AUTOMATED EXERCISE PREPARATION AND DISTRIBUTION FOR LARGE SCALE DIS EXERCISES

Barbara J. Pemberton, Douglas J. Classe,
Naval Air Warfare Center Training Systems Division
Orlando, Florida
Charles W. Bradley, Mike Wilson,
Hughes Surface Ship Division
Fullerton, CA

ABSTRACT

New automated approaches for preparation and electronic distribution of large scale Distributed Interactive Simulation (DIS) exercises is required to accommodate the increasing number of DIS exercises and geographically dispersed exercise participants.

This paper describes two prototype tools -- 1) automated DIS exercise preparation tool, and 2) an automated electronic distribution tool. The preparation tool uses an expert system to reduce the time to prepare large scale DIS exercises from weeks/months to minutes/days. The *electronic distribution tool* demonstrates a first implementation of the DIS "Set Data" protocol data unit (PDU) for electronic exercise initialization.

Three viewpoints of the automated tools are combined in this paper: 1) government -- requirement statement, and DIS implementation, 2) contractor -- systems analysis and expert system implementation, and 3) military -- ease of use, validation.

Future direction and joint applications of the automated DIS tools are also presented.

ABOUT THE AUTHORS

Barbara J. Pemberton is a Computer Scientist for the Department of the Navy at the Naval Air Warfare Center Training Systems Division. Mrs. Pemberton is currently the Principal Investigator for research of automatic exercise preparation/distribution and control using expert systems, Mrs. Pemberton holds a Master of Science in Management from Rollins College and a Bachelor of Science in Mathematics from the University of Tennessee. Her previous experience includes training system software acquisition and development at General Electric and Martin Marietta.

Douglas J. Classe is an Electronic Engineer for the Department of the Navy at the Naval Air Warfare Center Training Systems Division. He is currently responsible for system design and implementation of the automated DIS exercise preparation and distribution tool. He holds a Bachelor of Science Degree in Electrical Engineering from the University of Central Florida. His previous experience includes Department of Defense software acquisition for the Navy, and high frequency amplifier design using GaAs technology at Martin Marietta.

Charles W. Bradley is a Senior Systems Engineer with Hughes, Surface Ship Division. Mr. Bradley is responsible for expert system research. Prior to his employment with Hughes, Mr. Bradley worked for nine years developing, evaluating, and documenting tactics for new weapon systems as they were introduced into the fleet. Prior to his civilian employment, Mr. Bradley served for nine years as a commissioned officer in the U.S. Navy and was a qualified Surface Warfare Officer. Mr. Bradley has a Masters of Science degree in Operations Research from the U.S. Naval Postgraduate School, and a Bachelor of Arts degree from the University of Alabama.

Michael F. Wilson is a software engineer with Hughes, Surface Ship Division. Mr. Wilson has over 20 years of software experience. His most recent work includes the use of expert systems and graphical user interfaces to design and implement an automatic tool for exercise preparation for large scale DIS exercises. Mr. Wilson has a Bachelor of Science degree in Electrical Engineering from the University of Washington.

AUTOMATED EXERCISE PREPARATION AND DISTRIBUTION FOR LARGE SCALE DIS EXERCISES

Barbara J. Pemberton, Douglas J. Classe,
Naval Air Warfare Center Training Systems Division
Orlando, Florida
Charles W. Bradley, Mike Wilson,
Hughes Surface Ship Division
Fullerton, CA

INTRODUCTION

Today's *military strategy has changed from a focus* on a global threat to a focus on multiple regional conflicts [1]. Regional conflicts consist of confined and congested water and air space occupied by friends, adversaries, and neutrals. Rapid *preparation* and *distribution* of training exercises in a common Distributed Interactive Simulation (DIS) networked environment (Figure 1) is required for quick coordinated action by all forces (e.g., joint and/or coalition). The forces participating in a DIS exercise will be using many different types of systems with different exercise specification and initialization needs – man-in-the-loop training simulators, embedded training systems, wargaming simulators and live ranges.

