Integrating Training Simulations and e-Learning Systems: The SimSCORM platform

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ABSTRACT

From a technological, pedagogical, and commercial perspective, the world of training simulators has always been separate from the world of e-learning. There is a need, however, to merge both worlds. This would allow the pedagogical capabilities of the e-learning community to be combined with the operational training capabilities of simulators. Until now, this integration was held back due to the high cost and complexity of connecting training simulators with e-learning tools such as Learning Management Systems (LMSs). With the recent, rapidly growing adoption of standards for both simulation (e.g., HLA) and e-learning (e.g., ADL SCORM), integration can now be achieved much easier and at a lower cost.

TNO has studied the integration of e-learning and simulation and developed an approach based upon integration by means of *de facto* standards in both worlds. The SimSCORM platform was built as a proof of concept of this approach. The SimSCORM platform provides a dynamic integration of e-learning systems and training simulators. Although not a unique effort, TNO has chosen a rather distinctive and flexible approach. In this approach, each learning task in the LMS is treated as a separate simulation component, which has its own direct link to the HLA simulation. This integration allows real-time, two-way interaction between one or more simulator(s) and the active learning task running in the LMS. The LMS, which can be any LMS as long as it is SCORM compliant, can be used for tracking, evaluation, and administration of training results, as well as for configuring and starting scenarios for the simulator. As a result, the SimSCORM platform enables cost-effective reuse of expensive simulator features in e-learning settings, joint training simulations, real-time assessment using ADL SCORM objectives, team training, and requires no adaptations to the simulator or LMS as long as they are respectively HLA and ADL SCORM compliant.

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INTRODUCTION

Today's simulators can provide learners with powerful and realistic learning environments; whereas e-learning systems provide them with interactive, mostly theory-directed lessons based on multimedia modules. Integrating both kinds of systems will have considerable advantages, from a pedagogical, technical, and organizational perspective. But what are exactly the differences between training simulations and e-learning systems?

Training Simulators

Training simulators are dedicated and immersive learning environments that provide a high level of realism in visualization and interaction. Examples are flight simulators that train pilots or process simulations of a plant for training operators. Mostly, training simulators have a built-in Learning Management System (LMS) for tracking interactions with learning content and providing instructional content by means of an Intelligent Tutoring System (ITS) or Virtual Instructor (VI) for assessment, feedback, and management of training results. A disadvantage, however, is that these LMSs are mostly built specifically for a certain simulator or simulation domain and therefore lack interoperability of learning and instruction content. This means both types of content will require a costly reengineering for each new simulator and/or LMS.

E-Learning Systems

E-learning systems are (mostly) web-based learning environments that provide distributed learning, independent of time of place. Based upon profiles of each learner, certain multimedia modules will be offered and the resulting learning processes and evaluation tests will be tracked, administrated, and reported. Mostly, e-learning systems are either LMSs for managing learning processes, Learning Content Management Systems (LCMSs) for managing learning content, or a combination of both. Note that these L(C)MSs are domain independent, and widely available as Commercial of the Shelf (COTS) or Open Source (OS) applications. Due to a widespread compliancy to e-learning standards, almost all e-learning systems are interoperable with each other. A disadvantage, however, is that these e-learning standards are not really directed towards virtual environments, team training, and real-time assessment.

Integration benefits

Integrating training simulators and e-learning systems will result in a number of pedagogical, technical, and organizational advantages.

Pedagogical
With the introduction of new learning methods such as problem-based, competency-based or task-directed learning, the importance of meaningful integration of practice and theory, in both learning and evaluation, is becoming increasingly important. From a learner's point of view, a powerful learning environment should provide easy and seamless integration of practicing realistic learning tasks and studying theory that is supportive to that learning task.

Technical
Training simulators are traditionally strong in providing a fully interactive, multi-person (for team training), multi-modal task environment, with often excellent, real-time tracking of task performance. E-learning systems are traditionally strong in providing standardized and relatively cheap L(C)MS functionalities such as (a) managing interactions with learning content (e.g. tracking, administration, reporting) and (b) managing learning content (e.g. storing, delivery, maintaining) , and (c) providing instructional content (e.g. instructions, feedback, assessment), where and if necessary distributed in space and time. If training simulations and e-learning systems are interoperable and can make reuse of each

others functionalities, significant design, development, implementation and maintenance time and costs can be saved.

