ACHIEVING INTEROPERABILITY: A PERSPECTIVE FROM THE STRICOM FEDERATION

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The U.S. Army Simulation Training and Instrumentation Command (STRICOM) is involved with transitioning many simulations to the High Level Architecture (HLA). To coordinate efforts and share lessons-learned, several major STRICOM programs have joined together to create the STRICOM Federation. The STRICOM Federation will be comprised of federates representing a variety of real-time, platform-level training applications such as an Rotary Wing Aircraft (RWA) simulation, Close Combat Tactical Trainer (CCTT) manned module, CCTT Semi-automated Forces (SAF), and Modular SAF (ModSAF). Each of the participating federates provide an example legacy system migrating to the HLA. Using the Federation Development and Execution Process (FEDEP) model as a guide, the STRICOM Federation will integrate the respective federates and move toward achieving interoperability in an HLA federation execution. Commercial and government tools will be used to help achieve federation objectives. This paper will describe the lessons learned in the development of the STRICOM Federation. The application of tools and where they can best be used in the FEDEP process will also be evaluated.

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INTRODUCTION

The U.S. Army Simulation Training and Instrumentation Command (STRICOM) is involved with transitioning many simulations to the High Level Architecture (HLA). To coordinate efforts and share lessons-learned, several major STRICOM programs have banded together to create the STRICOM Federation. Initially, the STRICOM Federation will be comprised of federates representing a variety of real-time, platform-level training applications including an Rotary Wing Aircraft (RWA) simulation, a Close Combat Tactical Trainer (CCTT) manned module, CCTT Semi-Automated Forces (SAF), the Modular Semi-Automated Forces (ModSAF), and the Situational Awareness Tactical Internet Data Server (SATIDS). Once this core group of simulations has completed integration, other types of simulations can be included, such as high fidelity engineering simulations from the Research, Development, and Engineering Centers (RDECs) as well as aggregate level simulations.

Each of the participating federates provide an example legacy system migrating to the HLA. Using the Federation Development and Execution Process (FEDEP) model as a guide (See Table 1), the STRICOM Federation will integrate the respective federates and move toward achieving interoperability in an HLA federation execution. Commercial and government tools will be used to help achieve federation objectives. This paper describes the lessons learned in the development of the STRICOM Federation. The application of tools and where they can best be used in the FEDEP process is evaluated, and the methodologies of federation integration and levels of testing needed to achieve interoperability is discussed.

FEDERATION DEVELOPMENT AND EXECUTION PROCESS

The FEDEP is a guidance document that describes a high-level process for developing HLA federations. The FEDEP can be broken down to 5 major steps:

Step 1- Develop Federation Objectives: The federation sponsor and federation development team must define and agree on a set of objectives, and document what must be accomplished to achieve those objectives.
Step 2 - Conceptual Model Development: A representation of the real world domain of interest (entities and tasks) is developed, and described in terms of a set of required objects and interactions.

Define Federation Objectives	Develop Federation Conceptual Model	Design And Develop Federation	Integrate And Test Federation	Execute Federation And Analyze Results
Identify Needs Develop Objectives	Develop Scenario Perform Conceptual Analysis Develop Federation Requirements	Design Federation Develop Federation	Plan Execution Integrate Federation Test Federation	Execute Federation Process Output Prepare Results

Table 1 - Mapping of FEDEP to Five-Step Process

Step 3 - Federation Design & Development: Federation participants are determined (if not previously identified), and a Federation Object Model is developed to explicitly document information exchange requirements and responsibilities.
Step 4 - Federation Integration & Test: All necessary federation implementation activities are performed, and testing is conducted to ensure interoperability requirements are being met.
Step 5 - Federation Execution: The federation is executed, outputs analyzed, and feedback provided to the federation sponsor [1].

FEDERATION OBJECTIVES DEVELOPMENT

The federation sponsor and the federation development team should develop a problem statement, identifying items such as critical systems of interest, fidelity/resolution of the simulated entities, resources (funding) available, and due dates. Once this is done, the federation development team can begin translating these high-level needs to measurable federation objectives. The results of this effort could include a prioritized list of measurable objectives, federation development plan, identification of sponsor furnished equipment, and the operational context of the simulation, including details such as the geographical region, environmental conditions, threats, and tactics to be modeled.

