Navy Data Development Efforts for the *NET*work-centric *WAR*fare *S*imulation (*NETWARS*) Program

Albert Legaspi
OPNAV N6M TSG
SPAWARSYSCOM PD-13 TSG
4301 Pacific Highway
San Diego, CA 92110-5115
legaspi@spawar.navy.mil

Ranjeev Mittu
Naval Research Laboratory
Information Technology Division
4555 Overlook Avenue
Washington, DC 20375
mittu@ait.nrl.navy.mil

ABSTRACT

The Network Centric Warfare Simulation (NETWARS) program was initiated in 1996 by LT General Buchholz, the director for Command, Control, Communications, and Computer System, J-6 (Joint Staff). This was in response to concerns that C4ISR networks and systems, when exposed to full operational loading and unanticipated effects, may be susceptible to performance degradation and failure. The objective of the NETWARS program is to provide a simulation environment that allows the end user to conduct communications burden analyses, perform communication contingency planning and assess the performance of emerging communications technology. A key component to the success of NETWARS is service involvement. The services are providing the entities, traffic loading, networks/links, movement characteristics, and equipment models to be manipulated by the NETWARS toolkit. This paper describes the Navy data development efforts in all of these categories, and also discusses the long term goals in anticipation of supporting other Navy/DOD M&S programs.

1. INTRODUCTION

The goal of NETWARS [6] is to provide a Joint Task Force (JTF) simulation environment that allows the end user to determine bottlenecks in the military communications infrastructure and evaluate emerging communications technologies. This is accomplished through the development of a NETWARS toolkit, comprised of a front-end graphical user interface, and a back-end comprised of the OPNET simulation environment. The graphical front end allows the user to create JTF scenarios. This entails the specification, on a world map, of the entities involved in the simulation, their movement, communications devices and the networks and links utilized. The output of the front end is an ASCII Simulation Description File (SDF) which is submitted to the OPNET environment for simulation (Figure 1). Each service is responsible for providing simulation specific data, such as the entities involved in the scenario, their movement, communications devices located on those entities, networks and links utilized, traffic flowing in and out on those network/links, and finally models of the communications devices.

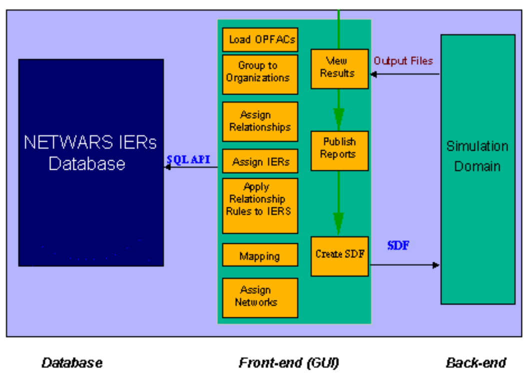

Figure 1: NETWARS Architecture

This paper describes the Navy's data collection and development efforts in these areas in support of NETWARS. This paper first provides a brief overview of the data needed by NETWARS. Next, we describe the shortfalls within the current "de-facto" Navy database and the inability to fully utilize it for NETWARS. Next, we describe the status of the Navy in obtaining NETWARS simulation data with regard to the planned scenarios, as well as provide a short and long-term approach for continually providing updated data. Next, we discuss the long term Navy vision in

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Navy Data Development Efforts for the NETwork-centric WARfare Simulation (NETWARS) Program**	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) **Naval Research Laboratory,Information Technology Division,4555 Overlook Ave. SW,Washington,DC,20375**	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
2002 OPNETWORK, Washington, D.C., Aug 2002.

14. ABSTRACT
The Network Centric Warfare Simulation (NETWARS) program was initiated in 1996 by LT General Buchholz, the director for Command, Control, Communications, and Computer System, J-6 (Joint Staff). This was in response to concerns that C4ISR networks and systems, when exposed to full operational loading and unanticipated effects, may be susceptible to performance degradation and failure. The objective of the NETWARS program is to provide a simulation environment that allows the end user to conduct communications burden analyses, perform communication contingency planning and assess the performance of emerging communications technology. A key component to the success of NETWARS is service involvement. The services are providing the entities, traffic loading, networks/links, movement characteristics, and equipment models to be manipulated by the NETWARS toolkit. This paper describes the Navy data development efforts in all of these categories, and also discusses the long term goals in anticipation of supporting other Navy/DOD M&S programs.

