

# EMBEDDED TRAINING INTELLIGENT TUTORING SYSTEMS (ITS) FOR THE FUTURE COMBAT SYSTEMS (FCS) COMMAND AND CONTROL (C2) VEHICLE

George M. Burmester  
U.S. Army STRICOM  
Orlando, FL

Dick Stottler  
Stottler Henke and Associates, Inc.  
San Mateo, CA

John L. Hart  
U.S. Army STRICOM  
Orlando, FL

## Keywords:

Embedded Training, Intelligent Tutoring Systems, Future Combat Systems, Command and Control, C2

**ABSTRACT:** *The FCS is a radical departure from the previous Army concept of operations. It is described primarily as a system of systems and is a new way to fight. The new concept of operations is network centric, with information from a large number of different types of sensors passing through the network to the C2 vehicle. This diverse information must be understood, situational awareness achieved, and, tactical decisions based on it must be made. Thus, the new soldier manning the FCS C2 platform is given much more information, more diverse in nature; and therefore has a much more cognitively challenging job.*

*Embedded training (ET) seeks to provide effective training anytime, anywhere. "Embedded training must allow individual and collective training on a digital terrain representation of the mission area and permit mission planning and rehearsal in both stand-alone and networked modes while enroute." [FCS Mission Needs Statement (MNS) 2001] Instructors are required to perform several instructional tasks, including instructing the student on relevant information, presenting appropriate examples, debriefing the student, and assigning remedial instruction. However, an instructor will not usually be available in the field, anytime, anywhere.*

*To realize the benefits of ET systems will require that these tasks, described above, be performed by software. This is the realm of Intelligent Tutoring Systems (ITSs). The ultimate FCS ITS would be interfaced to the ET simulation so that it could run the student through simulated scenarios and monitor his actions. The ITS would be able to plan a tailored course of instruction for the student FCS operator which would include basic system operation, tactical decision-making, and the employment of FCS systems during combat.*

*This paper seeks to describe the challenges for ITSs as they apply to ET for the FCS C2 Vehicle and the inherent difficulties in trying to train anytime, anywhere.*

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                            | Form Approved<br>OMB No. 0704-0188       |                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-------------------------------------|----------------------------|------------------------------------------|---------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. |                                    |                                     |                            |                                          |                                 |
| 1. REPORT DATE<br><b>2005</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                    | 2. REPORT TYPE                      |                            | 3. DATES COVERED<br>-                    |                                 |
| 4. TITLE AND SUBTITLE<br><b>Embedded Training Intelligent Tutoring Systems (ITS) for the Future Combat Systems (FCS) Command and Control (C2) Vehicle</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                            | 5a. CONTRACT NUMBER                      |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                            | 5b. GRANT NUMBER                         |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                            | 5c. PROGRAM ELEMENT NUMBER               |                                 |
| 6. AUTHOR(S)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                            | 5d. PROJECT NUMBER                       |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                            | 5e. TASK NUMBER                          |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                            | 5f. WORK UNIT NUMBER                     |                                 |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><b>Army Simulation, Training &amp; Instrumentation Command, Orlando, FL, 32826-3276</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                    |                                     |                            | 8. PERFORMING ORGANIZATION REPORT NUMBER |                                 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                    |                                     |                            | 10. SPONSOR/MONITOR'S ACRONYM(S)         |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                            | 11. SPONSOR/MONITOR'S REPORT NUMBER(S)   |                                 |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><b>Approved for public release; distribution unlimited</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                    |                                     |                            |                                          |                                 |
| 13. SUPPLEMENTARY NOTES<br><b>The original document contains color images.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                    |                                     |                            |                                          |                                 |
| 14. ABSTRACT<br><b>see report</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    |                                     |                            |                                          |                                 |
| 15. SUBJECT TERMS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    |                                     |                            |                                          |                                 |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES<br><b>12</b>         | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b> |                            |                                          |                                 |

# **EMBEDDED TRAINING INTELLIGENT TUTORING SYSTEMS (ITS) FOR THE FUTURE COMBAT SYSTEMS (FCS) COMMAND AND CONTROL (C2) VEHICLE**

## **AUTHORS BIOGRAPHIES:**

### **George M. Burmester:**

Mr. George M. Burmester is currently a Principal Investigator on the Embedded Training Advanced Technology Demonstrator for the FCS Program for STRICOM. He has over 17 years experience in military simulation and training programs. In addition to being a Principal Investigator and STO Manager, Mr. Burmester has additional experience as the Lead Systems Engineer for the Joint Simulation Systems program and the Lead Systems Engineer for a number of Tactical Engagement Simulation programs.

Mr. Burmester has a Bachelor of Science Degree in Electrical Engineering and a Master of Science Degree in Industrial Engineering, Simulation and Training Systems, both from the University of Central Florida.

### **Dick Stottler:**

Mr. Dick Stottler co-founded Stottler Henke Associates, Inc. (SHAI), an artificial intelligence consulting firm in San Mateo, California in 1988 and has been the president of the company since then. He has been principal investigator on a number of tactical decision-making Intelligent Tutoring System projects conducted by SHAI.