Organizational

For both training simulators and e-learning systems, creating lessons (in the simulation domain often called scenario's or scripts) is labor intensive work typically done by highly specialized educational designers. A lesson will define the learning task by setting the parameters of the environment, roles, entities, and activities, but also the instructional assessment (in terms of timing, accuracy, safety, success, etc.) on which a virtual instructor will operate. Although training simulation lessons and e-learning lessons may take place in the same curriculum and may adhere to the same pedagogical models, they are mostly built by different designers, using different editors and different design languages and implemented in different formats. Integration will improve the interoperability and reuse of these valuable lessons between training simulations and e-learning systems. Also, high level (and therefore less simulation domain dependent) lessons can be created before the actual training simulation is introduced, because generic e-learning editors can now be used instead of waiting for the proprietary simulation editors. Another benefit is the positive impulse it will provide towards standardization of user interfaces (e.g., same operation of editors for both types of systems) and technical and pedagogical terms (e.g., lessons versus scenario's, learning task versus case), providing more transparency for all stakeholders. Finally, performance evaluation can be standardized, as the same criteria, methods and technologies can be used for certifying and accreditation of training simulations, e-learning systems, and their learning content.

Integration, however, will not be simple. There are many different types of training simulators and e-learning systems, based upon different—often proprietary—technologies, structured according to different object-oriented approaches, embedded in different types of ICT infrastructure, and implemented according to different pedagogical models. And, last but not least, simulation and e-learning are separate communities with different origins, research interests and developers.

Integrating standards

To overcome this problem, several R&D efforts have been made to integrate the e-learning and simulation worlds via technical standards. The most relevant standards-based effort is made within the SCORM-Sim Study Group of the Simulation Interoperability Standards Organization (SISO, see http://www.sisostds.org), where several manufacturers and research organizations elaborate and explore the benefits of coupling SCORM (ADL Co-Lab, 2006) compliant LMSs with training simulations via widely used standards such as the Higher Level Architecture (HLA; Symington, 2000). The ADL SCORM and HLA standards will not be explained in detail in this paper, but for our purpose it is sufficient to say that they both aim at promoting the application of unified, interoperable technologies in respectively e-learning and simulation applications. The benefits of using these standards are the improved interoperability between different simulation environments and LMSs and better reusability of simulation components and learning content. Furthermore standardized and well-defined interfaces will improve the way of working, since development and research effort can easily be divided between the learning content, LMS and simulation developer, and their supporting communities. It will also allow developers and researchers to focus on their area of expertise and integrate solutions with third party LMSs, simulators and or learning content. This is important because today's, powerful learning environments require the integration of realistic simulation, authentic task environments and typical e-learning capabilities such as managing learning content and learning processes.

In this paper, we present, a standards-based integration of training simulators with e-learning systems is introduced. First, existing approaches are discussed. Then, the approach of TNO (the National Research Institute of the Netherlands; see www.tno.nl) in integrating training simulators with e-learning systems is presented. In this context, the SimSCORM platform that is created to demonstrate this approach is introduced. This demonstration uses a learning task in the car driving domain as an example. Finally, conclusions are drawn with respect to the technical and pedagogical advantages of TNO's approach for both the simulator and the e-learning community, and recommendations for future research are described.

APPROACH

There are several initiatives that concern the integration of simulation training in e-learning systems. Most of them are SCORM-based and are listed in the final report of the SISO SCORM-Sim Study Group (SISO, 2008). In essence these

initiatives use two different approaches; using an external communication interface or using an embedded communication interface. Furthermore HLA is often used as a standard for integration with the simulation environment. This is because both SCORM and HLA standards are the *de facto* standards within their domains and have many similarities:

- They both specify how to define content using a standard data model or template, such that content and information about that content can be shared between systems.
- They both specify a run-time environment that handles the sharing of content and information in a uniform way.
- They both enforce rules on the content and how information is shared.
- They both have large supporting communities.

This makes them a perfect match for integration, be it that there are several ways to do so. Both approaches will now be discussed. After that TNO's approach will be presented.

