Enriching ADL: Integrating HLA Simulation and SCORM Instruction using SITA (Simulation-based Intelligent Training and Assessment)

Dr. Jacqueline Haynes
Intelligent Automation, Inc.
Rockville, Maryland
jhaynes@i-a-i.com

Susan Marshall
US Army PEO STRI
Orlando, Florida
susan_marshall@peostri.army.mil

Dr. Vikram Manikonda and Preetam Maloor
Intelligent Automation, Inc.
Rockville, Maryland
vikram@i-a-i.com, pmaloor@i-a-i.com

ABSTRACT

The Joint ADL CoLab in Orlando, FL, in conjunction with Intelligent Automation, Inc. in Rockville, MD, is conducting research to include the use of High Level Architecture (HLA)-compliant simulations for on-line instruction and assessment. This research focuses on developing instructional paradigms, training-specific data structures and communication methods between a simulation, Shareable Content Object Reference Model (SCORM)-based instructional content, and a Learning Management System (LMS), to facilitate using simulation as an environment where an individual or a team can practice a skill (instruction) or demonstrate their level of performing the skill (performance assessment). An individual can practice a team skill in an environment where other trainees are practicing, or where other team members' functions are simulated by autonomous agents. A benefit is that the outcome of instruction can be assessed as a combination of knowledge, measured by objective testing, and performance, measured by the simulation.

This effort has technical and pedagogical challenges. Technically, the challenge is to develop a seamless interface between components conforming to different standards, a SCORM-compliant LMS and a HLA- compliant simulation. This requires design and development of Run-Time Infrastructure (RTI) adaptors and supporting data structures for distributed communication between the simulation federates and the LMS. Pedagogically, the challenge is to integrate the simulation into a rich instructional environment combining SCORM-based didactic instruction, interactive instruction and simulation.

The Discrete Event Simulation environment is currently developed to train Air Traffic Flow Coordinators in collaborative regional flow control (CRFC), using a simulation developed for NASA. This simulation trains ATFC's to optimize constraints on air traffic and their duration, related to system throughput, system-wide delay and controller workload. The result is a measure of efficiency in airspace utilization.

ABOUT THE AUTHORS

Jacqueline Haynes is co-founder, Executive Vice President and Director of the Education and Training Technology Group at IAI. Her background combines education and psychology with AI applications. She received her Ph.D. from the University of Maryland in Curriculum and Instruction, and did post-doctoral work there in artificial intelligence and intelligent tutoring systems. Previously she held was a faculty member at the University of Maryland, College of Education. Her research interests include research-based instructional design, tools for Web-based instruction, and reading comprehension.

Susan Marshall is a Principal Investigator on Advanced Distributed Learning (ADL) Research for Program Executive Office Simulation, Training and Instrumentation (PEO STRI), supporting the Joint ADL Co-Lab in Orlando. Previously she has been a project engineer on several programs, including the Advanced Gunnery Training System (AGTS) and War fighting Simulation (WARSIM). Susan has twenty years of experience as a civilian engineer for the Navy and Army, mainly in Software acquisition and testing. She has a B.S. in Electrical Engineering (EE) from Marquette University, and a M.S. in Industrial Engineering (IE) in Simulation from the University of Central Florida.

Vikram Manikonda is a Vice President and the Director of the Distributed Intelligent Systems at IAI. He received his B.E. degree in Electrical Engineering from the Birla Institute of Technology and Science, India, in 1992, his M.S. and Ph.D. degrees, both in Electrical Engineering, from the University of Maryland at College Park, in 1994

and 1997 respectively. His research interests include intelligent control, robotics, motion description languages, multi-agent systems for modeling and simulation, and air traffic control and management.

Preetam Maloor is a Research Engineer in the Education and Training Technology Group IAI. He is currently involved in the design and implementation of the Simulation-based Intelligent Training and Assessment (SITA) prototype. His research interests are in Artificial Intelligence applications in educational technology. He has several years of experience in the areas of Natural Language Processing, Speech Processing and Computer-Human Interaction. He has a Masters degree in Computer Science from Texas A&M University and a Bachelors degree in Computer Science and Engineering from the University of Bombay.

Enriching ADL: Integrating HLA Simulation and SCORM Instruction using SITA (Simulation-based Intelligent Training and Assessment)

Dr. Jacqueline Haynes
Intelligent Automation, Inc.
Rockville, Maryland
jhaynes@i-a-i.com

Susan Marshall
US Army PEO STRI
Orlando, Florida
susan_marshall@peostri.army.mil

Dr. Vikram Manikonda and Preetam Maloor
Intelligent Automation, Inc.
Rockville, Maryland
vikram@i-a-i.com, pmaloor@i-a-i.com

THE ADL PERSPECTIVE: WHY COMBINE HLA SIMULATION AND SCORM INSTRUCTION?