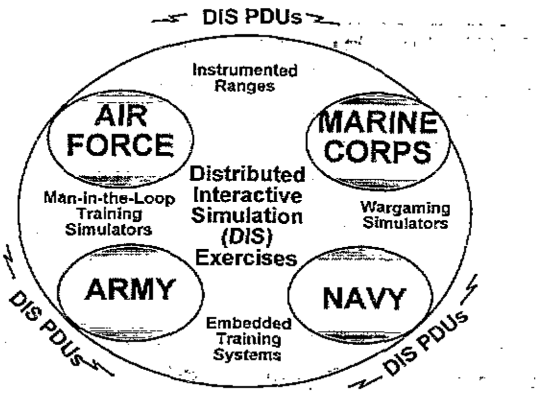


Figure 1. A DIS Training Environment

Today, creating training exercises is time consuming and labor intensive. The exercises are difficult to modify or vary in response to dynamically changing training requirements. In some cases, an exercise with 2000 objects (e.g., platforms, personnel) requires from weeks to months to prepare. Large scale *joint/coalition* exercises will require 10,000 to 100,000 or more objects. This implies a potential corresponding five to fifty-fold increase in the time to prepare a large scale exercise. Also, in current DIS demonstrations, the exercise initial conditions are manually entered by each participant into their system. A manual approach can easily lead to errors in platform placements and is a slow process.

Automated tools are required to -- 1) reduce exercise preparation time from *months/weeks* to *days/hours*, and also 2) electronically transfer in *minutes* 100,000 or more exercise objects to all DIS participants

OBJECTIVE

The objective of this paper is to describe two prototype tools: -- 1) Automated Exercise Preparation, Evaluation, and Preview (APEP) Tool-- to reduce exercise preparation time, and 2) *Automated Exercise Distribution and Display* (ADD) Tool -- to electronically distribute large scale DIS exercises to exercise participants (see Figure 2).

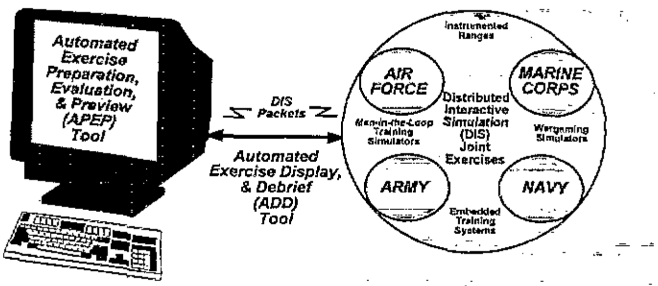


Figure 2. TWO TACTICS TOOLS -- Automated Exercise Preparation, Evaluation & Preview (APEP) *Tool, and* Automated Exercise Display & Debrief (ADD) Tool

The APEP Tool utilizes expert system technology and the ADD Tool utilizes simulation management DIS protocol data units (PDUs). A description of the two prototype tools, an evaluation of the APEP tool, and future expansion of the tools is presented in the following paragraphs.

AUTOMATED EXERCISE PREPARATION, EVALUATION, & PREVIEW (APEP) TOOL

The Automated Exercise Preparation, Evaluation, and Preview (APEP) Tool (Figure 3) overall concept consists of three capabilities: automated exercise force laydown based upon a specific training objective, 2) automated platform scripting using computer generated forces, and 3) automated association of training objectives with performance measurement criteria.

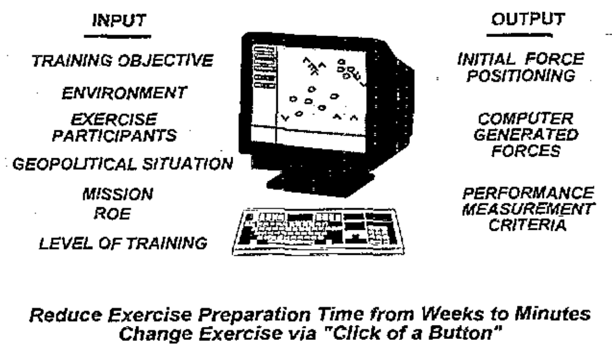


Figure 3. Automated Exercise Preparation, Evaluation, and Preview (APEP) Tool Overview

APEP Tool Prototype -- Training Exercise Force Laydown (TEFL)

The first APEP Tool capability prototyped is called Training Exercise Force Laydown (TEFL). TEFL is a proof-of-concept effort to demonstrate that one Training Supervisor can develop training exercises that:

(1) Represent non-trivial tactical situations, and comprise a relatively large number of both friendly and hostile units of all platform categories (e.g.,. surface, subsurface, and air).