External communication interface

In the approaches with an external communication interface, a locally installed application handles all communication between the active learning content and a simulation (for example, see Haynes, 2004). According to ADL SCORM, learning content always consists of smaller, independent modules called Sharable Content Objects (SCOs). Often, the locally installed application is responsible for launching and stopping the simulation, monitoring the learner's actions in the simulation and providing results to the active learning content (i.e., a SCO), that then can store in the LMS, see Figure 1. An advantage of this approach is that much of the communication and assessment logic is located in the application and not in the web-based SCO, which is beneficial as most workstations with web-browsers have limited resources and more restricted security policies.

A major disadvantage of this approach is that some kind of communication protocol between the application and the SCO is needed. This often leads to proprietary protocols and requires modifications to the LMS. Furthermore, the SCO will be highly depended on the performance measurement and the assessment that is performed by the application, and not by the SCO itself. This will restrict the interoperability of the SCO.

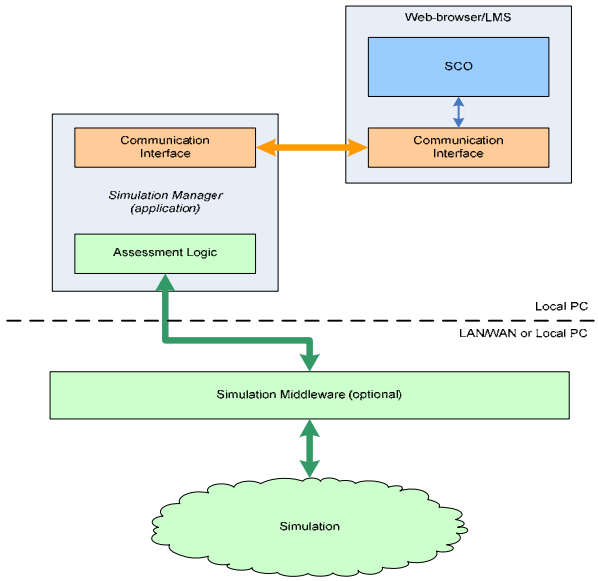

Figure 1. External communication interface with the simulation.

Embedded communication interface

In this approach, the communication with the simulation is handled by the SCO itself. Therefore, the SCO generally contains an asset that handles the communication with the simulation. In HLA terms this means the SCO can be treated as a HLA federate and has its own connection with the HLA federation, see Figure 2.

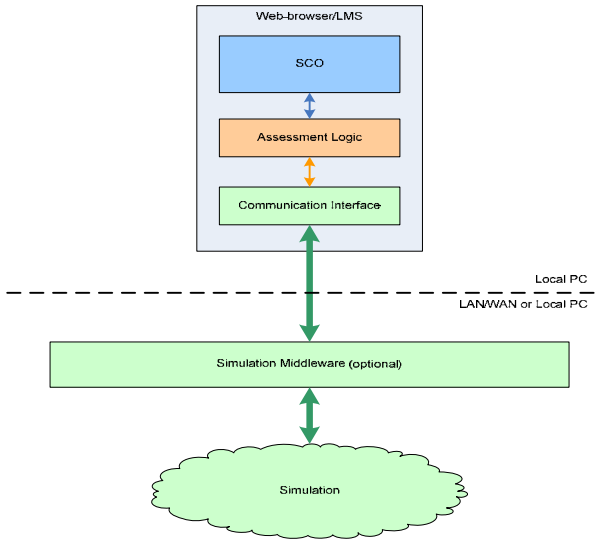

Figure 2. Embedded communication interface with the simulation.

Important advantages of this approach are that no other communication protocols then provided by SCORM and HLA are needed and that the SCO has its own link with the simulation. Therefore, the SCO is able to monitor and assess the learner's interactions based on the learning task it represents. This will lower the data exchange between the learner's PC and simulator and the development effort for the learning content, since the SCO only needs to deal with that part of the simulation data that is required to make an assessment for a specific learning task. Finally, the communication and assessment logic will be embedded in the SCO making the SCO more interoperable than the approach with an external communication interface.

A disadvantage is that the SCO requires more resources from the web-browser (memory and bandwidth) and a more flexible security policy (the SCO needs to access local resources outside the web-browser). But this may be acceptable when the learning task is not too complex and the simulator and the LMS are running in the same controlled environment (LAN/WAN). These conditions are often met, since a training course is usually divided into smaller learning tasks and the LMS is either connected to a dedicated high fidelity simulator via a company LAN, or is connected to a PC-based simulator running on the same computer as the web-browser.