Currently, he is working on an Intelligent Tutoring System for battalion commanders at the Command and General Staff College and an ITS prototype for the future combat system command and control vehicle, both funded by the US Army STRICOM.

### **John L. Hart:**

Mr. John Hart is the Chief Engineer of the Experiments and Demonstration Team and the Technology Manager of the Embedded Simulation and Training program at STRICOM. Mr. Hart has almost 12 years of service with the Department of Defense in the area of acquisition and the development of modeling and simulation technologies for military training systems.

His experience includes live simulation training systems that support the Combat Training Centers and maintenance training systems. He has experience as both a lead systems engineer and project director. In 1999, he was selected as a member of the Career Development Group. Most recently, he was accessed into the Army Acquisition Corps. He received his MS in Electrical Engineering from the University of Central Florida.

## INTRODUCTION

The Future Combat System (FCS) is a radical departure from the previous Army concept of operations. It is described primarily as a system of systems, and is not a specific vehicle, platform or weapon, but a new way to fight. From the FCS Mission Needs Statement (MNS) 2001, the definition of FCS is: "FCS is the networked system of systems that will serve as the core building block within all maneuver Unit of Action echelons to develop overmatching combat power, sustainability, agility, and versatility necessary for full spectrum military operations. It is comprised of a family of advanced, networked space-, air-, and ground-based maneuver, maneuver support and sustainment systems that will include manned and unmanned platforms."

The current vehicle centered concept of operations is transformed into a network of vehicles and sensors. The new concept of operations is network centric, with information from a large number of different types of sensors passing through the network to the command and control vehicle. This diverse information must be understood, situational awareness achieved, and, then, tactical decisions based on it must be made. Orders implementing these decisions are passed through the network to the chosen weapon system.

From TRADOC Pamphlet 350-70-XX (Draft), "Embedded Training is the ability to train a task using the associated operational system. Embedded training supports individual, crew, and collective training applications. Embedded Training includes system design that allows dual use of communication and instrumentation capability for training and tactical use and the use of system operating controls with appended/embedded training simulations." There are three methods for building embedded training technology into systems. They are: Fully Embedded – all embedded training systems are built into the primary system; Appended Embedded – the embedded training system is installed or attached to the primary system when needed, and removed when not needed; Umbilical Embedded – like appended, umbilical is attached to the prime system when needed and removed when not needed, however, it involves additional physical connections to external components such as computers, instructor/trainer consoles and other networks.

Intelligent Tutoring Systems are teaching software. They provide high quality, active learning that approaches the experience a student would receive working one-on-one with an expert instructor, who uses sound teaching strategies and is working with all necessary training resources. Intelligent Tutoring Systems enable simulations and other highly interactive learning exercises, which are excellent teaching aids, to be used without a human instructor being present. An Intelligent Tutoring System may be used in a classroom or for distance learning, delivered via a CD-ROM or via the Internet. Intelligent Tutoring Systems treat each student as an individual and can make "how to teach" decisions while teaching is in progress. This distinguishes them from even the best conventional computer-based training software, which is programmed only to anticipate likely responses from typical students.

## BACKGROUND

Let's examine the differences between the previous method of attack used by the vehicle centric concept and those of the proposed FCS network centric concept. Previously, the main battle tank included in one vehicle the human decision-maker, the sensor, and the utilized weapon system (main gun). In the network centric concept, the human decision maker in the C2 vehicle communicates through the network to several distributed sensors to detect, track, and identify enemy targets and communicates his destroy order to yet another "shooter" platform. Thus the new soldier manning the FCS C2 platform, when compared to his closest existing counterpart, the tank commander in a main battle tank, is given much more information, from many more sources, much more diverse in nature; has much more flexibility and many more options; and therefore has a much more cognitively challenging job.

The individual soldier in the FCS C2 vehicle will be performing his tactical functions in new ways with new systems and concepts. For example, he will be able to position a robotic observer (UAV, or deployed sensor) behind an enemy target as compared to the shooter. The increased flexibility allows him multiple ways to detect, track, and identify targets. Identification will be especially difficult in some environments. He must use this flexibility to employ his sensors to best advantage. He must be able to perform target recognition from sensor data not currently readily available to the individual soldier,

including images from UAVs, acoustic data, scout vehicle/sensor video, and even data from space-based sensors. The individual soldier will also have multiple options to attack and destroy a target including possibly robotic direct fire, indirect fire, smart indirect munitions, smart fire and forget systems, etc. With a wealth of network-provided data, the soldier should be able to maintain better situational awareness, but he must be able to deal with this increased information load. Tomorrow's soldiers will also have to make these decisions in a wider variety of more complex and ambiguous situations. Clearly more tactical decision-making instruction and practice is required.

