*OPNAV N81-NPS World-Class Modeling (WCM) Projects Overview 2004*

# Connecting Simkit Discrete Event Simulation (DES) and the Naval Simulation System (NSS) via Web Services for Extensible Modeling & Simulation (XMSF)-Capable Analysis

Dr. Don Brutzman, Dr. Arnie Buss, Curt Blais and CAPT S. Starr King USN
brutzman@nps.navy.mil +1.831.656.2149
Modeling Virtual Environments & Simulation (MOVES) Institute
Naval Postgraduate School, Monterey California USA

## 1. Overview

This project overview describes ongoing research and development using a transformational analytical modeling framework. Web services are used in an innovative way to connect multiple model components in a flexible, scalable, extensible architecture. Following the strategic trajectory of the XMSF effort, this work starts first with functioning exemplars, then progresses to supporting tools, and then steps up to world-class modeling challenges, analysis and results.

Key sources of functionality for these efforts include:

- Simkit discrete event simulation application program interface (API) developed by the Naval Postgraduate School (NPS),
- Combat XXI under development by the Army and Marine Corps at the Army TRADOC Analysis Center, White Sands Missile Range (TRAC-WSMR), which already incorporates Simkit,
- Naval Simulation System (NSS) developed by SPAWAR Systems Center, San Diego.

following projects are being performed by NPS in 2004 for U.S. Navy CNO staff, specifically OPNAV N81, as portions of the World-Class Modeling (WCM) family of projects.

*Technical Integration*

- WCM-09: Battalion Combat Modeling Module
- WCM-14: Special Operations Forces (SOF) Modeling (Detailed) for PR-07
- WCM-16: SAVAGE to Model Force Protection/Anti-Terrorism Modeling for PR07
- WCM-28: Analytical Workbench for Simkit Modeling

*Analytic Demonstration*

- WCM-15: Joint Forcible Entry Options (JFEO) Modeling in Combat XXI for PR07
- WCM-19: Improve Strike Module (Detailed) in Combat XXI for PR07
- WCM-25: Detailed Logistics Modeling for PR07
- WCM-37: MCO-1 Scenario Development in Combat XXI
- WCM-02: Operations Research Thesis-Research Projects

WCM-14, WCM-16 and WCM-28 are establishing web-services interoperability and logical connectivity between existing systems: Simkit/COMBAT$^{XXI}$, Naval Simulation System (NSS) and the X3D-based Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) model archive. WCM-15 and WCM-19 demonstrate an analysis capability using this set of hybrid discrete-event simulation (DES) tools. WCM-09 is investigating design of

improved aggregate attrition modeling for theater-level modeling. WCM-25 is laying the groundwork for advanced modeling of logistics in analytical combat models. Finally, WCM-37 is responsible for creation of scenarios in COMBAT$^{XXI}$ based on the MCO-1 2020 Scenario published in Defense Planning Scenario (DPS) or Multi-Service Force Deployment (MSFD) published by Office of Secretary of Defense (OSD) and vetted by the OPNAV staff.

Effective hybrid analysis taking advantage of the integration of components from these sources will provide demonstration of a broad, joint set of warfare capabilities. All work will reflect precepts of the XMSF program, utilizing Internet technologies and Web services for common data representations, semantics, protocols, and interchange. This work is expected to lead to application of the new analytical modeling capabilities to operational problems of interest that demonstrate the repeatable, scalable benefits of this technical approach.

## 2. Background

The Office of the Secretary of Defense (OSD) has identified a new Analytical Agenda seeking to transform the way the Department of Defense applies Modeling and Simulation (M&S) to challenges of today's warfighters. Primary focus areas of the analytical Agenda are:

- Service/Agency POM Development
- Studies: Program Budget Review, Defense Planning Guidance (DPG), Analyses of Alternatives (AOA)
- Capabilities-Based Future Force Planning and Future Requirements

The 2001 Quadrennial Defense Review (QDR) defined Capabilities-Based Planning, stating it "shifts the focus of U.S. Force planning from optimizing for conflicts in two particular regions -- Northeast and Southwest Asia – to building a portfolio of capabilities that is robust across the spectrum of possible force requirements, both functional and geographical." To support this concept, tools are needed that enable analysts to examine a wide range of variability in priority Red, Blue, and Green factors, in order to achieve a broad portfolio of military capabilities that will perform robustly in an uncertain future environment and that are linked to Joint Concepts of Operations. This requires a new class of M&S capabilities, moving away from monolithic, closed system designs to open, M&S frameworks that permit modular, loosely coupled components to be rapidly integrated to create agile analytical capabilities to address the variety of missions conducted by today's warfighters. These tools must be flexible, extensible, scalable to a variety of scales of combat, re-usable, executable in a desktop/laptop environment, convenient to use, able to exploit the best methods (functionality) available in various domains, and not bound to traditional approaches to combat modeling but able to model future concepts and to provide a framework for introducing wholly new concepts of warfare.

The pattern for success in this transformational endeavor is the Internet and World Wide Web. This computational environment has shown the capability to scale to global dimensions by providing a low cost-of-entry through establishment of standards for exchange of information across any platform and operating system. Recent emergence of the Extensible Modeling and Simulation Framework (XMSF) program from the Defense Modeling and Simulation Office (DMSO) reflects the desire to exploit the great success of Internet technologies, and the massive commercial investment in the advance of those technologies, to meet DoD M&S requirements across analysis, training, acquisition, and experimentation. XMSF is defined as a composable set of standards, profiles, and recommended practices for web-based M&S. The foundational precept is that Internet technologies, including Extensible Markup Language (XML) based

languages and service-oriented architectures (e.g., Web services), will enable a new generation of distributed M&S applications to emerge, develop, and interoperate.

## 3. Scope

Paramount project objectives are to produce a new dynamic for analytic capabilities by connecting diverse analytic tools using Web services. This effort involves software analysis, design, and development to review and upgrade existing code bases (Simkit and NSS) leading to integration of functional capabilities with the Simkit-based COMBAT$^{XXI}$ simulation. The effort also demonstrates the analysis capability of the hybrid tools through design and conduct of an examination of specific operational problems. Tasking requires expertise in Operations Research, Simkit Discrete Event Simulation software package, the NSS code base, along with the establishment and management of Open Source software archives for long-term viability.

## 4. COMBAT$^{XXI}$ Memorandum of Agreement

In order to perform the planned work, the NPS WCM team requires access to and use of COMBAT$^{XXI}$ source code and documentation. A Memorandum of Agreement (MOA) is in preparation by TRAC-White Sands (COMBAT$^{XXI}$ developer) and the Marine Corps Combat Development Command (MCCDC) to specify terms of use of the model for the WCM project. A synopsis of preliminary conditions from the COMBAT$^{XXI}$ MOA follows:

- COMBAT$^{XXI}$ will only be run on government computers at government facilities
- NPS-WCM team will have the ability to conduct demonstrations, write papers, give briefs, etc. using the version of COMBAT$^{XXI}$ provided for the duration of the FY 2004 projects beyond the end date of the projects.
- It is understood that COMBAT$^{XXI}$ is an unaccredited model and the versions provided for FY2004 work are pre-release versions. The earliest version of COMBAT$^{XXI}$ that will be a candidate for accreditation is 5.0, due to be released in Spring 2005
- Any changes to the COMBAT$^{XXI}$ base source code by WCM will be provided to TRAC-WSMR for review and possible inclusion
- Any code produced by WCM outside the COMBAT$^{XXI}$ source tree will be Open Source, in accord with WCM documents.

TRAC-Monterey will provide informal support in the form of allowing the WCM team access to its combat modeling labs, providing assistance from TRAC-MTRY analysts in running COMBAT$^{XXI}$, and access to training and demonstrations, as permitted. The WCM team will make all of its code available to TRAC-MTRY for its analytical efforts.

# Simkit Discrete Event Simulation (DES) Overview

## WHAT IS SIMKIT?

- A package (API) for easily creating Discrete Event Simulation (DES) models
- Written in Java, runs on any Java 2 platform and modern web browsers
- Open Source
- Installable from the web
- Small execution footprint
- Simkit is the simulation engine for Combat XXI, the Army's next-generation premier ground combat simulation (replacing CASTFOREM)

