workflow Evaluation

We initiated a task to extend the decomposition to a nodal depth that would allow interfaces to specific systems and eventually the web service representations of those systems to be specified and incorporated into the model (Figure 5). We included sequential relationships among the process elements to generate a separate global strike workflow model, which is consistent with the workflow structure represented in the GOC-CE. Based on that model, we developed two products. The first is a simulation, developed using the Process Model tool, to demonstrate the flow of the global strike process over time during the conduct of mission operations. The simulation supports "what-if" analysis as the global strike workflow evolves over time in an effort to increase its temporal efficiency and process product quality.

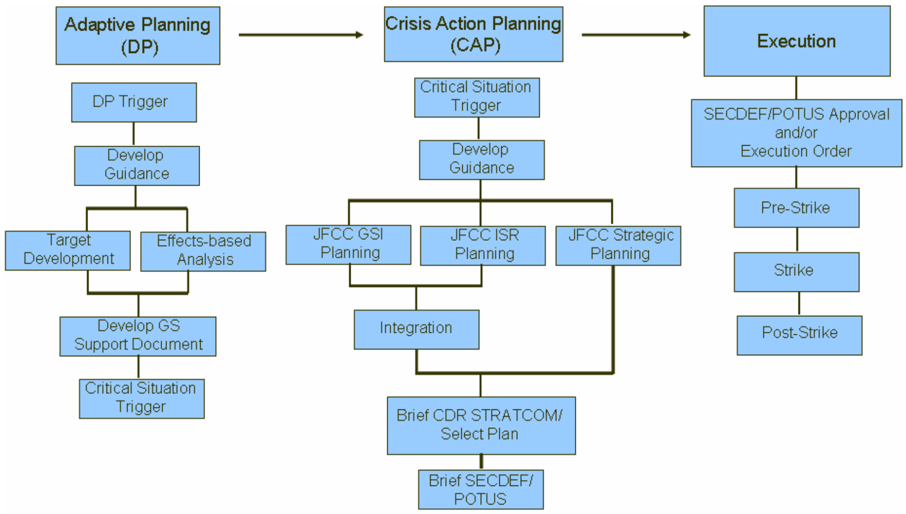


Figure 4. High-level decomposition of Global Strike Process Elements

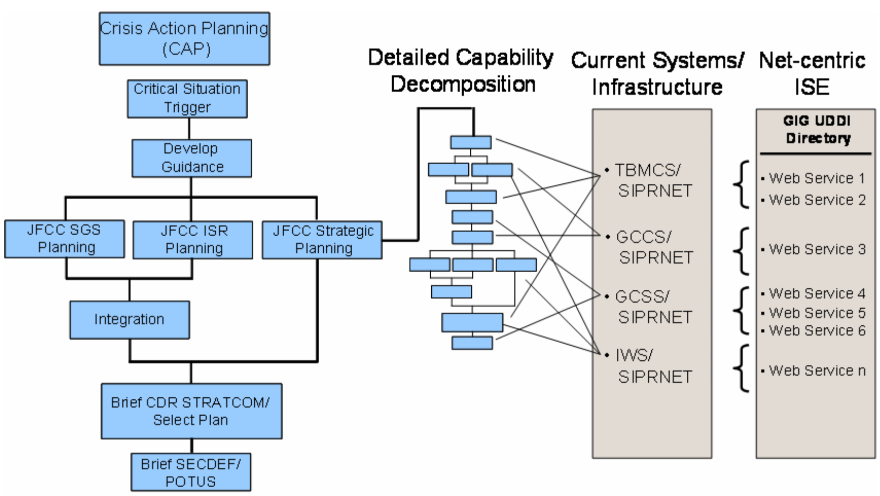


Figure 5. Example linkage between process nodal elements and systems/web services in an information sharing environment (ISE)

The second product is an executable model (EM) of the actual workflow, which is being developed to control, measure, and evaluate the conduct of a global strike operation in response to a scenario-driven event via an instrumented interface between the EM and the GOC-CE.

