AUTOMATIC SCENARIO GENERATION AND CONTROL FOR TACTICAL TRAINING SYSTEMS OF THE '90s

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ABSTRACT

New concepts are required for effective utilization of tactical training systems of the '90s. A ten-fold increase in the number of tracks* currently simulated for tactical training systems is a requirement. However, no corresponding increase in the number of training system instructors to generate or control training system scenarios using this increased number of tracks is anticipated. This paper presents the results of a research study, and describes ongoing development activities, that address two new concepts to meet the increasing demands on tactical training system instructors: automatic scenario generation, and automatic scenario control (Figure 1). Specific topics presented include fleet requirements for training systems scenarios of the '90s, followed by a discussion of recommendations for automation of the scenario generation, and scenario control processes to achieve these requirements.

*track -- information displayed and controlled at a training system instructor console, i.e., ships, aircraft, missiles, electronic warfare data, etc.

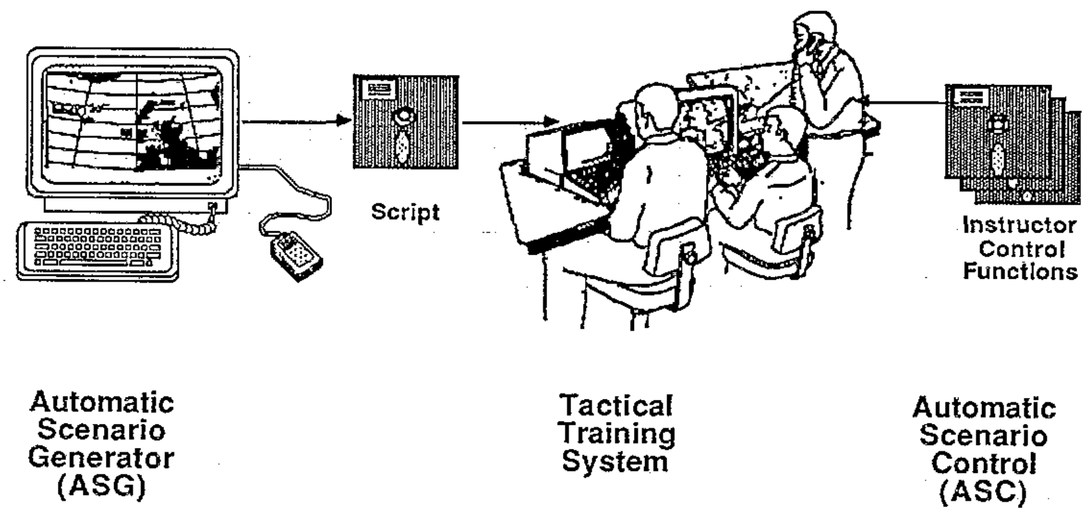

Figure 1. Tactical Training Instructor Components for the '90s -- Automatic Scenario Generator and Automatic Scenario Control

INTRODUCTION

Tactical training systems represent one of the most complex instructional environments in military training. The Navy has a considerable investment in tactical training systems covering a wide range of complexity, cost, and training missions. For example, the Aegis Combat Training Center (ACTS) and the Tactical Combat Direction and Electronic Warfare (TACDEW) training systems incorporate highly complex hardware and software to provide multi-platform battle force/group tactical team training in a multi-threat environment. At the other end of training complexity are smaller, tabletop devices such as the Naval Tactical Game (NAVTAG).

Tactical training systems provide a simulated environment or training system scenario in which one or more students employ naval doctrine and practice naval tactics. Doctrine may be defined as "right behavior"--"rules upon which we act spontaneously and without orders for the accomplishment of the mission."[1] Tactics refers to the handling of forces in battle. Tactics are not studies but techniques; not an art or a science, but the very action of men in battle. [1]

Instruction is designed into a training system via different training system scenarios. A ten-fold increase in the amount of information needed to generate and maintain training system scenarios is a requirement for the 1990s and beyond. No corresponding increase in the total number of instructors to generate and control scenarios is anticipated (Figure 2).