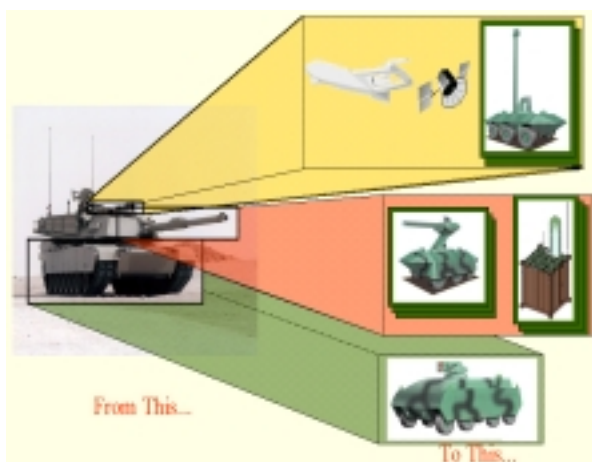


Figure 1. FCS Future

The FCS MNS 2001 describes many of the challenges that the individual FCS soldier will face. To validate the needs described here against the Army's projections, many quotes from that document are excerpted here, in quotation marks, where Italics have been added for emphasis. Clearly the cognitive demands on the individual soldier will increase. "They must see the parts – *detecting, identifying and tracking* enemy, neutral and friendly elements – while maintaining *situational awareness*, enabled by a *sophisticated set of sensors*. They must also see the whole, implying the capability to aggregate and fuse the parts, enabling *recognition of enemy patterns* of activity."

[MNS 2001] further describes what FCS soldiers must do. "Understand First." To understand, forces require the ability to *understand the patterns* in the common operational picture – operational concepts, schemes of maneuver, centers of gravity, decisive points, and vulnerabilities. ... Forces must simultaneously force the enemy to

understand last, using techniques such as *deception, pattern avoidance*, and irregular geometry."

Furthermore, the tactical distances for the FCS soldier are greater and therefore encompass much more space as described by [MNS 2001]. "Intelligence, Surveillance and Reconnaissance (ISR) capabilities and extended range direct and indirect fires expand the distance at which the tactical units can act first."

FCS soldiers will have to operate in a range of conflicts against diverse threats. "Future conflicts will range across the spectrum of warfare." Furthermore the conflict will typically be asymmetric, where the enemy will not stand and be fought but seek to hide within civilian populations, "exposing our forces to confusing situations where combatants and non-combatants are mixed,." According to [MNS 2001]. This implies a much greater need for more, and more diverse, training scenarios.

Obviously these increased cognitive skills and tasks require a new type of training. [MNS 2001] agrees stating "Our ability to dominate ... requires the integration of advanced materiel solutions and the proactive application of *changes to our Doctrine, Training, Leader Development, Organizations, and Soldier functions*." This is echoed by Enhanced Embedded Training (EET) [EET 2001], "The training of Warfighters, responsible for using complex weapon systems in combat, is increasingly challenging. The knowledge required to operate these systems effectively is very complex and changes very rapidly. Complexity is driven by several factors: a growing richness of features, combinations of interactions among a growing number of system components, and a growing range of operational scenarios that must be handled."

The fact that much of this new training must occur through embedded training is clearly described by [MNS 2001]. "The FCS must enable units to *rapidly deploy without the need for system specific training* prior to deployment and without placing an unacceptable burden on the soldier or individual platform. *It must provide common training* and training support capabilities in live; constructive and virtual environments for use at the institution, home station, combat training centers, and *deployed theaters*. It must include individual and unit training that provide realistic experiences and *be usable before, during, and after deployments* and while stationary or on the move. *Embedded training* must allow individual and collective

training on a digital terrain representation of the mission area and permit mission planning and rehearsal in both stand-alone and networked modes while enroute.”

Embedded training seeks to provide effective training anytime, anywhere. However, traditionally, observer/controllers and instructors are required to perform several instructional tasks. They instruct the student on the relevant principles and information, select and present appropriate examples, select scenarios for practice in a simulation, and brief the student before the scenario. They evaluate the student's actions, provide instruction and play the adversaries and team members during the scenario. They debrief the student after the scenario, infer the state of the student's knowledge and his ability to practically apply that knowledge in an operational context, formulate and administer remedial instruction to combat the deficiencies inferred, and retest the student to determine the effectiveness of the remediation. Also instructors perform longer-term instructional planning, determining which material to present in what order. Additionally, they try to identify the student's learning style in order to determine how to best instruct him. But an instructor will not usually be available in the field, anytime, anywhere. To realize the benefits of embedded training systems will require that these tasks, described above, be performed by software. This is the realm of Intelligent Tutoring Systems (ITSs).

