SCENARIO-BASED TRAINING: AN ARCHITECTURE FOR INTELLIGENT EVENT SELECTION

Milton L. Stretton
Sonalysts, Inc.
Dahlgren, VA
and
Joan H. Johnston, Ph.D.
Naval Air Warfare Center
Training Systems Division
Orlando, FL

ABSTRACT

The generation and delivery of highly complex team and individual scenario-based training is bounded by a variety of requirements. This training method must accurately replicate conditions that include a realistic environment, rapidly changing events, multiple information sources, rules and procedures, and time and command-induced performance pressure. Past research indicates that training scenarios should be tailored to incorporate events to create valid learning opportunities, stimulate desired performance, and provide team stress management insights. However, the complexity of tailoring this "curriculum" presents a daunting task for novice and expert shipboard trainers. Therefore, a strategy to intelligently manage the process of event selection was determined to be important. Following our analysis of the state-of-the-art in scenario-based training systems, it was evident that, during scenario development, the event selection or creation process was left to the user. This places a nearly impossible demand on novice trainers to ensure that scenarios and supporting products are related to the mission, training objectives, and past performance. Indeed, while this task is within the capabilities of expert trainers, it is very time consuming, and not often done. This paper outlines efforts to create a formalized, user-centered architecture for assisting trainers in the selection of scenario events using performance history data, mission criteria, trainee identification, and other factors. To enable this, an event library had to be created that would "understand" training objectives, complexity, and inter-event relationships. Success will provide the capability for novice and expert trainers to harness the power of scenario-based training.

ABOUT THE AUTHORS

Mr. Milton L. Stretton is a Vice President for Sonalysts, Inc., managing their Dahlgren, VA office. He is Sonalysts' principal investigator for training management and scenario development research being conducted for the Shipboard Instructor Training and Support (SITS) and Advanced Embedded Training System (AETS) programs. He received his degree and commission from the U.S. Naval Academy and has served on several ships in engineering, combat systems, and operations.

Dr. Joan H. Johnston is a Senior Research Psychologist at the Naval Air Warfare Center Training Systems Division. She is responsible for conducting behavioral research to develop training and simulation principles for the Tactical Decision Making Under Stress exploratory research program. She received her Ph.D. in Industrial/Organizational Psychology from the University of South Florida. Her research interests are in the areas of training for stress exposure, tactical decision making, and in the development of shipboard instructor training and support.

SCENARIO-BASED TRAINING: AN ARCHITECTURE FOR INTELLIGENT EVENT SELECTION

Milton L. Stretton
Sonalysts, Inc., Dahlgren, VA
and
Joan H. Johnston, Ph.D.
Naval Air Warfare Center
Training Systems Division
Orlando, FL

INTRODUCTION

Scenario-based training provides a situationally-based context for exercising team and individual knowledge, skills, and abilities. Typically, this training environment is highly complex and must exercise a wide variety of training objectives under realistic and controllable conditions. Characteristics of this highly challenging training medium include rapidly changing events, multiple information sources, rules and procedures, and time-and command-induced pressure (Cannon-Bowers, Salas, & Grossman, 1991). Past research has indicated that training scenarios should provide valid learning opportunities. This implies that performance must be observable and measurable (Hall, Driskell, Salas, & Cannon-Bowers, 1992) and this observation must be conducted within a structure that provides events that are related to learning objectives (Prince, Oser, Salas, & Woodruff, 1993). Research has also demonstrated that training for teams and individuals who perform their functions within stressful situations should be structured to improve performance under these stressful conditions (Hall, Dwyer, Cannon-Bowers, Salas, & Volpe, 1993).

For individual training, scenario construction and tailoring is complicated by the large number of objectives and events required to stimulate measurable observations and create the learning situation. However, in a team training environment a scenario must be orchestrated to satisfy not only training requirements for several individuals, but for the team as a whole within the same setting. For Navy team applications, this complexity is compounded by performing tasks in a changing operating environment. A wide range of supporting training material is also required for setting the stage and for providing rules under which the team must respond to the situation. Finally, scenario script construction must be controlled to provide an appropriate set of events tailored to training objectives, to controllable stress levels, and to support measurement, diagnosis, and feedback.
Currently, however, the selection and tailoring of such a complex "curriculum" presents a daunting task even for the most experienced Navy trainer. Extensive shore-based support activities and specialized training groups, independent of the personnel being trained, typically construct the scenario and supporting products over a period of weeks. Recent changes in Navy training and other services are placing pressure to reduce this support infrastructure, thus transferring this burden to the commands to develop their own training. Pre-scripted scenarios offer some solutions, but they do not support "just-in-time" training for new missions and they still require a large maintenance activity ashore. How does this movement of training development from the shore to the ship impact the quality of training? First, development is removed from the experts ashore and given to shipboard trainers whose instructional skills range from novice to expert. Second, shipboard trainers do not have the tools necessary to perform this function within their time and manning constraints.