TACTICAL TRAINING SYSTEMS

- Represent complex instructional environment
- Provide multi-platform battle force/group training (e.g., AEGIS, TACDEW, CTT)

TACTICAL TRAINING SYSTEM SCENARIOS

- Instruction is designed into training system via training scenarios
- Ten-fold increase in scenario information a requirement for 1990s

Figure 2. Tactical Training Systems

This paper presents fleet requirements for training system scenarios for the '90s, a detailed description of the overall scenario generation and control processes, and specific recommendations for modification of these processes to satisfy fleet requirements

TRAINING SYSTEM SCENARIO FLEET REQUIREMENTS

The fleet requirements for the '90s and beyond for training system scenarios are divided into two areas: scenario generation, and scenario control. Scenario generation is the effort required to identify and utilize a large amount of information to simulate a military engagement. Scenario control describes the instructor's effort to monitor and modify information (e.g., track course and speed), and evaluate student performance while a training system is being utilized to train students.

SCENARIO GENERATION

- INSURE ECONOMY OF TIME AND EFFORT OF SCENARIO SETUP
- MAKE USER-MACHINE INTERFACE AS EASY AS POSSIBLE TO USE

SCENARIO CONTROL

- REDUCE INSTRUCTOR WORKLOAD
- ALLOW INSTRUCTOR TO MONITOR MORE INFORMATION
- PROVIDE REAL-TIME PERFORMANCE MEASUREMENT AND FEEDBACK OF STUDENT/TEAM

Figure 3. Fleet Requirements for Tactical Training System Scenarios

Two fleet requirements for '90s scenario generation are: ensure the "economy of time and effort for scenario setup;" and make the user-machine "interface as easy as possible to use."[2]

Specific fleet requirements for '90s scenario control are: (1) reduce the instructor workload, e.g., assist the instructor with "modifying track parameters" such as course and speed during a coordinated attack for multiple tracks in a multi-ship training evolution.[3]; (2) allow instructor to monitor more information; and (3) provide real-time performance measurement and feedback of student performance[4] (Figure 3).

TRAINING SYSTEM SCENARIO GENERATION

Definition

Training system scenario generation is the activity of identifying training the objective(s), political situation, geographical location, environmental conditions, force composition, disposition, and force movement (friendly, neutral, adversary), tactics and rules of engagement. To describe force movement, a time line of events is created. The time line of events includes a time tag, location, track type, sensors, weapons, and movement of both friendly, hostile, and neutral tracks. Scenario generation is currently accomplished in non-real time and is a combination of both a manual and automated process.

Training system scenario generation is a highly complex task that requires the knowledge of military strategy from both officers and enlisted subject matter experts, and often contractor support. A survey of ten tactical training systems of varying complexity indicated that current scenarios utilize from 32 to 200 tracks. The time required to generate a single scenario may vary from one hour to six weeks to nine months and can require the full time efforts of four to eight subject matter experts, depending upon the particular system and training objectives.

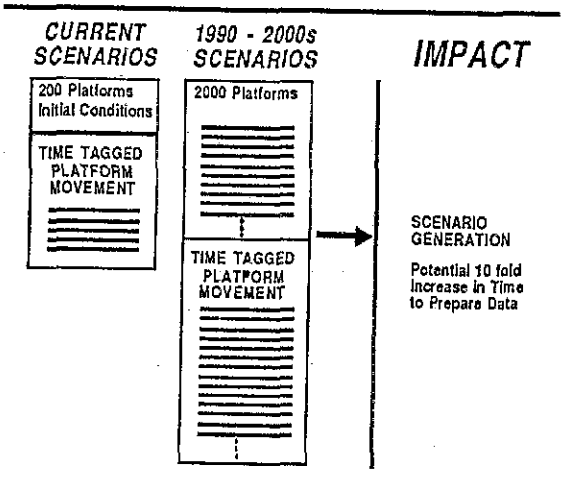

Figure 4. Significant Increase in Scenario Information

New and upgraded training systems are now capable of as many as 2000 tracks per scenario. The ten-fold increase in the number of tracks implies the potential for a ten-fold increase in the time required to fully prepare a training scenario. The potential increase in scenario generation time would severely restrict the development of new scenarios and incorporation of new training doctrine, tactics, and track capabilities into existing and/or future training systems (Figure 4).

The Scenario Generation Process

The process of scenario generation and modification consists of four steps (Figure 5): (1) establishing training objectives; (2) determining performance measurement criteria; (3) identifying initial conditions; and (4) preparing a timeline of events or track scripting.