TNO's approach

TNO has focused on an embedded approach. This allows the most flexibility and interoperability and has several advantages over the external approach:

Pedagogical

- All learning content related information, like training scenario description, assessment rules and learning objectives, are encapsulated in the content itself, creating a more holistic and interoperable perspective on the learning content.

- Support for real-time tracking and tracing of simulation interaction by the SCO itself, providing the content developer more control on what to train and how to measure performance.
- Support for multi-user training simulations, although SCORM is originally aimed at individual learning. This is because each SCO can operate as a participant in a joint simulation via the HLA connection and track individual training results. The tracking and tracing of team results is planned as future work.

Technical

- Integration of off-the-shelf LMSs and existing simulators, without any major modifications (only HLA and SCORM compliancy is required).
- Support for remote assessment via a standardized interface to reduce the complexity of the embedded assessment logic (and use of local resources). This will also provide a solution for the memory and bandwidth limitations typically associated with an embedded approach.

Organizational

- All learning content related information is encapsulated in the content itself, making it easier to create, manage distribute and reuse learning content.
- No additional maintenance effort is required for a separate application or any modifications to existing LMSs and simulators, only for the learning content.

To illustrate our approach, TNO has developed a software platform, called SimSCORM, and a small training scenario as a demonstrator. This platform and the demonstrator will be discussed in the next chapter.

RESULTS

The SimSCORM platform

The SimSCORM platform is build on the TNO Simulation Architecture (TSA; Huiskamp, 2007) that incorporates its own HLA Run-Time Infrastructure (RTI), libraries, and supporting tools. Any HLA environment could be used, but the benefit of TSA is that many simulators currently maintained by TNO and its large, international group of customers are build on TSA. TSA also contains code generators to automatically generate an HLA interface according to a Federation Object Model (FOM = description of all objects, attributes and interactions in a simulation environment). This makes it easier to work with existing simulators.

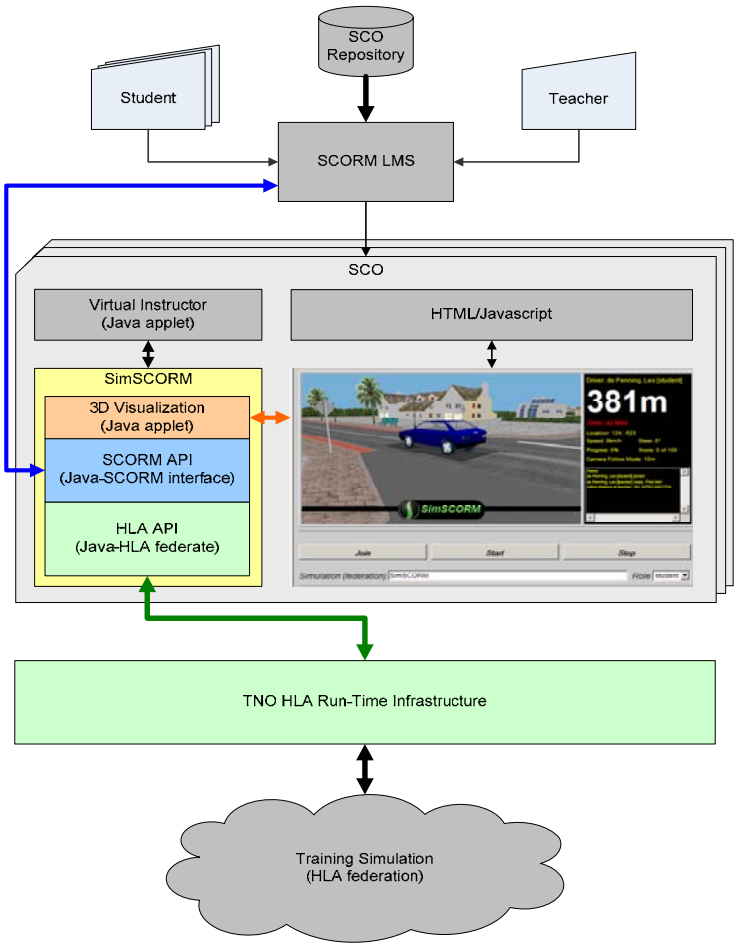

Figure 3. Context diagram of the SimSCORM platform.