In light of these issues and questions, the Navy research community has undertaken the task of developing tools for shipboard trainers to perform the functions of rapid scenario development, data collection, diagnosis, and feedback within this environment. This effort is associated with the development of advanced embedded scenario-based training systems for the Shipboard Instructor Training and Support and the Advanced Embedded Training research programs (Naval Air Warfare Center Training Systems Division, 1996). This paper outlines the process used to develop a conceptual architecture to support building scenario based training curriculum. The paper first outlines the process used and research results from reviewing current training systems. Second, the paper applies these results to the identification of functional areas where trainer support was needed. Third, the paper describes an architecture that is under development in the management of training events. A description of future efforts and a summary is also provided.

STATE-OF-THE-ART REVIEW

Past efforts in the development of scenario-based training system guidelines and review of training needs created the foundation for a state-of-the-art review of training systems. These works included: Pemberton, Classe, Bradley, and Wilson (1994) who provided information related to automated force laydown for large scale exercises; Prince, Oser, Salas, and Woodruff (1993) incorporated functional elements important to the stimulation of team and individual responses and for developing focused scenarios; and Salas, (1989); Swezey, Llaneras, and Salas (1992); and Tannenbaum, Cannon-Bowers, Salas, and Mathieu (1992) who added context relative to the design of systems for team training. Finally, Swezey and Salas (1992) contributed instructional features important for use in team-training development. These sources were combined with other efforts into a survey (Stretton & Lackie, 1996) which was used to determine the degree to which each functional area was supported.

Data from a review of over 20 systems was collected, cataloged, and analyzed to identify system needs for future training systems. Survey data were categorized by training objective identification, scenario development, data collection, assessment, feedback, and follow-on training preparation. This allowed identification of weak areas across systems to focus the development of a functional architecture for future scenario-based training systems. The following provides a high-level overview of the review findings:

- Sixteen of the systems allowed adequate scenario control (run, freeze, restart, etc.)
- Fourteen different entity databases existed
- Twelve different environmental data sources were used
- Six of the systems provided a means of assessing performance with system assistance
- Two systems provided feedback, outside of replay
- Two of the systems provided the software capability to state the training objectives to the trainers or the trainees
- Three of the systems semi-automatically developed the scenario, but only for time zero
- Two systems assisted in developing scenario products in addition to the script
- One system formally linked training objectives to events in software
- One of the systems provided resource management capabilities for training
- One system formally linked training objectives to the software-produced feedback
- Many of the systems were of limited use in scripting a scenario
- Human-computer interfaces for full scale training systems were very difficult to use for building a scenario as evaluated by their developers and users
- Few of the systems could communicate across other training systems.
- None of the systems established and stated performance goals for training

TRAINING MANAGEMENT ARCHITECTURE

Upon review of the above data, it became apparent that several systems currently exist that run and control scenarios. However, significant limitations were identified in the areas of training objective identification and traceability, scenario pre-training materials generation, and stage setting for scenario-based training tools. Therefore, the focus of the architecture definition concentrated on training preparation support. Figure 1 presents the scenario development goals and general capabilities projected for Training Management Module (TMM) Architecture and Figure 2 provides a concept for training management functional architecture. Identified are several key areas of functionality required for developing a scenario and setting the stage for the training. Each of these high-level functional areas are described below.

Mission Definition

In support of training objective identification and defining conditions and tactical parameters, the mission has to be identified. This capability will provide the user the ability to select the mission for which the ship will be training. In conjunction with identifying the mission, this functional area will also support the selection of the warfare area to be assessed for the training session. The mission and warfare area selection will result in identification of command/unit training objectives and corresponding measures. The processed mission-related objectives will be forwarded to the training objective identification, condition definition, and functional areas.