The fact that many of the functions performed traditionally by instructors and more recently by ITSs are required in an embedded training system for FCS are described by [EET 2001]. “EET systems can be used for initial skills training, operator and maintenance training, refresher training, combat skills training, and/or sustainment training. To accomplish this, an EET system must have the following capabilities:

- ♦ *A method for monitoring and assessing performance.*
- ♦ *A method of providing feedback to the operator to reinforce and to improve performance.*
- ♦ *A method of record keeping to allow management of individual and collective training and to identify training deficiencies.*

Also, a fully functional EET system should:

- ♦ *Simultaneously assess and record the performance of the operator(s) and react to that performance as the real*

*threat would, thereby providing realistic feedback on the accuracy and appropriateness of the performance.*

- ♦ *Provide an appropriate level of performance measurement and recording to allow feedback to individuals after a session, and, recording of performance data to provide for cumulative or aggregate records (individual, teams or battle groups) over time.”*

This discussion clearly envisions training to primarily occur in the context of simulated operational scenarios, with automated performance assessment, feedback, diagnosis and remediation. [EET 2001] goes on to explain that it envisions an embedded training system as one that: “Provides immediate feedback; Provides Just-in-Time training and mission rehearsal; Can adjust difficulty to level of learner; Can present concepts or processes dynamically and using multiple forms of representation; An infinitely patient instructor assistant that frees the live instructor to do other things; Reduces the training engagement simulation burden on Observe-Controller (OC)/Analysts.” Thus ITS technology is clearly called for.

For the individual soldier in the FCS command and control vehicle, the highest level of cognitive training relates to performing the tactical functions as discussed previously – sensor employment; detection, tracking, and identification; target recognition from diverse sensor data; and target engagement decisions, all in a variety of environments, situations, and against a variety of threats.

In complex domains such as FCS Command and Control vehicle tactical decision-making, instruction is often complicated by the need for the student to master a variety of concepts and to apply them in unique situations and in different sequences. In these kinds of domains, the student must develop a competence not only in the relevant facts and skills, but also an understanding of the concepts underlying effective decision-making. Instructional courses must be attuned to the trainee's background and needs, motivate him to develop an accurate and thorough understanding of the subject matter, and then effectively verify the correctness of his understanding and remediate inaccuracies.

## DISCUSSION

When students are required to be flexible in their understanding of principles and potential applications, the most effective teaching strategy is to maximize the role of the teacher to a one-on-one interaction. In fact, the well-known two-sigma problem is the fact that students receiving one-on-one instruction perform two standard deviations better than students receiving conventional instruction; the problem is to realize these benefits without requiring an equal number of teachers and students. One-on-one instruction maximizes the adaptability of the instruction process, to help the student construct and test a mental model on different circumstances. Unfortunately the financial and human resources are simply not available to provide this kind of one-on-one instruction for many complex domains. The FCS system of systems and related tasks and computer systems will be far more complex than current systems, and will be delivered at a time when downsizing has forced the Army to reduce its training budget and staff. The Army will have to do more with fewer resources.

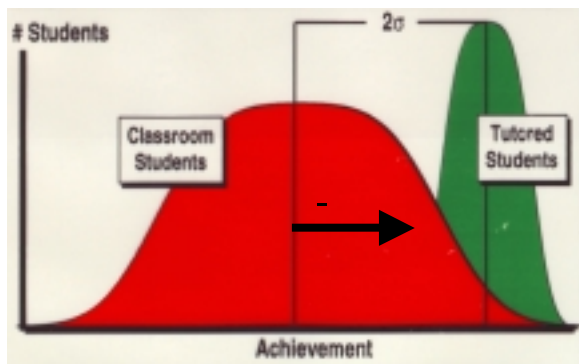


Figure 2. B. Bloom, 1984

The most important parameter in developing effective tactical decision-making skills is tactical experience, both individually and in teams. To maximize tactical experience, the number of tactical scenarios, their realism and their benefit to the particular trainee or team should be maximized. To increase the number of scenarios an individual or team can experience requires that non-training support players be eliminated and that the scenarios can be played on embedded systems. To maximize their benefit requires that scenarios should be selected or generated which are tailored to specific needs of a particular individual or team.

This obviously requires an automatic scenario selection and/or generation capability and models of the individual student and/or team.

The Army needs to have the flexibility to customize their own ITSs and enter their own scenarios in a user-friendly interface. By allowing instructor creation/modification of ITSs and tactical scenarios, turn-around time will be greatly reduced and precious development dollars saved. Miscommunication and communication overhead between instructor and developer is eliminated since the instructor becomes the developer of the ITS and scenarios, himself.

As described above, many of the capabilities required by the embedded training component of the FCS are currently provided by ITS technology. Also as described above, to maximize training effectiveness requires maximizing individual virtual instructor time per student. Yet for practical reasons, instructors will be unavailable. An ITS which automatically assesses the student performance in tactical scenarios and monitors his progress, remediates him on his weaknesses in his preferred learning style and provides him scenarios, designed to exercise those weaknesses, does maximize virtual instructor time per student, without requiring an actual instructor. This ability to adapt and customize itself to the student, requires that the ITS have a well-developed model of the student.