To support this and other related research projects, JHU/APL created a Global Information Grid (GIG) Test Bed, hereafter referred to as the Test Bed, which emulates GIG-like functionality. It supports the development and evaluation of net-centric services and capabilities in a GIG-enabled environment. It was developed based on a set of components designed to emulate GIG-enabled service-oriented-architectures by establishing an agile, reconfigurable infrastructure capable of testing a wide array of GIG implementation and utilization alternatives. It has been and will continue to be used to rigorously characterize GIG emulation fidelity and performance in the areas of transport, computing, and net-centric services**.** A graphical depiction of the FY06 instantiation of the Test Bed is shown in Figure 6.

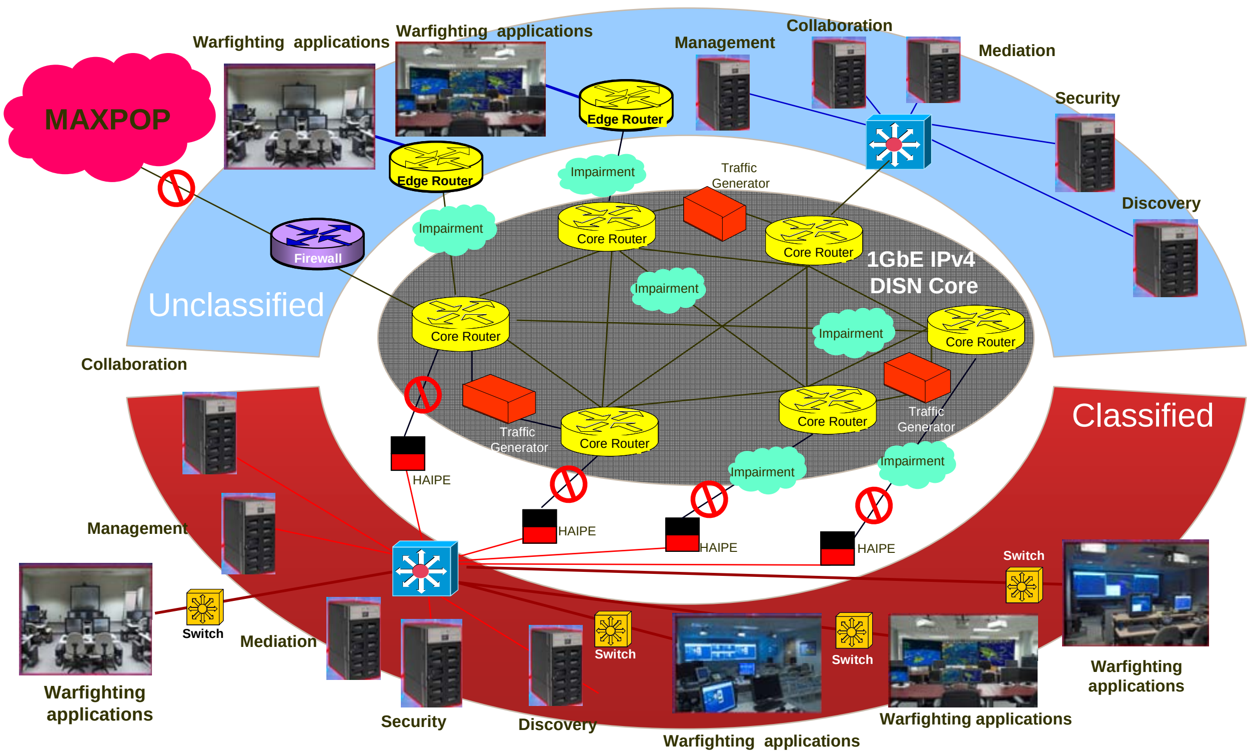


Figure 6. APL GIG Test Bed

The Test Bed is externally connected to the high speed Mid-Atlantic Crossroads (MAX) network, a consortium of higher education and research institutions in the Washington, D.C. area established for the purpose of providing advanced telecommunications infrastructure and services to the region, creating a focal point for collaborative regional experimental network research and development programs, and promoting a broader array of joint inter-institutional advanced computing and information technology initiatives. Max Network connectivity at JHU/APL will be further extended to include both the unclassified and classified Defense Research and Engineering Networks, i.e. the DREN and S-DREN respectively. Additional plans are being developed and coordinated to connect the Test Bed to the SIPRNET, the National

Research Laboratory GIG Evaluation Facility, the DOD Enterprise Computing Center and the Net-centric Enterprise Services (NCES) Service Integration Laboratory.