Training Administration and Objective Definition

One of the key elements in conducting effective team and individualized just-in-time training is understanding the objectives that have not been trained or are

GOALS

CREATE REALISTIC SCENARIOS BASED ON TEAM AND/OR INDIVIDUAL PERFORMANCE

LINK MISSIONS, TRAINING OBJECTIVES, PERFORMANCE MEASURES, AND EVENTS

COMMUNICATE THIS LINKAGE TO DATA COLLECTION TOOLS, MODELS, AND TRAINERS

CREATE A SCENARIO AND SUPPORTING MATERIALS IN LESS THAN 4 HOURS

FORMAT SCENARIO SCRIPT FILES TO BE COMPATIBLE WITH LEGACY SYSTEMS

PROVIDE LOGICAL AND USABLE DISPLAYS AND CONTROLS

OTHER GENERAL CAPABILITIES

VISUALIZATION OF TRAINING OBJECTIVES TO EVENTS

TRACING OBJECTIVES THROUGH TRAINING

MANUAL INPUTS FOR ESTABLISHING COMMAND TRAINING PRIORITIES

INDIVIDUALIZED TRAINING - TRACKS INDIVIDUAL AND TEAM PERFORMANCE

SUPPORT FOR NOVICE USERS

ABBREVIATED APPROACH FOR EXPERIENCED USERS

COMMON DISPLAY ELEMENTS ACROSS NOVICE AND EXPERIENCED USERS

CONTROLLABLE DEGREE OF STRESS

PROPS/ROLE-PLAYING ASSISTANCE

AUTOMATED AND SEMI-AUTOMATED PRODUCTION OF SCENARIO MATERIALS

Figure 1. Scenario Development Goals and General Capabilities

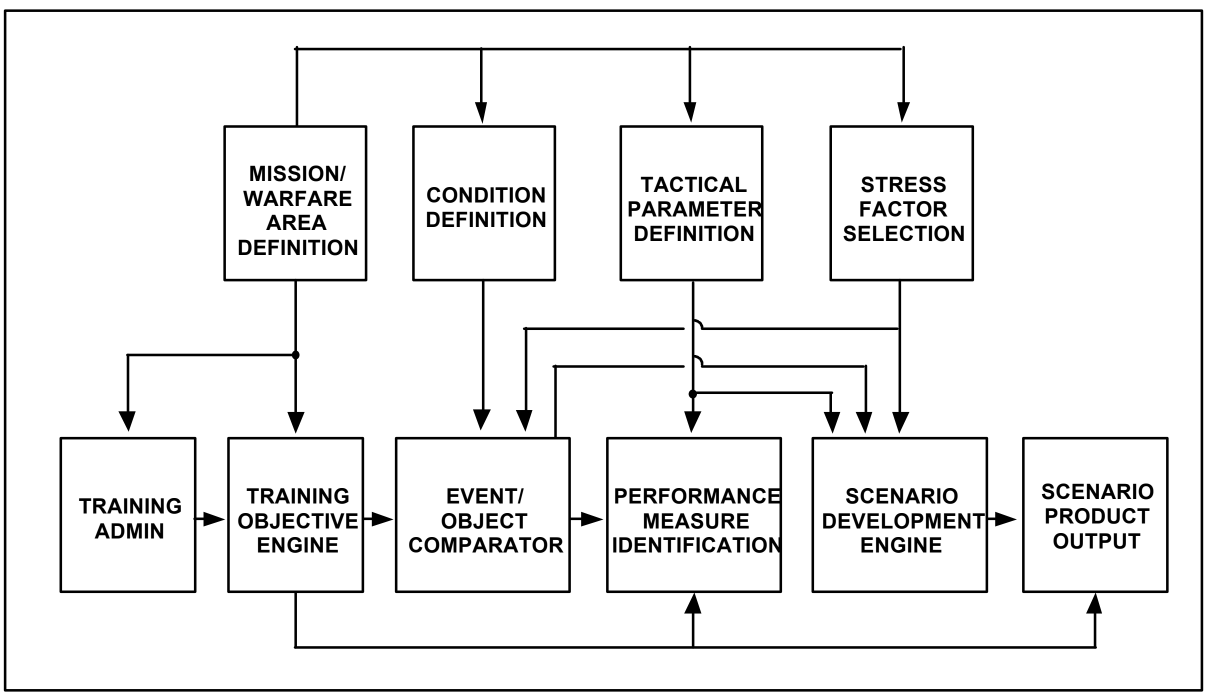

Figure 2. Training Management Functional Architecture for Training Preparation Support

deficient and what the mastery level is for each individual and the team. The questions that training administration and training objective identification must answer are as follows:

- Who is being trained?
- What is the performance history for each training objective?
- What missions have been trained?
- Does the commander or training officer have specific training requirements?
- Who are the trainers and what is their history?
- What are the candidate objectives for this training session?

The training administration functional area will require three basic inputs. First, administration will need past performance by individuals and teams. The system must support a database of the performance assessment, diagnostic, and debriefing results that serve as a means of tracking individual and team historical mastery of training objectives. These data will need to be accessible by individual, watchstation, and team composition. This also implies that the scenario developer must to be able to identify the individual being trained for a session.