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**	**Same as Report (SAR)**	**7**	

order to provide the capability of supporting Navy/DOD M&S programs in need of similar data. Lastly, we provide a brief summary and conclusions.

2. NETWARS DATA NEEDS

The NETWARS program has requested each service to provide specific simulation data. The NETWARS front end is responsible for manipulating this data into a form that is "compatible" with the OPNET simulation engine. The front end allows the user to specify the entities involved in the simulation (e.g., LHD ship) the Operational Facilities, or OPFACS, co-located on the entities (e.g., Fire Support Coordination Center FSCC), system equipment (i.e. SE) used by the OPFACS (e.g.. AN-WSC 3), networks and links connected to the SE, and finally the traffic/messages (i.e., Information Exchange Requirements or IERs) sent out on the networks. The front end also allows the user to specify movement trajectories for the entities as well as velocity to be executed during the course of the simulation. Once a scenario has been constructed in the front end, it is passed to the OPNET simulation engine for evaluation.

The Navy is working to provide entities, OPFACS, SEs, networks and links, and IERs for the different NETWARS scenarios. Four scenarios are being developed for evaluation in the NETWARS toolkit. These scenarios include a portion of the Unified Endeavor scenario from STOW97, appropriately modified to emphasize communications. This scenario is called South West Asia (SWA) 1000, and contains 1000 OPFACS and 5000 System Elements. A follow-up scenario to SWA 1000 is SWA 5000, to denote the increase to 5000 OPFACS and 20,000 SE's. The third scenario is the North East Asia (NEA) 5000 and the fourth scenario will be developed for the Quadrennial Defense Review (QDR). The current timeline for providing data has been extended, with August 2000 as the cutoff for the SWA1000 scenario, and February 2001 as the cutoff for the SWA/NEA 5000 scenario. The timelines for the other scenarios are still pending.

3. SHORTFALLS IN NAVAL ARCHITECTURE DATABASE (NAD)

The Naval Architecture Database (NAD) [5] has been developed by SPAWAR 051 and is the "de-facto" standard that implements the Naval C4ISR Operational, Systems and Technical Architectures. The NAD does have some of the structure to support the data necessary for NETWARS; however, certain key attributes are either missing or are vague. A review of the NAD revealed several deficiencies. The NAD does not contain any System Equipment (SE) relationships with OPFACS. It only contains descriptions of SHIP-to-OPFAC relationships and SE nomenclature. The NAD does contain the IER's, however, critical values and fields are either vague or non-existent. For example, the following fields are non-existent:

- urc_code,
- producing_echelon_code,
- consuming_echelon_code,
- application_name_prod_code,
- application_name_cons_code.

The IER attributes of frequency and size are often qualitative. For instance, the frequency values are defined as periodic, continuous and as-needed. The volume size values are defined as high, medium or low. Clearly, these are not sufficient for a detailed NETWARS simulation. In addition, the NAD does not contain a network/link relationship to the SE's.

In spite of the shortcomings of the NAD, certain information was obtainable. Specifically, the NAD was used to obtain "operational-level" type information such as OPFAC-to-OPFAC communication (i.e., which OPFACS communicate with each other), and also the OPFACS contained on the Navy ships. One of the goals of the Navy is to formulate a plan of action to integrate the data needed by NETWARS into the NAD. However, the data must be validated before being included in the NAD. This validation process will be handled by SPAWAR 051. The entire process can be seen in Figure 2.

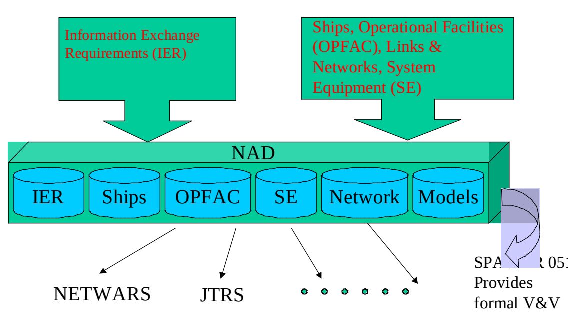

Figure 2: Plan of Action for Navy NETWARS Support

4. NAVY STATUS

The Navy has developed Amphibious Readiness Group (ARG) models that conform to NETWARS standards version 2. These models have been through an in-house verification and validation process, however the formal V&V process will be completed in December 2000. In the interim, the NETWARS Program Office has agreed to use these models, with an understanding that they have not been through a formal V&V process. The Navy will fully participate in the SWA5000/NEA 5000 study currently projected to start in FY 01.

