Evaluating Net-centric Command and Control via a Multi-resolution Modeling Evaluation Framework: a FY05 IR&D Project

Paul D. North
Steven L. Forsythe, Ph.D.
Valerie B. Barnes

Johns Hopkins University Applied Physics Laboratory
11100 Johns Hopkins Road
Laurel MD 20723-6099

Paul D. North
FAX: 240-228-6864
Phone: 240-228-6627
Email: Paul.North@jhuapl.edu

Steven Forsythe
FAX: 240-228-6921
Phone: 240-228-6879
Email: Steven.Forsythe@jhuapl.edu

Valerie B. Barnes
FAX: 717-261-0635
Phone: 717-261-0635
Email: Valerie.Barnes@jhuapl.edu

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Evaluating Net-centric Command and Control via a Multi-resolution Modeling Evaluation Framework: a FY05 IR&D Project**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Johns Hopkins University,Applied Physics Laboratory,11100 Johns Hopkins Road,Laurel,MD,20723-6099**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**29**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Evaluating Net-centric Command and Control via a Multi-resolution Modeling Evaluation Framework: a FY05 IR&D Project

Abstract

This paper presents the initial results of a multi-year, independent research and development command and control (C2) evaluation project. The purpose of the project is to develop and demonstrate a Multi-resolution Modeling Evaluation Framework (MRMEF), for evaluating whether or not the application of net-centric principles to C2 improves the effectiveness and efficiency of C2 in a complex, hybrid architectural environment. The MRMEF uses scenarios to bound the mission space to be evaluated and employs simulation techniques using multiple levels of fidelity or resolution to evaluate net-centric C2. This year's effort focused on the development of a high-level set of C2 processes depicting red and blue force activities in a Weapon of Mass Effect scenario. A constructive simulation was created using those processes to represent an "as-is" or non-net-centric model of that scenario. The simulation was executed and mission outcome results recorded. Two of the C2 processes were instantiated as real web services to represent a rudimentary form of a "to-be", i.e. net-centric, environment. A series of experiments were conducted to measure the time to complete each of these processes. The results were fed back into the simulation and an analysis performed to compare the "as-is" vs. "to-be" environments.

1. INTRODUCTION

1.1 Background

The Department of Defense (DOD) has embarked on a path to make force transformation an integral element of national defense strategy. Transformation is a continuing process involving the evolution of concepts, processes, organizations, and technologies. The term "network-centric warfare" is applied to the combination of emerging and evolving tactics, techniques, and procedures that a networked force can employ to create a warfighting advantage. Network-centric warfare is at the heart of force transformation. Successful transformation hinges on making the right investments in the right area to take full advantage of net-centric warfare and operations technologies and practices. (Garstka and Alberts 2004)

Net-centric command and control (C2) services are intended to help achieve information and decision superiority. Today operations occur in a complex environment characterized by a hybridization of net-centric and more traditional legacy command and control capabilities and processes.

Net-centric transformation and its associated practice of portfolio management require DOD decision-makers to understand the effects various net-centric command and control services have on operational outcomes. Modeling and simulation techniques as described in this paper can be adapted to provide a foundation for assessing net-centric command and control services.

1.2 Purpose

This paper presents the initial 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 and demonstrate a framework, referred to as the Multi-resolution Modeling Evaluation Framework (MRMEF), for evaluating whether or not the application of net-centric principles to command and control improves the effectiveness and efficiency of C2 in a complex, hybrid architectural environment where net-centric and legacy capabilities and processes co-exist and must interoperate. This approach uses scenarios to bound the mission space to be evaluated and employs simulation techniques using multiple levels of fidelity or resolution to evaluate net-centric C2 in that complex hybrid environment.

1.3 Scope

The scope of this paper includes a brief discussion of the challenges of net-centric command and control and the goals for evaluating net-centric C2. It presents a framework for conducting that evaluation using a multi-resolution modeling (MRM) approach. It concludes with a description and discussion of this year's portion of that multi-year, C2 evaluation effort.

2. CHALLENGES OF NET-CENTRIC C2

Military operations take place in environments which have legacy elements that are platform-centric and transformed elements that are net-centric. This situation is likely to continue for several years. The contrasts and challenges of this hybrid environment are highlighted in Figure 1.

Legacy Platform-centric:	Net-centric:
» System or systems-of-systems oriented architectures » Stovepipe characteristics; low interoperability » Limited standards » Un-tagged data » More traditional Task, Processing, Exploitation, and Dissemination approach » Multi-networked; point-to-point connections	» Service-oriented architectures » Core services (net-centric enterprise services) » Service interoperability » Well-defined standards » Meta-tagged data » Defined ontology » Information exchange cultural shift (Power to the Edge; Task, Post, Process, and Use) » Global Information Grid (GIG)

Figure 1. Command and Control Operations Occur in a Complex, Hybrid Environment

Analyzing command and control performance and effectiveness must be accomplished in the context of the entire chain of events in which the C2 activities occur. Modeling and simulation provide techniques to facilitate the evaluation of new C2 services in the context of a realistic operational scenario. The scenario defines parameters to bound the evaluation.

Our hypothesis is that net-centric principles advance C2 capabilities. Testing that hypothesis involves addressing these questions:

- What are the performance bounds and conditions?
- Where is net-centricity appropriate for C2? Where is it inappropriate?
- How does net-centricity affect the strategic and national levels?

The expected outcome is that net-centric C2 is very beneficial in most cases but, perhaps, not in all.

The challenge of evaluating net-centric C2 is:

- To develop an approach to evaluate the effectiveness of net-centric C2 processes and services in a complex, hybrid architectural environment, and
- To combine those results with lifecycle costs to facilitate better-informed architecture and technology deployment decisions

The latter challenge, however, was not addressed during this year’s effort.

3. NET-CENTRIC C2 EVALUATION GOALS

Command and control as defined by DOD is

> The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. (DOD 2001 as amended through 30 November 2004, 101)

While this definition is still applicable today, the way in which C2 is currently being implemented in a net-centric Global Information Grid (GIG)-enabled environment is quite different from the way it was implemented when this definition was created, and those differences significantly contribute to the complexity of evaluating net-centric C2. For example, prior to the net-centric revolution, C2 was largely achieved via the use of stand-alone, stove-piped legacy systems that communicated with one another via point-to-point network connections. The evaluations of those systems were often limited to demonstrating that the systems met their requirements and were able to effectively communicate with one another over tightly restricted point-to-point connections. Today, and increasingly in the near future, commanders employing net-centric C2 implementations will take advantage of distributed computing and communications environments that involve applications developed as services that utilize scalable, service-oriented architectures. Moreover, those net-centric C2 services must interface to some degree with existing legacy C2 systems since the legacy systems can’t be replaced by their net-centric equivalents instantaneously.

