Advances in Navy Data Development Efforts for the NETwork WARfare Simulation (NETWARS) Program

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ABSTRACT

LT General Buchholz, the J6 director for Command, Control, Communications, and Computer Systems, initiated the Network Warfare Simulation (NETWARS) program in 1996. 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) that 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.

This paper describes the Navy's data collection and development efforts in these areas in support of NETWARS. In section 2 we provide a brief overview of the data needed by NETWARS. In section 3, we describe the shortfalls within the current "de-facto" Navy database of communications traffic, and the inability to fully utilize it for NETWARS.

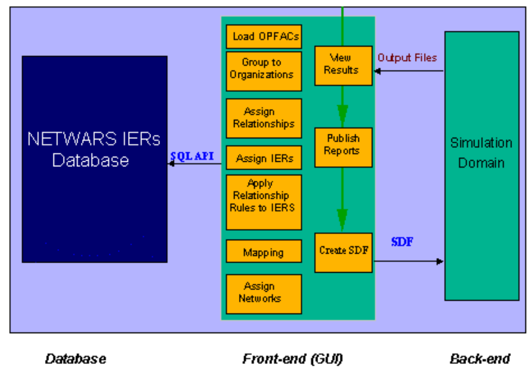

Figure 1: NETWARS Architecture

In sections 4 & 5, we describe the status of the Navy in obtaining NETWARS simulation data with regard to the planned studies, as well as provide a short and long-term approach for continually providing updated data. In section 6, we discuss the long term Navy vision in order to provide the capability of supporting Navy/DOD M&S programs in need of similar data. In section 7, 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 upcoming NETWARS studies.

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14. ABSTRACT

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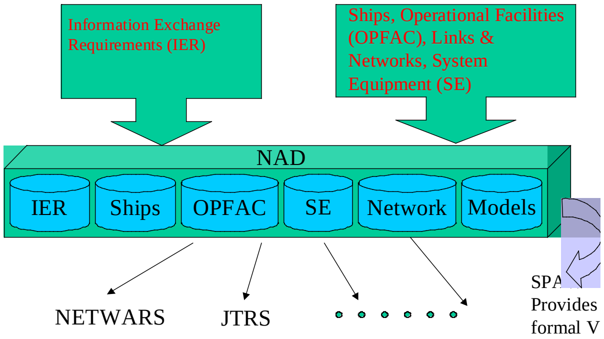

Figure 2: Plan of Action for Navy NETWARS Support

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 the relationship between System Equipment (SE) and Operational Facilities (OPFACS). OPFACS are representations of a grouping of SE’s, intra-nodal connections and operational behaviors that are capable of movement. Multiple OPFACS can reside within the same vessel or shore site. The NAD only contains descriptions of which OPFACS reside on different ships and provides a description of SE types. The NAD does contain the IER’s, however, critical values and fields are either vague or non-existent. For example, the NAD leaves out the following fields:

- 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 specify the protocols and system interconnect information that is essential to model SE to SE connectivities.

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. SPAWAR 051 will handle this validation process. The entire process can be seen in Figure 2.

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.

4. IER SHORT AND LONG TERM APPROACH – NAVY STATUS

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

Since our presentation at OPNETWORK 2000 last year, we have developed a systematic approach for collecting IER data in a hierarchical fashion. We start with the warfare area, then proceed to the scale/intensity of the conflict, phase of operation, specific mission/operation within that phase, the Universal Naval Tactical List (UNTL) tasks that are associated with mission/operation as well as associated conditions and standards that apply for that UNTL task, and finally the IER’s associated with this entire hierarchy. This is seen in figure 3 below.

This approach provides a logical and systematic mechanism for IER collection, and all IER data that is collected will be mapped to this approach, including all short and long-term plans. We have had a preliminary discussion with Amphibious Group 2 (PHIBGRU2) communications officers and staff, and have received positive feedback regarding this approach. Moreover, we have begun collecting IER data through interviews with PHIBGRU2 staff.

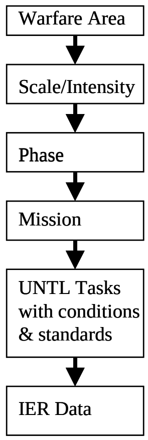

Figure 3: IER data collection approach.

With reference to the above figure, our initial warfare area is:

- Amphibious Warfare (AMW)
- scale/intensity corresponding to “low”
- phase corresponding to “Assault”,
- Missions corresponding to Destruction Fire Missions, Neutralization fire missions, harassing fire missions, interdiction fire missions illumination fires and suppression fires as well as screening and obscuration fires.
- Each of these missions correspond to UNTL task corresponding to NTA 3: Employ Firepower.