(2) Are random enough in friendly and hostile unit placement to avoid the problem of trainees being able to unreasonably predict what will happen during training;

(3) Employ force laydowns which are tactically sound, both from a friendly force and a hostile force point-of-view;

(4) Support specific training objectives selected by the Training Supervisor;

Furthermore, this single Training Supervisor can *obtain these exercise force laydowns with the* TEFL within *minutes,* instead of the *weeks/months* required with the current manual processes.

The basis of the TEFL concept is to employ Artificial Intelligence techniques - specifically expert systems - to provide automation for training exercise force laydown. The Training Supervisor specifies only the "kind" of training he wants to conduct in high level, abstract, descriptive terms, and then TEFL's embedded expert system automatically infers the details of both the friendly BLUE and hostile RED Force laydown.

How a Training Supervisor Uses TEFL

First, the TEFL Training Supervisor selects a Training Objective from a menu of eight. These include:
(1) Strike Ashore
(2) Initial Approach from Seaward
(3) Long Range Battle Group Anti-Air Warfare
(4) Short Range Battle Group Anti-Air Warfare
(5) Coordinated Battle Group Anti-Air Warfare
(6) Submarine vs Ship Anti-Submarine Warfare
(7) Submarine vs Submarine Anti-Submarine Warfare
(8) Coordinated Battle Group Anti-Submarine Warfare

Next, the Training Supervisor selects BLUE and RED ships, submarines, and aircraft (by specific hull, pendant, or side number) to be included in the training exercise. TEFL employs a Technical Data Base indicating the specific sensors, weapons, and combat support equipment for each platform.

Finally, options specifying tactical constraints and limitations are specified by the Training Supervisor (e.g. initially Hot or Cold state-of-war; use of nuclear weapons possible; heavy jamming environment).

When all of the exercise descriptors have been input, the Training Supervisor initiates the TEFL expert system by selecting the menu button LAYDOWN. TEFL then automatically determines a laydown position - an exercise start position - for each of the BLUE and RED units in the specified exercise forces. Initial course, speed, altitude (for aircraft), depth (for submarines), sensor employment, and weapons status are also determined. Units are automatically plotted on the TEFL PPI display. Tabular, alpha-numeric displays of unit position and kinematics status can also be displayed. Both displays can be printed.

TEFL -- "Click of a Button" Exercise Variability

The Training Supervisor may save the current exercise and re-load at a later time. If the TEFL menu laydown button is "clicked," a new exercise force position will be computed that will still accomplish the original training objective. The TEFL system currently can vary any one or more of 17 parameters (e.g., battle group speed, range, RTF bearing) and maintain the original training objective. This feature of "click of a button" variability makes preparing initial force positioning for a training exercise occur in minutes.

Knowledge for the RED Force Laydown expert system was obtained from "Soviet Naval Tactics," Dr. Milan Vego; Naval Institute Press; 1992 [2]. Dr. Vego has 12 years commissioned service in the Yugoslav Navy, and during that period, worked closely with the Soviet Navy. He defected to the United States from Yugoslavia and has since worked closely with the U.S. defense establishment. Dr. Vego's book deals with Soviet Naval Tactics when the ex-Soviet Union was the principal threat to the United States. He maintains that countries with exported Soviet or Russian ships, aircraft, submarines, sensors and weapon systems are very likely to employ tactics closely patterned on those outlined in his book.

TEFL Expert System Implementation

TEFL is implemented using a commercial off-the-shelf (COTS) expert system shell [3], and graphical user interface (GUI) [4]. The TEFL system components are shown in Figure 4. A TEFL knowledge base is defined as a file that contains both rules and objects. There are three main TEFL knowledge bases -- 1) Top Level Force Laydown, 2) BLUE Force Laydown, and 3) RED Force Laydown.