Training is the keystone to success for any organization; this is even truer for our military services. With the resulting complexity of military operations in today's world it is vital that our service members and their leaders, at all levels, receive the best possible training available. The importance of ensuring our service members receive the best possible training is reflected in the Department of Defense's (DoD) Advanced Distributed Learning Initiative (ADL, 2003). The purpose of this effort is to incorporate the use of on-line computer-based instruction within the DoD, thereby providing service members and their leaders access to critical training whenever and wherever it may be required.

As the United States military continues its move towards the use of on-line, computer-based instruction, the inclusion of simulations, for the purpose of student practice and assessment, provides important enrichment to the learning environment. The linkage of simulations to on-line instruction provides the student the ability not only to demonstrate his or her understanding (science) of the instructional material presented, but also the application (art) of that instructional material in a realistic environment. We can no longer afford to allow our military members to learn on the job. This approach has the potential to be too costly in both lives and material. Additionally, learning and training should ideally adapt to the needs of the student or students providing an "on demand" like capability, so too must the evaluation tools to validate that learning. Again, simulations have the potential to support this capability by providing scenarios focused specifically on the learning desired.

The DoD simulation High Level Architecture (HLA) provides a common communications interface for simulations, thereby allowing different simulations to "join" together in a common environment and exchange data to provide a more robust and realistic virtual training environment. HLA also provides a common format for the exchange of this data, providing simulation developers with a common underlying structure on which to develop their product.

The DoD Sharable Content Object Reference Model 2004 (SCORM 2004) (ADL, 2003) provides much of the same capability for developers of on-line, computer-based instruction. SCORM 2004 provides an underlying structure for the development of distributed learning, allowing the reuse of instructional content, assets, and resources. It provides common interfaces supporting the exchange of data between the Learning Management System (LMS) or Learning Content Management System (LCMS) and the Sharable Content Objects (SCO).

If we are to provide a learning environment as described above to our service members, the linkage of HLA and SCORM 2004 is the logical first step. Both provide common communication interfaces requiring a "standard" organization for their respective data and both are, or are in the process of becoming internationally recognized standards. The integration of SCORM 2004 and HLA specifications represents both a technical and instructional design challenge. However the resulting benefits to our service members is well worth the potential cost of the required research and development effort.

This paper describes a research project funded as a Broad Area Announcement (BAA) through the Joint Advanced Distributed Learning Collaborative Laboratory (Joint ADL Co-Lab) located in Orlando, Florida. The work is being conducted as a joint effort between the Joint ADL Co Lab (US Army PEO STRI, 2004) and Intelligent Automation, Inc. (IAI, 2004) of Rockville, MD.

PREVIOUS EFFORTS IN SIMULATION-BASED TRAINING

One of the successful and widely publicized efforts in simulation-based training include the Modular SemiAutomatic Forces (ModSAF) (Ceranowicz, 1994) program, a joint effort between the Defense

Advanced Research Project Agency (DARPA) and the U. S. Army Simulation, Training and Instrumentation Command (STRICOM). The goal of ModSAF was to provide a platform within which all services could expand the synthetic battle space. ModSAF has been followed up with Joint Semi-Automated Forces (JSAF) and One Semi-Automated Forces (OneSAF) (Wittman and Harrison, 2001) programs. These initiatives are aimed at providing an integral simulation service to the Advanced Concepts and Requirements (ACR), Training, Exercises, and Military Operations (TEMO), and Research Development and Acquisition (RDA) domains.

Simulations have been widely adopted in every aspect of Medical training ranging from systems for training anesthesiologists to react to emergency situations (Gaga et al, 2001) to training emergency corpsmen in initial casualty assessment, management, stabilization and transport (Badler et al, 1995). Industrial applications of simulations range from training/re-training workers in the operation of computer-controlled manufacturing equipment (Ho et al, 1995), training mining equipment operators (Freedman, 2000), and the well-known and proven use of flight simulators for training pilots (Caretta and Dunlap, 1998).

TECHNICAL AND INSTRUCTIONAL CHALLENGES

SITA (Simulation-based Intelligent Training and Assessment) is a prototype system being developed by Intelligent Automation Inc. SITA uses the Collaborative Regional Flow Control (CRFC) Decision-Support Tool (Satapathy et al, 2002), which is a HLA-compliant simulation developed by IAI for NASA Ames. CRFC-DST, a Discrete-event Simulation, is built on the Cybele™ platform (see http://www.opencybele.org), an open-source platform for building HLA-compliant distributed simulations (Aronson et al, 2003). The CRFC simulation is designed as a decision support tool for air traffic flow coordinators (ATFC's) who monitor and control all (commercial, military, and general aviation) air traffic in one or more of the large sectors of the nation's air space. The initial CRFC data is taken from historical air traffic, and the user's manipulation of several constraints and their duration influences the subsequent air traffic flow in his/her region, in adjacent regions, and throughout the national airspace. This simulation can be used to train ATFCs to optimize utilization of airspace for system throughput, system-wide delay and controller workload. The result is a measure of efficiency in airspace utilization.