Furthermore we have also begun collecting data for:

- Warfare area corresponding to Strike Warfare (STW). Specifically, our initial focus is on IER’s that pertain to Close Air Support (CAS).
- Again we have chosen a scale/intensity of “low”.
- The phase is “execution”,
- The missions are Artillery Air Spotting, BHA/BDA, Coordination and Terminal Control of CAS Assets, NSFS Air Spotting, Radio Relay for the Tactical Air Control Party, and Visual Reconnaissance.
- Again, we have mapped each of the missions to their corresponding UNTL tasks.

Each of the missions were collected from unclassified Naval Warfare Publications (NWP). Naval Warfare Publications (NWP) contains doctrine and tactics, techniques, and procedures (TTP) for the employment of naval forces. The NWP hierarchy provides a framework for naval doctrine and TTP that follows the Joint Publication structure.

Tactics are the employment of units in combat or the ordered arrangement and maneuver of units in relation to each other and/or the enemy in order to use their full potential. The target audience is commanders of units to which the tactics apply, and their immediate superiors in command.

Techniques describe employment of specific components and systems of ships or aircraft. They are generally written for watch supervisors and operators.

Procedures are instructions, often detailed, for operation of specific systems and equipment. Procedures are often more rigid and directive than other levels of tactical guidance, due to the technical limits of weapons, ships, aircraft and other equipment. Procedures are written for equipment or system operators.

The principle means for disseminating TTP to the Navy is through NWPs. NWPs disseminate information on a broad scale from top-level doctrine to operational level tactics and eventually down to procedural NWPs, which discuss the operation of specific systems.

Although the NWP’s provide a good foundation for validated missions/operations, this data is somewhat outdated. During our visits with PHIBGRU2, we realized that certain missions were renamed or dropped altogether in favor of others.

One note worth mentioning is the fact that we have not yet begun capturing the conditions under which the IER’s apply or the standards to which they must achieve success. Conditions exist in the areas of “physical environment”, “military environment”, and “civil environment”. As an example, several conditions from “physical environment” under which IER’s are valid include:

- Terrain elevations
  - Very High (> 10,000 ft), High (6,000 to 10,000 ft), Moderately High (3,000 to 6,000 ft), Moderately Low (1,000 to 3,000 ft), low (500 to 1,000 ft) and Very low (, 500 ft).
- Electromagnetic Effects
  - Extensive, minor or none
- Humidity
  - Very low (<10%), Low (10 to 50%), Moderate (50-75%) and High (>75%)

The standards are tied to specific UNTL tasks. For example, for NTA 3.0 (Employ Firepower), a few examples of standards for success include

- Percent of high priority targets successfully attacked,
- Percent of actual weapons used compared to projected.

The IER is a function of conditions and standards. Capturing conditions and standards for IERs will be an area of future interest, as this will take considerable investment of resources. Additionally, data that helps satisfy the long-term IER goals (such as threading, trigger events, etc.) are being collected whenever possible. The data collected to date has been provided to the NETWARS program for inclusion in their studies.

In addition to interactions with PHIBGRU2, we have collected IER data through the Fleet Battle Experiment India (FBE-I) exercises. We are coordinating with Navy Warfare Development Command at Patuxent River to collect SNMP data for the following systems: PTW+, GCCS-M and LAWS. The mission area for which data will be collected is Time

Critical Strike, and will be integrated with the data already collected through PHIBGRU2 interviews.

The Network Operations Analysis Capability (NOAC) was briefly described in [9] and more information can be found in [2]. NOAC supports network analysis by providing actual data as inputs to analytical tools.

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). JIFM was briefly described in [9]. 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 4.

The Tool for Interoperability Risk Assessment (TIRA) is a SPAWAR effort, leveraging work from the Distributed Engineering Plant (DEP) and Joint DEP. TIRA was briefly described in [9]. TIRA provides risk assessment and analysis with regards to the interoperability of joint and Navy systems.

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.