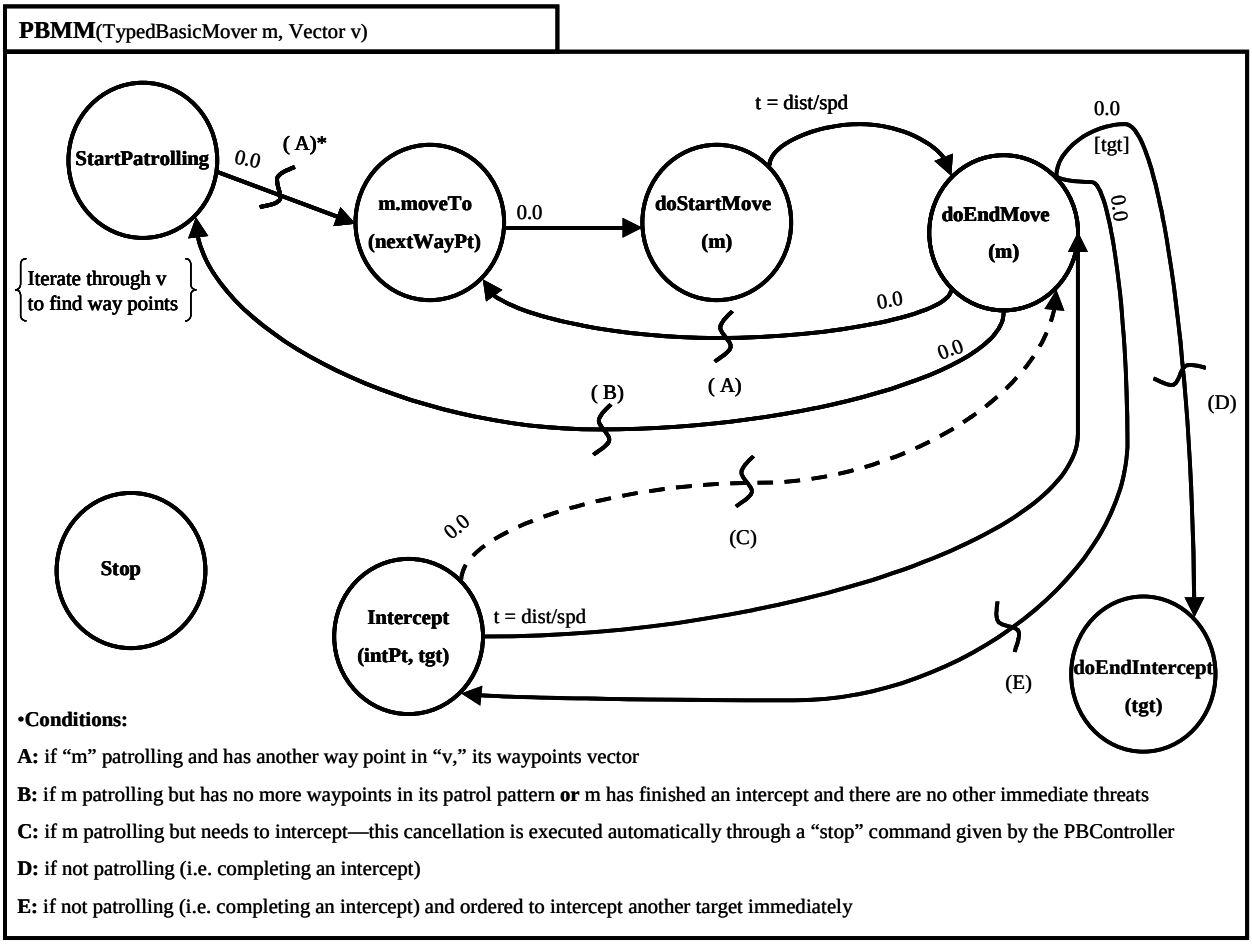
## WHAT ARE THE ADVANTAGES OF SIMKIT?

- Based on Event Graph Methodology, the simplest and most flexible formalism for DES modeling
- Supports component-based simulation modeling (LEGO Framework)
- Extremely flexible and extensible
- Allows separation of model constructs from data gathering without compromising ability to estimate Measures of Effectiveness (MOEs)
- Formalism ensures that any possible MOE can be estimated from properly constructed model
- Use of listener patterns supports very loose coupling of components
- Wide range of situations capable of being modeled in Simkit

## EXAMPLE SIMKIT MODELS

Several example excerpts are presented that are representative of the diversity of Simkit capabilities.

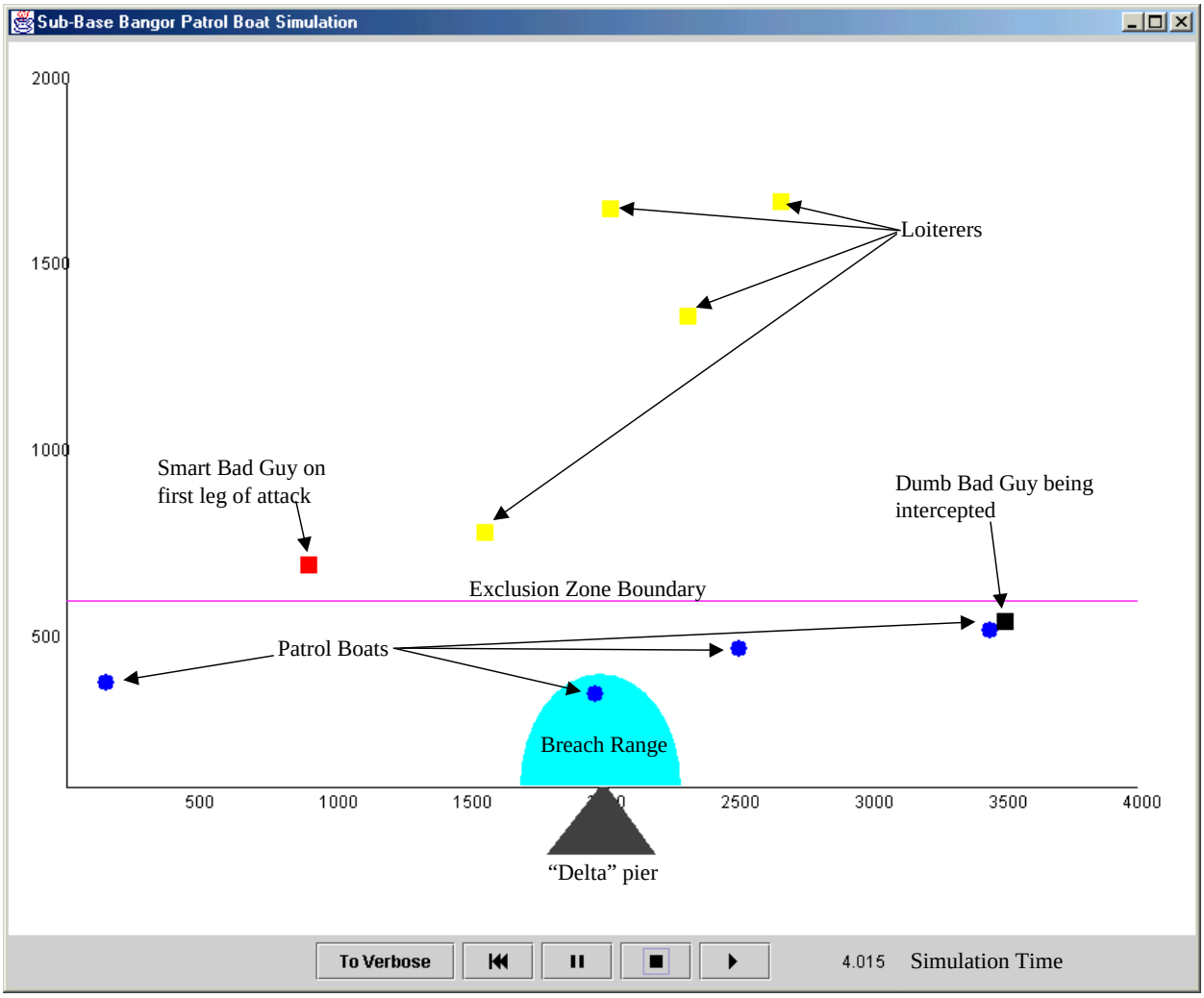
The following is an Event Graph representation of a "Mover Manager" component that controls the behavior of a patrol boat that is protecting a high-value unit against a terrorist attack on a waterfront (Childs, 2002).




Mover Manager for Patrol Boat (Childs, 2002)

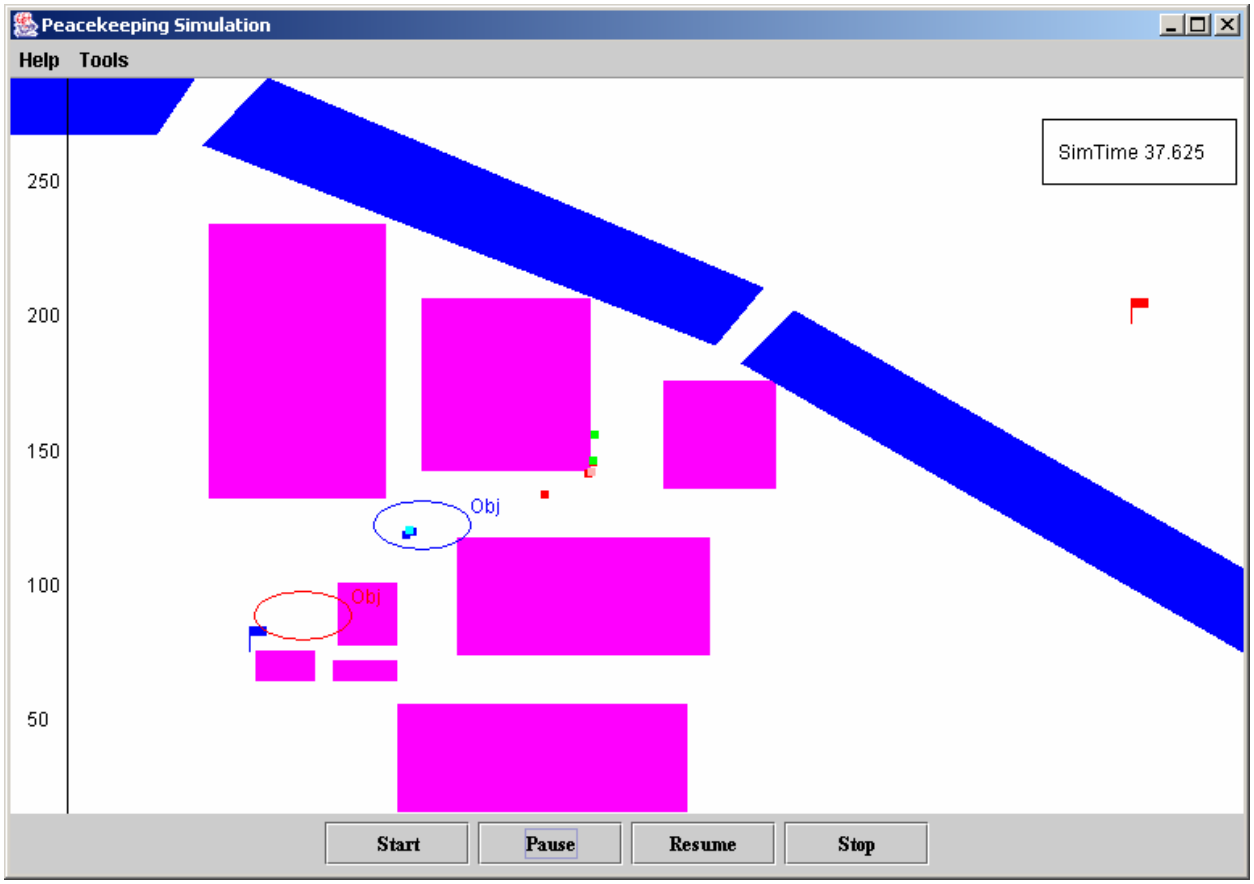
The formal descriptions represented in the above simulation graph diagram also map directly to software model instantiations using the Simkit library. Looking ahead, we expect to produce an integrated development environment which provides a visual simulation graph editor. This tool will also load/save/edit such models via an XML file format, run simulations, allow distributed operation, provide statistics and plotting support, and enable debug/diagnosis operations.