Since V&V models are projected to be available for the SWA/NEA 5000 study, the Navy NETWARS team, with concurrence from the Navy Modeling and Simulation Management Office (N6M), will place all IER development efforts to support the SWA and NEA 5000 study. All products (e.g. IERs and models) that will be available for the SWA 1000 will be provided to the NETWARS program office with an understanding that the data may not accurately reflect Navy networks and its associated traffic.

Since an in-depth analysis of the NAD revealed several key deficiencies, the Navy NETWARS team met to discuss a long-term strategy to obtain the data needed by future NETWARS scenarios.

5. IER SHORT AND LONG TERM APPROACH

The Navy has chosen to develop short term, as well as long term plans for data development. The motivation for this decision is so that NETWARS, and other programs like Joint Tactical Radio System (JTRS) [1], project milestones and timelines are met, while at the same time the long term resources and tasks are on track so that detailed data can be collected and formally verified and validated. For example, a short-term solution might be to obtain only those IER attributes that will at the very minimum allow a simulation to occur. These attributes would include producing OPFAC, consuming OPFAC, size of the IER generated by the producing OPFAC and sent to the consuming OPFAC, and frequency of the IER sent by the producing OPFAC to the consuming OPFAC. The longer-term goal would be to obtain other IER attributes, such as producing/consuming echelon code, trigger events, threading events, and task-to-IER relationships. The types of IER's to be collected include voice, data and VTC. Table 1 lists the short and long term approaches for IER data collection.

Table 1: IER Short and Long Term Plan of Action

	Short Term	Long Term
Data IER	• Personal Interviews (Phibgru) • Ship Logs	• NOAC • DERA (JIFM) • TIRA • Ship Logs
Voice IER	• HDD Parameterization • Personal Interviews (Phibgru) • Ship Logs	• UCLA Work • Ship Logs
VTC IER	Combination of Above	Combination of Above

The Network Operations Analysis Capability (NOAC) [2] supports network analysis by providing actual network data as inputs to analytical tools. The collection of network data will be accomplished via network sniffers and managers such as HP OpenView and HP Net-Metrix. A prototype demonstration will be operational on the USS Coronado in August 2000.

The Defense Engineering and Research Agency (DERA) in the UK is also involved in several programs dealing with the collection of IER data. One specific program is called the Joint Information Flow Model (JIFM). A unique approach taken by JIFM includes collection of the IER in user terms, and not in terms of bits or bytes. The advantage to this approach is that it can be used to define a set of doctrinally based IER's, from which future IER's can be developed. In addition to JIFM, DERA is also developing a simulation environment called the Information and Network Simulation and Evaluation Tool-set (INSET). The relationship between JIFM and INSET can be seen in Figure 3.

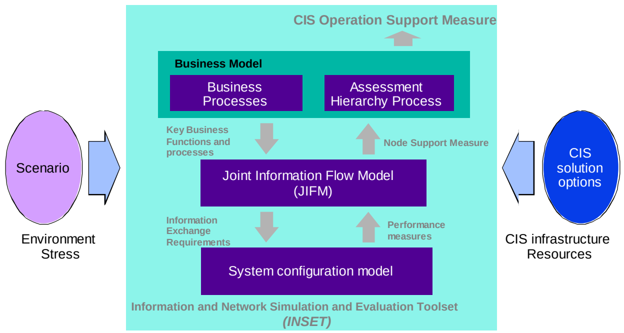

Figure 3: JIFM and INSET

The Tool for Interoperability Risk Assessment (TIRA) is a SPAWAR effort, leveraging work from the Distributed Engineering Plant (DEP) and Joint DEP. TIRA provides risk assessment and analysis with regards to the interoperability of joint and Navy systems. The test results captured through TIRA include network information (e.g., OTCIXS), information type (e.g., voice, video, etc), sending and receiving applications, mission area and network latency. One of the long-term objectives is to assess whether or not TIRA can be used to provide data to NETWARS.