The goal of the STRICOM Federation was an HLA Interoperability Demonstration that would help coordinate efforts and share lessons-learned as various STRICOM programs made the transition to HLA. While the participating simulations were chosen based on funding status and compatible HLA implementation timelines, the CCTT system was quickly identified as the critical simulation of interest in the federation. The federation will consist of the CCTT Highly Mobile, Multi-Wheeled Vehicle (HMMWV) manned module, CCTT SAF, a PC-based RWA from Ft Rucker, ModSAF, and SATIDS (See Figure 1).
All of the participating simulations were existing distributed simulations based on the Distributed Interactive Simulation (DIS) protocol and were in the process of migrating to the HLA. Comparing existing capabilities for the various federates, it was decided that the federation would demonstrate basic battlefield functionality that had been provided under DIS including visual detection, movement, weapon fire/detonation, vehicle collisions, and damage assessment. Radio communications and laser designation were considered but were deemed to be high risk, based on limited funding and interoperability implementation issues.

The terrain database to be used for the Interoperability Demonstration was driven by the CCTT. The existing terrain databases for CCTT are high fidelity and limited in number. Primary 2 (Southwest US) was chosen since there are several relatively flat areas that can be used to provide high correlation among converted databases.

CONCEPTUAL MODEL DEVELOPMENT

The goal of this phase is to create a representation of the real world domain of interest (entities and tasks), described in terms of required objects and interactions.

Scenario development

The exercise scenario identifies the major entities that must be represented by the federation and the relationships between the entities over time. The effects of environmental conditions on entity behaviors should also be captured. For the STRICOM Federation, an existing CCTT scenario, Scout Platoon Fundamental Training, was modified based on the federation's existing simulation capabilities.

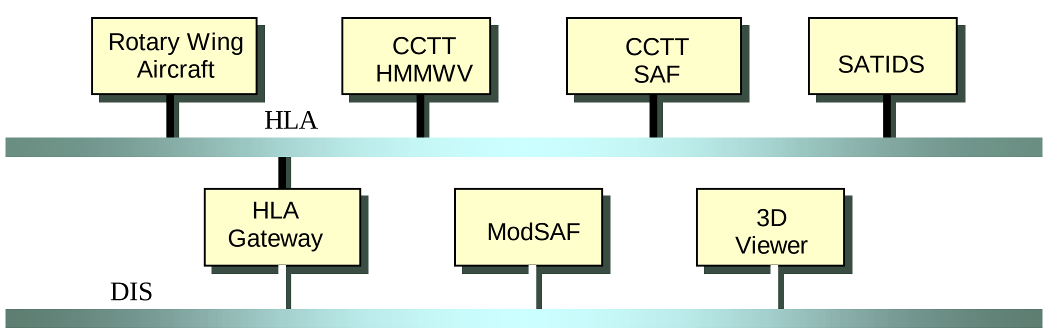

Figure 1 - The STRICOM Federation

Conceptual analysis

The focus of Conceptual Analysis is to utilize the scenario to identify federation objects, static and dynamic relationships between object classes, and behavioral aspects of each object class. When these elements are documented in the Object Model Template format, it is considered an ideal Federation Object Model (FOM), since it was generated independently of whether there are existing simulations that can support it.

Because the STRICOM Federation was centered around legacy DIS simulations, the conceptual analysis was completed informally, using the pre-existing Real-time Platform Reference Federation Object Model, or RPR FOM. The RPR FOM maps simulation data exchanged between legacy distributed simulations using the DIS protocol into object classes and interactions. The companion document to the RPR-FOM is the Guidance, Rational, and Interoperability Modalities for the Real-time Platform-level Reference Federation Object Model and captures how the data in the RPR FOM is to be used.

FEDERATION DESIGN & DEVELOPMENT

The primary purpose of the Federation Design phase is to determine which simulations will be used in the Federation. Simulation Object Models (SOM) can be used to assess whether an existing simulation supports the federation objects and interactions of interest. The Object Model Library (OML), a repository of HLA Object Models, can support this activity.

The STRICOM Federation had specifically identified several DIS-based legacy simulations. Preliminary SOMs were used to help define federate roles in the scenario and to identify interoperability issues related to the objects and interactions supported. Since these systems had not worked together using DIS, interoperability issues such as terrain correlation and environment representation had to be addressed in addition to HLA migration strategies.