The system will also need the capability to monitor training objective and mission sessions over time to determine the frequency of performance and identify those objectives that have not been trained and to track highly perishable skills. This monitoring capability will contribute to the identification of recommended training objectives to a candidate list of objectives for training.

In addition to identifying individual and team deficiencies, mission experience by individual and team, and the warfare area, training personnel will need to be able to manually specify training requirements. For example, a commander should be able to state that a certain mission, warfare area, and geographic location be trained for a given period. The operator will then input these command requirements as high priority objectives for each training event.

Next, the system will then process the data associated with trainers, trainees, performance history, training objective history, and manual preferences. This data will be used for comparing historical training objective performance by the team being trained with training objectives that pertain to the mission as identified in the mission definition. This comparison will result in candidate objectives training with minimal operator intervention. This working list and trainer and trainee information will then be forwarded to other functional areas for use. Figure 3 provides a notional display for training objective identification.

Condition Definition

Each mission will have a set of conditions that are associated with performance. Condition definition function will address three main tasks. First, military definition will define the antagonist or antagonists, their own order of battle, and the friendly order of battle. Military definition will use inputs from mission selection and identified ship objectives. Training objectives and ship objectives must automatically coincide with a military definition that will provide a capability for simulation which will support exercising objectives. Stress variable selection will also assist in this definition by defining the numbers required to achieve selected levels of stress. Military definition information will be sent to event generation, tactical definition, and scenario development output products.

Another important part of the condition definition function is environmental definition. Environmental condition functionality will include the geographic location development to include antagonist area of operation, elevation data, slope data, and important landmass profile information. Environmental conditions will also include equipment performance factors such as radar or visual detection capabilities.

The final portion of condition definition is civil definition. This function will provide the geopolitical situation development. A geopolitical situation is characterized within the system and database structure as consisting of political, economic, military, and cultural summary information.

Tactical Definition

Tactical definition provides the major functional areas of tactical context and outcome performance measure definition. An example of this is the definition of the rules of engagement (ROE). Templates will be provided for each mission type. The operator will be able to accept default ROEs generated by the system or modify and save changes for the upcoming scenario and for future scenario opportunities. The ROE must have the ability to transfer discrete performance values to the performance measurement module.

Tactical parameter definition will also provide similar capabilities for generation of mission situation summaries, commercial and general aviation and shipping status, and call signs and identification friend