The complicated hybrid architecture environment and the highly-distributed GIG significantly contribute to the complexity of evaluating and measuring the technical, functional, and mission effectiveness of net-centric C2 processes and services. The goals of the C2 evaluation approach described in this paper must address these additional levels of complexity. Those goals, in general, are:

- To demonstrate that a simulation-based methodology is an effective means for evaluating command and control in a hybrid platform-centric and distributed net-centric environment;
- To demonstrate that constructive, virtual, and live simulation techniques can effectively mitigate some of the challenges of evaluation in that hybrid environment;
- In the context of a specific operational scenario,
  - To identify how and where the application of net-centric principles augments the effectiveness of existing C2 capabilities
  - To identify potential gaps where the application of net-centric principles fails to augment or actually degrades C2 capabilities.

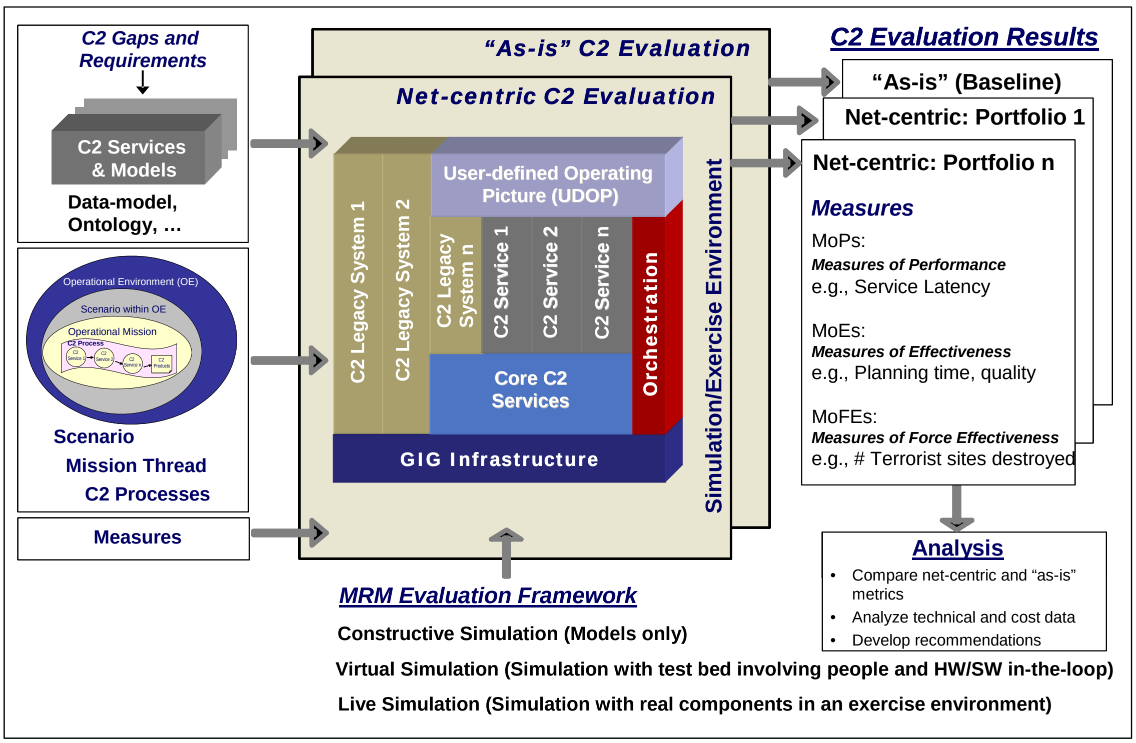
In this year’s portion of the multi-year IR&D effort, we focused on establishing a baseline for conducting such an evaluation and for demonstrating MRMEF concepts.

4. MRM EVALUATION FRAMEWORK (MRMEF) APPROACH

4.1 Description

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 over more traditional approaches for analyzing 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 (Smith 1998). An overview of the MRMEF is shown in Figure 2.

Figure 2. 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" processes and executing that model as a constructive simulation within the framework. A second model is developed representing the net-centric equivalent of those processes. The net-centric processes, which may involve a hybrid of legacy and net-centric components, both real and simulated, are 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 whether the application of net-centric principles and components to an existing "as-is" process has enhanced or degraded engineering, command and control, and/or mission-level performance as measured via measures of performance (MoP), effectiveness (MoE), and force effectiveness (MoFE), 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.

4.2 FY05 MRMEF Demonstration

This year, a Multi-resolution Modeling Evaluation Framework (MRMEF) was developed and demonstrated. The objectives of this work were to:

- Develop a framework for evaluating net-centric command and control based on an MRM approach
- Demonstrate how the application of those framework concepts could be used to evaluate whether or not the application of net-centric principles to command and control improves the effectiveness and efficiency of C2 in a complex, hybrid architectural environment

4.3 Demonstration Approach

The demonstration approach consisted of executing the following steps, which are graphically shown in Figure 3 and described below:

- **Step 1**:

  Develop or utilize an existing scenario to bound the evaluation problem space. A Weapon of Mass Effect (WME) scenario, developed by another group at APL involved in a related project, was used to accomplish that goal. The scenario depicted the activities of a terrorist organization, i.e. the red force, to accomplish the sale, movement, and launch of a WME and the actions of the U.S. Armed Services, i.e. the blue force, to counter or deter those activities by preventing the sale, intercepting the WME, disabling or inhibiting the launch site, or shooting down the WME delivery missile.

- **Step 2**:

  Develop a low-fidelity constructive simulation based on a set of current, “as-is” C2 processes that represent the activities of the red and blue forces in the scenario as they would be conducted without the inclusion of net-centric capabilities. The Arena modeling and simulation tool was used to accomplish this task. The Step 2 portion of Figure 3 is shown here for illustrative purposes only to convey the notion that the constructive simulation consists of a large number of processes represented by the yellow-colored symbols.

  Develop a set of metrics to evaluate the performance of those processes at the engineering, command and control, and mission levels via MOPs, MOEs, and MOFEs, respectively. In particular, we focused on measuring the percent occurrence of each possible mission outcome, an MOFE, e.g. % of simulation runs in which the WME sale was deterred, the WME launcher destroyed, etc., and an MOP, which involved the time to complete two processes related to collaborative course of action planning: Find Pattern, a process for identifying personnel roles needed to participate in the collaborative planning session to address the WME problem and Create Workspace, a process to create the environment needed to support the collaboration session.

- **Step 3**:

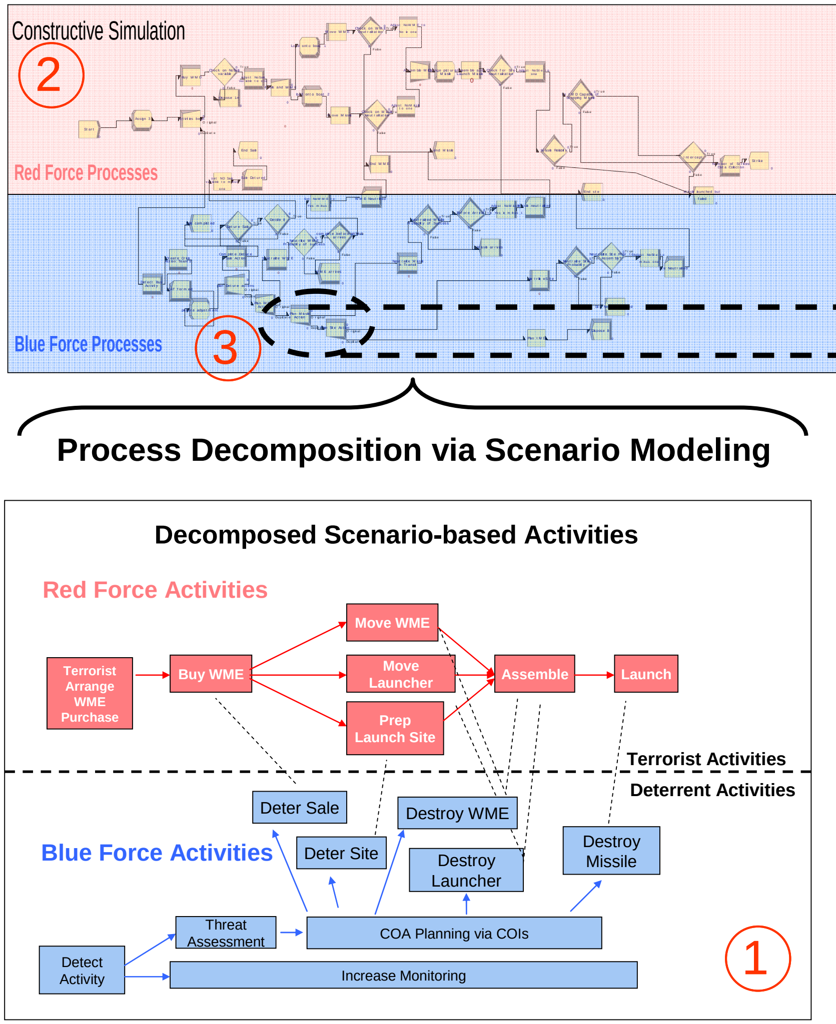
  Modify the constructive simulation by replacing one or more of the “as-is” processes with “to-be”, net-centric web services, which perform the same functions as those processes but in a net-centric way. The two processes chosen were the collaborative course of action planning processes from Step 2, defined above.

- **Steps 4 and 5:**

  Conduct a series of experiments to measure time to complete execution of the web services. Ideally, those services would have directly interacted with and be measured in the context of the constructive simulation via an in-the-loop software test-bed, which is collectively referred to as a virtual simulation. However, due to fiscal constraints a test-bed was not developed this year; rather, an independent set of “time to complete” tests were executed on the web services and fed back into the constructive simulation via manual manipulation.

- **Step6:**

  Compare the results of “as-is” with the “to-be” runs of the simulation to determine if the inclusion of net-centric capabilities had an effect on the mission outcomes of the scenario.



Experimental Results

6 Notionally, reduced the probability of missile launch

5

Experiment Run #	Time to Complete (Seconds)	
	Find pattern	Create Workspace
1	9	32
2	8	30
3	8	26
4	7	29
5	8	25
6	8	29
7	6	24
8	7	25
9	8	27
10	7	24
Min	6	24
Max	9	32
Mode	8	29

4

- Collected real data from real services
- Characterized the data: triangular distribution
- Served as basis for comparison and analysis

Figure 3. C2 Process Decomposition, Constructive Simulation and Evaluation

4.3.1 Demonstration Assumptions and Constraints

Although the MRMEF is intended to support cost analysis as well as an evaluation of C2 performance and effectiveness, that function will not be included in the FY05 prototype effort. The cost analysis capability is expected to be evaluated in FY06.

5. RESULTS

This year's effort involved the development of a high-level set of C2 processes depicting red and blue force activities in a Weapon of Mass Effect scenario. A constructive simulation was created using those processes to represent an "as-is" or non-net-centric model of that scenario. The simulation was executed and mission outcome results were recorded. Two of the processes related to collaborative planning, Find Pattern and Create Workspace, were instantiated as real web services to represent a rudimentary form of a "to-be", i.e. net-centric, environment. A series of experiments were conducted to measure their time to complete. The results were fed back into the simulation, which included those timing parameters at the process level, and an analysis performed to compare the "as-is" vs. "to-be" results to determine if the inclusion of net-centric capabilities had an effect on the mission outcomes of the scenario. The comparison results, although preliminary and notional, demonstrated a positive effect. There is no claim the reduced "time to complete" task results would correspond to actual task reduction times in an operational environment. However, if the results hold in that environment, one could expect to observe a reduced probability of missile launch because of the introduction of more time-efficient net-centric services during collaboration processes.

6. CONCLUSIONS

Based on the above results, the project achieved its goal of demonstrating an approach for analyzing the potential impact of net-centric services and capabilities on command and control. As net-centric C2 services continue to be developed in the future in the context of service-oriented architectures and deployed in the field to support real-world operations, there is a need to ensure these services operate properly in both a unitary mode and in end-to-end orchestrations with other services and systems. The benefits of applying a multi-resolution modeling approach as described in this paper to the complex problem of evaluating services and legacy systems that need to interoperate with each other in order to facilitate effective C2 are:

- Reduced deployment risks;
- Better informed architectural and deployment decisions by DOD managers;
- Increased return on investment via reduced operations and maintenance costs;
- Enhanced best-of-breed selection among competing portfolio capabilities;
- Improved techniques, tactics, and procedures and concepts of operations via in-the-loop resource experimentation; and

7. REFERENCES

1. Garstka, John and David Alberts, *Network Centric Operations Conceptual Framework* Version 2.0, Evidence Based Research, Inc., Vienna, VA, June 2004. http://www.oft.osd.mil/ncw.cfm

2. DOD, Director for Operational Plans and Joint Force Development (J-7), *Department of Defense Dictionary of Military and Associated Terms,* Joint Publication 1-02 (JP 1-02), 12 April 2001 (As Amended Through 30 November 2004). http://www.dtic.mil/doctrine/jel/doddict

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

Evaluation of Net-centric Command & Control (C^2)

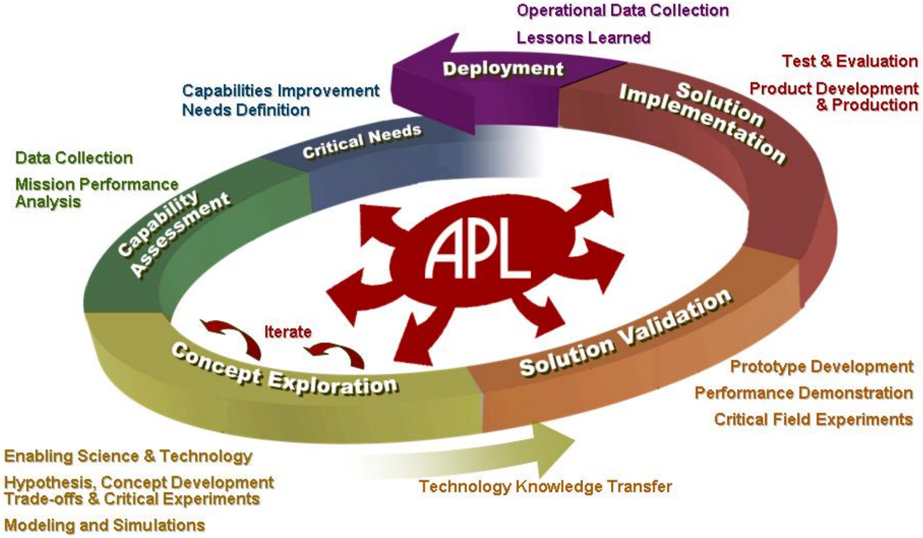
Steven L. Forsythe, Ph.D.