The CRFC-DST supports multiple concurrent users, who can then observe the effect of single as well as multiple AFTCs' decisions on air traffic patterns. The CRFC is "a well-behaved simulation" (DMSO, 2001), which has been used to model as many as 120,000 flights. Figure 1 is a screen-shot of the simulation's graphical user interface (GUI). Figure 2 illustrates the CRFC-DST simulation model. Here the acronyms stand for NAS: National Air Space; ASDI: Aircraft Situational Display to Industry and ETMS: Enhanced Traffic Management System. Please refer to Satapathy (2002) for further details.

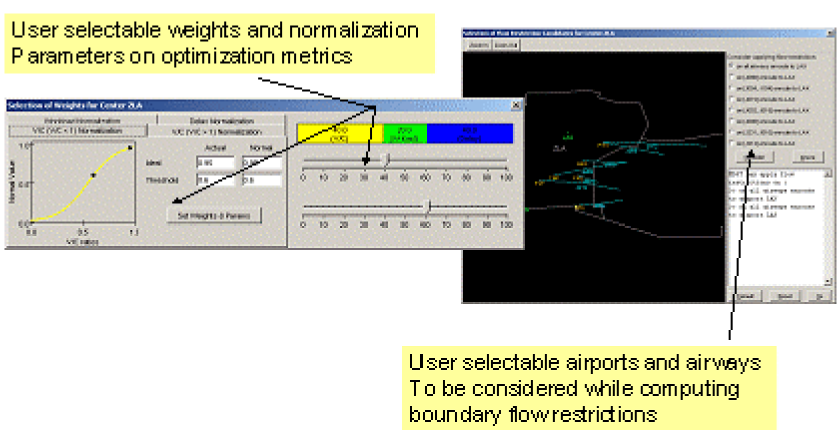

Figure 1. CRFC Simulation Graphical User Interface

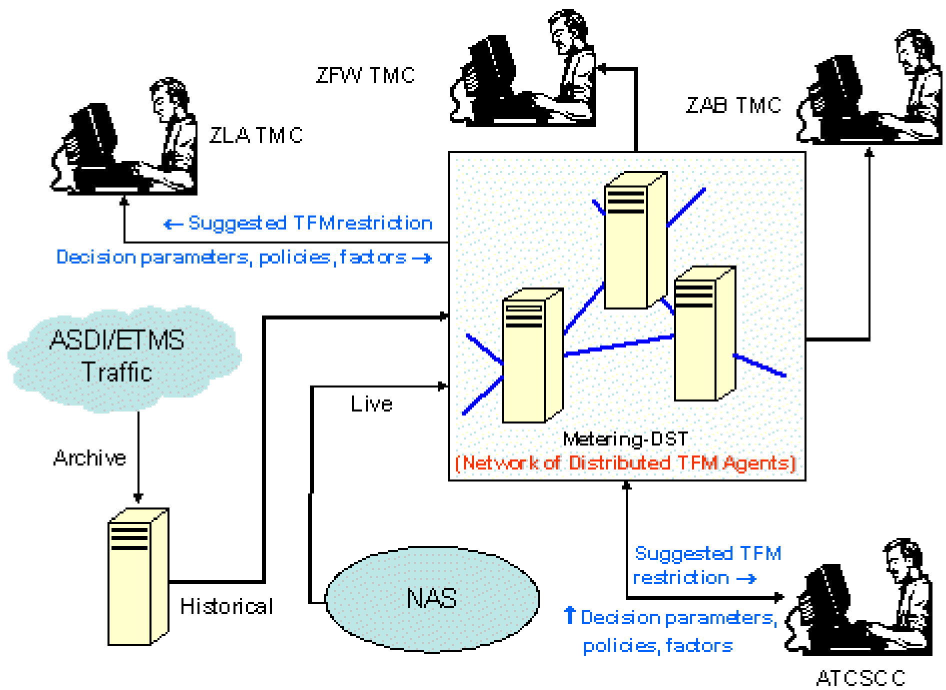

Figure 2. Collaborative Regional Flow Control Simulation Model

Instructional Uses of Simulation in SITA

SITA illustrates three instructional uses of simulation:

1. Pre-assessment of *knowledge*, where the learner is asked specific questions about a portion of the running simulation he/she is observing, where the questions can be modified independently from the simulation (in a SCO).
2. Practice of *skills*, where the learner can use knowledge information he/she learned through didactic instruction (instructor-directed content acquisition), or interactive instruction (instruction using multiple sequences of information presentation-student activity-feedback-next presentation). Either of these can be used individually or as part of a *team*. For both of these scenarios, the learner(s) receive *immediate feedback* in the form of specific results shown in the simulation.
3. Final assessment, where the learner's relevant knowledge (*facts*) and skills (*performance*) can be assessed within a single, cohesive training and assessment environment, providing immediate feedback and specific, targeted remediation as necessary.

Technical challenges

For an architecture to fully support the interfacing of a SCORM-complaint LMS with the HLA-complaint simulation, it needs to satisfy the following minimum requirements:

- It must be able to launch the HLA federate[1] from the LMS.
- It must be able to monitor the student's performance in the simulation.
- It must be able to communicate the results of the student's performance in the simulation back to the LMS.