- ESTABLISH TRAINING OBJECTIVES
(e.g., AAW, Inner Air Battle, Multi-Unit, ... , TAO Training)
- ESTABLISH PERFORMANCE MEASUREMENT CRITERIA
(Blue Force MOE, Blue Force MOP, Component MOP)
- IDENTIFY INITIAL CONDITIONS
(e.g., level of conflict, location, environment, intelligence data, force definition)
- COMPLETE TIMELINE OF PLATFORM MOVEMENT
(e.g., speed, heading, sensor status, weapon status)

Figure 5. Scenario Generation/Modification Steps

To establish training objectives, the instructor reviews materials such as the Naval Warfare Publications, Tactical (TAC) notes, TAC memos, Tactics guides, track capabilities publications (maneuvering, sensors, weapons), etc., for friendly, adversary, neutrals, and environmental data. The instructor must be familiar with the training objectives such as those listed in the Anti-Air Warfare Continuum[5], how to present the training objectives, and how to measure the student's performance.

For example, the instructor must select and design the AAW training objectives to include detection, tracking, identification, and threat assessment, assignment of weapons systems, target acquisition, weapons firing, and kill assessment.

During the scenario generation process, quantitative performance measurement and feedback of student/team performance is implicitly made a part of the scenario via the instructors' choice of initial conditions and platform movement, and not explicitly a part of the information designed into the training system scenario. For example, an instructor may consider those actions that lead to a blue force measure of effectiveness (MOE), however, there is no provision allowed by the training system to explicitly enter this intent and subsequently track the student/team performance automatically. This means that quantitative measurements of how well students/teams have met a training objective are not immediately available and often not available at all.

The initial conditions considered while preparing a scenario include, the level of conflict (e.g. cold, hot war), location (e.g., North Pacific, North Atlantic, etc.), environment (e.g., season, day/night, weather, etc.), intelligence data, and force definition (e.g., multi-unit, battle group, carrier, etc.) for friendly, neutral and adversary.

Each initial condition may also involve several additional considerations, such as functional factors affecting force definition.. For example, one functional factor may be ship stationing versus threat axis, another functional factor may be prevention of mutual interference including assignment of fire control radar channels, etc.

Current training system scenarios not only require the scenario developer to enter data to identify and initialize each track, but also require a timeline of platform movement to be created. That is, the instructor must make an entry each time a track parameter is to be changed (e.g., speed, heading). For example, one training system exercise with 147 tracks requires 17 pages of information to be entered. This process is labor intensive and hinders the development of new scenarios or modification of old scenarios. With the anticipated ten-fold increase in the number of scenario tracks, the scenario just described would require entering over 170 pages of information.

The scenario modification process consists of the same steps as scenario generation described above. Because students often share "lessons learned" about training system scenarios, automated methods to modify training system scenarios need to be implemented so that more than one scenario with the same training objective(s) can be prepared with a minimum of additional instructor effort.

Automatic Scenario Generator (ASG)

Major technological advances in hardware and software are now available to automate the scenario generation process to reduce the time and effort to generate a scenario and also make the user-machine easy to use. In-house research efforts have demonstrated ASG concepts via utilization of an artificial intelligence/expert system shell in a workstation environment. Ongoing research efforts will yield an ASG task analysis, system requirements specification, and feasibility demonstration of a low cost ASG. The following paragraphs discuss ASG system design issues, technologies for implementing an ASG, and expected quantitative improvement of the overall scenario generation process.

ASG Design Issues

ASG design issues include: (1) *Ease of Modification* Can the ASG system be changed to represent a different but similar functional area? For instance, can an ASG designed to accomplish AAW training objectives be easily modified to accomplish ASW training objectives without major reprogramming? If the ASG is a rule based expert system, can small changes be made to the rules without major reprogramming? Can these changes be made by instructors?; (2) *Supportability* The ASG technology demonstration will eventually be transitioned to a form that is amenable to be supported by Navy resources. Can the technology be transferred to that form, i.e., Ada language, off-the-shelf hardware, etc.?; (3) *Availability/Compatibility* Can the technology be transferred to a configuration that is easily interfaced to existing systems? Can the technology operate on a variety of off-the-shelf hardware. Can the technology be embedded in tactical systems, if necessary?; (4) *User-friendly User-machine Interface* Does the ASG minimize instructor required input? Does the technology provide supporting rationale for the plans it produces? Does the system advise the user when the data is not adequate for effective planning?

Will the system query the user for additional data if data is lacking?