The Hierarchical Data Dictionary (HDD) represents a hierarchical organization and description of the information (IER's) in the NAD. In other words, each IER in the NAD is categorized according to the HDD. The HDD parameterization technique involves the determination of the IER size and IER frequency driving parameters for each of the HDD entries associated with the IER's. This is very similar to the approach DERA is undertaking with JIFM. The benefits of this approach are that there are far fewer HDD entries than there are IERs in the NAD. Also, it has the advantage that the IERs are developed in operator terms.

6. COMMUNICATIONS MODELS

The NETWARS program provides an M&S capability to the Commanders-in-Chief (CINCs). The NETWARS toolkit provides a robust capability to analyze the impact of new technology on battle group communications and the performance of large-scale communication environments such as in a JTF. The NETWARS analysis requirements highlight the need for models with varying levels of fidelity and aggregation [3]. The ability to interface a variety of models with differing levels of fidelity has several technical challenges. For example, in order to determine the impact of new radios on the communication performance of a JTF, it may be necessary to insert a high fidelity model of a radio into a low fidelity environment. In previous NETWARS demonstrations, this procedure resulted in very long run-times for the simulations. This issue of multi-resolution modeling has been a concern in the M&S community.

The Navy has recently developed an innovative approach that resolves problems through multi-resolution modeling. The Navy's approach utilizes functional models and integrated analytic techniques [3] [4]. This approach has been presented at previous J6 technical working groups and resulted in positive collaboration with the Air Force, Marines and Army. In addition, these functional models will enhance the Naval Space Command Modeling initiatives in analyzing bandwidth requirements for an ARG and BG for the year 2005. These Navy-specific models validated the multi-resolution approach and modeling standards methodologies.

The architecture of these models was produced to reduce simulation run-time and provide a mechanism to run low fidelity with high fidelity models. The key to reducing the run-time was an implementation of hybrid models that included equations or curves of network performance. With a discrete time simulation engine, much processing is required to track/process all events created by the interaction of models. The Navy had successfully deployed, in previous work, a method of reducing the number of events, which in turn significantly reduced simulation run-time. Additional functions are also included in this work to further reduce run time, such as centralizing network switching/routing. This work also provides an alternate to OPNET's traditional pipeline. Models of communication links provide a medium that has attributes to account for effects of propagation [2].

6.1 Modeling Approach

The NETWARS program requires JTF simulation scenarios with up to 20,000 nodes. In order to accommodate manageable run-time requirements of scenarios with large numbers of nodes and to produce MOEs and MOPs of appropriate accuracy, performance functions are used where appropriate to compute the performance of simulated device and entity models. A performance function is a mathematical function that computes the specific performance value(s) based on the current operating point in the operating range of a device or entity. Examples of performance results include message delay and loss across a point-to-point link, message latency through a switch, and access delay through a media controller. Performance functions are to be based on analytical results, field exercises and tests, and more detailed and focused simulation studies of devices. The structures of performance functions include mathematical equations and table look-ups. The modular development of models allows for the enhancements and updates of performance functions as required. Figure 4 provides an illustration of the use of performance functions in the calculation of performance results for simulated device models.

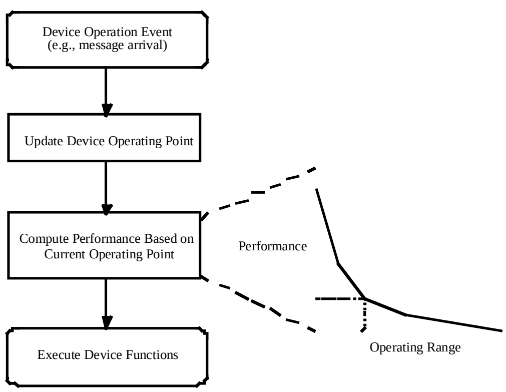

Figure 4: Performance Function Approach

The MAC function library was designed to model the effects of shared communications media on message transmissions. These effects include message delays and losses. The MAC function library utilizes performance functions to characterize these effects by including both the transmission medium and the contention protocol in a single link model entity. The modularity and flexibility of these functions facilitate the modeling of a variety of serial, bus and wireless link types. Link model performance and operation are derived from performance functions, as illustrated in Figure 5. Message delays and loss effects are determined from performance functions that are based upon several link conditions. Link conditions may consist of several factors, such as the number packet arrivals per unit time or the number of active traffic sources, or taps, on a link.