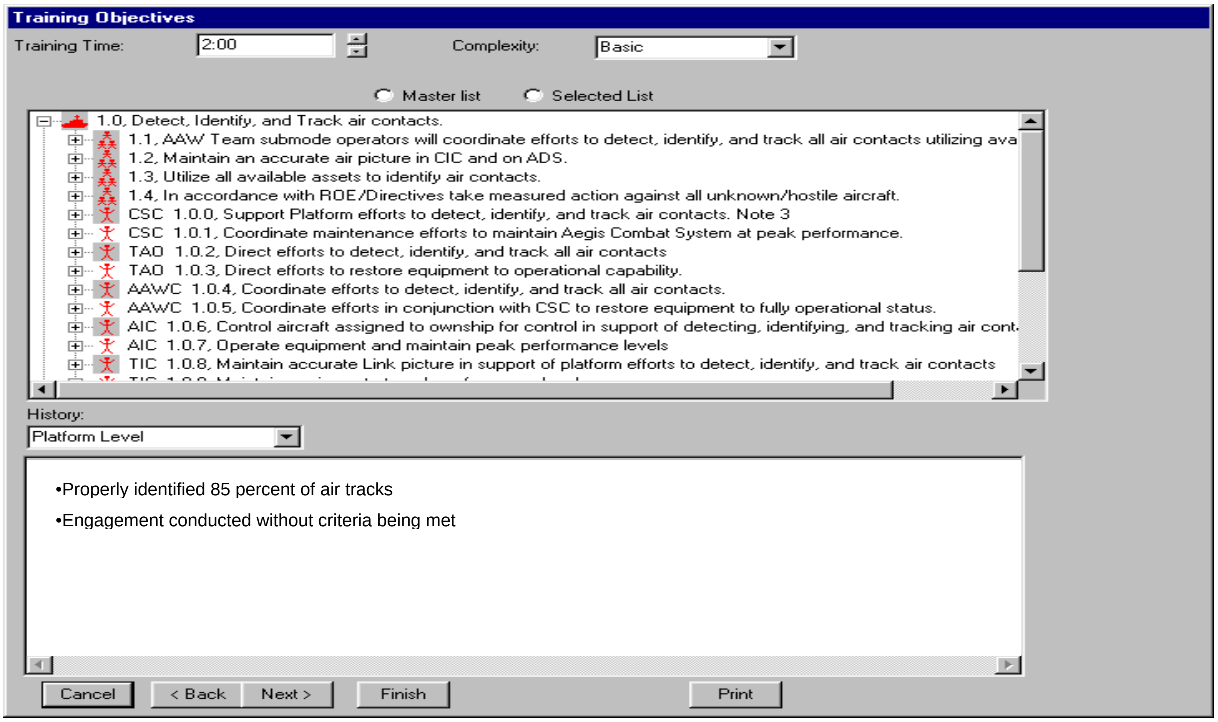

Figure 3. Notional Training Objective Identification Display

or foe (IFF). Other functions of tactical definition will be the development of identification procedures templates and the use of standard or user-defined operational tasking messages that support training.

Stress Factor Control

The stress factor selection process will provide the scenario developer with the capability to control scenario difficulty. This capability will require little user interaction and provide information describing the impact of changing the various control parameters. Stress factor control areas include track control, threat control, tactical control, and environmental control. Track control will allow the scenario developer to use a simple user interface to control track density and ambiguity. Threat control parameters related to stress include the type of units (capabilities), the number of units associated with events; profile and reaction time controls, ambiguity level (threat tailing a commercial unit or identification ambiguities), and others. Stress factor selection associated with tactical parameters will also be provided to the scenario developer. Stress factor control will provide inputs to the own ship definition process. These inputs will include equipment status, switch-setting requirements for training, and casualty control inputs. Finally, environmental stressors will be controllable by the scenario developer. These parameters will control environmental effects that can impact operational performance.

Event Selection

Event selection and scenario definition are the heart of scenario development for correlating between training objectives and the events that are used in the scenario. This function supports the operator in selecting appropriate events to stimulate actions relative to identified training objectives.

Complexity requirements for events will be a system estimate of operator and team proficiency that controls the default level of difficulty for the events and existing scenarios. This estimate will be modifiable by the operator to increase or decrease default difficulty values.

The candidate training objectives identified in training administration will be analyzed to determine what classes of events will stimulate objectives. The system will check these events to determine if they are compatible to be run within the same scenario and correspond to condition definition parameters (military and environmental) and stress factor selection (clutter level, commercial air, shipping, etc.).

TMM events will be divided into two major categories: tactically significant events and background events. Tactically significant events will be the focus of trainer attention and are primarily constructed to elicit a response from the team being trained. Background events will be created to simulate the remaining events that form the operational environment of the scenario.

An event organizer will use the settings, such as time available for training and specified time goals between events, to organize the events into a recommended, logical sequence and associated force laydown. The event organizer will also identify events in the library that form logical alternatives to the selected event. This information will support the scenario development engine to allow the user to select alternative force laydown schemes for the scenario.

Scenario Definition

The process and functional overview described thus far has focused on the process used to build a new scenario and to prepare support products and information. This section discusses the functions not only to use the information described in the previous sections to continue the scenario development process, but also to describe the process of selecting an existing scenario and the process and functions used in modifying a scenario that closely meets the training requirements.

Building a New Scenario. For developing scenarios without prior data, the scenario development engine will focus all of the scenario preparation from the previous functions into a laydown of the scenario into the tactical operating area. Considering selections in mission definition and condition definition, entities used in the scenarios will be defined by order of battle, modified by stress factor definition parameters and compiled into events with associated training objectives and performance measures. Condition definition information will provide geographic placement context and other background environmental event information.

The scenario development engine will display the scenario in a geographic context for the user. This display will identify the critical training events. These system-selected events displayed for the user will be modifiable within scenario development system set limitations. For example, way points for an event may be repositioned within the context of the training objective and scenario time limits. In addition, a set of alternative scenario events that will also meet the training objectives will be displayed to the user when desired. The alternative events may include:

- Different approach paths,
- Variations on points of origin,
- Types and classes of tracks, and
- Kinematics (altitude, course, and speed).

The operator will be able to easily review these options from a list, select an alternative event, and visualize the change in the scenario laydown if the alternative were to be used. Upon initial review and determination of the scenario laydown and script, the operator will have the capability to pre-play the scenario in real time, fast speed, or slow speed. This will be the operator's validation of the scenario.

Using an Existing Scenario. If during the training objective identification process it is determined that an existing scenario meets the requirements for this training opportunity, the user will have the capability to select the existing scenario. The user will be presented with several types of information that will assist in this determination. A summary screen will be available that provides access to mission definition, condition definition, tactical parameter selection, and stress factor selection to allow the scenario developer to "pull the string" on the scenario support structure.