The SimSCORM platform and its context are depicted in Figure 3. It shows that a user (student, teacher, etc.) receives a SCO (stored in a repository) from the SCORM compliant LMS. This can be either requested by the user or directed by the LMS, based on SCORM Sequencing & Navigation (SN) rules. Basically, this SCO presents a learning task to the user via a HTML/JavaScript based user-interface in a web-browser. The SCO can be regarded as a simple Virtual Instructor (VI) that runs a training scenario which contains learning objectives and assessment rules and that is specific to one learning task. The VI uses the SimSCORM platform as an Asset to communicate with the HLA simulation, the SCORM LMS and the 3D viewer. It configures and monitors the simulation, assesses the student according to the specified SCORM learning objectives and reports the results back to the LMS. The LMS then decides which SCO to present next, based on the learner results and defined SCORM SN rules in the content package. Typically a SCORM content package (CAM) contains one SimSCORM platform as a resource that the SCOs in the package refer to as an Asset.

Global Architecture

As can be seen in Figure 4, the SimSCORM platform provides Java interfaces to the HLA RTI and the SCORM LMS. It contains several functions to join, start, stop, monitor and configure a simulation and read and write learner results in the LMS to support these training scenarios. Furthermore the platform contains a VRML interface to support visualization of the simulation or learner results in 2D and 3D.

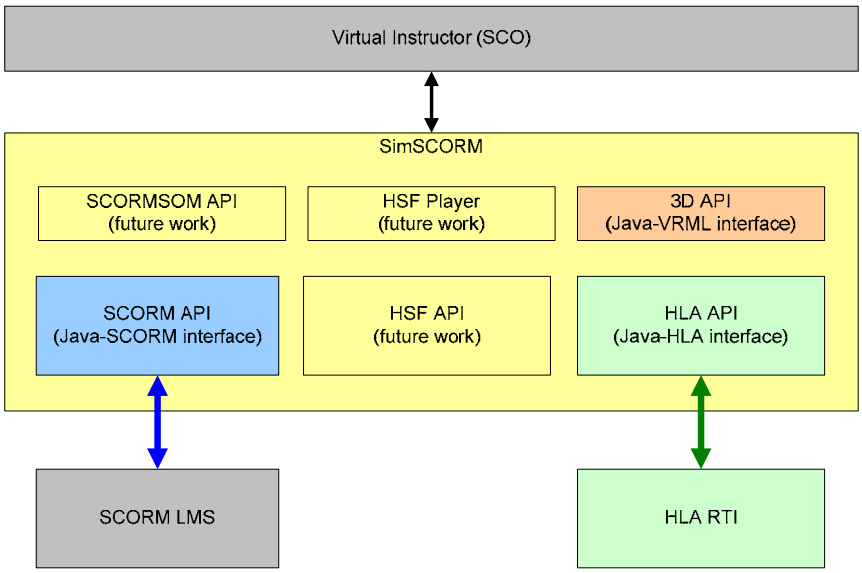

Figure 4. Global Architecture of the SimSCORM platform

The SimSCORM platform itself is built as a modular and generic platform that can be applied in virtually any HLA and SCORM environment. Using this platform, a content developer can focus more on the learning content itself and does not need to worry about the technical details of a HLA and SCORM integration effort. Typically, the content developer will use the HLA API to configure and monitor the training scenario (context) and the SCORM API to monitor and report progress on the learning objectives (goals). On top of that, the VI needs to assess the learner's activities within that scenario and report back the results to the LMS. Currently, the VI is implemented as a Java applet for the demonstrator described in the next chapter.

Scenario player

In the future the SimSCORM platform will also provide a generic player (HSF Player) that supports the VI in playing training scenarios and doing assessment based on a standard scripting and/or data definition language. We have called this language the High-level Scenario Format (HSF) and is intended to be a result of TNO's standardization effort within the SISO SCORM-Sim Study Group. To support the HSF Player a HSF API will be implemented, enabling the use of external and/or SCORM embedded HSF data.

Remote assessment and Team training

Another future component will be a SCORMSOM API that will provide the platform with a means to communicate SCORM information between HLA federates and SCOs, providing support for remote assessment, team assessment and standardized simulator-based feedback and instruction. The support for remote assessment will also reduce the complexity of the embedded assessment logic (and use of local resources).