The following image is a screenshot from an animation of the scenario. The various entities are each controlled by a distinct set of behaviors specified by their own "Mover Manager." Since the animation is very loosely coupled with the simulation model, the same model is used both for display of individual runs as well as for batch runs in non-graphical mode for analysis.




Screenshot of Waterfront Force Protection Model (Childs, 2002)

Yet another example of Simkit's use in unconventional settings is a model of peacekeeping operations in an urban environment. What makes such situations challenging for traditional DoD wargaming models is that the measures of performance are often inverted. For example, instead of attempting to maximize enemy casualties, peacekeeping operations seek to minimize casualties of the antagonists. The following is a screenshot from an agent-based model of peacekeeping operations written in Simkit (Erlenbruch, 2002):




Agent-Based Model of Urban Peacekeeping (Erlenbruch, 2002)

**SOME RECENT NPS THESES USING SIMKIT**

MARGOLIS, MICHAEL, Captain, U.S. Marine Corps, "Operational Availability and Cost Trade-Off Analysis for the Multi-Mission Maritime Aircraft," MS in Operations Research, September 2003.

NAWARA, TERRENCE, LT U.S. Navy, "Tactical Route Planning for Submarine Mine Detection and Avoidance," MS in Operations Research, September 2003, Advisor: Steven E. Pilnick.

FUTCHER, FRANK W., Lieutenant Commander, USN, "Selective Offload Capability Simulation (SOCS): An Analysis Of High Density Storage Configurations," MS in Operations Research, September 2003, Advisor: Kevin R. Gue.

HAVENS, MICHAEL E., Lieutenant, U.S. Navy, "Dynamic Allocation of Fires and Sensors," MS in Operations Research, September 2002.

CHILDS, MATTHEW D., Lieutenant Commander, USN, "An Exploratory Analysis of Water Front Force Protection Measures Using Simulation," MS in Operations Research, March 2002.

ERLENBRUCH, THOMAS, Captain, German Army, "Agent-based Simulation of German Peacekeeping Operations for Units up to Platoon Level," MS in Operations Research, March 2002.

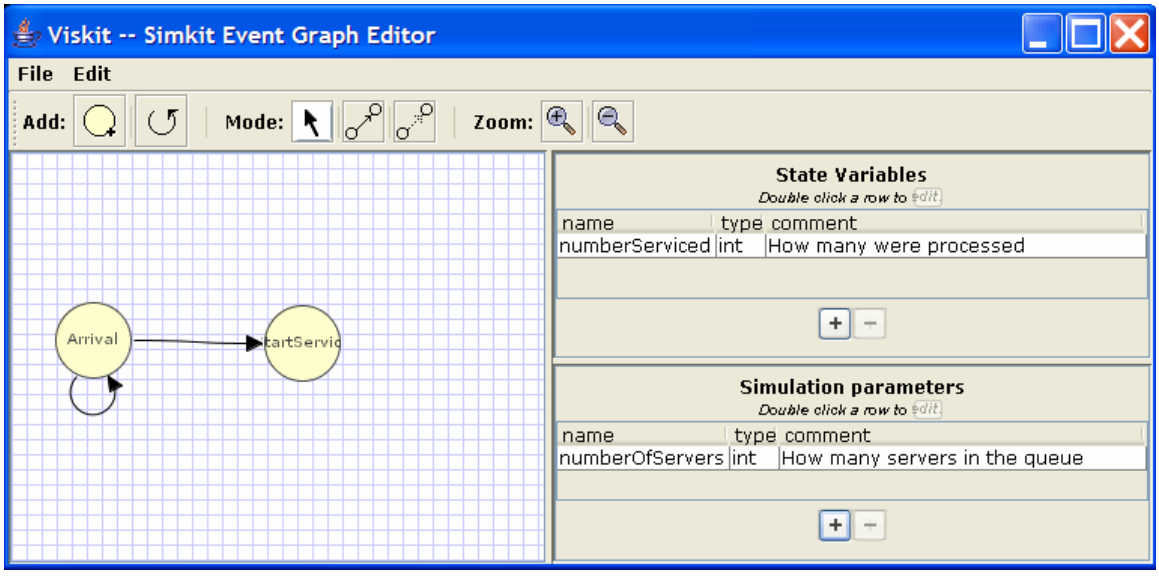
# Visual Simulation Toolkit (Viskit)

Viskit is a graphical tool for modeling diverse processes by building simulation event graphs and then conducting Discrete Event Simulation (DES) analysis. Built using the Simkit library and available as open source, Viskit is a key product and enabling tool in the NPS WCM effort.

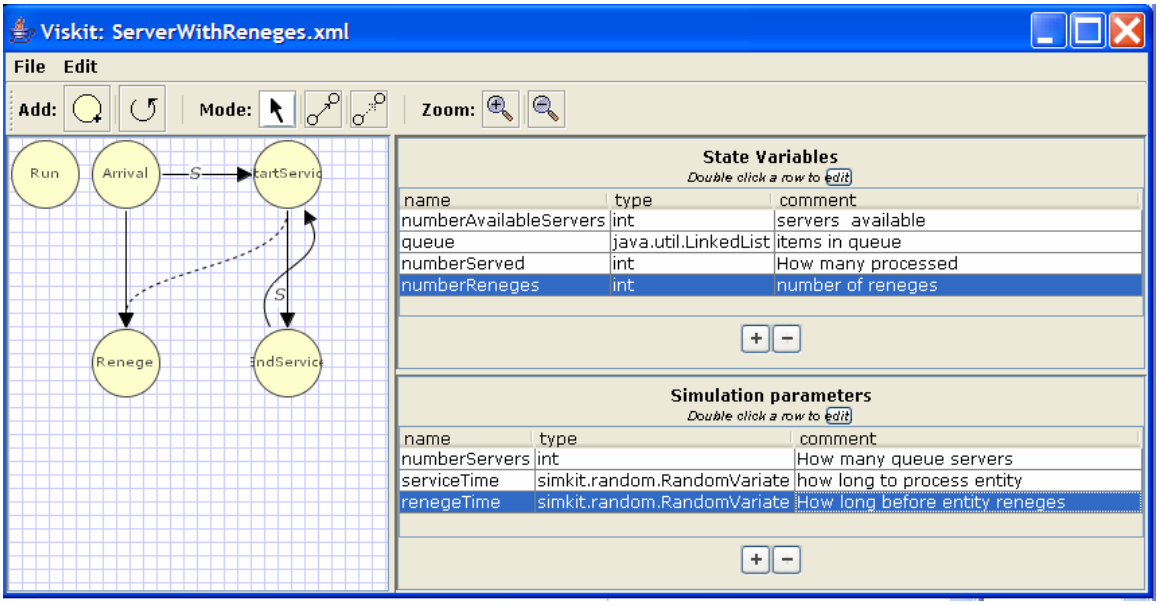
Event graphs are a conceptually clear and widely employed technique for describing any discrete event simulation. To date, analysts have used event graphs in a paper-and-pencil way to describe and understand a gigantic variety of simulations. After manually drawing such event-graph models, analysts then manually translated DES models and concepts into running code. This process requires substantial expertise, is time consuming and is sometimes a problematic mismatch between analyst capabilities and necessary programming skills. There is also a danger of mismatch or drift between the event-graph diagrams (which are used as a modelling and design tool) and the corresponding software code that hopefully implements them.

Viskit allows analysts to draw event graphs, model system interrelationships, and then automatically generate and run Java programs that directly implement the event graph. Key excerpts of source code must be inserted by the analysis author, but the bulk of programming effort is performed by the tool. We expect Viskit to greatly facilitate modeling and analysis of WCM projects, provide a growing library of well-documented models, and further extend the capabilities of the Simkit-based models used in the Combat[XXI] system.