To accomplish these tasks, the design of SITA has been guided by the following requirements:

- Providing a channel for communication between the LMS and the CRFC simulation
- Transmitting and translating user and control data to and from the LMS (SCORM format) and the CRFC simulation (HLA format)
- Evaluating user performance outcomes using efficiency metrics provided by the simulation
- Providing a centralized capability (inside the SCO) to start and stop the CRFC simulation

For the current effort, we are using Avilar Webmentor (see http://www.avilar.com), a commercial LMS that supports SCORM 1.2. The basic architecture of SITA (Figure 3) consists of three major interface modules, RTI[1]-SCO interface module, Simulation Manager and the Launcher/Collector Applet, which together enable communication between the SCO and the HLA Simulation. The role of each module is described briefly.

RTI-SCO Interface
This interface communicates user-input simulation parameters and CRFC-DST computed performance metrics back to the SCO via the Launcher/Collector Applet.

Simulation Manager
This element controls the initialization, start-up, and termination of CRFC-DST simulation.

Launcher/Collector Applet
This module:

- Acts as an interface between the SCO and the Simulation Manager, to start or stop the simulation.
- Acts as an interface between the SCO and the RTI-SCO Interface, to save and restore user performance and simulation state data.
- Decodes and evaluates effectiveness metrics provided by the CRFC simulation, and provides these to the SCO.

Upon initialization, the student's simulation settings are read from the Learning Management System (LMS) by Sharable Content Object (SCO). The SCO then launches the simulation by sending a *start simulation* command to the *Simulation launcher/collector* applet, which runs in the same client browser context as the instructional content (SCO). The applet connects to the *Simulation Manager*. The Simulation Manager starts the simulation federates. The Simulation GUI will be displayed on the same client machine as the SCO. Communication between simulation federates and the LMS is achieved via the *RTI-SCO Interface*, the *Simulation launcher/collector applet* and the *LMS Adapter*.

Both HLA and SCORM are evolving interoperability specifications/standards. The HLA specification/standard evolved from the training simulation community into a data interoperability medium for such systems. ADL defines the Sharable Content Object Reference Model (SCORM 2004) which is an evolving interoperability specification for Web-based distributed learning.

ADL's interest in supporting this R&D effort considers how a technological marriage could best be applied to the needs of the Warfighter. The vision for the program is to "provide the student a richer, more robust learning environment in which active interaction with simulations supports instruction by integrating HLA-compliant simulations with SCORM-conformant instruction." (DMSO, 2001; ADL, 2003).

Our approach to developing both technical architecture and instructional models for this program is to place high priority on working within the framework of the existing standards and specifications, wherever possible. This priority poses a challenge because of the changes taking place in SCORM in 2003, until the recent release of SCORM 2004. However, while there are important enhancements in SCORM 2004 which we would prefer to use in SITA (most importantly sequencing), there is currently (as of the writing of this paper) no available ADL-approved LMS supporting the sequencing functions. Accordingly, in SITA, sequencing of content objects is accomplished by instruction to the user contained in an initial SCO followed by further instruction in each SCO assigned to a student. IAI's continuing work in this area will focus on using SCORM's simple sequencing rules, once an appropriate LMS enabling these features becomes available.

[1] HLA Terminology (please see https://www.dmso.mil/public/transition/hla/ for further details)

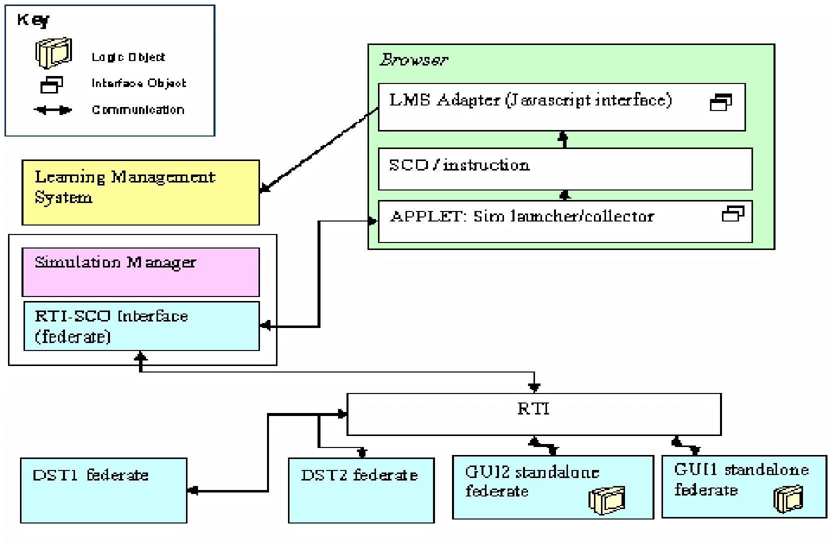

Figure 3. SITA Architecture

INSTRUCTIONAL DESIGNS AND SIMULATION

Hood (1997) categorized four types of simulation-based training: (1) *Gaming* where one or more players must follow a formalized play with pre-set rules; (2) *Role-playing* in which students assume specific roles in simulated situations; (3) *Simulators* where humans directly interact with machines in realistic situations; and (4) *Modeling* where experiments are modeled by physical or symbolic representations of the system. Suitability of a simulation type to a particular domain depends on the training needs and the characteristics of that domain. The CRFC-DST simulation is a combination of (2), (3) and (4): trainees assume the role of TFasMC for a specific region, and practice using the available control methods (selection of routes, constraints and duration).