## Functional FCS ITS Description

As described in the Methodology Section below, the FCS ITS development project includes tasks for analyzing the tasks to be trained, both from a behavioral and cognitive perspective, and for designing the ITS, based on that analysis. The former is made more challenging by the fact that the FCS does not yet exist, is still being designed, and therefore there are no individuals actively performing the job for which the ITS will be designed. However, the tasks to be trained, the tactical decision-making, are similar to tasks for which ITSs have already been developed, most notably the tactics ITS for tank and mechanized infantry company commanders [Stottler and Pike 2002]. So, from the similarity of FCS tactical decision-making to other tactical decision-making tasks for which ITSs have been developed, the ITS functional description for those ITSs can be adapted and the discussion below incorporated to create the first pass FCS ITS functional description



presented here. From our experience with other tactical decision-making ITSs, we do anticipate that this description will be very close to that of the final system. This is because it relies primarily on a very well accepted instructional technique for tactical decision-making, practice in simulated scenarios with after action reviews.

The main goal of the FCS ITS is to train FCS command and control vehicle crew members to make high quality planning and execution decisions in tactical scenarios. This training will occur primarily in simulated scenarios. However, there are significant prerequisites, which must also be taught. Before the student can be expected to perform in scenarios involving both planning and real-time execution, he must first be able to make tactical plans alone, with relatively little time pressure. Before he can be expected to create high quality plans for FCS elements he must understand the capabilities, limitations, and associated tactics of the FCS platforms. Additionally he must understand how to use the software tools required by the ITS which are a plan editor and a real-time tactical scenario simulation system, the OneSAF Testbed (OTB). (OTB is the current version of OneSAF, available for integration and testing purposes. When OneSAF is available, it will replace OTB in the FCS ITS Architecture.)



Figure 3. OTB Screen Dump

The FCS ITS will teach the tactical employment of FCS systems and related tactical decision-making to FCS command and control vehicle tactical decision-makers. When a new student logs on he will be first asked some questions about his background, experience, FCS knowledge, and familiarity with the required software tools. These questions include level of education achieved, rank, highest unit commanded, types of units served in, advanced weapon and sensor system familiarity, FCS familiarity, and familiarity/comfort with the plan

editor and OTB. The ITS will use this information to make initial estimates as to the student's mastery of various principles, including FCS knowledge and tactics, general tactical knowledge and the use of the required software tools. It will also be used to select scenarios, other exercises, types of hints, and other forms of instruction. The FCS ITS will include both tactical planning and execution scenarios.

If the ITS estimates that the student's mastery of FCS related principles is low, then before doing simulated exercises, the student will first be put through FCS refresher exercises. If the ITS estimates his skill with the plan editor is low, he will first receive a very short course on how to use it. An introductory lesson will explain with detailed steps how to create a plan overlay and find and place the most relevant symbols. His ability to create plans with the software will then be tested in simple scenarios.

After the FCS and plan editor refresher exercises (if they were needed), the ITS will begin to tutor the student on general tactical principles. If it estimates his mastery is relatively high it will proceed immediately to tactical decision games presented and answered as plan overlays. If not, it will first present general tactical principle courseware. For each tactical decision game (TDG), the ITS will analyze the student's plan (given as a plan overlay) and automatically create a debriefing describing what parts of his plan are right, what parts are wrong, and gives an expert's rationale for the best options. For poor decisions, the ITS will lower its estimate of the mastery of principles related to those decisions, and provide remedial materials on those principles, before presenting any more TDGs. These principles include both general tactical principles and FCS specific tactics.

For the TDGs and the 3-D dynamic scenarios, the ITS will initially select exercises based on the need to test untested principles, following each by a debriefing and detailed information on the principles missed. The ITS will then begin to also retrieve scenarios that exercise the principles in which the student's mastery is weakest. Furthermore, for any scenario using principles that the ITS believes the student is weak in, it will provide him hints for the scenario, if they are available. These are generally questions designed to get him to think about the most important tactical principles required in the scenario.

After the student has demonstrated (or learned) his mastery of general tactical



principles in the TDGs, he will proceed to that portion of the course that requires him to show that he can apply these same principles in a 3-D virtual reality dynamic tactical simulation (OTB supplemented with a 3-D Viewer). (If his knowledge of OTB is low, he will first be given a short OTB use course including scenarios where he is controlling FCS vehicles executing simple plans). Additionally, more operations-oriented principles (such as knowing when and how to use UAV sensors) will also be tested. The student will be given a short situation description and then will proceed to create a plan for the mission. After the plan is debriefed by the ITS and corrected by the student he will execute the mission in OTB. After the scenario ends, the event log will be analyzed by the ITS to automatically determine which actions were correct, incorrect, or omitted, and the underlying principles that were understood and applied or not.

After the scenario, the student will be debriefed with an After Action Review. All the things he did right and wrong are reviewed and he is told about the relevant principles. For the failed principles he is given detailed information and an example for each. The mastery level estimates for all principles involved are updated. Based on these, a new scenario will be retrieved. Scenarios will be selected that test untested principles and test recently failed principles. The prototype will have different instructional methods for students with little mastery or experience compared to students with a lot of mastery and experience.

### FCS ITS Implementation

The FCS ITS proof-of-concept prototype is based on an existing ITS engine and authoring tool and runs on a Linux system to allow demonstration both at STRICOM's demonstration facility in Orlando and on an FCS command and control vehicle prototype. The high-level architecture is shown below.