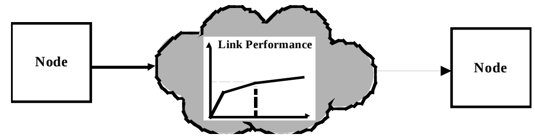

Figure 5: MAC Layer performance function

Network routing provides the capability for message delivery among nodes across a network. Network elements, such as routers and switches, typically utilize routing protocols to build and update routing tables in a distributed fashion. A centralized process that facilitates the modeling of these routing protocols has been developed for the Navy Battle Group model suite. This routing process is responsible for the development and maintenance of the routing topology for the entire network model. Centralized management of the routing process may significantly increase simulation efficiency with respect to run-time performance for large-scale network simulations. The routing process maintains a central routing topology in a format that is compatible with the structure that is defined within the OPNET routing kernel procedure package. This allows the process to implement routing functions and interoperate with many elements of the OPNET routing kernel procedure package. The routing process also supports flexibility objectives by extending routing services to most packet-switched protocols and link layer switching protocols. Initially, the routing process supports the OPNET minimum-hop routing algorithm. The routing process can be enhanced in the future to support static, user-defined routes and dynamic routing protocols such as the Routing Information Protocol (RIP) and Open-Shortest-Path-First (OSPF).

6.2 Navy Carrier Battle Group

The modeling approach described above was implemented in the development of Navy NETWARS models. At the Network editor layer of OPNET, models of each class of ships in a traditional battle group were developed by populating an appropriate set of C4ISR systems that are provided by the Navy system OPNET palette. At the link/physical layer, each ship is provided RF resources based on Operational Navy communication plans. Additional details on the construction of an Amphibious Readiness Group and Carrier Battle Group are available in references [7] and [8].

Figure 6 is an example of a Carrier Battle Group

Figure 6: Network Editor View of a Navy Carrier Battle Group

The approach above provided significant reduction in run-times, that in turn provided Navy analysts the capability to perform multiple "what-if" type experiments. Recently, JMSAC analysts studied the performance of a fairly complex system, which in past simulation studies were difficult to perform due to lengthy run times.

6.3 Automated Digital Network System

Automated Digital Network System (ADNS) incorporates the latest advances in commercial and military communications technology to maximize bandwidth, enabling seamless information sharing through flexible, adaptive and interoperable systems and services. ADNS provides both tactical improvements to the warfighter and non-tactical quality of life services to sailors at sea and ashore. It is based on industry accepted standards for management, routing and switching, using commercial off the shelf (COTS) products. ADNS interfaces user information systems available to the platform and will be present on all Navy platforms. The various Information Exchange Subsystems (IXS) currently in place today utilize proprietary protocols to serve very specialized interests. These IXS will hinder the migration to an open architectural approach. In order to shift away from stovepipe IXS protocols, information system applications need to be restructured to support an IP based network. A significant number of issues need to be addressed such as precedence, priority, and timeliness. ADNS provides baseband connectivity and networking services (voice, video, and data) to/from end user systems (Navy, Allied and Joint). ADNS uses standard compliant, commercial networking products and control technology to achieve Joint and Allied interoperability.

ADNS initially débuted in Joint Warfighter Interoperability Demonstration 95 (JWID 95) where it was extremely successful in providing specific capabilities, such as IP routing and dynamic bandwidth management. ADNS demonstrated a marked improvement in resource utilization by routing data from multiple sources over otherwise idle communications paths. This capability provides efficient access to single or multiple satellite channels. These and other
early results validated the ADNS approach and set the stage for future developments to achieve the Copernicus vision.

A simulation (Figure 7) was performed in a network of 5 ships connected via SATCOM (e.g. EHF, SHF, UHF) and Point-to-Point links (e.g. HF and UHF LOS). Performance runs on latency of HTTP downloads via SATCOM with Bit-Error-Rate 10^{-6} through 10^{-9} were obtained in a pre-defined scenario [8] with run-times of less than 3 minutes