Historical information on the existing scenario shall be available to the operator for review. This information will include:

- Training objectives satisfied,
- Teams and individuals trained,
- Last date used,
- Stress variable and difficulty settings, and
- Individual and team performance data summary.

This information will support the trainer in determining whether a scenario has been used previously by the team or individual, why the scenario was used, and performance information. This will assist in determining whether it is appropriate for reuse or requires modification.

Modifying an Existing Scenario. Modification of an existing scenario may be conducted for several reasons. First, the trainer may not want to use the identical scenario to train the same set of objectives to prevent conditioning to a single situation. Second, all of the objectives required for training may not be stimulated by a given scenario, thus requiring modification. Third, similar events could be used but the trainer could vary the stress factor selection values to make the events more difficult.

Methods for modifying scenarios will include deletion/addition of events, varying stress factors and difficulty, changing the order of events, modifying the threat sector, moving the theater of operations, and varying the location within a theater of operations. Addition of events will be conducted based on the need for satisfying an objective that was not met by the original scenario. Added events will "bring" training objectives and measures with them. The user will be able to select an event that will stimulate the required objective.

Modifying the scenario will be conducted by changing the stress factors and difficulty level of the scenario. This will cause variations in track density, clutter loading, and other settings that control the tempo and density of the scenario. The trainer will be able to modify the scenario by varying the order in which critical events occur.

The system will support modifications by changing own ship location within the area of operations. Changes in threat points of origin will also be supported to cause changes in threat sectors and thus operator expectations.

The user will be able to modify the theater of operations. This modification will retain the classes of events required to change the objectives but result in near automatic changing of antagonist, country, order of battle, and track types resulting from the repositioning of the area of operations. The user will need the capability to review the changes throughout all of the functions described previously in this section as well as the summary of the scenario. Figure 4 illustrates a notional display for viewing the scenario.

Products Management

TMM output products will be available to four sources. First, output products need to be made available in the form of data files to appropriate software modules. Second, output products shall be sent to a printer for hard copy to support training briefing, trainee briefing, scenario run support materials (scripts for role players, reference materials for team, and support information for the trainers). Third, scenario development output products shall be made available to a hand-held device for display to the trainers. Finally, and most importantly, the scenario development scenario file output products shall be provided to selected scenario run devices for scenario implementation and control.

Many of the products will require output in several formats to many locations. TMM will account for the differences in these types of unique output requirements for all output information. Figure 5 presents a notional display to support products management.

EVENT STRUCTURE CHALLENGES

Many of the functions and automation features previously described in this paper imply the need for a high level descriptive language for event definition and utilization. Current methods of scenario development require each entity to be fully defined and scripted with each changing course, altitude, speed, and action defined by the user at the time of implementation. For large scale exercises with hundreds or thousands of tracks this becomes an unmanageable situation. Hence, current development takes weeks or months. Therefore, the main technical challenge of this effort is to streamline the process of scenario development to an acceptable level for shipboard trainers given their workload and time constraints.

What is the critical link in making this happen? How much can events be abstracted to maximize tactical reality while minimizing the trainer's need to intervene in scenario development? What archiving mechanisms are needed? How should these events be related to the training objectives? What is a team-level event? Platform-level event? Individual operator event? How are these orchestrated into a scenario? How much must individual events "know" about other events?

These questions led to the development of some initial requirements for intelligent event selection and definition. The automated knowledge elements of events have to be constructed to understand geography, objectives, measures, and other events. After reviewing several real-world cases and determining what critical events are, trainers were interviewed to gather knowledge on the thought process that was used to construct events within scenarios. This information led to an initial high level knowledge representation for events. The knowledge an event must include factors such as antagonist, origination point, objective, relation to own ship, relation to platforms of interest, political boundaries, international airspace, ROE, and relationship to other events. With this high level understanding of how the event fits within a general context, the event will be able to understand how it can implement itself within a specific location. This will allow automated repositioning of events to different theaters, theater locations, and how they play out with other events. This effort is still in definition and initial implementation.