Technologies for Implementing an ASG

The technologies to automate the steps of the scenario generation process to yield an automatic scenario generator (ASG) include a combination of one or more of the following: knowledge engineering, object oriented analysis/design, expert systems, neural nets, multi-windowing, and graphics (Figure 6).

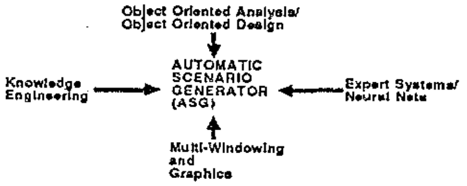

Figure 6. Technologies for Implementing an Automatic Scenario Generator

Knowledge Engineering Various knowledge engineering techniques may be used to define the training objectives and content of prestored track, geographic, environmental, and performance measurement information. Knowledge engineering techniques are also needed to identify the knowledge that could be varied and yet maintain the same overall training objective(s) within a scenario. Current ASG knowledge engineering and knowledge acquisition research is utilizing NAVTRASYSCEN'S Visual Interactive System for Task Analysis (VISTA).[6]

Object Oriented Analysis/Design Once the knowledge to describe the establishing of initial conditions and force laydown is obtained, an object oriented analysis (OOA)/design (OOD) of the ASG data base can be performed. An OOA/OOD approach will permit quick data access and minimization of data stored.

Expert Systems/Neural Nets The initial force laydown will be accomplished by combining both expert systems rule-based and/or object based technology with a procedural language such as Ada. Scenario track scripting may be a combination of expert systems and neural nets.

Multi-Windowing and Graphics Multi-windowing and graphics are the major technologies for making the user-machine interface easy to use. Current methods for instructors to interface with training systems during the scenario generation process is primarily based upon "textual" and limited graphics presentations. Recent studies indicate that a "picture" or "icon" approach can improve the user's overall productivity by 75%.[7] Information displayed on a computer screen using icons can reduce user response time to the information displayed by 25-30% relative to information displayed using alphanumerics.[8] Therefore, the incorporation of icons into the scenario generation/control process can significantly improve ease of use and reduce user interaction time. One example of an icon based user-machine interface is the Navy Personnel Research and Development Center's (NPRDC) Batman & Robin system.[9]

Expected Quantitative Improvement of the Automatic Scenario Generation Process

The expected improvements to the automated scenario generation process are (Figure 7): (1) reduction of overall time to create a scenario by over 75% (e.g., reduce a typical scenario generation time from six weeks to one week); (2) reduction of the amount of information required to specify a scenario by over 90% (i.e., scenarios will be

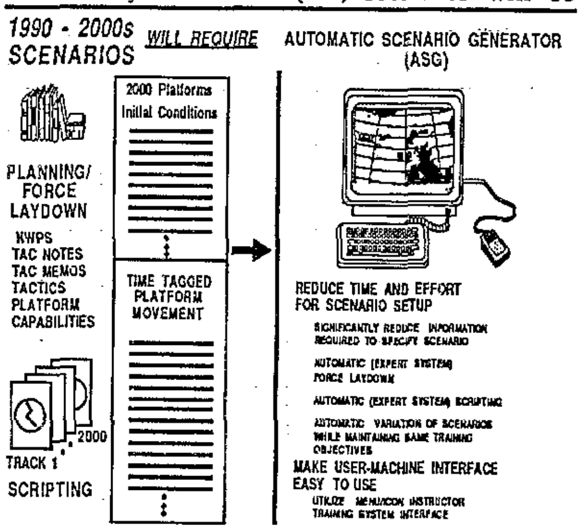

Figure 7. Automatic Scenario Generator (ASG)

defined in terms of a few high-level training objectives rather than by a large number of individual tracks, and automatic force laydown and scripting will be provided); (3) increase in the variability of scenarios to provide unique training exercises while maintaining the same training objective; (4) easy modification of the automatically generated scenario via an icon/pictorial user-machine interface; (5) no increase in the number of instructors required to create scenarios as a result of a ten-fold increase in scenario complexity.

TRAINING SYSTEM SCENARIO CONTROL

Definition

Scenario control is the term applied to one of the training system instructor's functions while a training system is operating with students. Instructor scenario control includes two primary efforts: control of track movement, sensor status, and weapon state for one or more friendly and/or adversary tracks: and analysis of student performance with appropriate feedback.