Top Level TEFL Control Expert System Knowledge Base

The first expert system controls top-level TEFL operation based on Training Supervisor inputs specifying the BLUE and RED Forces; the exercise training objective; and any desired operational limitations and constraints. It controls the overall geometry of the placement of the RED Target on the playing area, the direction from which BLUE approaches RED; and the distance of the BLUE Force Center (BLUE Zulu Zulu) from the RED Target.

BLUE Force Knowledge Base

Once the RED Target, the RED Airfield and the BLUE Force Center has been placed. The individual BLUE ships submarines and aircraft can be placed about BLUE Force Center.

RED Force Knowledge Base

Once the BLUE forces have been laid down, then the RED forces are laid down. Depending on the exercise objective, some of the RED units are placed with respect to the BLUE forces (e.g. the RED surface and subsurface tattletales are placed around the BLUE CV).

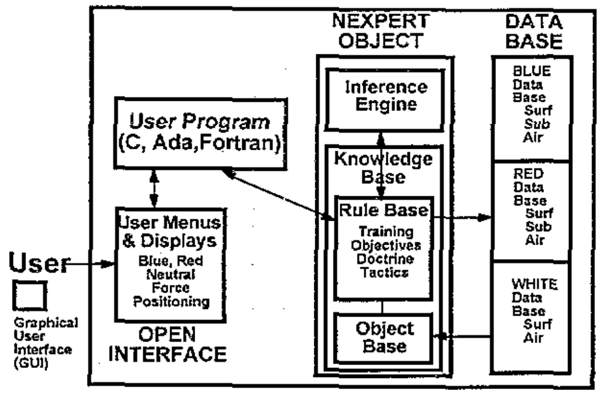


Figure 4. APEP Tool Software Components

Directions for Future TEFL Development

The current experimental concept TEFL successfully demonstrated that a single Training Supervisor can quickly and easily generate RED and BLUE Force laydowns for relatively large, tactically non-trivial exercises which provided variability in training and are tailored to specific training objectives. Nevertheless, there is still additional TEFL development work needed to provide full exercise generation and execution support for shipboard
Training Supervisors. TEFL features that need to be added include:

(1) Expanding the Expert System to address unit laydown for additional warfare areas (other than the current CV BG Strike Ashore area) to include: (a) amphibious operations; (b) mine laying, mine hunting, and mine sweeping; (c) cruise missile (e.g. TLAM) strike ashore; (d) war at sea exercises (including long and medium range over-the-horizon targeting (OTH-T) and surface ship anti-ship cruise missile (ASCM) attack); (e) convoy escort; and (f) combined warfare including elements of all warfare areas.

(2) Increasing the number of RED and BLUE platform classes so common platforms from each service can be included in Joint Force training exercises.

(3) Incorporating map data bases so that force lay downs could be generated with respect to geographic location of forces and the proximity of cities, naval bases, air fields, industrial facilities, roads, railroads, political boundaries, and geographic features.

(4) Integrating TEFL with standard naval tactical and intelligence data bases (e.g. Naval Warfare Tactical Database (NWTDB)).

(5) Add neutral WHITE ships, aircraft and even submarines that could serve as background platforms in the environment to the BLUE and RED combatants.

(6) Allow the operator to specify time-of-day and weather conditions (e.g. wind speed and direction, sea state, atmospheric temperature profile with altitude, bathythermograph data, cloud cover).

(7) Provide a Computer Generated Forces (CGFs) capability for automated platform scripting. This means the Training Supervisor would not have to manually script each platform. The Training Supervisor could then preview the likely training exercise outcomes based upon CGF movements. Additionally, performance measurement criteria to be gathered, stored, and computed in real-time for instructor display and debrief can be identified. With the availability of CGFs, any platform not modeled by a DIS exercise participant could be modeled by the CGFs of TEFL.