Studies (Bredmeier and Greenblat, 1981; Rosenfeld, 1985) have shown that simulation-based training is better than or equal in effectiveness to conventional training methods while providing a unique advantage: In simulation-based training, a student can observe the impact of his or her choices and actions without having any effect on the real-world operation (Smith and Ragan, 1999), thus greatly reducing or completely eliminating any risks involved. A study by Experience Builders (2003) concludes that learners undergoing simulation-based training, compared to conventional training methods, have four advantages: They:

1. achieve deeper understandings
2. retain knowledge longer
3. show a greater interest in the subject matter; and
4. are better able to transfer their learning to their job

Each of these is important as a learning outcome, and for military training are critical to improving the warfighter's readiness, competence and to improving training efficiency. The TFMC task in SITA is but one example of using simulation-based training to gain understanding about the efficacy of new methods of assessing task performance as well as improving training of individuals and teams in ways to optimize their performance.

The Instructional Design requirements for SITA were:

1. Use simulation for interactive instruction, practice, and assessment.
2. Provide a variety of instruction methods: didactic, interactive, and simulated.
3. Provide activities for individual practice in monitoring and controlling air traffic flow within a designated air space.
4. Provide activities for collaborative practice in predicting and managing flow control over contiguous sectors of air space.
5. Provide motivating, game-like interactivity.
6. Assess individual and group outcomes.
7. Provide assessment formats, including performance-based and open-ended text.

8. Adapt the instruction to meet each learner's needs, as indicated by individual and group assessment performance.

The SITA SCOs include didactic instruction, simulations, and assessments. Components of the courseware are completed in order, and each component can be launched only when the previous one has been completed successfully. The following SCOs are used in the instruction: (1) Pre-test; (2) Didactic instruction; (3) Interactive instruction; (4) Individual simulation; (5) Team simulation; and (6) Post-test. The instruction design for the Didactic SCO is given in Figure 4. The designs for Individual and Team simulation instruction SCOs are given in Figure 5 and Figure 6 respectively.