Paul North

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Purpose

To describe APL's approach for evaluating Command and Control (C^2) in a hybrid Net-centric environment



Critical Challenges:

- **Evaluating C2**
- **Evaluating the impact of net-centricity on force effectiveness**

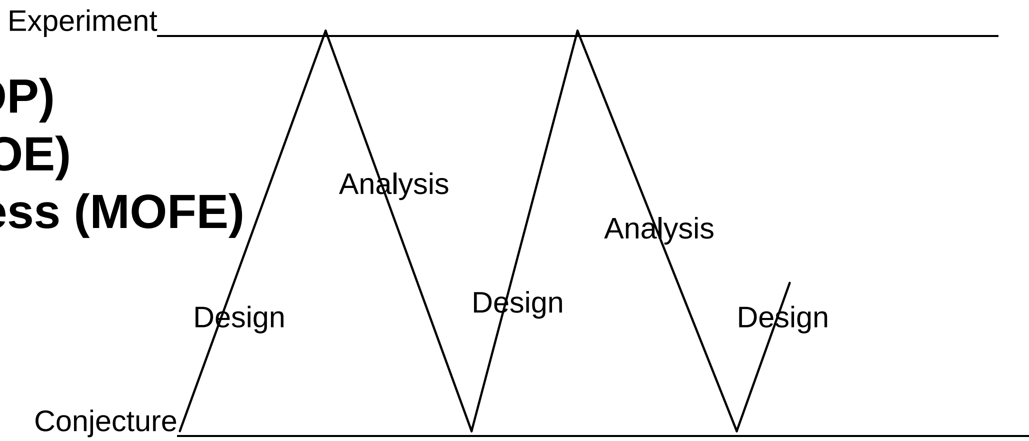
Specific Objectives

1. **Evaluate the extent to which:**
   - **Net-centricity improves Command and Control (C^2) and related applications**
   - **The GIG infrastructure and Core Services will effectively and efficiently support C^2 and related applications**
2. **In order to achieve objective #1, we need to:**
   - **Develop a theoretical framework for C2**
   - **Methodology for net-centric experimentation**
   - **Infrastructure for net-centric experimentation**
   - **Improved tools for automated C2 data gathering and analysis**

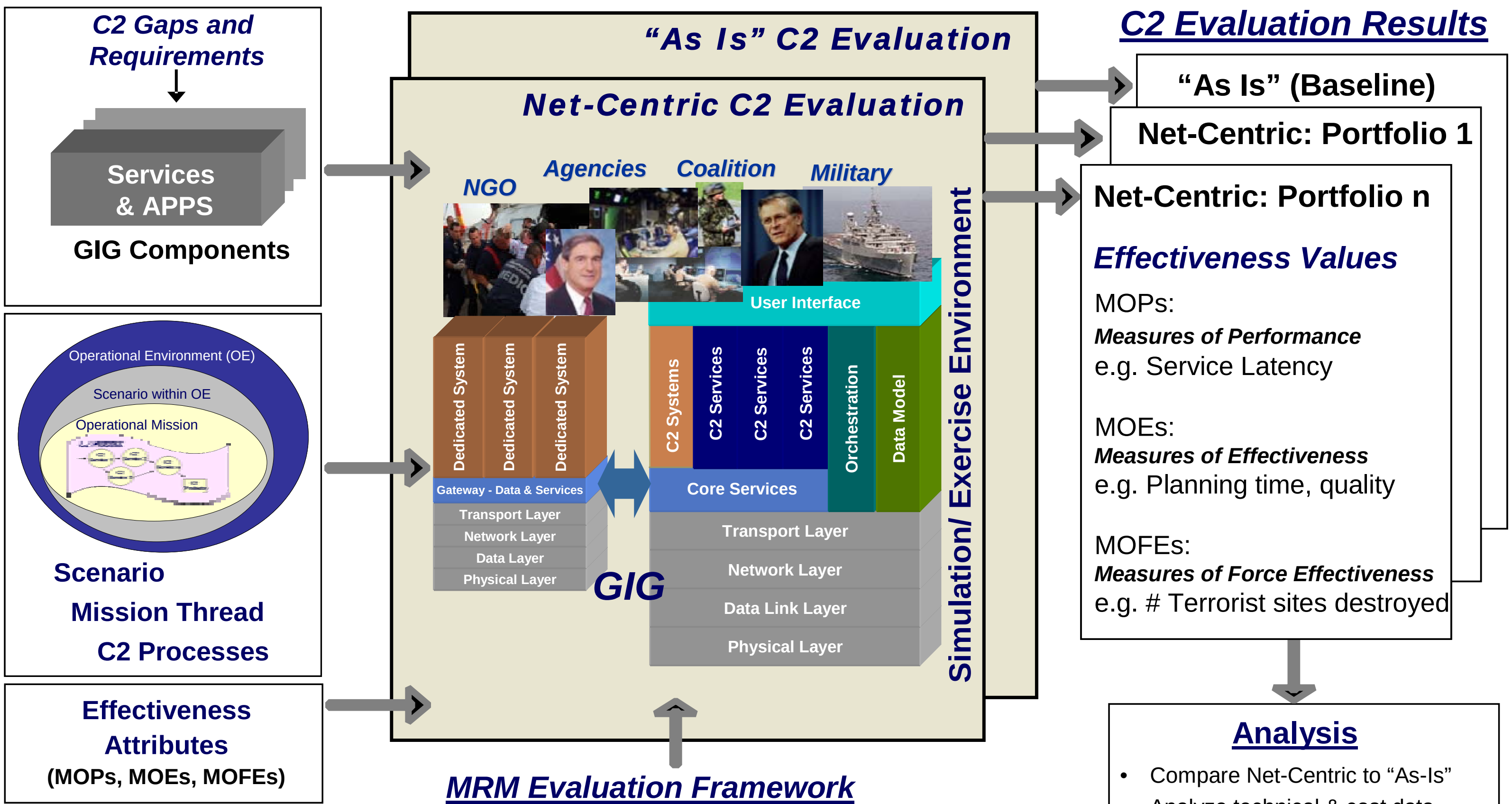
APL

Methodology for Net-centric Experimentation

- **Multi-Resolution Methodology For Net-Centric Experimentation**
  - **Combine models with different levels of resolution to achieve the needed insights**
  - **Constructive, Virtual & Live environments enable trade-offs between cost, repeatability, and fidelity**
  - **Appropriate C2 measures:**
    - **Measures of Performance (MOP)**
    - **Measures of Effectiveness (MOE)**
    - **Measures of Force Effectiveness (MOFE)**
  - **Supports the iterative nature of experimentation**



Multi-resolution Modeling Evaluation Framework (MRMEF)