System Evaluation

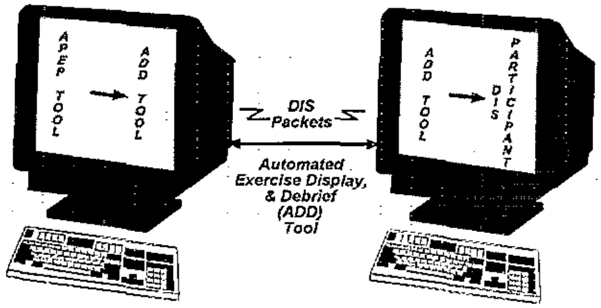
The TEFL automated exercise force laydown prototype tool is being evaluated by both naval active duty and reserve personnel (see ADVISORS), academia, and NAWCTSD research and engineering personnel.

Navy military personnel have independently validated each of the TEFL training objectives and subsequent force laydowns with an optimum force composition for both BLUE and RED Forces. The need to add the features listed under Directions for future TEFL Development were independently derived by the Navy personnel and TEFL developers. Additional features desired by the Navy personnel include: 1) allow the selection of aircraft squadrons instead of the selection of individual aircraft, 2) the ability to display sensor, and weapons inventory by platform.

For quicker verification of the TEFL expert system rule base, an automated tool is needed to check for: 1) redundant rules, 2) conflicting rules, 3) subsumed rules, 4) circular rules, 5) unnecessary IF conditions, 6) Dead-end rules, 7) missing rules, and 8) unreachable rules [5].

AUTOMATED EXERCISE DISTRIBUTION & DISPLAY (ADD) Tool

The second tool, Automated Exercise Distribution and Display (ADD) tool, electronically distributes the output of the APEP tool to the DIS training exercise participants using DIS protocol data units (PDUs). This tool is used after the APEP tool has created a battle force laydown for a specific training objective (see figure 5). A "handshaking" paradigm between two ADD tool processes using DIS *simulation management* PDUs was designed to implement a quick method of electronically transmitting the initial training exercise data to each DIS exercise participant.



Electronically Distribute Large Scale DIS Exercises

Figure 5. ADD Tool

Initialization Data Requirements

There is basic initialization information which all simulators require at start up. Initial position, and an initial velocity vector are examples of initialization data required by almost all simulators. However, there is also data which is simulator dependent (e.g., terrain data, environmental conditions, mission, and rules of engagement). Implemented in the ADD tool prototype is the transfer of platform type, platform mission, hull number, initial position, and initial velocity.

DIS PDU Selection

Discussions were held between NAWCTSD and the DIS Simulation Management Subgroup on which PDUs are best suited for electronic training exercise distribution. The conclusion was that a tool for electronically transferring training exercise preparation data had not yet been implemented using Simulation Management DIS PDUs. The guidance received from the DIS Simulation Management Subgroup was to implement the ADD tool using any PDU(s) which seem appropriate, however the message PDU should only be used for documentation. It was later decided by NAWCTSD that the *action request, action response, and set data* PDUs would be used in the ADD tool prototype.

System Design Issues

Several System level design issues surfaced during the design and implementation of the ADD Tool prototype. Two of these are:
1) *Distribution of a single exercise to a single exercise participant* -- The initial ADD Tool effort was targeted to downloading a single APEP training exercise to a single DIS training exercise participant. This effort enabled a quick *implementation and test of the handshaking* algorithm. Issues dealing with multiple exercise participants were left to be solved later.
2) *Distribution of a single exercise to multiple exercise participants* -- Downloading a single training exercise to several DIS exercise participants or several different simulation host computers has been investigated.

The first problem to overcome is how to assign simulation entities to simulators. There are two parts to this problem: a) how to assign each platform to the most appropriate simulator, b) how to handle the discrepancy of a simulator requesting to participate in a training exercise when no appropriate platforms are available in the current APEP training exercise.

The second problem is to resolve the inconsistencies in the initialization data requirements of heterogeneous DIS simulators participating in a common DIS training exercise.