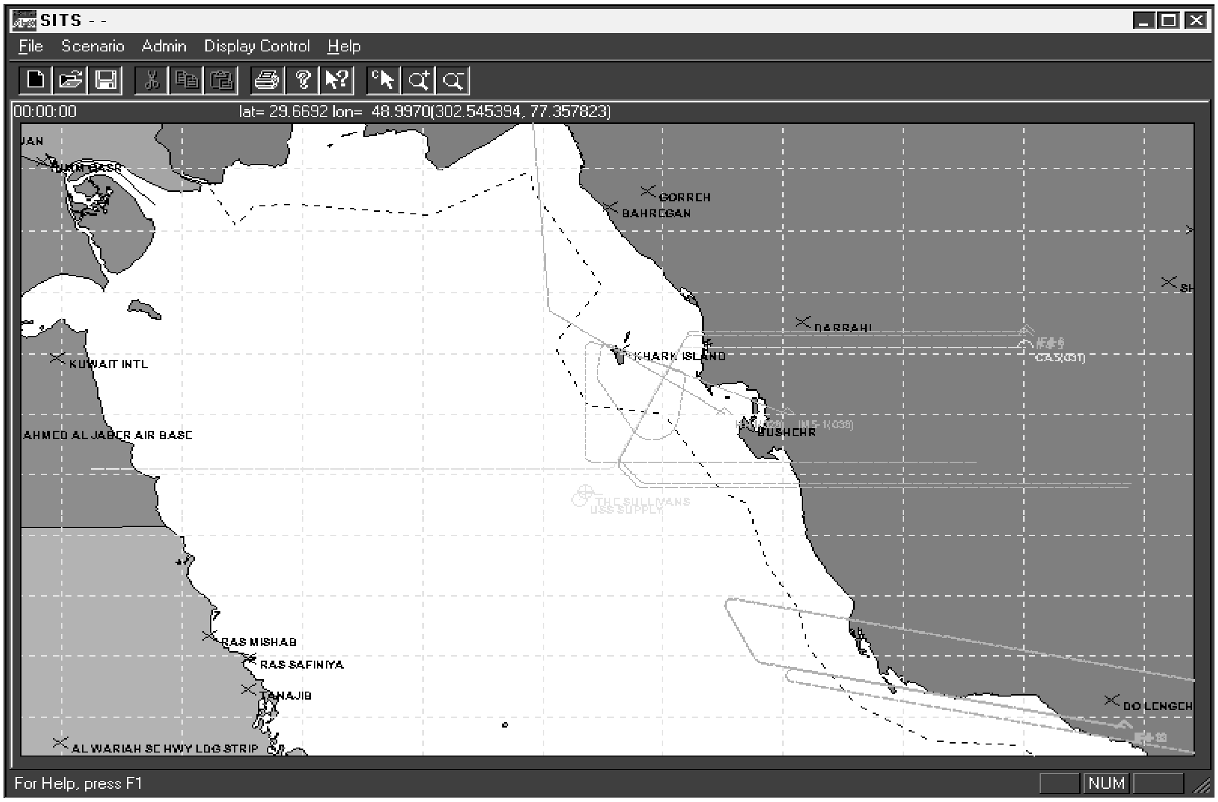

Figure 4. Notional Training Management Module Main Display

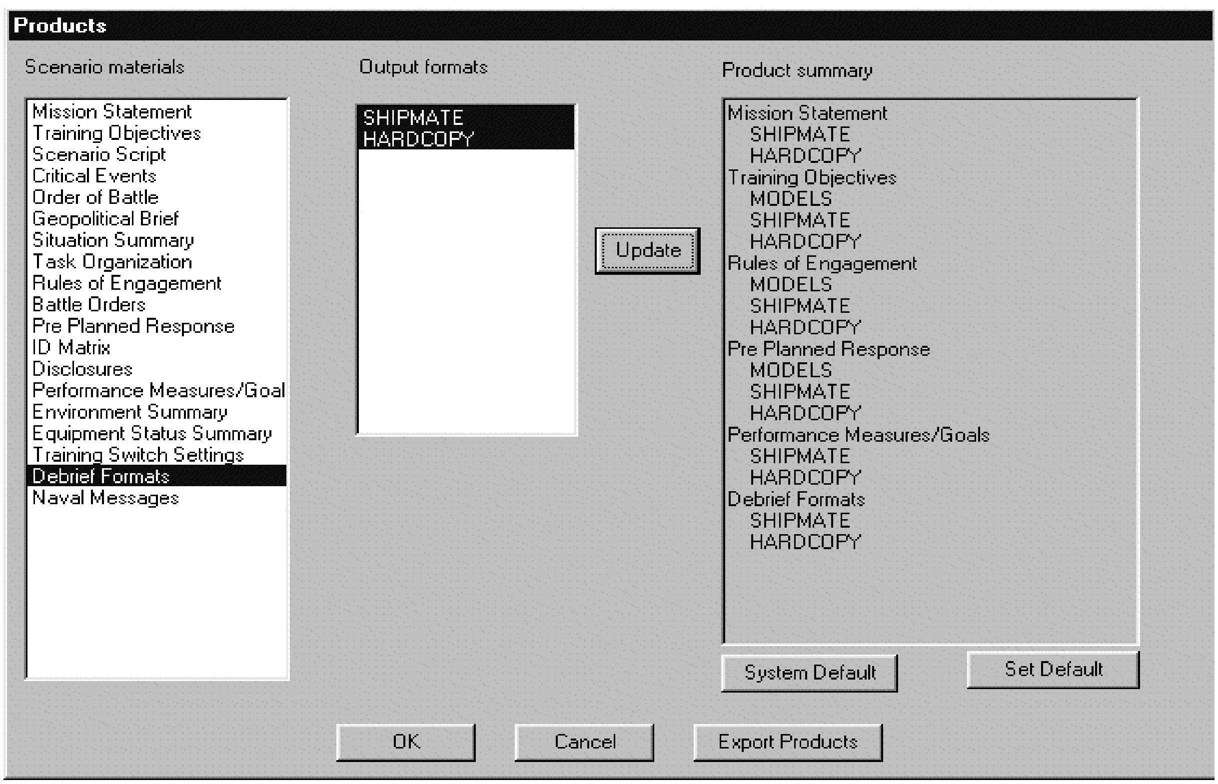

Figure 5. Notional Products Management Display

SUMMARY

Establishing an architecture for conducting tailored individual and team training scenarios and the associated support materials can have a great payoff for training effectiveness. Current capabilities do not fully support tailored scenario-based training. A state-of-the-art review identified current and future system deficiencies that were used to develop a conceptual architecture for the shipboard TMM. The technical challenge within this architecture was identified as the intelligent event manager and the construction of the event library. An event management capability could greatly reduce the time and effort required to develop and manage large scale training exercises, and to improve flexibility in developing just-in-time scenarios for a larger variety of missions. Although the focus of the research to date has been conducted within a single warfare area for a single ship, the findings suggest the potential for application to: other shipboard training, such as engineering and navigation; multi-ship training; managing disparate resources within large-scale training exercises; and non-military training applications.

REFERENCES

Cannon-Bowers, J.A., Salas, E., & Grossman, J.D. (1991, June). *Improving tactical decision making under stress: Research directions and applied implications.* Paper presented at the International Applied Military Psychology Symposium, Stockholm, Sweden.

Hall, J.K., Driskell, J.E., Salas, E., & Cannon-Bowers, J.A. (1992). Development of instructional design guidelines for stress exposure training. *Proceedings of the 14th Annual Interservice/Industry Training Systems Conference* (pp. 357-363). Washington, D.C.: National Security Industrial Association.