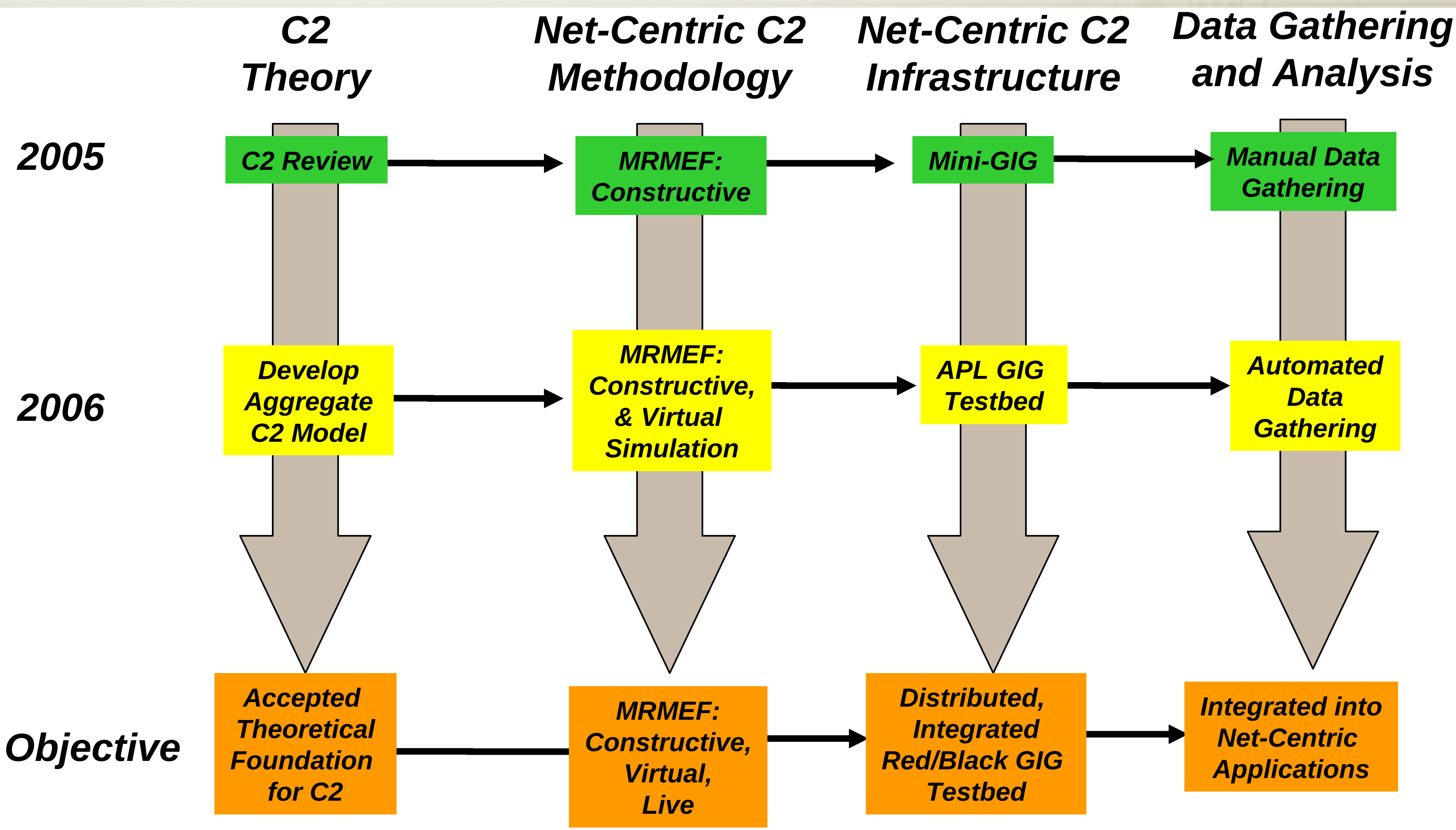
Analysis

- Compare Net-Centric to "As-Is"
- Analyze technical & cost data
- Generate recommendations

- **Virtual Simulation (Simulations with a Test Bed involving Constructive Simulations with People & HW/SW In-The-Loop)**
- **Live Simulation (Simulation with real components in an exercise environment)**

APL

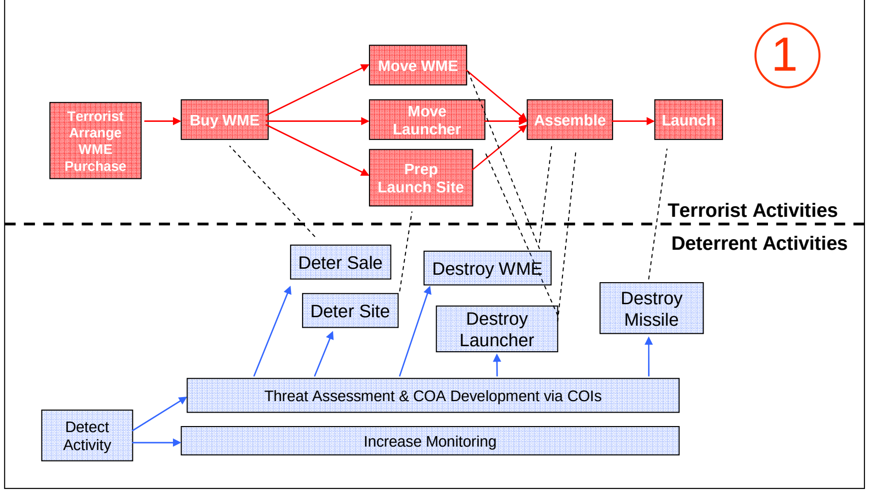
APL C2 Evaluation Objectives



APL

FY05: Performed Initial Measurements of Web Service & Human-in-the-loop (HITL) Execution Time