High Level Implementation

A handshaking paradigm was designed using the DIS action request and action response PDUs. The action request PDU is used to initiate the download process. Action response PDUs are used to respond to the action request PDU, as described in the DIS 2.0.3 standard [6]. Embedded in the handshaking scheme is the transmission of DIS set data PDUs. The set data PDUs carry the exercise initialization data described earlier.

Detailed Implementation

The ADD Tool consists of two major functions -- ADD sender and ADD receiver. The ADD sender software physically resides on the APEP Tool hardware platform. The ADD receiver software physically resides with each DIS exercise participant's simulator (see Figure 6).

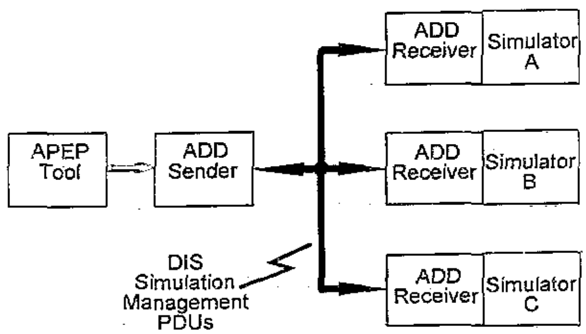


Figure 6. *ADD Tool Architecture*

Upon invocation of the ADD tool, an ASCII output file from APEP is read and parsed into the ADD tool's data structures. Once all the training exercise preparation data is loaded into memory, the start of the DIS simulation management *handshaking paradigm begins.* To initiate the handshaking algorithm, an action request PDU is sent from the ADD sender to the ADD receiver. The action id field in the action request PDU is filled with an action id enumeration equal to "RECEIVE_SCENARIO." This enumeration is an extension to the DIS 2.0.3 standard and is required to complete a DIS training exercise download.

The ADD receiver responds by sending an action response PDU back to the ADD sender. Within the *action response PDU, the request status* enumeration field is set to "PENDING." This enumeration is in accordance with the DIS 2.0.3 standard. The sender then knows the receiver is ready to accept the exercise preparation data.

Three set data PDUs are then sent by the ADD sender to the ADD receiver. The first set data PDU contains high level BLUE and RED Force information, the second set data PDU transmits detailed BLUE platform data, and the third contains detailed *RED platform data (see table 1).* Lastly, an action response PDU with the request status enumeration field set to "COMPLETE" is sent from the ADD receiver back to the ADD sender. The handshaking algorithm now is complete and the ADD sender is ready to download the training exercise data to another simulator. A summary of the ADD Tool operation is shown in Figure 7.

First Set Data PDU	
BLUE Force Center Location	x, y, z
BLUE Force Velocity Vector	speed, heading
RED Force Center Location	x, y, z
RED Force Velocity Vector	speed, heading
Second Set Data PDU	
For Each BLUE Platform	platform type
	mission
	hull number
	location x
	location y
Third Set Data PDU	
For Each RED Platform	platform type
	mission
	hull number
	location x
	location y

Table 1. Contents of Set Data PDUs

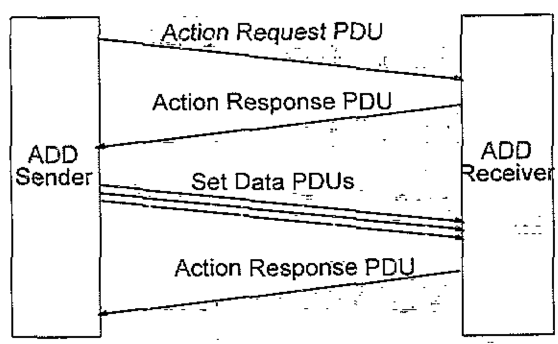


Figure 7. ADD Tool Exercise Download

Add Tool Statistics

The ADD tool prototype contains over 2,200 lines of C source code. The prototype was designed with a functional decomposition approach using a UNIX C compiler/linker and the vi editor. Approximately 700 lines of code were opportunistically reused from another NAWCTSD research project. The ADD tool prototype currently operates on a SUN SPARC under the SUNOS 4.1.2 operating system.