The Test Bed is the research platform on which the EM and a working version of the GOC-CE will be installed and the workflow of the global strike process evaluated.

The EM, developed using Microsoft's Windows Workflow Foundation (WF), is a real-time, executable model of the global strike workflow as represented in the GOC-CE. It supports an onboard knowledgebase that stores historical workflow element completion times that are used to drive the rate at which the workflow is executed during the conduct of a scenario-based, global strike mission. It also stores the completion times of each workflow element during any given execution run of the EM. Thus, the EM knowledgebase maintains information enabling a comparison of current to past executions of the global strike workflow (Figure 7). Real-time execution status of the EM is provided as visual cues, e.g. color-coded status buttons, to exercise participants responsible for completing workflow elements via an instrumented interface between the EM and the GOG-CE portal (Figure 8). The EM is also capable of interfacing with external workflow support objects (EWSO) that can facilitate the conduct of work and the completion of work products on behalf of global strike participants. The EM is made aware of work element completion times via either depression of GOC-CE work element completion buttons or the activation and termination of EWSOs by the EM on behalf of a global strike participant. Both capabilities are currently under development.

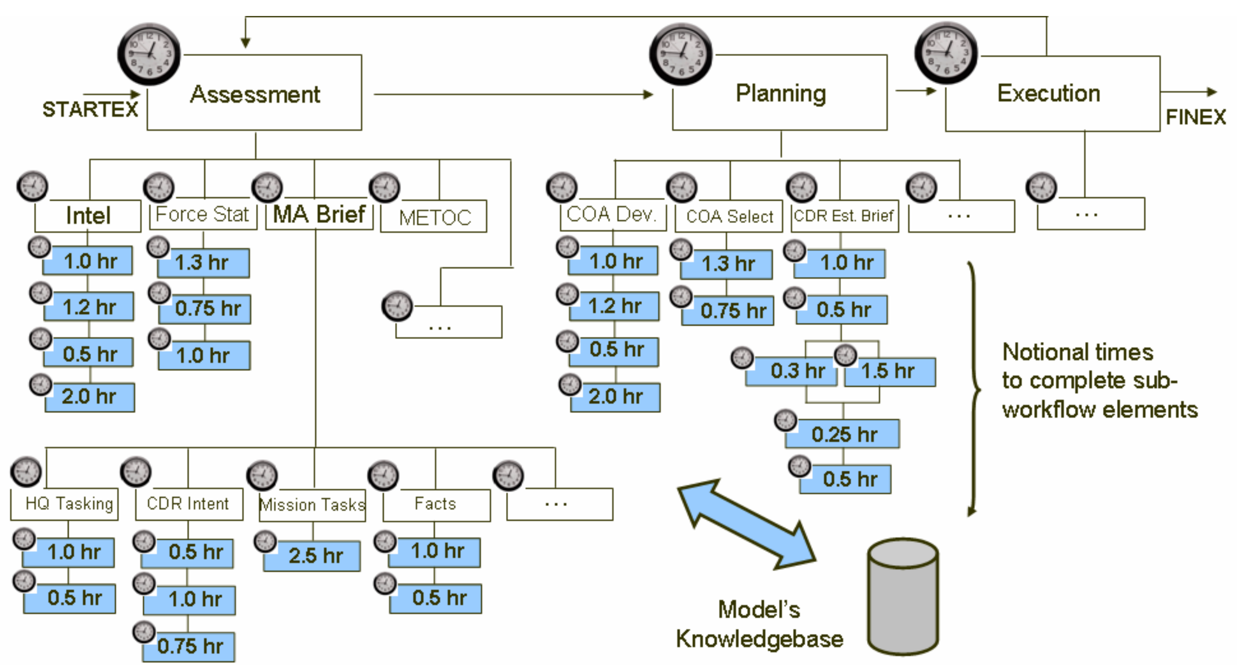


Figure 7. Partial Representation of the Global Strike Executable Workflow Model

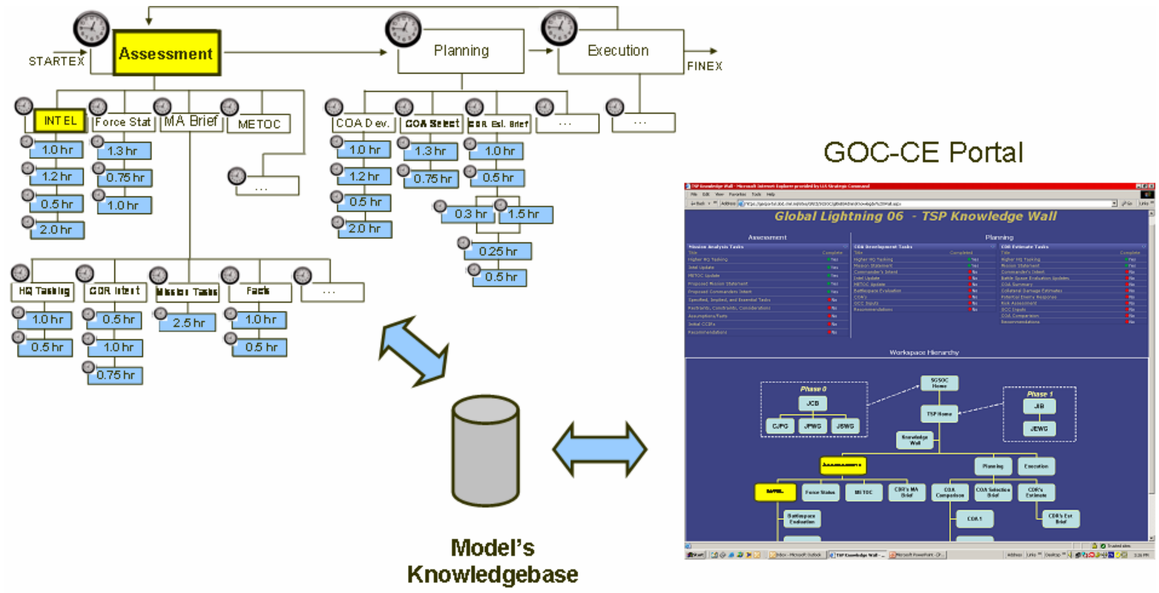


Figure 8. Partial representation of the visual status interface between the EM and the GOC-CE