The ten-fold increase in the number of tracks in the '90s implies a significant increase of the amount of information instructors monitor and control while a training system is operating with students. Training system scenario control is becomes more complex as the operational complexity of sensors and weapons increases. Therefore, further automation of the scenario control process incorporating an easy to use user-machine interface is essential for the '90s.

The Scenario Control Process

To control movement, sensors and weapons of one or more friendly and/or adversary tracks, the instructor requires tactical knowledge. Instructors, as tactical decision makers, face the same difficulties as in a real naval environment. For example, tactical decision makers must monitor and act upon the activities of many enemy tracks threatening a naval carrier task force. A major problem for the decision maker is coping with threat surges that involve numerous waves of rapidly incoming hostile aircraft. The high data rate of advanced processing systems creates large volumes of multi-sensor information which the operator must analyze and correlate in order to assess the situations as it unfolds. The information is often incomplete, inaccurate, and ambiguous as a result of sensor limitations, threat deception, and other factors. This places a tremendous burden on the decision maker, who must absorb and assimilate this data in real time to correctly interpret the intentions of enemy tracks, and to make time-critical tactical decision on which the survival of the task force depends.[10]

Training system scenario control and modification of tracks/conditions during training system operation is a difficult task due to the increasing number of tracks and complexity of operation of sensors and weapons that are a part of a scenario. Scenario control is also difficult because the instructor not only is responsible for track parameter modification, but also is simultaneously responsible for student/team performance evaluation. The instructor/operator workload has been increasing in complexity over the last ten years. No significant reduction of complexity is expected in the future.

In today's training systems, quantitative performance measurement may be available from analysis performed on a large amount of information recorded as the exercise is executed. This analysis often takes hours, days, or weeks before it is available to the instructor and student. Of training systems surveyed in FY90, no system surveyed calculated a score of student performance automatically.[4]

Performance measurement and feedback should be tied to specific student actions, and should be provided as soon after the action as practical without being disruptive. Feedback on performance processes could also be generated intrinsically; an enemy track may immediately react to seize a tactical advantage if a student commits a tactical blunder. Intrinsic feedback can provide valuable instructional guidance, is naturally non-disruptive, and has a high degree of face validity.

Automatic Scenario Control (ASC)

Major technological advances in hardware and software are now available to automate the scenario control process to reduce the instructor workload, allow the instructor to monitor more information, and permit real-time performance measurement and feedback of student performance. The following paragraphs present several ASC system design issues, technologies for implementing an ASC, and expected quantitative improvement of the overall scenario control process.

ASC Design Issues

Automatic scenario control design issues include: (1) *Supportability* Can the technology demonstration concepts be transitioned to a form that is amenable to be supported by Navy resources? Can the technology be transferred to that form, i.e., Ada language, off-the-shelf hardware, etc.?; (2) *Availability/Compatibility of Hardware* Can the technology be transferred to a configuration that is easily interfaced to existing systems? Can the technology operate on a variety of off-the-shelf hardware? Can the technology be embedded in tactical systems, if necessary?; (3) *User-machine Interface* Is the user interface structured in a way that will enable a reduction of instructor workload, while allowing the instructor to monitor/control more information? Will the system query the user for additional information if information is lacking?; (4) *Real-time Operation* Will the technology support real-time operations (real-time in the context of battle simulations means updates on the order of every minute or less)? Will the technology require special processing resources, such as parallel processors, to maintain real-time?; and (5) *Retrospective Reasoning* Will the system be able to show the user the logic it used to arrive at maneuvering and scoring decisions?

Technologies for Implementing an ASC

The technologies to automate the scenario control process are similar to those that were discussed under automatic scenario generation above. Additional work to further define the application of technology will be occurring in FY91-92.

Object Oriented Track/Force Modeling with Rule Based Expert Systems for Intelligent Scenarios Current scenario generation and control is based upon scripted scenarios. These scenarios script the actions of forces so that without trainer intervention, the scripted forces follow a time tagged series of events after scenario start. In contrast, an intelligent scenario will produce force "objects" with attributes, capabilities and assignments (missions). At scenario start these objects take actions based on their attributes, capabilities, missions, and a set of rules. The rules force the object to react to actions taken by other objects (including the trainees, or instructors) within the scenario producing a dynamic, intelligent scenario. Intelligent scenarios intrinsically provide automated scenario control.