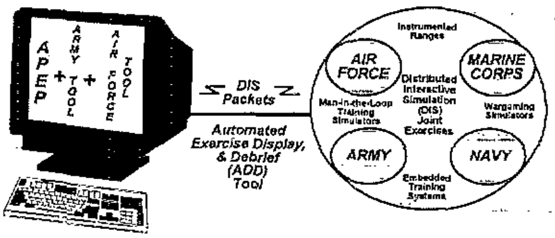
ADD Tool Future

Projected future enhancements to the ADD prototype include: 1) exercise download to a DIS simulation manager ; 2) support for multiple levels of DIS simulation management; 3) integration with the Naval Warfare Assessment Division's Warfare Assessment Model (WAM) modified for real-time display and debrief.

FUTURE APPLICATIONS -- APEP, ADD TOOLS

The APEP Tool is currently being used for evaluation by the NAWCTSD research and engineering department and military advisors. The tool is expected to be demonstrated at the 16th I/ITSEC DIS demo. Additionally, Integration with the Battle Force Tactical Trainer (BFTT) demonstrations is in progress.

To support joint exercises, the APEP tool can be integrated with other services' exercise preparation tools (Figure 8). An initial investigation of the Army's RASPUTIN exercise preparation tool indicates that the two tools could be joined to accomplish joint exercise preparation.



Reduce Exercise Preparation Time from Weeks to Minutes

Electronically Distribute Large Scale DIS Exercises

Figure 8. Joint DIS Exercise Distribution and Display

Although the ADD tool currently operates with the APEP prototype tool, the concepts and software can be applied to future joint/coalition systems.

Display and debrief of joint DIS exercises will initially involve each service's normal display techniques, however, a unified joint display and debrief tool will eventually be necessary.

REFERENCES

[1] "From the Sea - A New Direction for the Naval Service," a Navy and Marine corps White Paper
[2] "Soviet Naval Tactics, "Milan Vego, Naval Institute Press, 1992
[3] NEXPERT OBJECT ™ -- Expert System,. Neuron Data, Palo Alto, CA
[4] OPEN INTERFACE ™ -- Graphical User Interface (GUI),. Neuron Data, Palo Alto, CA
[5] "The Engineering of Knowledge-based Systems", Avelino J. Gonzalez and Douglas D. Dankel
[6] -- "Proposed IEEE Standard Draft Standard for Information Technology - Protocols for Distributed Interactive Simulation Applications, " Version 2.0.3, STRICOM, DMSO

ADVISORS

Cdr. Neil Tollefsrud USNR-R graduated from the U.S. Naval Academy in 1975 and has a Bachelor of Science in Systems Engineering and Masters of Engineering Administration. He served onboard the USS Biddle CG-34 and at the Fleet Combat Training Center Atlantic. He currently works for Martin Marietta as a staff systems engineer in Orlando, FL.

Cdr. Ronald W. Wetmore USNR-R graduated from the United States Naval Academy in 1976 with a BSEE. He served on active duty for 6 years and qualified in Submarines. As a reserve officer he has supported NAVSEASYSCOM and served as exercise support for both U.S. and NATO exercises. Cdr. Wetmore hold a Master of Science in Nuclear Engineering from MIT and a Masters of Business Administration from Florida Tech. He currently works for Martin Marietta as Manager of External Tank Operations for the Space Shuttle at Kennedy Space Center.

Lt. Rodney A. McAvoy USNR-R graduated from the University of Mississippi with a bachelors degree in Marketing. He served as a surface warfare officer onboard the USS Forrestal and USS Dale. At the Naval Air Warfare Center Training Systems Division, he was an assistant project manager for a fleet battle group training system.

He currently works as a Regional Manager for Waterpoint in Fort Worth, Texas.

Lt. Jeff Weinrich USN is a 1984 graduate of Jacksonville University, with a BA in History. He has served onboard the USS Patterson (FF-1061), USS Spiegel Grove (LSD-32), at Assault Craft Unit Two, and Navy Support Facility Diego Garcia. His current duty is at the Naval Air Warfare Center Training Systems Division as the assistant project manager for Surface Propulsion Training Devices.