Hall, J.K., Dwyer, D.J., Cannon-Bowers, J.A., Salas, E., & Volpe, C.E. (1993). Toward assessing team tactical decision making under stress: The development of a methodology for structuring team training scenarios. *Proceedings of the 15th Annual Interservice/ Industry Training Systems Conference* (pp. 87-98). Washington, DC: National Security Industrial Association.

Naval Air Warfare Center Training Systems Division (1996, October). *Research and Development Project Summaries*. Orlando, FL: NAWCTSD.

Pemberton, Barbara J., Classe, Douglas J., Bradley, Charles W., & Wilson, M. (1994). Automated exercise preparation and distribution for large scale DIS exercises. *Proceedings of the 16th Annual Interservice/Industry Training Systems Conference* Washington, DC: National Security Industrial Association.

Prince, C., Oser, R., Salas, E., & Woodruff, W. (1993). Increasing hits and reducing misses in CRM/LOS scenarios: Guidelines for simulator scenario development. *International Journal of Aviation Psychology*, *3*, 69-82.

Salas, E. (1989). A standardized methodology for team training design. In D. Daniel, E. Salas, & D.M. Kotick (Eds.), *Independent Research and Independent Exploratory Development (IR/ IED) Program: Annual report FY 1988* (NTSC 89-009), (pp. 45-48). Orlando, FL: NTSC.

Swezey, R. W., Llaneras, R. E., & Salas, E., (1992). Ensuring teamwork: A checklist for use in designing team training programs. *Performance & Instruction*, *31*, 33-37.

Swezey, R. W., & Salas, E. (1992). Guidelines for use in team-training development. In R.W. Swezey & E. Salas (Eds.), Teams: Their training and performance (pp. 219-245). Norwood, NJ: Ablex.

Stretton, Milton L., & Lackie, John H. (1996). *Shipboard Instructor Training and Support: Scenario Development Functional Architecture Overview*. Unpublished Manuscript.

Tannenbaum, S. I., Cannon-Bowers, J.A., Salas, E., & Mathieu, J.E. (1992). Deriving theoretically-based principles of training effectiveness to optimize training system design. *Proceedings of the 14th Annual Interservice/Industry Training Systems Conference* (pp. 619-631). San Antonio, TX: National Security Industrial Association.