As shown in Figure 4, the existing C++ ITS engine and Java ITS user interface will be ported to run under the Linux operating system. The ITS authoring tool will be left running in Windows NT, to save development funds for other tasks and because it is not necessary to have the authoring tool on the vehicle. The content will be authored with the authoring tool, then the ITS content files will be transferred to the Linux system.

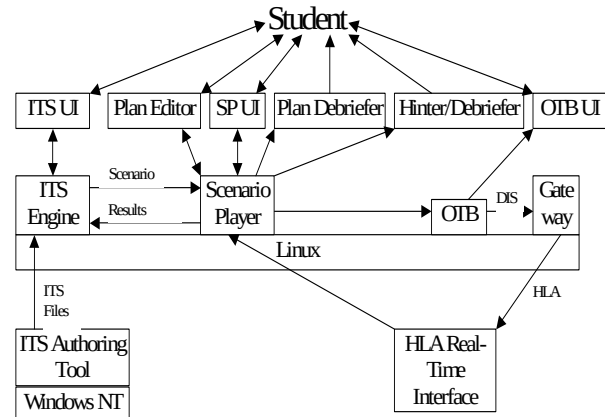


Figure 4. FCS ITS Architecture

The ITS engine presents the course information to the student as well as assessing their performance in scenarios and performing the remedial course of study. Based on the prerequisite requirements described in the previous section, a structure for the course is suggested and shown below:

1. How to use the Plan Editor (prerequisite for FCS Tactical Planning)
2. FCS Description (prerequisite for FCS Tactical Planning)
3. FCS Tactics (prerequisite for FCS Tactical Planning)
4. FCS Tactical Planning (learning objective and prerequisite for FCS Tactical Execution)
5. How to use OTB (prerequisite for FCS Tactical Execution)
6. FCS Tactical Execution (learning objective)

The ITS will include two types of scenarios – Tactical Planning Scenarios and Tactical Planning and Execution Scenarios. The planning-only scenarios will be presented in the fourth chapter until the student demonstrates his ability to make correct tactical plans. The planning requires FCS specific tactical principles as well as general tactical principles. The student will first be presented with the tactical situation through the scenario player's user interface (SP UI in Figure 4) then inputs his plan with a simple plan editor. The Plan Debriefier provides a debriefing on the student's plan. The automatic debriefing capability is one of the most challenging (and necessary) aspects of an ITS because typically the student has a lot of freedom in the actions that he can take. That is, there is not one right sequence of actions that

he can be checked against. This challenge is the reason that most CBT systems only allow assessment based on multiple choice or fill in the blank questions, which is, of course, very unrealistic from an operational perspective.

In order to perform the evaluation and assemble the debriefing, the Scenario Player module includes a set of correct and common incorrect plans for each scenario and these are compared to the student's plan. The closest matching plan is used as a basis for debriefing. Each stored plan is annotated with explanations as to the strengths and weaknesses of the overall plan and the rationale why the various symbols are good or bad tactical choices in terms of their type and general and exact location of the symbol.

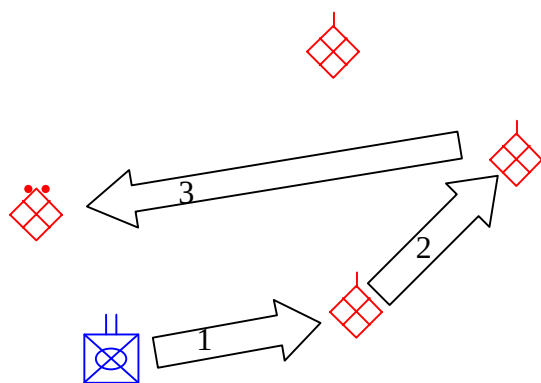


Figure 5. Simplified Example Correct Plan

If the student's plan matched a good plan (that is, his overall solution is pretty good) his debriefing consists of a symbol by symbol description of the discrepancies between his and the expert-entered good plan along with the stored rationale. For example, his plan may have shown the route of a direct fire vehicle that left it unmasked to enemy observation and fire for a portion of the route when a completely terrain-masked route was available. If the student's plan matches a previously entered bad plan, he is told the overall weaknesses of that plan and then presented with the best expert entered plan for that scenario, with all the associated explanations and rationale. Our experience with tactical plans show that the large majority of student planning mistakes do tend to be covered by from one to a few common bad plans. An example might be the use of the direct fire and other ground vehicles in a traditional movement to contact maneuver

when UAVs are available for reconnaissance. This type of poor plan might be common in students with a strong armor background having trouble adjusting to full realm of capabilities that FCS will provide.

Chapter 6 scenarios begin in an identical way, except that after the student's plan is debriefed, he is instructed to execute, in OTB, one of the correct tactical plans. As shown, the scenario player launches the appropriate scenario in OTB. We use the version of OTB created by Fort Knox, which includes approximate models for robotic FCS vehicles. The student interacts with OTB through the standard OTB user interface. OTB broadcasts DIS packets. These are intercepted by a gateway and converted to HLA messages. These are read by a real-time interface that filters and converts them to a form useable by the scenario player. The scenario player includes finite state machines to determine the correctness of the student's actions in the specific scenario and which principles are understood and can be applied and those that aren't or can't. The scenario player uses this information both to provide hints in real-time and an after action review. It also sends these results back to the ITS engine which can decide if additional material or scenarios are needed by the student.