Supporting tools

Since the SimSCORM platform is based on TSA it benefits from the existing tools in the TSA, such as a Java code generator, which assists and simplifies integration with existing HLA simulations. With this code generator a HLA interface to a simulation can easily be generated based on an existing FOM.

Demonstrator

To demonstrate the capabilities of HLA-SCORM integration, a small SCO has been developed on top of the SimSCORM platform. In this SCO, the student's task is to find the teacher's car as fast as possible by driving in a virtual environment. The demonstration supports multiple students and teachers driving in the same virtual world. Figure 5 shows a student's SCO in an open-source LMS (Moodle, www.moodle.org).

Figure 5. The SimSCORM demonstrator with an HLA compliant driving simulator (left) and a Moodle-based student interface (right).

The student in Figure 5 drives a scenario in the driving simulator. This scenario, a 3D real-time visualization of the student's performance and the control of the lesson, are all contained in a SCO that is managed by Moodle. Results are stored automatically in Moodle, and both students and instructors have access to all the typical LMS functionalities from Moodle.

The same SCO can also be used by the teacher to monitor the students driving around in the same simulation environment. To support this the concept of roles was introduced. To maximize the SCO's reusability this concept was implemented on the HLA side only, but further investigation will be required to result in a standard solution (either SCORM, HLA or HSF-based).

The demonstrator can run standalone, where the vehicles are controlled via the web-browser using keyboard and mouse, or connected to external driving simulator which controls the vehicles via HLA. Also the virtual world is visualized via the graphics interface of the SimSCORM platform.

Projects and Standardization

The first results from the demonstrator and the SimSCORM platform are positive. The demonstrator has been easily integrated with existing high fidelity simulators, and provides a real-time 3D visualization of the student's performance inside an off-the-shelf LMS for both teacher and student. We are currently investigating the possible use of SimSCORM in a F16 maintenance trainer, to support web-based training for maintenance procedures with detailed tracking and tracing using a SCORM compliant LMS. Until now, our experience is that both development effort of the training tasks and the integration effort with existing LMSs and simulators will be minimal.

TNO is participating in the SISO SCORM-Sim Study Group to further support the standardization effort on integration of simulation and e-learning. One of the aimed results is a conceptual reference model, where HLA and SCORM will be the most important pillars. Besides that, a third pillar is needed to standardize the definition of training scenarios, learning objectives and assessment rules. With HSF TNO may contribute to the development of that standard.

CONCLUSIONS

The SimSCORM platform provides a standards-based and dynamic integration of training simulators and e-learning systems. SimSCORM is a flexible multi-user platform that can be used to connect to virtually any HLA-compliant training simulation with a SCORM-compliant LMS. As it requires no adaptations to the simulator or LMS, as long as they are respectively HLA and SCORM compliant, SimSCORM allows cost-effective development of the learning task and simulation environment at hand.

The current advantages of SimSCORM are:

- Support for development of SCORM-based learning content for simulation-based training resulting in less development effort.
- Use of interoperable standards HLA and SCORM resulting in less integration effort.

- Real-time and two-way interaction between the simulator and the active learning task in the LMS.
- Simulation configuration and control.
- SCORM-based tracking and tracing of simulation interaction and learning processes.
- Real-time assessment of training using SCORM objectives.
- Dynamic learning content via SCORM Sequencing and Navigation.
- Team training (including instructor views).

TNO has successfully implemented SimSCORM in several projects and is participating in the SCORM-Sim Study Group to contribute to their standardization effort on the integration of simulation and e-learning.

Future work

The current SimSCORM platform proves to be a good base for integration of simulation-based training in standard e-learning systems, but there are still some open issues that needs to be addressed in the future. These issues will mainly be solved in future projects and the collaboration with the SISO SCORM-Sim Study Group. The main issues are:

- Distribution of individual training results to other users to support team training, simulator-based feedback and remote assessment (SCORMSOM API).
- A (SCORM-based) standard for defining training scenarios, learning objectives and assessment rules (HSF). This will further increase the interoperability of the training content.

- A generic scenario player for playing, monitoring and assessing training simulations according to SCORM objectives (HSF Player).
- A generic SCORM-based editor for training scenarios (HSF Editor).
- Logging and playback of training scenarios via a HLA logger, which logs all HLA communication. This allows a complete after action review of the entire training scenario.
- Research and implementation of a standard solution for the definition and handling of roles.

ACKNOWLEDGEMENTS

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