Expert Systems for Friendly/Opposing Forces Situation Assessment There is R&D activity in industry and military laboratories aimed at developing software models of opposing forces. Approaches to modeling a single track, or two, operating as a tactical unit, have been independently developed by several organizations.

Naval Air Development Center (NADC) has developed a multiple threat/multiple hypotheses expert system based "plan recognition "(e.g., "situation assessment") model that encompasses multiple tracks, operating singly, or in combinations, carrying out plans in pursuit of shared higher level goals.[10]

Due to the increase in the amount of information that an instructor is required to monitor/move and, therefore, the corresponding increase in the number of tactical decisions that the instructor must make, the incorporation of expert system multiple threat/multiple hypotheses plan recognition models similar to that developed by NADC will be required.

Neural Nets The use of neural net technology for opposing force situation assessment has been demonstrated in industry. It is believed that the neural net approach provides a quicker development environment for some problems. However, the determination that neural nets are feasible for real-time applications has not been made. Neural nets are appropriate for pattern matching/classification involving large, complex input volumes, for classifying information based on limited or partial input, and when classification needs to be adaptive. [11]

Automatic Real-time Performance Measurement and Feedback One basis for providing automatic performance measurement and feedback is the "Procedures Manual Operational Readiness Assessment of Naval Exercises, Volume II AAW."[12] A specific technology to support the automatic real-time reporting of student/team performance measurement and feedback is not currently identified. One attempt to utilize expert systems technology did not perform in real-time. Additional studies are needed in this area.

Expected Quantitative Improvement of the Automatic Scenario Control Process

A further task analysis of the instructor control functions needs to be performed. Initial goals for an automatic scenario control include: (1) provision of at least one window at the instructor console that contains an automated situation assessment of opposing forces for at least one warfare area; (2) provision of at least one window that displays real-time student/team performance measurement and feedback information (Figure 8).

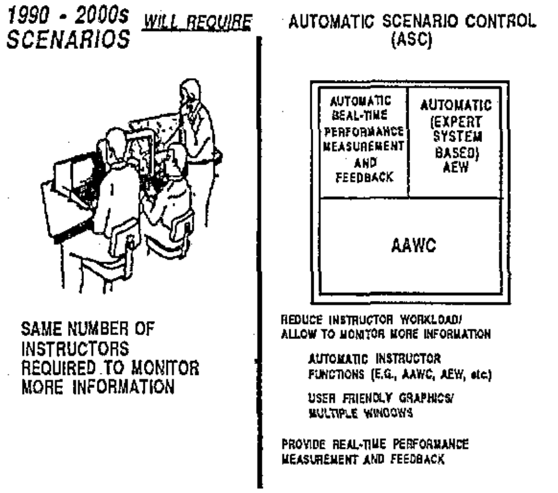

Figure 8. Automatic Scenario Control (ASC)

SUMMARY

This paper discusses fleet requirements for training system scenarios in the two areas of automatic scenario generation and automatic scenario control. Major technological advances in hardware and software are now available to automate the scenario generation and control processes to meet the fleet requirements of reducing time and effort to generate and/or control scenarios, while making the user-machine interface as easy to use as possible.

The overall improvement goals for automatic scenario generation and control processes are show below (Figure 9).

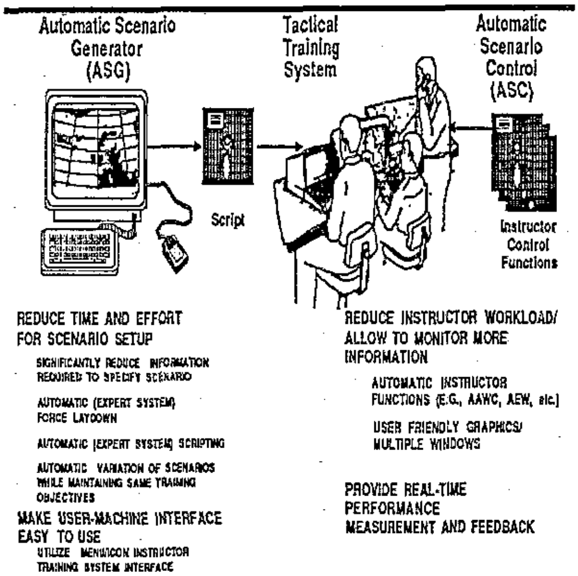

Figure 9. Tactical Training Instructor Components for the '90s -- Automatic Scenario Generator and Automatic Scenario Control

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