As mentioned above, assessment is a challenging and necessary component of an ITS. Assessing the correctness of actions in a real-time free-play scenario is especially challenging since the same scenario, with different students (executing different actions) can evolve into very different kinds of situations and what is considered tactically correct depends so much on what the situation is at a given instant. We have found in a variety of domains that both general and scenario-specific Finite State Machines (FSMs) are highly adept at determining the correctness of student decisions made during the execution in a tactical scenario running in a free-play real-time simulations. Shown below in Figure 6 is a simple evaluation FSM. The "Proceeding" state is highlighted in green to indicate it is the initial state. While proceeding down a road at the bottom of a narrow canyon, the FCS C2 vehicle and screening force encounters a roadblock. This causes the FSM to transition to the "Blocked" state. If the student correctly deploys UAVs to investigate behind the obstacle and the high terrain on either side, then he has successfully shown he knows when and how to

deploy his UAV assets and the FSM transitions to the "Success" state and the student receives credit for being able to apply the relevant principle relating to UAVs. However, if he merely proceeds, without first deploying the UAVs, the FSM will follow the "Proceed" link and transition to the "Fail UAV Recon" state and the student would fail the applicable UAV principle. Additionally if he deploys ground vehicles as he would have done before FCS, he also fails the applicable UAV principle.

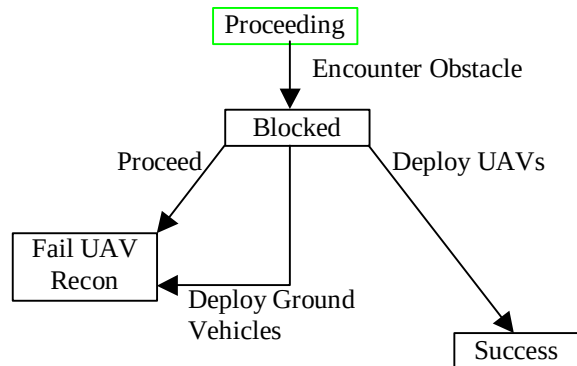


Figure 6. Simple Evaluation FSM

The FCS ITS prototype will support different types of students with different instructional methods. Students who are evaluated as already having a good understanding of FCS tactics and the other prerequisites will be allowed to proceed directly to the simulated scenarios which require them to enter a plan, receive a plan debriefing, then begin its execution. During tactical execution, they will be assessed in real-time, if appropriate given hints, and receive an automatic debriefing. This allows knowledgeable students to maximize their tactical decision making practice on scenarios selected by the ITS to exercise their weakest areas.

Students who lack FCS or other requisite knowledge will be supported with a different instructional method whereby the new material is first presented, illustrated with examples, then the student is tested with at first simple scenarios, with hinting. They are automatically debriefed and the ITS generates remedial sequences including additional practice scenarios after mistakes. The ITS will also control advancement, based on performance in simulated scenarios, to later chapters. It will gradually increase scenario complexity and reduces the amount help the student is provided.

## METHODOLOGY

### FCS ITS Development

There are a number of tasks that will be accomplished to develop the FCS ITS. The main ones are listed below:

- ◆ Analyze FCS C2 Vehicle Crewmen Tasks and Tactics
- ◆ Knowledge Engineering
- ◆ Design the FCS C2 Tactical Decision Making ITS
- ◆ Define Planning and Execution Scenarios
- ◆ Software Development
- ◆ Input Knowledge and Develop Courseware
- ◆ Testing
- ◆ Evaluate

#### **Analyze FCS C2 Vehicle Crewmen Tasks, Tactics, and Decision-Making Process**

Tasks relating to tactical decision-making for the FCS C2 vehicle crewmen will be determined. These will be analyzed to determine the relevant tactics and tactical decision-making process. FCS experts themselves will plan and execute simulated FCS scenarios, describing their thought processes out loud. The critical decisions for each scenario will be identified and each one will be analyzed in terms of its goals, inputs, cues, challenges, the background skills and knowledge required to make the correct decision, and the outputs resulting from the decision.

#### **Design the FCS C2 Tactical Decision Making ITS**

Based on the analysis of the tasks, tactics, decision-making process, needs and existing ITS and simulation capabilities, the FCS C2 Tactical Decision Making ITS will be designed in detail. This included the structure of the course, the object-oriented design of the software components, and an identification of which existing software components could be reused and which would be developed from scratch or enhanced.

#### **Define Planning and Execution Scenarios**

Working closely with the FCS experts, several tactical planning and execution scenarios will be defined. Each scenario is appropriate for the individual tactical decision-maker in the FCS C2 vehicle. Each scenario will

include a description of the situation, and a briefing with instructions. Each will include from 2 to 5 annotated plans (representing 1-2 correct solutions and 1 – 3 common incorrect solutions) used for automatic comparison and debriefing. Each scenario also will include the FSMs for determining the correctness of actions in the execution phase.