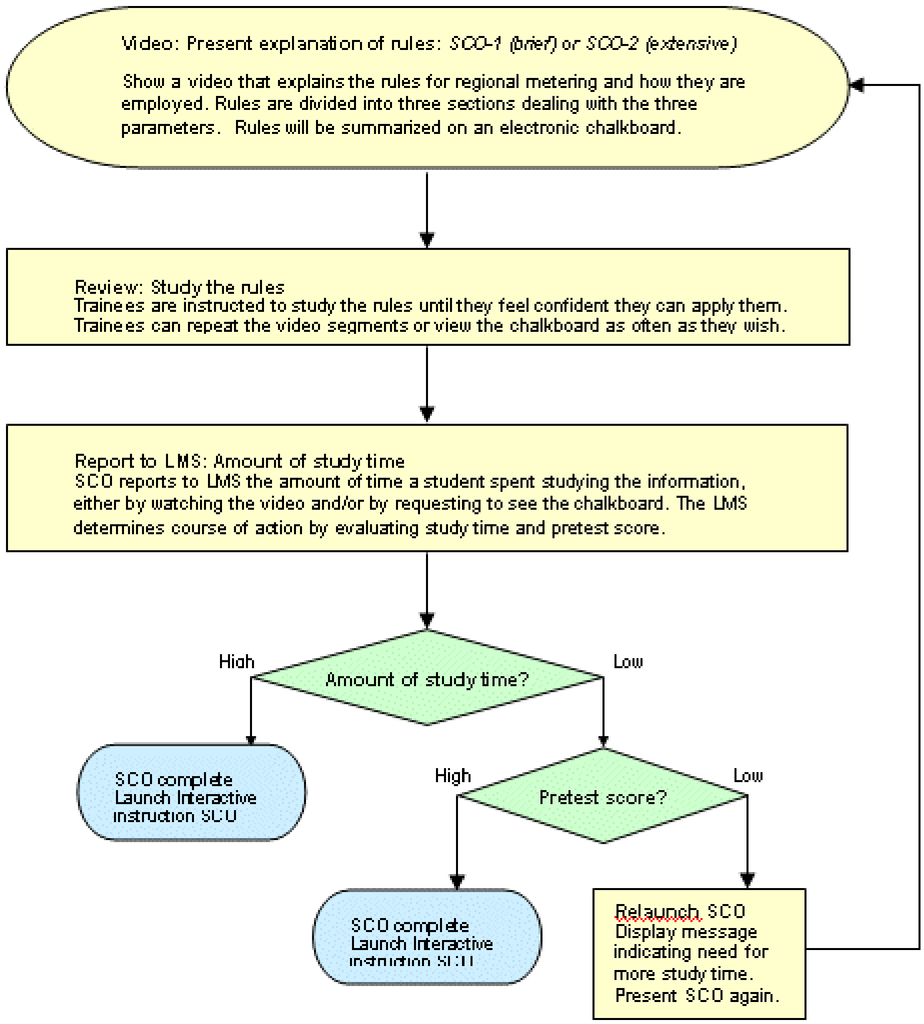

Figure 4. Didactic instruction SCO

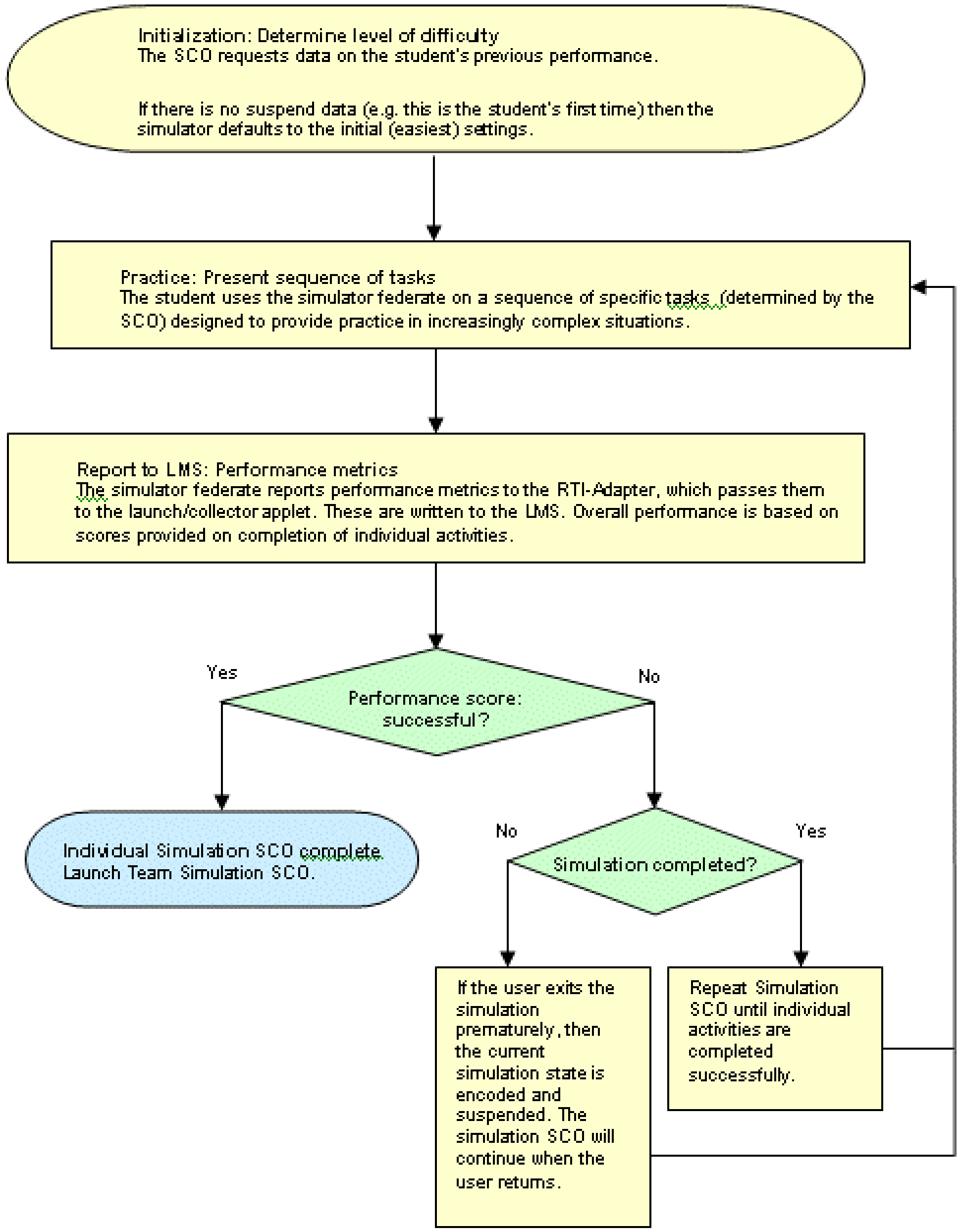

Figure 5. Individual Simulation SCO

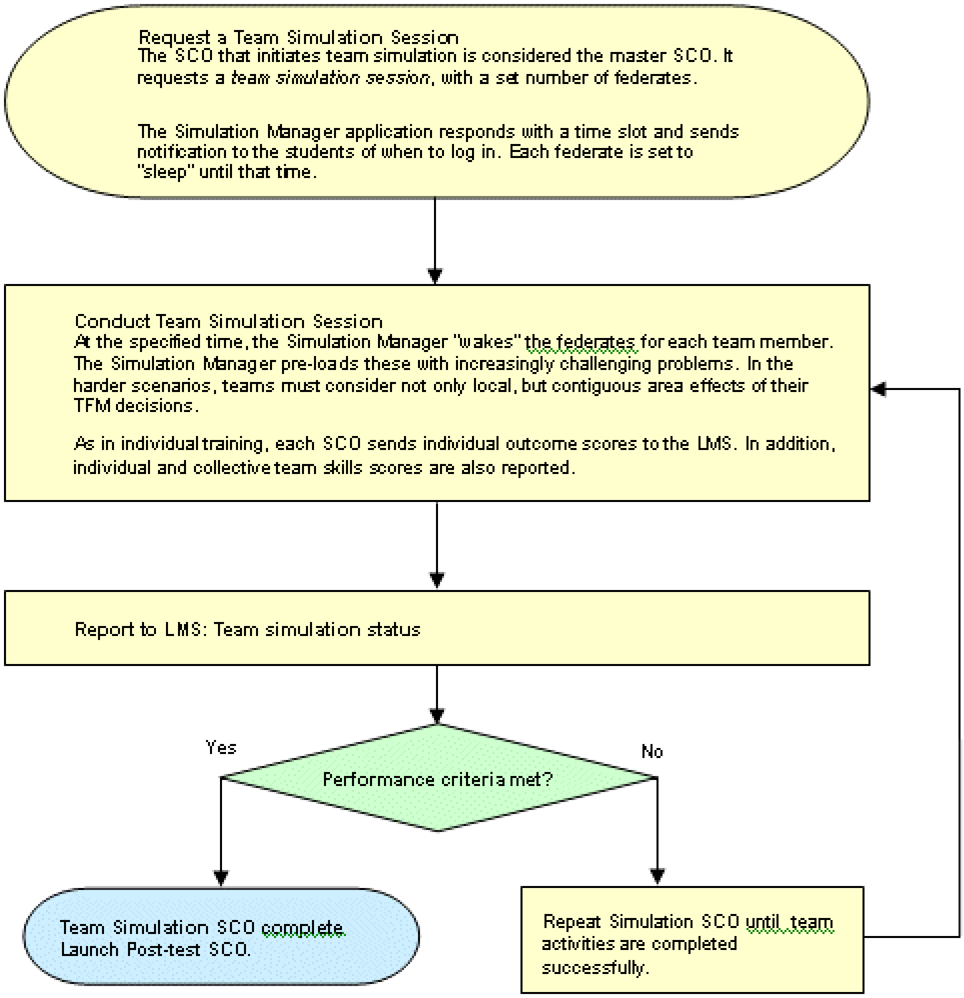

Figure 6. Team Simulation SCO

Use of Simulation in Instruction

The CRFC-DST simulation is used throughout the instruction. In the Pre-test, the simulation is used to present information, and the learner is asked questions about the specific scenario(s) depicted. This is accomplished by running the simulation briefly, then capturing either a static image of the simulation (i.e., a "screenshot,") or a video image of the simulation for a brief segment (i.e., a "movie"). From the outset of instruction, the student becomes familiar with the concepts and actions contained in the simulation, and its motivating, game-like qualities are employed even in assessment. In didactic instruction, the terms, concepts and interactions inherent in the simulation are specifically taught. This is not teaching how to operate the simulation, but rather the knowledge needed to become proficient in the CRFC task, as embodied in the simulation. The instruction can be directed toward individuals or toward a group where the information taught relates to the inter-dependence of decisions between TFMCs. Because SITA is developed using an agent-based infrastructure, team practice can occur either between two or more trainees, or between trainees and autonomous agents. This is of great benefit when and where teams are not available for synchronous training.

The interactive instruction components show the outcome of a student's response to a specific question by presenting a screenshot from the simulation illustrating the outcome of his/her choice. An important element of this interactive instruction is that a team can practice their skills together, with increasingly larger groups of students interacting to view the effect of their control decisions on the efficiency of airspace use over a wider geographic area. For other domains, this design may be of even greater benefit. For example, in medical training, a student could be presented with a case, provide a diagnosis and the recommended course of treatment for a disease. Following this, agents representing various symptoms could then show their reaction to time elapsed and the treatment suggested, showing, rather than telling the medical student the result of his/her decisions.