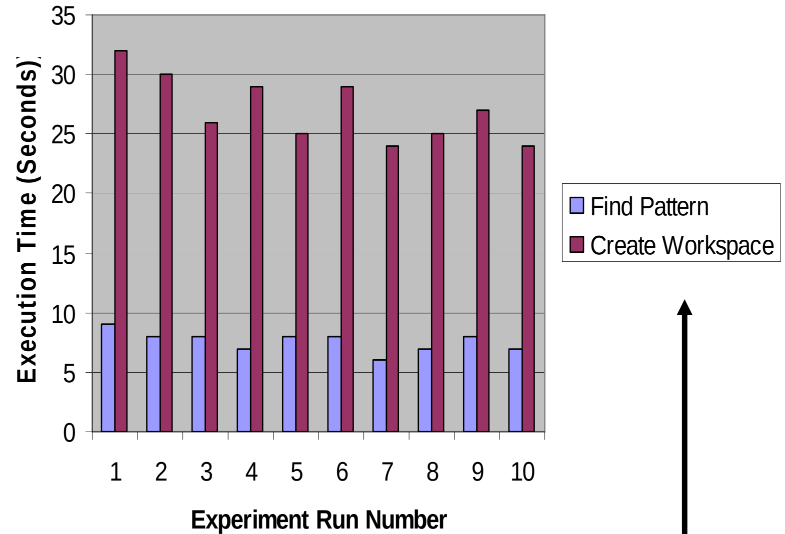
Decomposed Scenario-based Activities

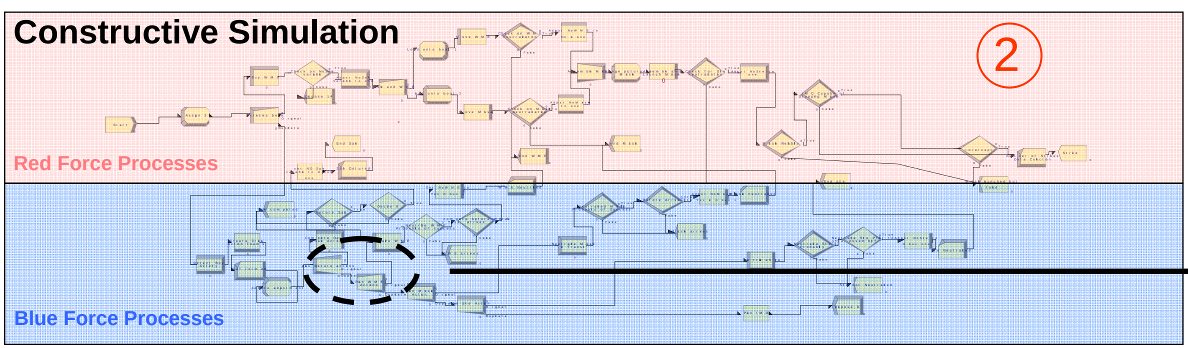


Process Decomposition via Scenario Modeling

Timing Results

Application Execution Time





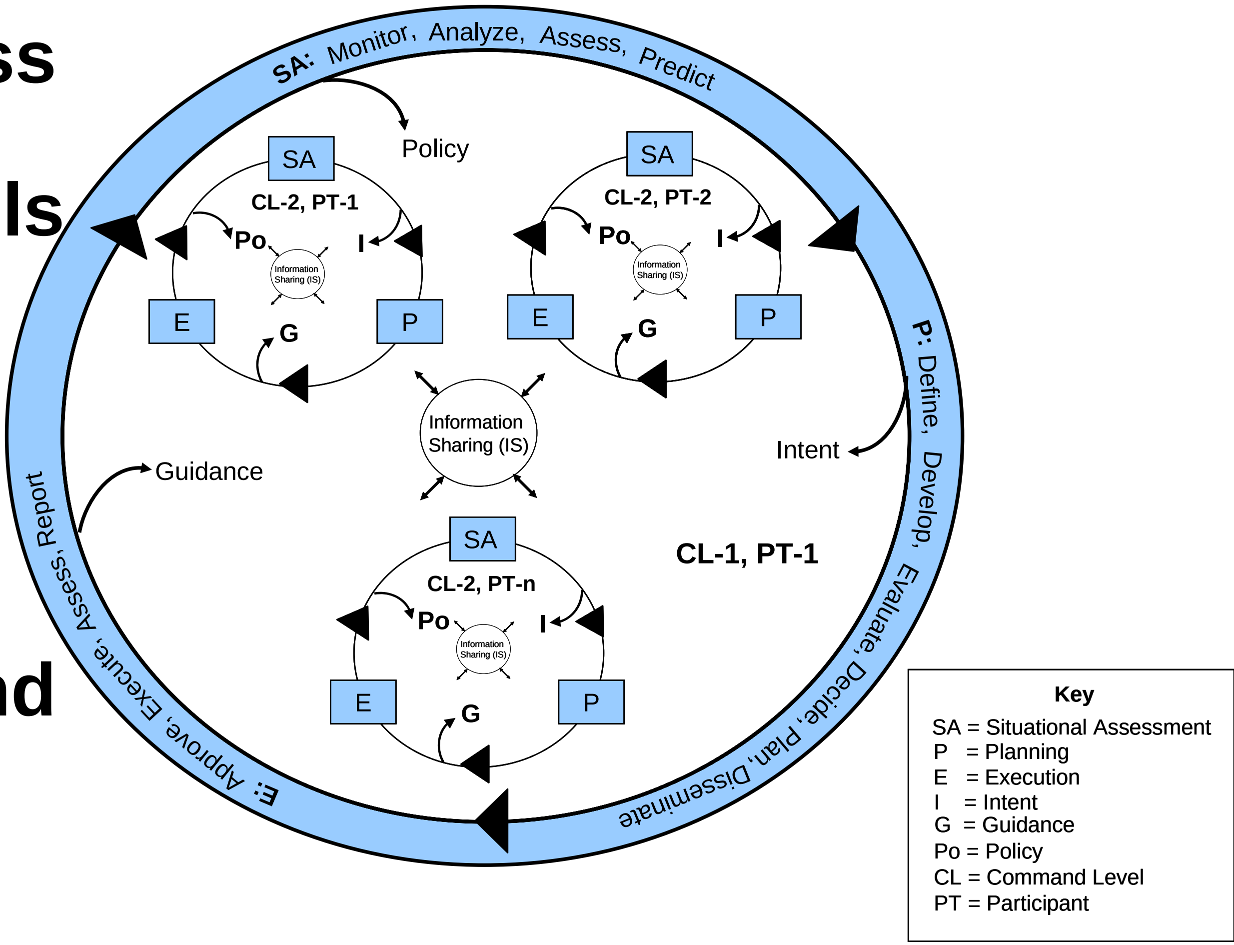
- Created two web services
- Measured service and HITL execution time

Theoretical Framework for C2

- **Synthesize and aggregate current C2 models**
  - **OODA**
  - **MAAPPER**
  - **Enterprise Theory of C2 (EC2) developed by Jay Bayne, Echelon 4 integrates:**
    - **Systems Engineering (Cybernetics)**
    - **Organizational Theory**
    - **Cognitive Science**
- **Key concepts:**
  - **The same C2 structure and processes occur at all levels of an organization**
  - **Consistent relationships among C2 actors**
  - **A standard approach to C2 allows**
    - **Efficiencies of C2 tool development & training**
    - **Better interoperability**
    - **Enhanced operations**

Developed Aggregate C2 Process Model

- Combined process elements from existing C2 models
- Situational awareness, planning, and execution apply recursively to all levels of command