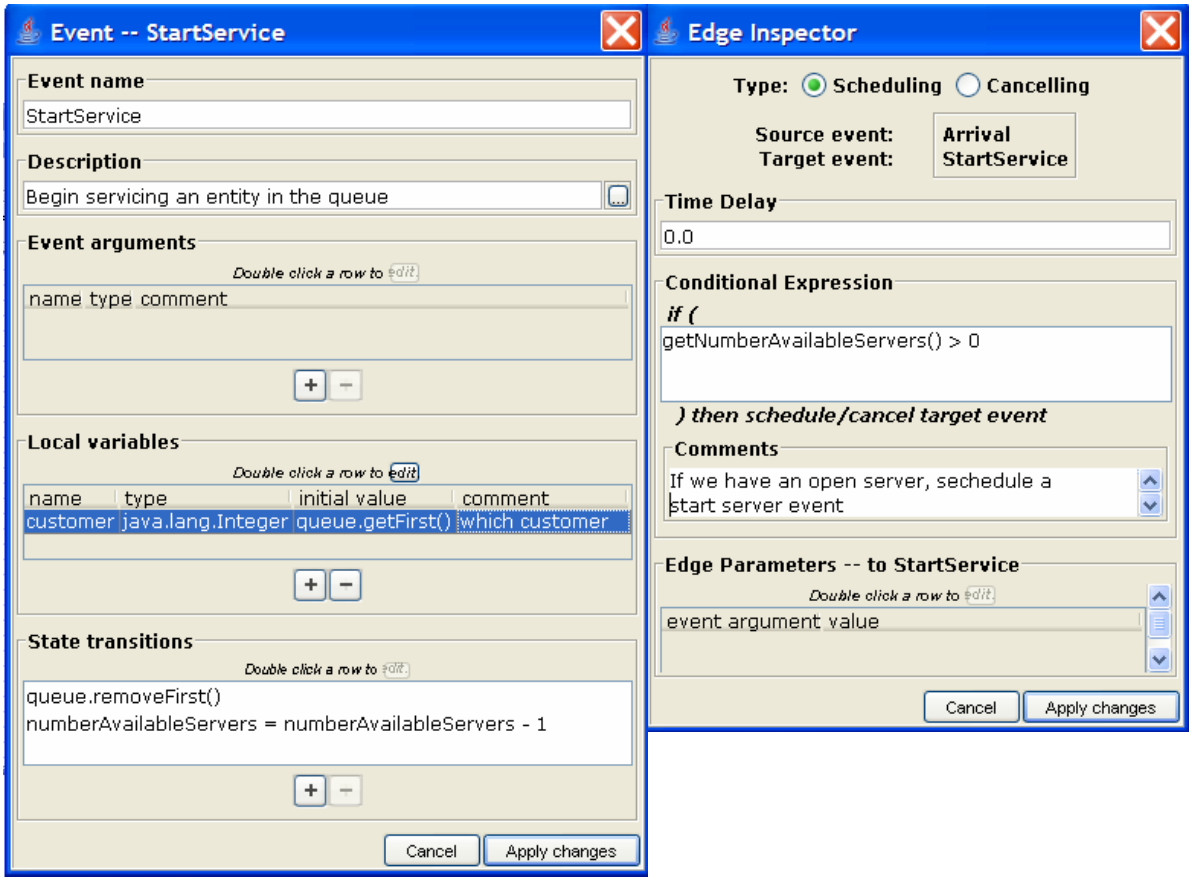
The screenshot below shows an event graph that represents a simple DES arrival process with one simulation state variable, numberArrivals. Graphical user interface (GUI) elements allow professional-grade construction, annotation and analysis of DES models.




In the Simkit methodology, nodes represent state changes while arcs represent scheduling preconditions. Prior-event cancellation is represented by dotted-line arcs. State-transition code and conditional event-scheduling code correspond to each visual element. The best-practice design conventions of Simkit modeling are maintained throughout. The next figure shows a more involved example.




Inspector panels for both nodes and arcs can be brought up by double-clicking any object on the screen. Example node state-transition and edge event-scheduling inspectors are seen in the next figure. The state transition shows the number of available servers being decremented by one. The edge inspector shows that a new event is scheduled only if additional servers are available. Note that some knowledge of Java programming is helpful, but the tool carefully structures the analyst's inputs into intuitive fragments that clearly capture the intended model functionality.



A model "Save" operation writes out the description of the event graph, including state transitions, to an equally comprehensive XML file. An example XML definition of an event-graph state transition—a fragment excerpt from the overall event graph—is shown below:

```
<Event name="Arrival">
        <StateTransition state="numberArrivals">
            <Assignment value="numberArrivals + 1"/>
        </StateTransition>
        <Schedule priority="0.0"
                  delay="interarrivalTime.generate()"
                  event="Arrival"/>
        <Coordinate y="60" x="90" annotation="GUI layout hint"/>
</Event>
```

Thus, XML is used as the native file format for Viskit. This technical approach greatly facilitates the validation, modification, exchange and interoperation of Simkit models and simulations.

Viskit automatically generates a Java implementation of the event graph from the XML file, using the Simkit library and DES design patterns developed by NPS as the software basis. Such simulation models can then be run as part of the Viskit integrated development environment, as independent standalone programs, as later-embedded classes in larger systems such as Combat[XXI], or within powerful programming/debugging editors such as the open-source *Netbeans* environment. From a programming viewpoint, this is an exceedingly powerful combination of options.

An example fragment of the generated code is shown below:

```
public class ArrivalProcess extends SimEntityBase {

    private simkit.random.RandomVariate interarrivalTime;
    protected int numberArrivals;
// …
    public void doArrival() {
        numberArrivals = numberArrivals + 1;
        firePropertyChange("numberArrivals",
                           numberArrivals);
        waitDelay("Arrival",
           interarrivalTime.generate(),new Object[]{},0.0);
    }
```

The current state of the Viskit software allows analysts to draw event graphs in Viskit, save them to an XML file, and generate a Java Simkit implementation. While we can generate Java implementations of event graphs, many simulations require multiple event graphs to work together in larger abstractions called "assemblies." A similar GUI for composing event-graph assemblies is under way, and integrated collection of statistical data is a forthcoming capability. Use of Viskit will soon undergo beta testing by OR students in a new Advanced Simkit course. An active, archived mailing list and distributions of Simkit/Viskit code are available online at http://diana.gl.nps.navy.mil/Viskit

# Naval Simulation System (NSS) Overview

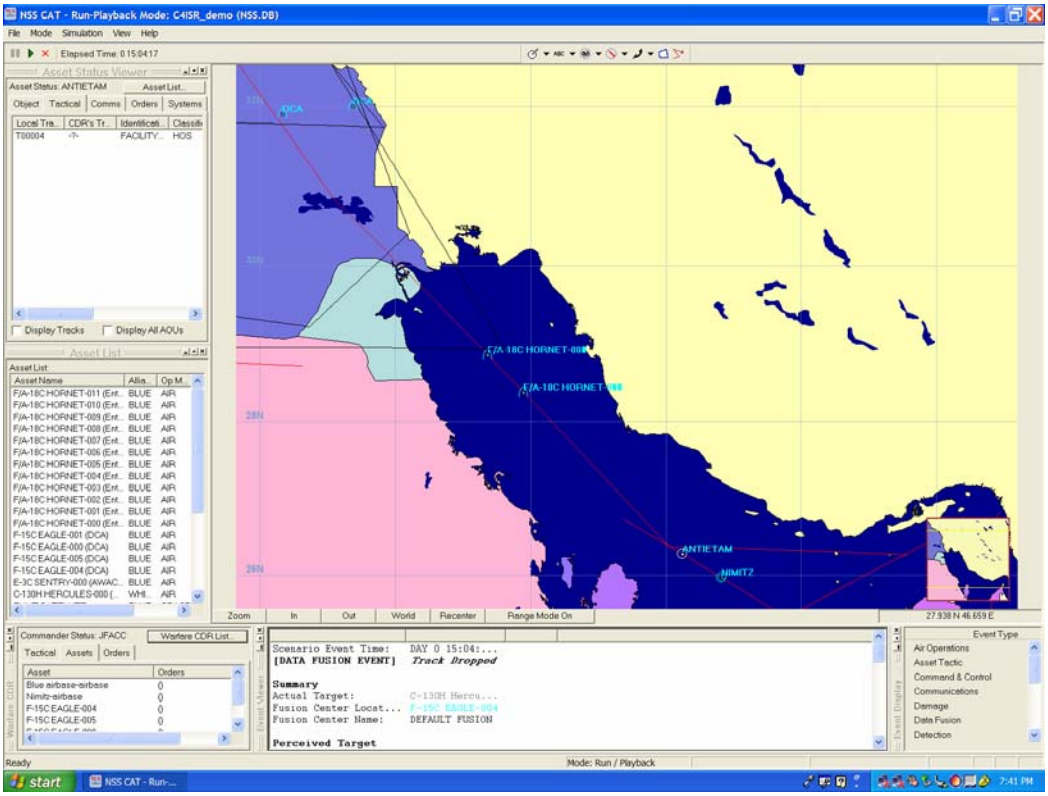
## WHAT IS THE NAVAL SIMULATION SYSTEM (NSS)?

- Computer-based framework for C4ISR-centric multiwarfare simulation
- Constructive, analytical simulation model of naval theatre operations supporting:
  - Naval and Joint operations planning and decision support
  - C4ISR analyses/assessments
  - Fleet exercises and experiments
  - Fleet training
- Representation of surface, subsurface, air, ground, and space assets
- Intended to provide valid warfare models, certified data to populate the models, simulation capability to execute the models over time, and support tools to assist user in scenario setup and analysis of results
- Program Management: NAVAIR under sponsorship of CNO (N6M) and COMPACFLT (N64).
- Prime Development Contractor: Metron, Inc., Solana Beach CA
- Support and V&V Contractor: Rolands & Associates Corporation, Monterey CA
- Under development since 1994 and used for numerous analysis support efforts for the Fleet and DoD acquisition communities
- Written in C++, runs on any PC under Windows
- Allows configuration of multiple "study nodes" on a network for distributing replications to multiple machines

## PRIMARY SOFTWARE COMPONENTS

- NSS Client Applications. Permit user visualization and control of system processes, including simulation instance development, scenario plan development, interactive execution, batch run management, and post-processing. Includes:
  - COA Analysis Tool (CAT). Facilitates detailed, comprehensive NSS scenario file generation. Provides maximum user flexibility in accessing simulation capabilities.
  - Warfare-Specific Support Tools. A set of focused tools for Fleet warfare plan evaluation: Strike Warfare Decision Aid to develop candidate Master Air Attack Plan; Targeting Management System to generate the strike target list; Theater Missile Defense COA Support Tool to evaluate TBMD RECCE plans.
  - CAT Demo Tool. For playback presentation of completed simulation event streams to analysis decision makers.
  - Network Monitor. To facilitate user monitoring and override control of NSS network activities.
  - Database Modernizer. Converts older versions of the NSS database to the most current format, thus making them compatible with the current software version.
  - Configuration Editor. Used to determine the current NSS installation configuration.
  - NSS Server. Manages NSS simulation execution resources on the local area network (LAN). Coordinates network access to the NSS Database by NSS Clients and Model Engine Nodes.

- NSS Model Engine Node. Parses and executes user defined simulation scenarios as directed by the Server. Generates scenario event stream, MOE output data, and execution status. Installed as a module on one or more network machines.
- NSS Database. Contains persistent and volatile data constructs that are processed by the NSS Server, Clients, and Model Engine Nodes. The NSS Database resides within the OODBMS Server (see Required COTS Software below).