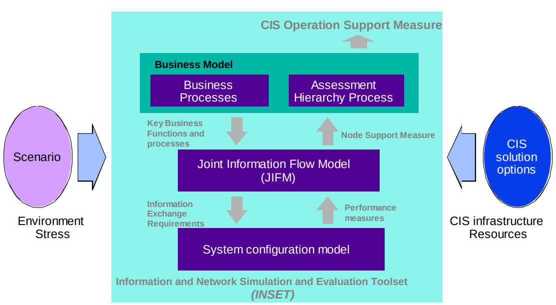

Figure 4: JIFM and INSET

5. COMMUNICATIONS MODELS - NAVY STATUS

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 Additional problems include interfacing models of different fidelities, as well as insuring that the low fidelity models provide the necessary IERS and MOE's and MOP's that are required of the simulation. 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].

5.1 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 5 provides an illustration of the use of performance functions in the calculation of performance results for simulated device models.

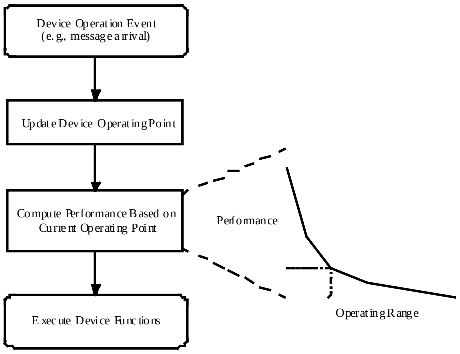

Figure 5: Performance Function Approach

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 6. 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.

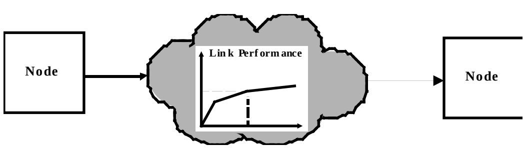

Figure 6: MAC Layer performance function

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 is described further in [9].

One of the key inputs to the models is data in the form of IER's. The IER data drives traffic generation within the simulation. The models, regardless of their fidelity, must support the IER's required for determining the MOE's and MOP's. This generally requires detailed IER information to have been obtained. In fact, the simulation is often only as accurate as the IER data that is fed into it, thus the need for detailed, accurate IER data is great. As the collected IER data becomes more complete, the results obtained from the models will become more accurate and dependable.

5.2 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].

The Navy's modeling approach provided significant reduction in run-times that in turn provided Navy analysts the capability to perform multiple "what-if" type experiments. Recently, Joint Maritime Systems Analysis Center (JMSAC) analysts studied the performance of a fairly complex system, which in past simulation studies were difficult to perform due to lengthy run times.

The models are currently being used and/or evaluated by:

- Assistant Secretary of Navy (RDA) Chief Engineer (ASN RDA) Bandwidth Assessment Team – the C4ISR communications models were used, and assessed, in how well they support Time Critical Strike missions.

- Naval Space Command (satellite communication division) – They are performing an assessment of existing satellite communication resources supporting a small conflict to a major theater of war. The communications models described here are used as a baseline for comparison.

- SPAWAR PMW-187 - Naval Sensor System Initiative (NAVSSI) used the Carrier models to determine the added performance of fielding IT-21.

- High Performance Computing Management Office for Force Modeling and simulation is using the models to port into another simulation engine (sequential and parallel) for better run-time

6. LONG TERM NAVY VISION

The long-term vision within the Navy NETWARS working group is to eventually incorporate 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 7). Discussions are on going with N6M, SPAWAR 051, NRL and Silver Bullet Solutions Incorporated (SBSI).

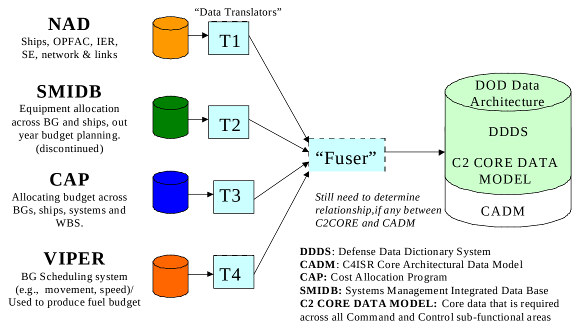

Figure 7: Long Term Navy Vision

7. SUMMARY AND CONCLUSIONS

In the category of IER collection, we plan to continue with the amphibious warfare area (i.e., the missions associated with AMW) as well as in STW. This should provide sufficient validated data for the NETWARS studies. Our efforts will also focus on including condition/standards associated with the IERs, as well as triggering effects, threading, etc. The Navy's strategic plan for collecting detailed IER's will support many analysis requirements including NETWARS.

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 being conducted within NETWARS, the Navy is currently taking models through a formal V&V process. This will ensure that each system (including protocols), IER and transmission medium is accurately reflected.

8. ACKNOWLEDGEMENTS

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