FY06: Infrastructure for Experimentation

New Tools Enhance APL's Experimental Capabilities

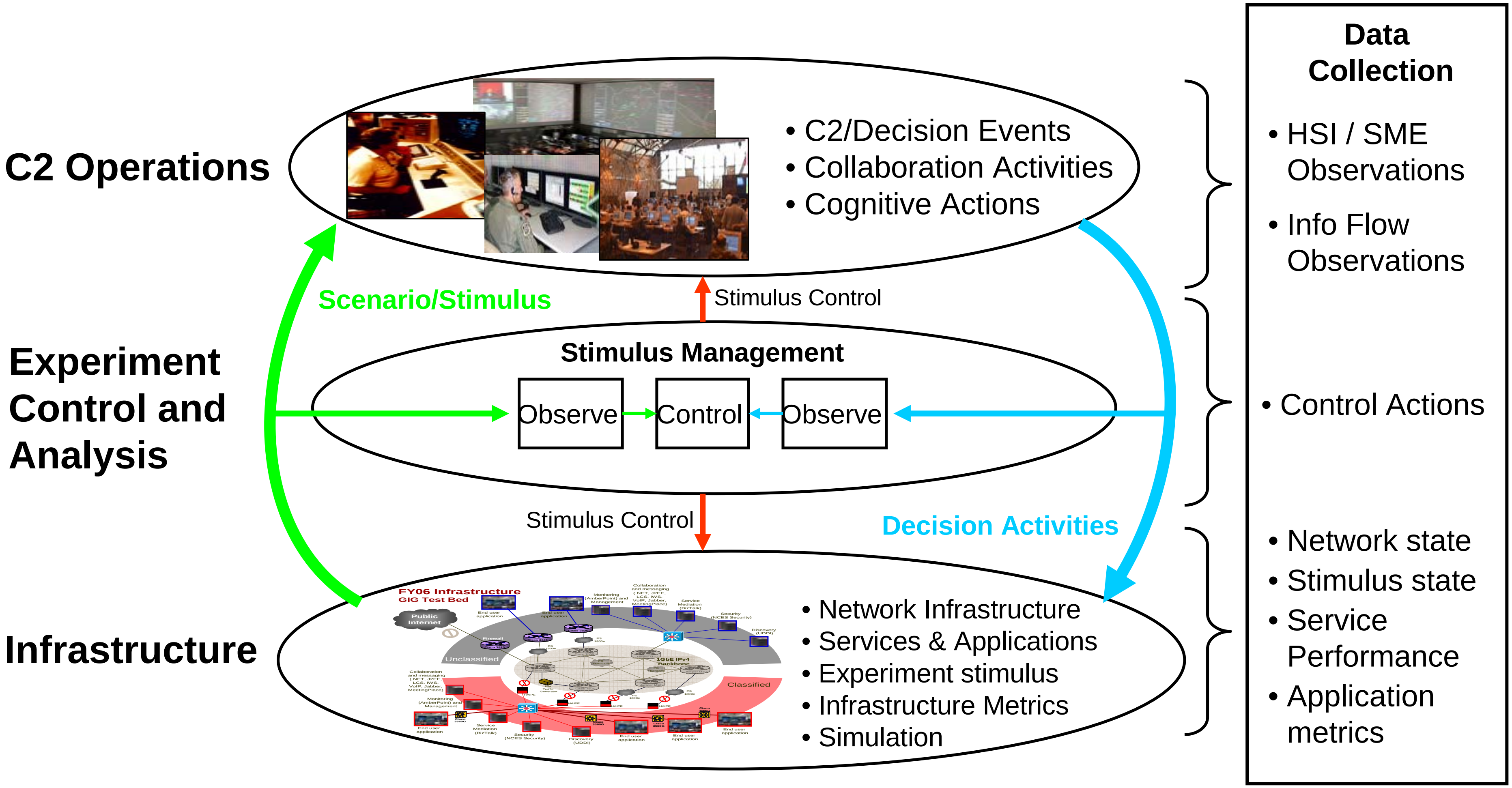
Agent-based simulation used as controllable scenario-generator

- **Joint Semi-Automated Forces simulation (JSAF)**
- **Supports agent-based free play**
- **Provides data to data fusion and visualization applications**
  - **Ground truth**
  - **Entity perception**
- **Interacts with other simulations and SOA-based applications via:**
  - **Web-service/HLA translation interface**
  - **HLA (High Level Architecture)**
  - **DIS (Distributed Interactive Simulation)**

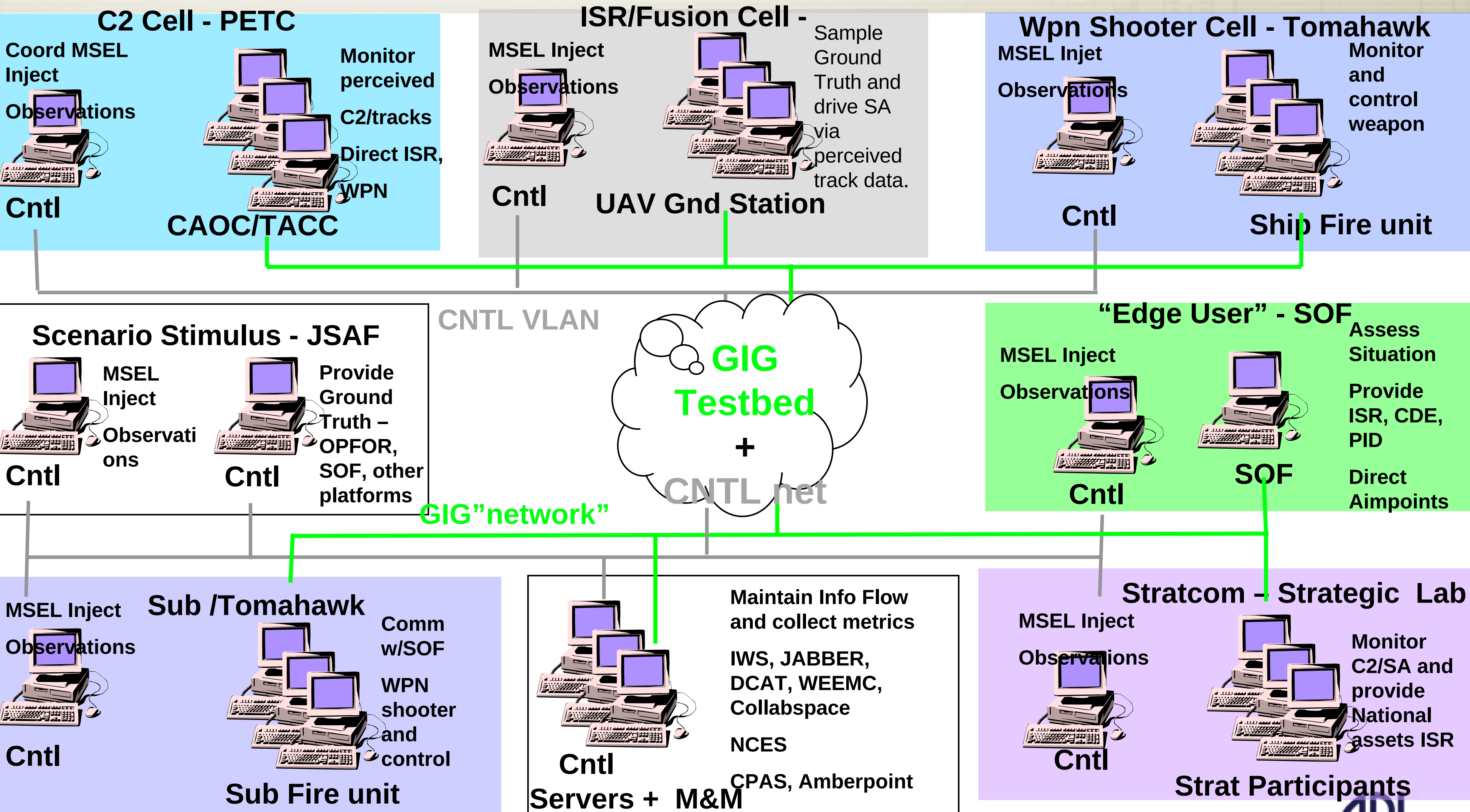
Experiment architecture and infrastructure supports automated data collection based on metrics related to:

  - **Systems/Technology**
  - **Operational C2 processes**

Functional C2 Experimentation Architecture



Experiment Implementation
Vignette 1 Example



APL

Scenario Overview

Based on the MRM Evaluation Framework develop two scenario vignettes for current CEI

- **Vignette 1 – Global Strike**
  - **Information was received regarding the planned meeting of a high value target (HVT) in a mountainous village of Middle East country**
  - **A COA was developed and will be executed to insert a SOF team to either a) capture the target or b) eliminate the target via a Tomahawk strike**

- **Vignette 4 – Emergency Disaster Response**
  - **An accident at the Calvert Cliffs Nuclear Power Plant resulted in the release of a radioactive plume**
  - **A COA was developed and will be executed to evacuate the surrounding community as quickly as possible in a manner that minimizes the evacuee's exposure to the plume during the evacuation process**

Operational Context Vignette 1

Participants:

Friendly: C2 node, ISR cell, Weapon Shooter, SOF team

OPFOR: Terrorist Cell meeting, Terrorist forces in area

Non-Combatants: local population

Goal:

Strike Terrorist Cell meeting.

Manage C2/ISR and strike assets. Minimize casualties to friendly forces and non-combatants.

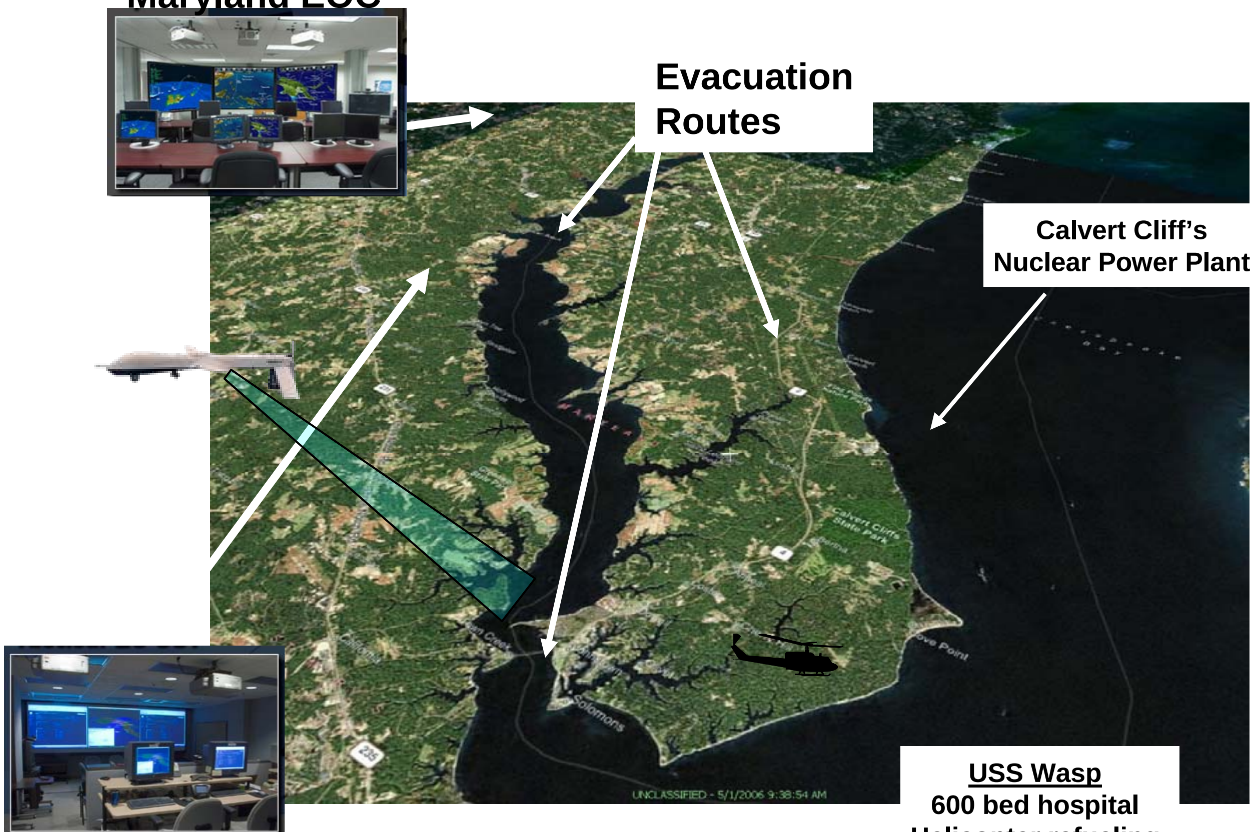
Execute C2 processes and procedures stimulated by:

1. **OPFOR actions**
2. **non-combatant actions.**

Sample C2 Experiments: Vignette 1, Experiment 1

- Evaluate if there is there a significant operational escape and avoid advantage to providing SOF teams with red force position information via fused ground track data vs. local sensing of red force positions (e.g. visual, motion sensors, etc.)
- Technology Focus: Data Fusion vs. local sensing
- Operational Focus: Effect on probability of enemy avoidance
- Measurements
  - Measures of Effectiveness (MOEs)
    - # of red force (RF) detection events
    - # of SOF team compromise events
    - # of successful Tomahawk engagement events
    - # of successful target destruction events
    - Probabilities of each of the above
  - Measures of Performance (MOPs)
    - Ground track update rate
    - Accuracy of fused vs. simulation ground truth RF position data

Operational Context Vignette 4



Participants:

Maryland EOC, Arlington EOC, USS WASP, Local Chiefs of Police, local population

Goal:

Evacuate the area surrounding the Calvert Cliffs Nuclear Power plant following a disaster

Manage evacuation assets from both Federal and State agencies. Minimize civilian casualties.

Execute C2 processes and procedures stimulated by:

1. **Nuclear Plume movement**
2. **Evacuee actions**
3. **Traffic accidents**

Sample C2 Experiments: Vignette 4, Experiment 1

- Evaluate whether the availability of radioactive plume tracking data to the MD EOC allows that team to make better evacuation decisions compared with in-the-field reports of radioactive measurements
- Technology Focus: Data Fusion vs. local sensing
- Operational Focus: Effect on evacuation decision-making success
  - **Proposed Measurements:**
    - **Measures of Effectiveness (MOEs)**
      - % of evacuees exposed to the plume
      - Of those exposed, degree of exposure to the radioactive plume
      - Level of SA in the EOC regarding the plume location at defined periods of time
      - Level of SA in the field regarding the plume location at defined periods of time
    - **Measures of Performance (MOPs)**
      - Time to alter evacuation flow after a shift in plume direction
      - Response time of the weather web service to requests for weather/plume updates by the simulation tool
      - # of communication events needed to establish effective SA regarding the plume location at defined periods of time

APL

Why Conduct Evaluations?

- **Supports value-based selection of net-centric services**
- **Guides architecture decisions regarding core service selection, GIG capabilities & performance requirements, etc.**
- **Helps define/refine net-centric implementation standards (NCIDS)**