NSS map view and status screen during model execution of a user-defined scenario

- Commercial Off-the-Shelf (COTS) Software
  - Database Management System Server. Contains the NSS Database. Interfaces exclusively with DBMS Clients. Note: NSS development to date has been tightly coupled with ObjectStore OODBMS.
  - Database Management System Client. Facilitates NSS component access to the NSS Database via the DBMS Server. Note: NSS development to date has been tightly coupled with ObjectStore OODBMS.
  - Spreadsheet Application. Facilitates automated manipulation and presentation of NSS interaction table input data and MOE output data. Note: NSS development to date has been moderately coupled with Microsoft Excel.
  - Word Processor. Used to generate preformatted Software Change Requests (SCRs). Note: NSS development to date has been loosely coupled with Microsoft Word.
  - Mathematical Optimization Application. Used in conjunction with NSS optimization code to provide plan recommendation services. Used by the warfare-specific support tools. Note: Currently, NSS optimization services are provided using the COTS GAMS linear and integer programming (LP/IP) solver package.

## SOME RECENT NPS THESES USING NSS

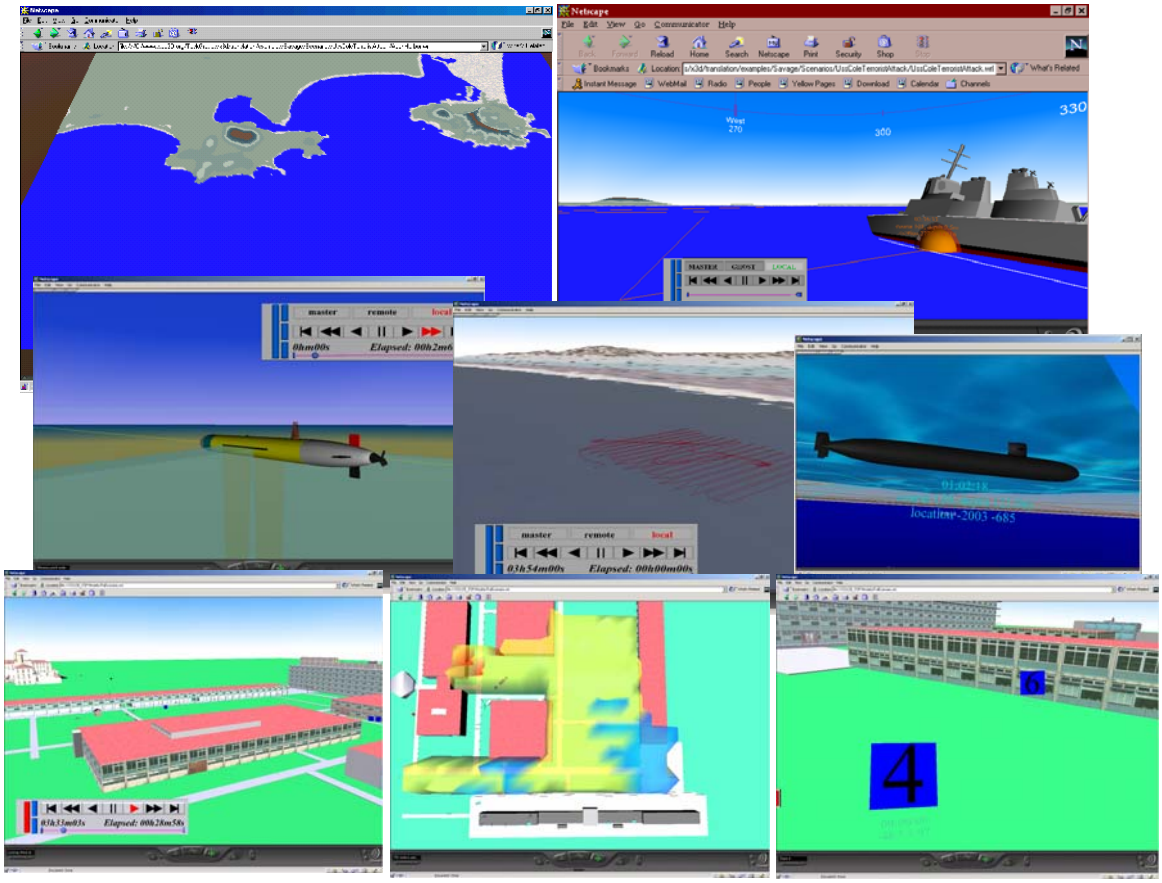
HOUT, GARY, NSWC-Crane, "Toward XML Representation of NSS Simulation Scenario For Mission Scenario Exchange Capability," MS in MOVES, September 2003.

CLAUDIO, JESUS, CPT U.S. Marine Corps, "An Aircraft Survivability Analysis Using Naval Simulation System," MS in Aeronautical Engineering, September 2003. SECRET

# Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) Overview

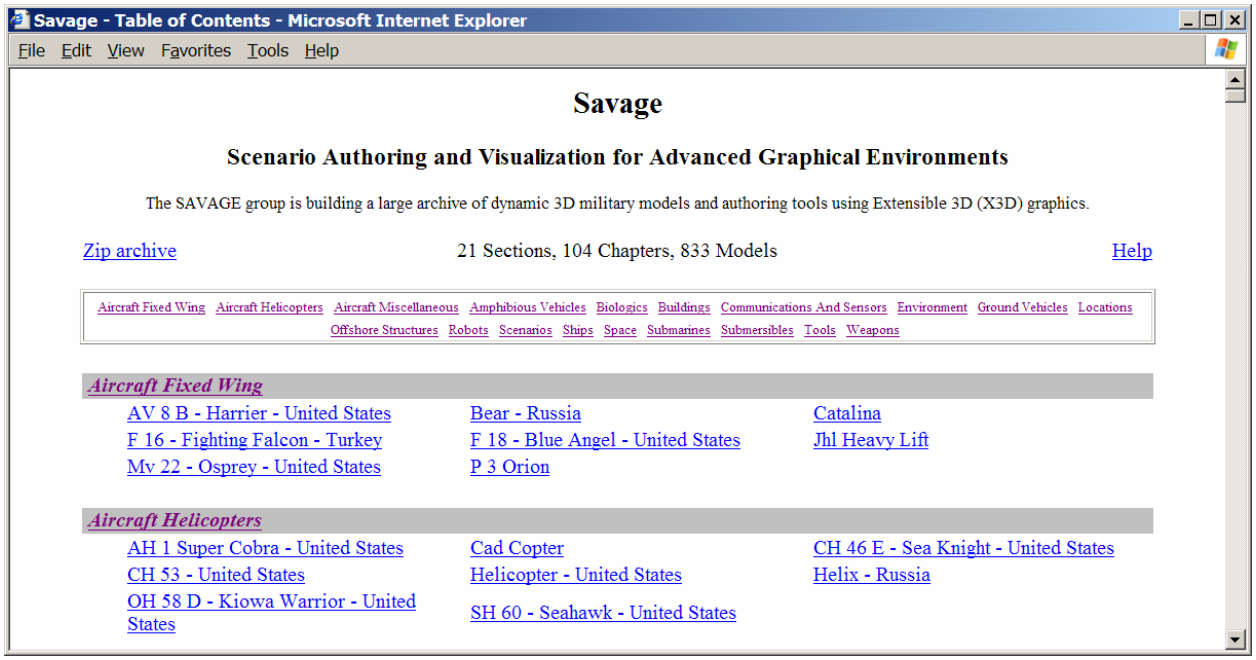
## WHAT IS SAVAGE?

- A library of military 3D models, authoring tools, physics-based models and scenarios
- Available on the Internet at http://web.nps.navy.mil/~brutzman/Savage/contents.html)
- Written in Extensible 3D Graphics (X3D), the next-generation 3D standard for the World Wide Web (http://www.web3d.org/fs_specifications.htm). X3D offers an XML encoding that captures and extends the Virtual Reality Modeling Language (VRML) standard.



Hundreds of scenarios and projects can be rapidly modeled using the SAVAGE 3D library.

The SAVAGE library has been used for reconstruction of real-world events such as the terrorist bombing of the USS Cole in Aden Harbor (top row), the USS Greeneville/Ehime Maru collision (far right, second row above), as well as for Autonomous Underwater Vehicle (AUV) mission planning and visualization (left and middle pictures, second row) and for visualization of Joint Experimentation Limited Objective Experiment scenarios (bottom row).




The SAVAGE library of models: http://web.nps.navy.mil/~brutzman/Savage/contents.html

## WHAT ARE THE BENEFITS OF SAVAGE?

- Over eight hundred open source 3D models, physics-based models, model components, authoring tools, and scenarios to facilitate rapid development of immersive, interactive, and dynamic Web-based scenes
- Models are readily incorporated into applications built using the Xj3D open source implementation of the X3D standard, freely available for use in building Web-based 3D applications
- Extensive and consistent documentation in all model files
- Continuing expansion of the library through model submissions from beginning and advanced X3D courses (MV3204 and MV4205)
- Models and tools have been used for detailed reconstruction of real-world events such as the USS Greeneville and Ehime Maru collision and the terrorist bombing of the USS Cole in Aden Harbor

## SOME RECENT NPS THESES USING SAVAGE

HUTTON, CLAUDE, MAJ USMC, "3D Battlespace Visualization Using Operational Planning Data," MS in Computer Science, September 2003.

NEUSHUL, JAMES, CAPT USMC, "Interoperability, Data Control and Battlespace Visualization using XML, XSLT and X3D," MS in Computer Science, September 2003.

HARNEY, JAMES, LT U.S. Navy, "Analyzing Anti-Terrorist Tactical Effectiveness of Picket Boats for Force Protection of Navy Ships Using X3D Graphics and Agent-Based Simulation," MS in Computer Science, March 2003.

NICKLAUS, SHANE, MAJ USMC, "Scenario Authoring and Visualization for Advanced Graphical Environments," MS in Information Technology Management, September 2001.


## Extensible Modeling & Simulation Framework (XMSF) Overview

http://www.movesinstitute.org/xmsf/xmsf.html

### WHAT IS XMSF?

The Extensible Modeling and Simulation Framework (XMSF) provides the technical basis for transformational interoperability via XML interchange, profiles, and recommended practices for web-based modeling & simulation.