## 2.4 Service-based Data Collection, Analysis, and Reporting (SDCAR)

At the completion of a global strike exercise, the EM will have captured completion times of each of the workflow elements of the global strike process. By comparing the current set of completion times with historical completion times, the EM will be able to analyze and identify potential problematic areas in the workflow where either historical completion times were exceeded by a given threshold or where one or more work elements were either partially completed or not completed at all. In addition to that level of analysis, we wanted to be able to perform a detailed analysis of software services if they were associated with problematic areas of the workflow identified via the EM. A capability, referred to as Service-based Data Collection, Analysis, and Reporting (SDCAR) is being developed to facilitate such an analysis and to augment the overall EM analysis approach.

The SDCAR is being prototyped to serve as a standardized way by which net-centric services can be analyzed while executing in their native environments. It is envisioned the SDCAR capability will be transitioned to the family of Net-centric Enterprise Services and be managed within the GIG infrastructure.

The SDCAR capability is being designed as a web service, which will be discoverable via a Universal Description, Discovery, and Integration (UDDI) registry. A probe, i.e. software analysis code, will be inserted at execution time into the target application or service, remotely configured, and used to analyze the target software. Analysis will include defining the target software's class and method structure, identifying the amount of time spent in each invoked method, the amount of CPU cycle and I/O time consumed by the application, etc. The SDCAR will be able to analyze the results and provide analysis data back to the user/designer either in real-time via a graphical user interface or via a post-processing reporting mechanism.