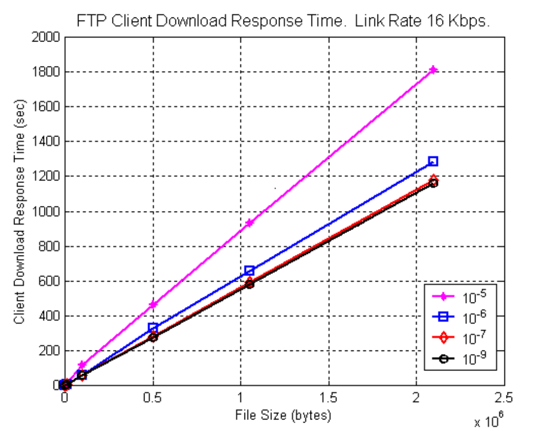

Figure 7: HTTP Latency results

7. LONG TERM NAVY VISION

The long-term vision within the Navy NETWARS working group is to eventually incorporate all of the aforementioned data into the NAD (or at least an interim database until V&V can be done). Over the course of the year, discussion within the Navy NETWARS working group has brought forth a vision to integrate many of the Navy databases into one "logical" database that is both CADM compliant, as well as compliant with the DOD Data Architecture (Figure 8). Discussions are on going with N6M, SPAWAR 051, NRL and Silver Bullet Solutions Incorporated (SBSI).

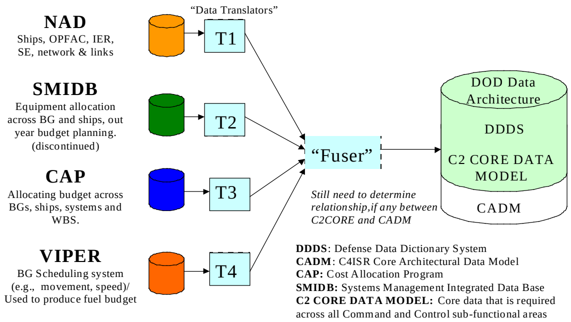

Figure 8: Long Term Navy Vision

8. SUMMARY AND CONCLUSIONS

The Navy's extensive experience in network modeling and simulation has resulted in an innovative approach to handling the multi-resolution objectives of NETWARS. This technology was used in the development of C4ISR communication systems for an ARG. In addition, models of a Battle Group are being built for future NETWARS studies.

In anticipation of studies that are to be included in the QDR, the Navy is currently taking models through a formal V&V process. This will ensure that each system (including protocols), IER and transmission medium are accurately reflected. The Navy's strategic plan for detailed IER's will support many analysis requirements including NETWARS.

9. ACKNOWLEDGEMENTS

The authors would like to acknowledge the sponsorship and support of OPNAV N6M.

10. REFERENCES

[1] Joint Tactical Radio System (JTRS) Web Site: http://www.jtrs.sarda.army.mil.

[2] Legaspi, Albert. Network Operations Analysis Capability (NOAC)

[3]. Legaspi, Albert., Ivancic, Carl., NETWARS C4ISR Communications Modeling Standards

[4]. Legaspi, Albert., Staley, Thomas., Dave', Nikhil., Ivancic, Carl., Alspaugh, Chris., Amphibious Readiness Group Multi-Resolution Technology Modeling Report, 30 March 2000

[5] Naval Architecture Database (NAD): http://www.silverbulletinc.com.

[6] NETWARS Program Web site: http://www.disa.mil/D8/netwars/index.html.

[7]. Navy NETWARS Carrier Battle Group OPNET Models, Joint Maritime Systems Analysis Center (JMSAC), SPAWARSYSCEN D822, June 2000.

[8]. Navy NETWARS Amphibious Readiness Group OPNET Models, Joint Maritime Systems Analysis Center (JMSAC), SPAWARSYSCEN D822, March 2000.

11. AUTHOR BIOGRAPHIES

Albert K. Legaspi is the Head of the Information Systems Analysis Branch, SPAWARSYSCEN D822. He was previously the Directory of the Technical Support Group (TSG) for the Naval Modeling and Simulation Office OPNAV N6M and is attached with SPAWAR Systems Command PD-13. He is currently the Navy technical representative to the Joint Chiefs of Staff (JCS) NETWARS project. Dr. Legaspi holds a B.S. in Electrical Engineering and Mathematics, M.S. and Ph.D in Electrical Engineering, all from UCSD and UCLA. Dr. Legaspi was the chairperson of IEEE Communication Society for San Diego Charter in 1995.

Ranjeev Mittu is employed as an Electronics Engineer at the Naval Research Laboratory in Washington, DC. He is currently providing technical support to the NETWARS project. Mr. Mittu holds an M.S. degree in Electrical Engineering from the Johns Hopkins University in Baltimore, Maryland.