- Broad technical interoperability is provided by open standards, XML-based markup languages, Internet technologies, and cross-platform Web services.
- Supports diverse distributed modeling and simulation applications. Also enables simulations to interact directly and scale appropriately over a distributed network through composable and reusable model components.
- Employs mainstream practices of enterprise-wide software development.
- Provides support for all types and domains of modeling and simulation (constructive, live, virtual, and analytical).
- Excellent support for ISO Extensible 3D (X3D) Graphics Specification with industry-academic-government activity in multiple standards consortia

### WHAT ARE THE ADVANTAGES OF XMSF?

- Comprehensive support by Open Standards in Web, Internet, and XML technologies. As predicted by an authoritative research workshop, Web services allow self-validating syntax + semantics to achieve cross-cutting interoperability in modeling and simulation.
- Testing and acceptance of common data and metadata standards provides semantic consistency among systems and services. Best-of-breed capabilities are kept in registries.
- Profiles are specification suites based on international standards, which define common capabilities for content production user/application support.
- Active working-group efforts in Simulation Interoperability Standards Organization (SISO) (http://www.sisostds.org) and Web3D Consortium (http://www.Web3D.org) provide a growing foundation in Web-based open standards.
- Ongoing development of exemplars provides easier entry to XML and Web services.

Data-driven conversion capabilities and application ubiquity provides both best business case and best technical case on a DoD-wide scale.

# WCM-09 Battalion Combat Modeling Module

**Partner Investigator**: Dr. James Taylor, NPS Operations Research Department

**Intended Outcomes**

- **Model Review:** Review (and document the review) of previous work on the hierarchy-of-models approach for the representation of large-scale combat (particularly the use of ATCAL Methodology by the Army's Concepts Evaluation Model (CEM) and the Air Force's Thunder model). The theoretical basis of all such applied implementations of G.M. Clark's ideas for developing such a hierarchy of models should be considered and taken as the point of departure for new theoretical developments in the hierarchy of models, as well as Taylor's new methodology for Lanchester attrition-rate coefficients. This review should identify functional requirements for multi-resolution modeling that can help generate an aggregated-force combat module for large-scale ground combat for a joint campaign model (implemented in a collaborative M&S framework involving NSS, Simkit, and COMBAT$^{XXI}$).
    - Taylor, J.G., "Research on Attrition Calibration (ATCAL) Methodology," Project Briefing presented to Director of U.S. Army Concepts Anaysis Agency (CAA), December 8, 1997.
    - Taylor, J.G., Various Unpublished Working Papers concerning ATCAL prepared for the Simulation and Analysis Center (SAC) of OSD PA&E, Operations Research Department, Naval Postgraduate School, 1997-1998.
    - Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On the Theoretical Bases of the Attrition-Calibration (ATCAL) Method, with Applications to Algorithm Development," Proceedings of the First National Meeting of the Military Applications Society, Huntsville, AL, May 1998.
    - Taylor, J.G., Yildirim, U.Z., and Murphy, W.S., "Hierarchy-of-Models Approach for Aggregated-Force Attrition," Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, December 2000.
    - Taylor, J.G., PowerPoint Slides for MV4656 "Low-Resolution Combat Modeling and Simulation," MOVES Academic Group, Naval Postgraduate School, May 1999 www.npsnet.org/~jtaylor/MV4656.html (especially Part G4 "Determining Numerical Values for Attrition-Rate Coefficients").
    - Taylor, J.G., "New Methodology for Lanchester Attrition-Rate Coefficients," Proceedings of the Millennium Attrition Symposium, Military Applications Society (MAS) of INFORMS, Houghton, MI, August 2001.

- **Theory Development:** Develop a theoretical basis for the hybrid methodology and establish the necessary models, with source code, at NPS to support follow-on software development work.
    - Determine theoretical and implementation shortcomings of previous and existing work on the hierarchy-of-models approach for modeling large-scale ground combat (especially ATCAL).

- Develop theoretical basis for a new hybrid methodology for a ground-combat module within the context of a joint campaign model (implemented in a collaborative M&S framework involving NSS, Simkit, and COMBAT$^{XXI}$); such a theoretical basis could lead to a spectrum of possible approaches for model implementation, characterized by different time lines of completion and risk.
- Determine approaches and their limitations for sensitivity analysis.

- **Technical Report:** Produce a thorough technical report suitable for publication and broad use. The report will cover the strengths and limitations of current methodologies, in combination with possible new capabilities based on hybrid combinations of hierarchical combat models.

- **Follow-on Planning**: Propose the follow-on year 2 plan for implementation and evaluation.

# WCM-14 Special Operations Forces (SOF) Modeling Project

**Intended Outcomes**

- **Framework Definition:** Assess existing programs and capabilities. Identify capabilities of Simkit, NSS, and Combat XXI.

- **Standards Identification:** Identify specific standards to be applied to the program, focusing on research directions of the XMSF project and warfare information modeling efforts such as the Battlespace Management Language (BML) and Battlespace Generic Hub. Define the basis for information interchange.

- **Design and Develop Baseline Model Framework:** Create the initial architectural framework for the analytical model, designing functions for input display, scenario construction, data extraction, and display of results. Integrate selected NSS C4ISR and Naval warfare functional capabilities with Combat XXI ground engagement functionality.

- **Demonstration Scenario:** A FORCEnet scenario will be designed and implemented using functional components within the new framework. The demonstration will be a notional SOF scenario that measures the contribution of C3 links to the mission and a Fires network to support Joint ops ashore.

# WCM-15 Joint Forcible Entry Options (JFEO) Modeling In COMBAT$^{XXI}$

**Intended Outcomes**

- **Problem Definition and Experimental Design:** Demonstrate the capability to examine specific analysis questions, identifying the system and force characteristics to be studied. Identify various options to be investigated and design experiments to be run. Prepare a document defining the analytical design to address the operational issue under examination.

- **Scenario Development:** Determine an appropriate operational setting for the study. Input necessary force structures, initial conditions, command relationships, communications characteristics and other database and scenario initialization data needed to represent the scenario in the integrated NSS/COMBAT$^{XXI}$ model. Coordinate with NSS-specific scenario developers to ensure consistency in representations of the battlespace for the study. Prepare a scenario description document.

- **Model Execution and Analysis**: The ability to conduct a full study with the integrated NSS/COMBAT$^{XXI}$ model is dependent on successful completion of the WCM-14 tasking (SOF Modeling for PR-07). Preparations for conducting the study can proceed as described above in Tasks 1 and 2 in parallel to software development efforts. A key checkpoint in the progress of the development effort and readiness of the software to support this study will occur in June 2004 during the Military Operations Research Society (MORS) Symposium to be held at NPS, Monterey CA. Based on the progress of the development effort, N81 will decide on the direction for continuation of this task (WCM-15); either:

    - Demonstration of the designed scenario with identification of shortcomings in the integrated framework that need to be addressed before it can be employed for the full study, or
    - Execution of the study by conducting necessary model replication runs to obtain statistical data supporting analysis of results. Prepare a document describing model outcomes, with lessons learned and recommendations for further study.

# WCM-16 SAVAGE for Force Protection/Anti-Terrorism (AT/FP) Modeling

**Intended Outcomes**

- **Requirements Analysis and Software Design:** Working with N81 analysts, determine functional capabilities needed to explore FP/AT problems of interest to N81. Perform software design to modify and expand capabilities of the NPS planning tool to meet required capabilities for the studies.

- **Software Implementation and Test**: Implement and test software modifications to the NPS FP/AT planning tool. Demonstrate new and enhanced capabilities of the model to perform desired studies. Work will include upgrading the implementation to use the SimKit discrete event simulation library.

- **Problem Definition, Scenario Development, Model Execution and Analysis:** Perform systems analysis to specify the analysis question, identifying the setting, threat and force protection characteristics to be studied. Identify various options to be investigated and design experiments to be run. Determine an appropriate operational setting for the study. Input necessary force structures, weapons characteristics, initial conditions, and other database and scenario initialization data needed to represent the scenario in the model. Conduct necessary model replication runs to obtain statistical data supporting analysis of results. Prepare a document describing the analysis problem, experimental design, scenario and model outcomes, with lessons learned and recommendations for further study.

# WCM-19 Improve Strike Module in COMBAT$^{XXI}$ for PR07

**Intended Outcomes**

- **Problem Definition and Experimental Design**: Demonstrate the capability to examine specific analysis questions, identifying the system and force characteristics to be studied. Identify various options to be investigated and design experiments to be conducted. Prepare a document defining the analytical design to address the operational issue under examination.

- **Scenario Development**: Determine an appropriate operational setting for the study. Input necessary force structures, initial conditions, command relationships, communications characteristics and other database and scenario initialization data needed to represent the scenario in the integrated NSS/ COMBAT$^{XXI}$ model. Coordinate with NSS-specific scenario developers to ensure consistency in representations of the battlespace for the study. Prepare a scenario description document.

- **Model Execution and Analysis**: The ability to conduct a full study with the integrated NSS/ COMBAT$^{XXI}$ model is dependent on successful completion of the WCM-14 tasking (SOF Modeling for PR-07). Preparations for conducting the study can proceed as described above in Tasks 1 and 2 in parallel to software development efforts. A key checkpoint in the progress of the development effort and readiness of the software to support this study will occur in June 2004 during the Military Operations Research Society (MORS) Symposium to be held at NPS, Monterey CA. Based on the progress of the development effort, N81 will decide on the direction for continuation of this task (WCM-15); either:
    - Demonstration of the designed scenario with identification of shortcomings in the integrated framework that need to be addressed before it can be employed for the full study, or
    - Execution of the study by conducting necessary model replication runs to obtain statistical data supporting analysis of results. Prepare a document describing model outcomes, with lessons learned and recommendations for further study.