## 3. RESULTS

This research project is in the developmental phase. As such, no global strike workflow evaluation results are currently available; however, a number of intermediate accomplishments have been achieved, which include: the demonstrated use of the JHU/APL Test Bed, active design and development of the EM, and the successful installation and configuration of a working version of the GOC-CE in the Test Bed environment. A preliminary set of analysis and evaluation results demonstrating the value of the EM and supporting SDCAR capability is expected during the fourth quarter of FY 07.

## 4. CONCLUSIONS

It is postulated the use of a mission-based, executable workflow model in concert with a supporting ADCAR analytic capability will serve as an effective means for evaluating net-centric C2 processes because it:

- Employs a disciplined, system engineering process
- Quantifies shortfalls within the mission-based workflow
- Identifies areas for capability improvements
- Provides focus for future capability development efforts and acquisition decisions

Although this project is still a work in progress, we expect the above mentioned value propositions to be demonstrated over the course of the next several months.

## 5. REFERENCES


1. Forsythe, S. L., P. D. North, and V. B. Barnes, “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. P. D. North, 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.

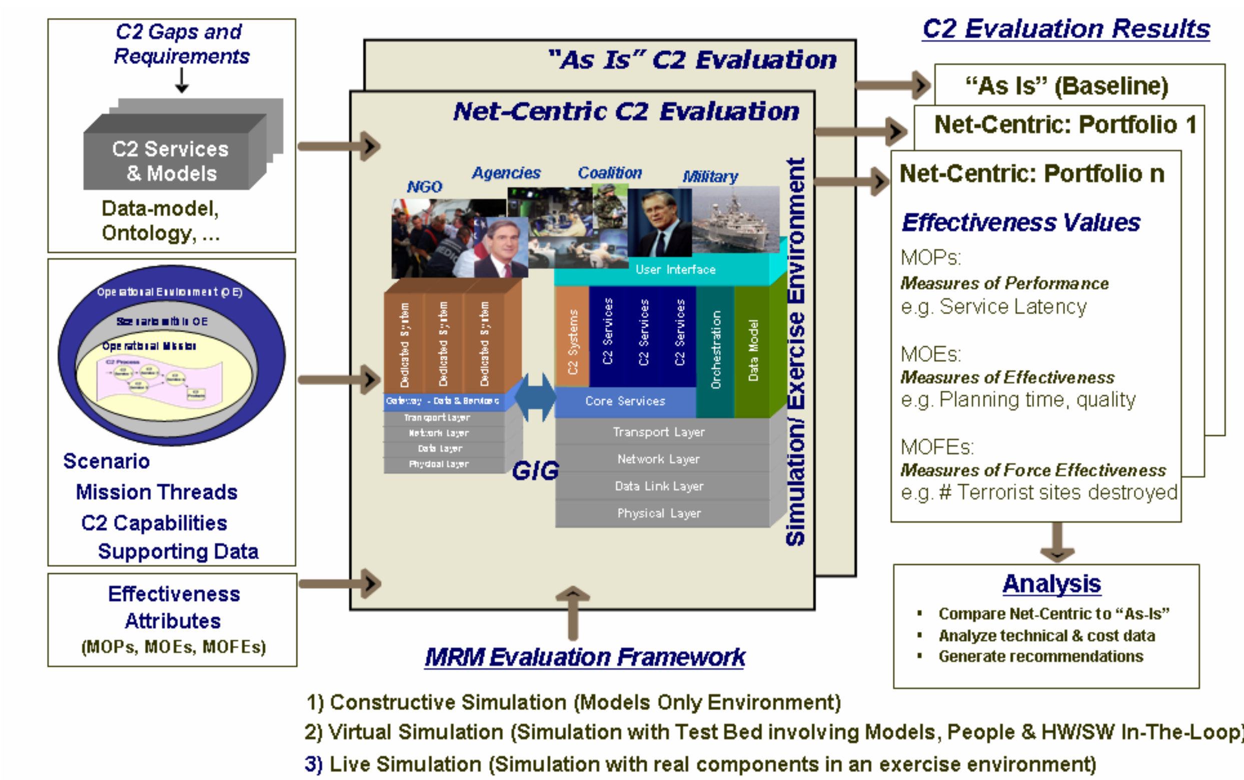


**Figure A-1. Multi-resolution Modeling Evaluation Framework**

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.