Post-testing in SITA is greatly enhanced by using the simulation. While conventional assessment (i.e., multiple choice items, short answer items, etc.) can be used to measure acquisition of specific information, there is little support for assuming that factual knowledge is sufficient for task performance. However, in SITA both can be assessed. SCO's containing conventional assessment items are administered first, and then a subsequent SCO is selected based on scores from the first portion of the test. Based on responses to specific items, one of four simulation scenarios is selected to determine whether or not the learner can perform the CRFC task using knowledge he/she has acquired. This selection of scenario allows for the assessment of performance to be based on the interaction of acquired knowledge and skill, rather than on knowledge and skill as separate components. The simulation captures specific decisions the trainee has made over a set period of time, as well as the final efficiency metric produced by the DST itself. This combination of knowledge assessment and performance assessment is a potentially powerful assessment model that warrants detailed further study.

CONCLUSION

In this paper, we presented SITA, a prototype system that integrates HLA compliant simulation with SCORM complaint instruction to provide a more robust and realistic virtual training environment. Our motivation for linking simulations to on-line instruction was to provide the student the ability not only to demonstrate his or her understanding of the instructional material presented, but also the application of that instructional material in a realistic environment. We described the technical challenges involved in integration of two diverse standards, SCORM and HLA and the instructional challenge of making simulation an integral part of the training process. We hope that this combination of knowledge assessment and performance assessment will provide a greater scope of instructional options to distributed learning developers in military and non-military training environments. There are many questions warranting further research in how best to use simulations most effectively for training and assessment purposes.

REFERENCES

ADL, (2003). http://www.adlnet.org.

Aronson, J., Manikonda, V., Peng, W., Levy, R. & Roth., R. (2003). An HLA Compliant Agent-based Fast-Time Simulation Architecture for Analysis of Civil Aviation Concepts. *Spring SISO Simulation Interoperability Workshop,* April 1-4, 2003, Orlando, Florida.

Badler, N., Webber, B., Clarke, J. R., Chi, D, Hollick, M., Foster, N., Kokkevis, E. , Metaxas, D., Ogunyemi, O. , Kaye, J., & Bindiganavale, R. (1995). MediSim: Simulated Medical Corpsmen and Casualties for Medical Forces Planning and Training. *The National Forum: Military Telemedicine On-Line Today. Research, Practice and Opportunities,* IEEE Computer Society Press.

Bredemeier, M. E. & Greenblat, C. S. (1981). The Educational Effectiveness of Simulation Games: A Synthesis of Findings. *In Greenblat, Cathy Stein and Richard D. Duke (editors), Principles and Practices of Gaming-Simulation.* Beverly Hills: Sage Publications.

Carretta, T R. & Dunlap, R D. (1998). *Transfer of Training Effectiveness in Flight Simulation: 1986 to 1997.* Retrieved June 16, 2004, from http://www.stormingmedia.us/81/8182/A818263.html

Ceranowicz, A. (1994). Modular Semi-Automated Forces, *Proceedings of the 1994 Winter Simulation Conference,* pages. 755-761.

DMSO, (2001). http://www.dmso.mil/public.

Experience Builders, (2003). *A Comparison of Simulation-Based and Conventional Training Methods.* Retrieved June 16, 2004, from http://www.experiencebuilders.com/eb/why/white_papers/SimulationEffectiveness.pdf

Freedman, P. (2000). 3D Simulation for Training Mining Equipment Operators. *IEEE Canadian Spring Review.*

Gaba, D. M., Howard, S. K., Fish, K. J., Smith, B. E, & Sowb, Y. A. (2001). Simulation-Based

Training in Anesthesia Crisis Resource Management (ACRM): A Decade of Experience. *Simulation and Gaming, Volume 32,* pages 175-193.

Hood, P. (1997). *Simulation as a tool in education research and development,* EdTalk.

Ho, L. K & Vance, J. M., (1995). Virtual Training in Manufacturing Systems Using TELEGRIP. *Deneb User Group IX Meeting Proceeding*, October, 1995, Ypsilanti, Michigan.

IAI (2004). Intelligent Automation, Inc. http://www.i-a-i.com

Rosenfeld, F. H (1985). *The Educational Effectiveness of Simulation Games: A Synthesis of Recent Findings. In Greenblat, Cathy S. and Richard D. Duke (editors), Gaming-Simulation: Rationale, Design, and Applications.* New York: John Wiley.

Satapathy, G., Manikonda, V., Robinson, J. & Farley, T. (2002). En-Route Sector Metering using a Game-Theoretic Approach. *AAAI Game Theory and Decision Theory Workshop,* July 28-31, 2002, Edmonton, Canada.

Smith, P.L., & Ragan, T.J., (1999). *Instructional Design (2nd ed.).* Upper Saddle River, NJ: Prentice Hall, Inc.

Sterling, B (1993). *The Value of Training Like You Intend to Fight. War is Virtual Hell,* Wired Ventures Ltd.

Sweet, D., Manikonda, V., Aronson, J., & Roth, K. (2002). Fast-Time NAS Simulation for Analysis of Advanced ATM concepts. *In Proceedings of AIAA Modeling and Simulation Conference and Exhibit,* August 5-8, 2002, Monterey, California.

Wittman, R. L. & Harrison, C. T. (2001). OneSAF: A Product Line Approach to Simulation Development. *Technical Paper, MITRE.*