# WCM-25 Detailed Logistics Modeling for PR07

**Partner Investigator**: Dr. David Schrady, NPS Operations Research Department

**Intended Outcomes**

- Logistics Modeling of Sea Based Operations. NPS will model in detail the flow of commodities and forces from CONUS to a forward logistic site (FLS) and from the FLS to the ships of a sea base. The deployment of forces from the sea base and their sustainment ashore will also be included in this modeling. The modeling will be general enough to accommodate a variety of scenarios; i.e., forces sizes, distances, durations, present and potential capabilities, etc. Measures of performance will include force-closure time to the sea base, force deployment times from the sea base to objectives ashore, the degree to which the forces ashore can be sustained without creating a combat-service-support area ashore, the needed frequency of replenishment of commodities to sea-base ships, and the ability of sea-based transportation assets (tilt-rotor, helicopter, LCAC, etc.) to satisfy the tactical, logistical, and medical sortie requirements. Connectivity with other large-scale simulation environments will be provided by adding the Logistics Protocol Data Units (PDUs) to the NPS open-source implementation of the IEEE Distributed Interactive Simulation (DIS) Protocol. These modeling capabilities will be designed to be compatible with the NSS/Combat XXI effort conducted by NPS under the World Class Modeling project. The fundamental goal is to enable integrated, tactically grounded logistics assessments in concert with the world-class modelling capabilities provided by the forthcoming hybrid NSS/COMBAT$^{XXI}$ /Simkit system.

- MCO-1 2020 Scenario Construction and Preliminary Analysis. NPS will prepare an action plan for implementing software capabilities and then executing the following FY2005 goal efforts. These specific goals may require slight modification in order to align well with evolving assessment requirements and NSS/COMBAT$^{XXI}$ /Simkit/DIS tool capabilities. Immediate execution of the produced plan will be feasible beginning 1 OCT 2004.

    - **Goal 2005-1: MCO-1 2020 Scenario Construction and Preliminary Analysis**. NPS will construct an MCO-1 2020 Scenario based initially on the existing Defense Planning Scenario (DPS) or MSFD published by OSD. NPS will participate in the N81 sponsored Campaign Analysis Integrated Process Team (CAIPT) to collect data, CONOPS and other information to build the scenario tailored to OPNAV staff requirements. NPS will brief the status of the model and will make the model and scenario available for review. NPS will present their initial finding with analysis directed to the questions and issues identified by the CAIPT.

    - **Goal 2005-2: MCO-2 2020 Scenario Construction and Preliminary Analysis.** NPS will construct an MCO-2 2020 Scenario based initially on the existing DPS or MSFD published by OSD.

- **Goal 2005-3: Swing Scenario Construction and Preliminary Analysis.** NPS will use the scenarios built in Tasks 1 and 2 and construct a scenario where the two MCOs are being executed in a concurrent environment. NPS will work with the CAIPT to run different variants of the scenario where the timing of events may be compressed, reversed or coordinated by opposing forces.

- **Goal 2005-4: Develop Integrated Campaign Analysis Logistics Modeling & Simulation Capabilities**
  - Continue the effort started under the TACLOGS capability to model the theater logistics operations to support the Campaign Analysis identified in Tasks 1& 2. These modeling capabilities will be designed to be compatible with the NSS/Combat XXI effort conducted by NPS under the World Class Modeling project.

  - Continue the development of the EXLOGSS tool to enable the NSS/Combat XXI to model the logistics and sustainment efforts for expeditionary warfare of the future as identified under the Seabasing concept spelled out in Seapower 21. These modeling capabilities will be designed to be compatible with the NSS/Combat XXI effort conducted by NPS under the World Class Modeling project.

# WCM-28 Analytical Workbench for Simkit Modeling Project

**Intended Outcomes**

- **Model Capture and Upgrade:** Gather previously developed models from student theses and faculty research that used the Simkit software. Update those implementations for the current version of Simkit. Create a unified repository of the source code and model components with annotations facilitating access and use by an automated simulation development tool. Prepare a summary document describing the model capabilities collected into the repository. For example, simulations developed in the following student theses are candidates for the repository of models:
    - MARGOLIS, MICHAEL, Captain, U.S. Marine Corps, "Operational Availability and Cost Trade-Off Analysis for the Multi-Mission Maritime Aircraft," MS in Operations Research, September 2003.
    - NAWARA, TERRENCE, LT U.S. Navy, "Tactical Route Planning for Submarine Mine Detection and Avoidance," MS in Operations Research, September 2003, Advisor: Steven E. Pilnick.
    - FUTCHER, FRANK W., Lieutenant Commander, USN, "Selective Offload Capability Simulation (SOCS): An Analysis Of High Density Storage Configurations," MS in Operations Research, September 2003, Advisor: Kevin R. Gue.
    - HAVENS, MICHAEL E., Lieutenant, U.S. Navy, "Dynamic Allocation of Fires and Sensors," MS in Operations Research, September 2002.
    - CHILDS, MATTHEW D., Lieutenant Commander, USN, "An Exploratory Analysis of Water Front Force Protection Measures Using Simulation," MS in Operations Research, March 2002.
    - ERLENBRUCH, THOMAS, Captain, German Army, "Agent-based Simulation of German Peacekeeping Operations for Units up to Platoon Level," MS in Operations Research, March 2002
    - FRICKE, CAROLYN S., Lieutenant Commander, U.S. Navy, "Operational Logistics Wargame," MS in Operations Research, December 2001.
    - SAN JOSE, ANGEL E., Lieutenant Commander, Spanish Navy, "Analysis, Design, Implementation and Evaluation of Graphical Design Tool to Develop Discrete Event Simulation Models Using Event Graphs and Simkit," MS in Operations Research, September 2001.
    - LENHARDT, THOMAS A., Captain, U.S. Marine Corps, "Evaluation of Combat Service Support Logistics Concepts for Supplying a USMC Regimental Task Force," MS in Operations Research, September 2001.
    - MACK, PATRICK V., Lieutenant, U.S. Navy, "THORN: A Study in Designing a Usable Interface for a Geo-Referenced Discrete Event Simulation," MS in Operations Research, September 2000.
    - TURNER, THOMAS E., Major, U.S. Marine Corps, "A Simulation of the Joint Tactical Radio System Bandwidth Requirements to Support Marine Corps Ship to Objective Maneuver in 2015," MS in Operations Research, September 2000.
    - WOODAMAN, RONALD F.A., Major, U.S. Marine Corps, "Agent-Based Simulation of Military Operations Other Than War Small Unit Combat," MS in Operations Research, September 2000.

- ARMO, KNUT R., Commander, Royal Norwegian Navy, "The Relationship Between a Submarine's Maximum Speed and Its Evasive Capability," MS in Operations Research, June 2000.
- AYDIN, ERHAN, LTJG, Turkish Navy, "Screen Dispositions of Naval Task Forces Against Anti-ship Missiles," MS in Operations Research, March 2000.
- LE, HUNG B., Lieutenant, U.S. Navy, "Advanced Naval Surface Fire Support Weapon Employment Against Mobile Targets," MS in Operations Research, December 1999.
- KRIZOV, DAVID P., Major, U.S. Marine Corps, "Tactical Exercise Review and Evaluation System," MS in Operations Research, September 1999.
- STERBA, JOHN R., Lieutenant, U.S. Navy, "Operational Maneuver from the Sea Logistics Training Aid," MS in Operations Research, September 1999.
- TROXELL, ANTHONY W., Lieutenant, U.S. Navy, "Naval Logistics Simulator," MS in Operations Research, September 1999.
- UTAAKER, INGE A., Commander, Norwegian Navy, "Distribution of Firing Directions in a Coordinated Surface-to-Surface Missile Engagement," MS in Operations Research, September 1999.
- GRABSKI, MARK V., Captain, U.S. Army, "Assessing the Effectiveness of the Battlefield Combat Identification System," MS in Operations Research, June 1999.
- HEATH, GARRETT D., Captain, U.S. Army, "Simulation Analysis of Unmanned Aerial Vehicles (UAV)," MS in Operations Research, June 1999.
- POURNELLE, PHILLIP E., Lieutenant, U.S. Navy, "Component Based Simulation of the Space Operations Vehicle and the Common Aero Vehicle," MS in Operations Research, March 1999.
- SCHREPF, NORBERT, Captain, German Army, "Visual Planning Aid for Movement of Ground Forces in Operations Other Than War," MS in Operations Research, March 1999.
- ARNTZEN, ARENT, Lieutenant Commander, Royal Norwegian Air Force, "Software Components for Air Defense Planning," MS in Operations Research, September 1998.

- **Analytical Simulation Workbench:** Design and develop a prototype Analytical Simulation Workbench to access the repository of model components and to assist the user in composing a simulation model from the existing components. Prepare a guidebook describing use of the Workbench to develop a simulation. Provide demonstration of the prototype workbench.

- **Final Report:** Prepare a final report describing the design and development of the Analytical Simulation Workbench and providing a guidebook for use of the Workbench.

# WCM-37 MCO-1 Scenario Development in Combat XXI

**Intended Outcomes**

- **Design Scenario:** Design an expeditionary warfare scenario based on the MCO-1 2020 Scenario published in Defense Planning Scenario (DPS) or Multi-Service Force Deployment (MSFD) published by Office of Secretary of Defense (OSD). Modify the scenario as called for by the OPNAV staff through the Campaign Analysis Integrated Process Team (CAIPT). Coordinate delivery of the CONOPS and other material from the OPNAV staff.

- **Implement Scenario:** Implement the scenario defined above in Combat XXI. Instantiate all the units, conditions, and associated data in Combat XXI.

- **Test Scenario:** Test the implemented scenario to ensure it operates reliably and units and forces in the scenario behave in accordance with the design.

- **Transfer Scenario:** Deliver the scenario to organizations identified by the OPNAV staff.

- **Provide Support:** Document development of the scenario and deliver a technical report upon completion of transfer to designated organizations. Make personnel available to answer any questions regarding the scenario during execution of the WCM project.