### **Software Development**

Since much of the needed FCS ITS capabilities already existed, much of the software development consists of porting the existing software written in C++ and Java for Windows to Linux. The ported components include the C++ ITS Engine, the Java ITS UI, a Java Plan editor, a C++ Case-Based Reasoning (CBR) module to perform plan comparisons, a C++ FSM evaluator, a C++ real-time hinting mechanism and an existing C++ Scenario Player for a very similar domain (tank company commanders).

After porting the existing software, some changes will be made to customize it to the particulars of FCS tutoring. These improvements include changes to the ITS UI, augmenting the Plan editor for these types of plans, adding FSM primitives, adding plan comparison methods, integrating the real-time hinting mechanism, and making changes to the Scenario Player to support a more unified planning and execution scenario. This task also involves developing required content, such as tactical principle descriptions. To provide hints in real-time requires that the scenario player be instantly aware of actions taken in OTB. Therefore we need to develop a real-time HLA interface. We will be able to take advantage of an existing HLA interface developed for a very similar ITS.

### **Input Knowledge and Develop Courseware**

We will input the required tactical knowledge in appropriate electronic form. This included structuring the course (chapters, sections, etc.), inputting the scenarios, inputting the annotated plans, creating the FSMs, and inputting multimedia tactical principle descriptions.

### **Testing**

During the development of the ITS we will test the individual components. After the various components are integrated, we will test the final integrated version to make sure that it operated correctly on several sequences for

each scenario.

### **Evaluate**

We will evaluate the result of each task as it proceeded. Additionally we will evaluate the FCS ITS through demonstrations to and feedback from tactical experts and instructors.

## **RECOMMENDATION**

Embedded training offers a high potential payoff. This payoff will come in several forms. First, once implemented embedded training will reduce the logistics requirements for training while on deployments. Another payoff will come in the form of increased realism for home station training. With fully embedded training systems the potential exist to conduct a CTC like exercise at home station against an OPFOR that acts and reacts like the CTC OPFOR.

And lastly another benefit from the implementation of the embedded training system will be mission planning and rehearsal for tactical missions. The same simulation tools that are used for training can be accessed for the use of mission planning and rehearsal such as digital terrain and battlefield visualization from simulated sensors. The use of the simulations allows the planner to see the plan from any perspective with the digital environment that is used for training.

In order to make the leap-ahead with the embedded training technology there must be an assessment made and feedback provided to the trainee. The intelligent tutoring software provides that instructor in the vehicle to perform the assessment. The intelligent tutor offers another aspect that a human can't provide. The intelligent tutor can provide an objective assessment of the exercise data measured against a performance standard.

The performance standards are being defined along with the operational concept of the Objective Force. As these standards are developed the under lying standards for the Intelligent Tutoring System can be developed concurrently.

In order to take advantage of this technology, we must not be focused on the training of the force, but expand our field of view to the operational duties as well. Imagine if a commander used a system with the foundation of an Intelligent Tutor System during the planning of an operational exercise. During the planning the software could alert the

commander to weaknesses in the developed plan. Decision aids can be derived from the Intelligent Tutor System to provide operational battlefield assistance.

## CONCLUSION

This research has shown many benefits to embedding training into vehicle systems. The focus of the research has been a proof of concept Intelligent Tutoring System for individual vehicles. Starting at this level assures that each vehicle will have the instructional and assessment capabilities for the individual and crew training. Embedded training needs to cross a full spectrum of training from individual to collective team training. The issues associated with the Intelligent Tutoring System could easily be applied to the collective training through the identification of performance standards.

With the award of the FCS Lead Systems Integrator (LSI) contract and the development of the Unit of Action Operational concept, standards for performance can be identified and applied to an Intelligent Tutor System. Under the current schedule, a proof of concept demonstration in early 2003 will meet the timeline for the FCS Block I Technology Assessment. The proof of concept system will establish the architectural considerations for implementation in 2006 for the second FCS block upgrade. It is the Intelligent Tutor System that will allow embedded training to reach its maximum potential as a technology for the Objective Force. Having soldiers who can make effective, rapid decisions on the battlefield will increase the survivability and the lethality of the Objective Force.

## REFERENCES

- [1] [MNS 2001] Mission Needs Statement for Future Combat System (FCS), Potential ACAT 1, Working Draft Version 2.5, 10 October 2001
- [2] "Embedded Training Concept", TRADOC Pamphlet 350-70-XX (Draft), HQ United States Army TRADOC, 25 March 1997
- [3] Faber, Terry D., [EET 2001] *"Enhanced Embedded Training (EET), What is it? What is it good for? How do we get it?"*, prepared for the 3rd Annual Testing and Training: A National Partnership Symposium and Exhibition, Army Training Support Center (ATSC), 22 October, 2001
- [4] Stottler, R. H., Pike, W., "An Embedded Training Solution: FBCB2/Tactical Decision Intelligent Tutoring System", I/ITSEC Conference 2002