# WCM-02 Operations Research (OR) Thesis-Research Topics

**Intended Outcomes**

OPNAV N-81 has provided 10 research areas for investigation by NPS Operations Research (OR) faculty and students in FY04. For each task undertaken, deliverables include a project report and student thesis. Project funding provides support for thesis advisors labor, student travel, conference attendance, and other expenses for accomplishment of the work. Follow-on work in FY05 is possible. Topics of interest include:

- Fog of War
- Decision Making in the Face of Uncertainty
- Impact of Information Overload on Commanders' Decisions
- Afloat C2 Requirements and Limitations to Support Integrated Logistics
- Tracking of Medical Services to Support Casualties
- Effects of Morale on Combat Performance
- Training Effects on Combat Performance
- Measuring Impacts of Effects-Based Operations (EBO)
- Configuration Impacts of Command and Control Organizations on Net-Centric Warfare
- Effectiveness of Using of Open-Source Coding Practices for Verification, Validation and Accreditation (VV&A)

These thesis efforts help train future analysts and further provide detailed theses on projects of real-world interest. NPS will provide a final report on the overall effort, assessing benefits of the directed thesis program, lessons learned, best practices, and recommendations for future work. The following specific research is now being undertaken:

- **Task 1: Decision Making in the Face of Uncertainty**

**Faculty Researcher:** Assistant Professor Robert A. Koyak
**Description:** Naval forces have demonstrated capabilities for crisis response from the "three hub" posture iterated in the Chairman's periodic Global Naval Forces Presence Policy (GNFPP) messages. Global CONOPs and the Fleet Response Policy provide alternative concepts for naval force employment. Given programmed naval force structure, the work will characterize the risk (as measured by lack of coverage, response time, availability of naval forces, etc.) of various employment policies (for example, GNFPP-like rotational deployments or more flexible FRP-like employment).

- **Task 2: Impact of information Overload on Commanders' Decisions**

**Faculty Researcher:** Research Assistant Professor Nita Lewis Miller
**Description:** Refine the researcher's recently developed Dynamic Model of Situated Cognition that accounts for many aspects of the cognitive processes involved in C2 systems. Eye-tracking technology will be used to study attention shifting, which was recently tied to decision makers' attempts to process large amounts of information. This applied research will also investigate the impact of intelligent filtering on attention shifting, level of processing, and decision quality.

- **Task 3: Tracking of Medical Services to Support Casualties**

**Faculty Researcher:** Professor Moshe Kress
**Description:** Propose and implement an in-context decision support system that will enable Navy (OPNAV) decision makers to determine optimal mixes of medical resources and capabilities that best satisfy responsiveness and operational requirements for medical services.

- **Task 4: Effects of Morale on Combat Performance**

**Faculty Researcher:** Research Assistant Professor Jeff Crowson
**Description:** Form a morale model which provides combat performance as the outcome variable. A variety of measures will be used to determine optimal ranges for a broad list of contributing factors: manpower policies, socialization, training, leadership, rewards, unit cohesion, ideology/cause, preconceptions of combat, etc. The model will then be used to predict the effects of these factors and possible interactions among them.

- **Task 5: Chat-oriented $C^4I$ Architectures in Network-Centric Warfare**

**Faculty Researchers:** Professors Donald P. Gaver, Patricia A. Jacobs
**Description:** Network-centric architectures for information sharing among warfighters can now take advantage of flatter, less-hierarchical peer-to-peer (P2P) structures. Information gathered by mobile nodes may remain at (or near) P2P endpoints, until requested by other users or else distributed via tactical chat to groups with shared interests. Mathematical-probabilistic descriptions of information requirements and simulation-based analytic tools will be developed to evaluate more flexible/fluid P2P regimes for information acquisition, storage, and sharing.

Goals include initiation of research and development for new methodologies that might measure the impact of improvements in military subject areas that have not been easily quantified. In general, OR students are expected to include the following steps in their chosen topic:

- Conduct a survey of the particular area of interest.
- Identify and synopsize relevant theories in the area of interest.
- Research candidate data techniques and analysis methods that are supportable by commercial, military and government agencies.
- Select the best methodology to analyze their problem-domain issues.
- Implement the methodology in a common collaborative analytical environment.
- Conduct analysis using the selected methodology (including Modeling and Simulation) in the area of interest.
- Utilizing emerging NPS WCM capabilities using Naval Simulation System (NSS), Simkit/Viskit and/or Combat$^{XXI}$ is specifically encouraged.
- Report the results in a thesis and final briefing.

As feasible and appropriate, thesis research work will implement insights into the collaborative analytical framework being developed by the MOVES institute under the World Class Modeling effort. We expect to establish a growing and ongoing body of work that provides direct value to current and future N81 operational assessment challenges.

# A Transformational Framework for Design, Development, and Integration of Simulation Models

Don Brutzman, Arnold Buss, LCDR Phillip E. Pournelle[1], Curt Blais, John Ruck[2]

MOVES Institute
Naval Postgraduate School
700 Dyer Road
Monterey, CA 93943

[1]Deputy Chief of Naval Operations (OPNAV N81)
2000 Navy Pentagon (Rm 4D453)
Washington, DC 20350-2000

[2]Rolands & Associates Corporation
500 Sloat Avenue
Monterey, CA 93940

A new class of Modeling and Simulation (M&S) capabilities is needed to support transformational studies and analyses. Software architectures for analytical M&S tools need to move away from monolithic, closed system designs to open, M&S frameworks. New frameworks are needed to permit modular, loosely coupled components to be rapidly integrated to create agile analytical capabilities that can address the variety of missions conducted by today's warfighters. Tools built on these frameworks must be flexible, extensible, scalable to a variety of levels of combat, re-usable, executable in a desktop/laptop environment, convenient to use, able to exploit the best methods (functionality) available in various domains, and not bound to traditional approaches to combat modeling but able to model future concepts and to provide a framework for introducing wholly new concepts of warfare.

The Extensible Modeling and Simulation Framework (XMSF) is a composable set of standards, profiles, and recommended practices for web-based M&S that has been emerging as a framework capable of supporting these capabilities. This paper presents an architectural framework for design, development, and integration of simulation models built on XMSF using two existing simulations: Naval System Simulation (NSS) and Simkit. The capabilities will be demonstrated by a web-based simulation model composed using C4ISR elements from NSS together with land-based units from Simkit. The framework provides the needed flexibility with its use of standards suggested by XMSF, especially the exclusive use of Extensible Markup Language (XML) for data transfer. This ensures that additional components can be easily added to the framework without requiring substantial internal modification. This framework therefore illustrates the ability to achieve the requirements for M&S listed above.

Submitted to 72nd MORS Symposium, WG 31 Computing Advances in Military Operations Research

# NSS, Simkit, and COMBAT$^{XXI}$ using XMSF Web Services for Joint Modeling and Analysis

Curt Blais, Arnold Buss, Don Brutzman, John Ruck[1], Don McGregor

MOVES Institute
Naval Postgraduate School
700 Dyer Road
Monterey, CA 93943

[1]Rolands & Associates Corporation
500 Sloat Avenue
Monterey, CA 93940

The elements of SEAPOWER 21...Sea Strike, Sea Shield and Sea Basing...commit the Navy to building, training and operating a force that maximizes the contribution of war winning capabilities in the joint battlespace anytime, anywhere. Tying the three pillars of SEAPOWER 21 together is FORCEnet. FORCEnet is the operational construct and architectural framework for naval warfare in the information age, integrating warriors, sensors, command and control, platforms, and weapons into a networked, distributed and joint combat force. SEAPOWER 21 will be implemented by a Global Concept of Operations (GLOBAL CONOPS) that will provide our nation with widely dispersed combat power from platforms possessing unprecedented joint warfighting capabilities.

The study measures the impact of FORCEnet, improved C4ISR, Seabased forces, SeaStrike and the other pillars of SEAPOWER 21 on the joint ground warfight. It utilizes the improved joint modeling capability based on a composite model using Naval Simulation System (NSS) for sea strike and the COMBAT$^{XXI}$ to model the ground combat. The models are linked using the Extensible Modeling and Simulation Framework (XMSF), which utilizes web services. This implementation is an examplar for a transformational framework for design, development, and integration of simulation models, a larger effort to provide modeling and simulation interoperability using principles of XMSF.

Submitted to 72nd MORS Symposium, WG 29 Modeling Simulation and Wargaming

# Simkit Analysis Workbench for Rapid Construction of Modeling and Simulation Components

Arnold Buss, Don Brutzman, Curt Blais, Rick Goldberg, Don McGregor, John Ruck[1]

MOVES Institute
Naval Postgraduate School
700 Dyer Road
Monterey, CA 93943

[1]Rolands & Associates Corporation
500 Sloat Avenue
Monterey, CA 93940

A recurring dilemma in the use of simulation models for analytic support of decision-making has been the length of time required to build the simulation model. Although emerging simulations have improved over legacy models, the problem persists. It is particularly difficult to create a simulation model using existing tools that captures only the desired elements affecting the performance measures to be studied. Additionally, there is often a lack of rigorous methodology underlying the model's design.

Simkit is an Object-Oriented API for creating discrete Event simulation (DES) models in Java. Based on a solid Event Graph methodology, Simkit has been used to quickly create models in a wide range of areas, including logistics and operational support, undersea models, and models that evaluate algorithms for allocation of weapons and sensors to targets in ground combat. Simkit's component-oriented approach facilitates the composition of models using some pre-built and some custom simulation components.

This work demonstrates a Graphical User Interface (GUI) for the creation and analysis of Simkit models. It utilizes XML to represent the components, so there is built-in interoperability with many other tools. Specifically, simulation components and models designed in this manner will be capable of interacting with models with Extensible Modeling and Simulation Framework (XMSF) capabilities. In component design mode, a new component is created by drawing the Event Graph and filling in parameters, so that the simulation modeler need not be a sophisticated programmer. In component construction mode, components are hooked together to create a model. In analysis mode, the models are exercised and run according to the desired experimental design. The workbench also has a number of examplar models that have been extracted from recent NPS Master's Theses.

Submitted to 72nd MORS Symposium, WG 26 Analysis of Alternatives