During the initial development of the STRICOM Federation, the simulations involved were at various stages of HLA migration. Some had recently completed HLA compliance certification while others were still working on software development. In addition, each of the simulations involved used different terrain database formats, including E&S, MulitGen OpenFlight, and the Compact Terrain Database (CTDB).

HLA Implementation

There are several implementation methods for converting existing simulations to HLA. Many DIS-to-HLA gateways and middleware solutions are available on the market, or the HLA interface can be developed from scratch. Each method has associated cost/performance trade-off and compatibility issues.

For example, as the Run-time Infrastructure (RTI) evolves, many of these software packages lag the RTI development. Since current copies of the RTI are not backward compatible with older versions, this lag could prevent federations from using the latest version of the RTI.

In addition, many of the current Gateway and middleware solutions are FOM dependent. These FOM dependencies restricted the STRICOM Federation to the RPR FOM. Some of the HLA tools are further limited in the hardware platforms and operating systems supported. Given the many compatibility issues among implementation methods, federate migration to HLA must be done while simultaneously considering the issues of the entire federation.

HLA Gateway. The STRICOM developed HLA Gateway accesses data directly from the network and performs the conversion between the DIS and HLA protocols. While this is the least costly and most non-intrusive approach, there is a performance penalty in increased latency. Also, the Gateway is not FOM flexible, supporting only certain versions of the RPR FOM. Since ModSAF is to be replaced with OneSAF, more expensive implementations could not be justified.

Middleware. The Simulation Middleware Object Classes (SMOC) developed by the Naval Air Warfare Center **-** Training Systems Division was used as a software wrapper around the RWA's DIS interface. The RWA software exchanges DIS formatted data with the SMOC software, which handles all necessary calls to the RTI. While this method involves some software development, there is an increase in performance over the Gateway approach. Also, SMOC allows some flexibility in FOM implementation, with minor software modifications.

For the CCTT HMMWV, the Agile FOM Framework (AFF) was used. As with SMOC, the simulation software must be modified to interface to the AFF software. However, the interface software uses a library of converters that provides a level of FOM flexibility without software modification [2].

Native HLA Interface. For the CCTT SAF, the DIS interface software was removed and an HLA interface developed. While this is potentially the most expensive option, there is more control over the HLA interface software baseline. The software can also be leveraged to support the other manned modules in the CCTT configuration.

Terrain Database Correlation

For the Interoperability Demonstration, the Primary 2 database developed under the CCTT program was chosen, representing the National Training Center (NTC). With each simulation using various Image Generators (IGs) and terrain database formats, the Primary 2 database developed for an E&S IG needed to be converted to formats required by the other IG systems. Database conversion usually results in terrain correlation problems.

To minimize Synthetic Environment (SE) miscorrelation issues, the Synthetic Environment Data Representation and Interface Specification (SEDRIS) project was conceived and implemented to capture and provide a complete (terrain, ocean, atmosphere, and space) data model of the physical environment, access methods to that data model, and an associated interchange format. These SEDRIS developed mechanisms facilitate interoperability among heterogeneous simulations by providing complete and unambiguous interchange of environmental data. The range of M&S applications addressed in the SEDRIS development includes training, analysis, and system acquisition and supports visual, computer generated forces, and sensor perspectives. The data interchange specification supports the pre-runtime distribution of source data, three-dimensional models, and integrated databases that describe the physical environment for both simulation and operational use.

Using the SE requirements, a SE Integration Agent collaborates with industry to develop the necessary SE components. Tools are used to convert, validate and integrate these components into a Master SE Database in the SEDRIS Transverse Format (STF). The SE Integration Agent then collaborates with industry to convert the Master SE Database into formats required by participating simulations. The end result is a fully integrated, common synthetic environment [3].

HLA Software Development/Test Tools

Achieving interoperability among heterogenous simulations in a distributed environment is no easy task. With developers located at different sites, ensuring that all federation agreements have been properly implemented by each federate is difficult.

STRICOM's Federation Test System (FTS) is an HLA development/testing aid specifically designed to support HLA software development. The goal of the FTS is to facilitate the discovery of problems early in the federation development process, thereby reducing integration time and ensuring a successful Federation Execution. As a surrogate for other federates in the federation, the FTS sends data to the simulation and analyzes data from the simulation. Using the FTS, known data values can be sent through RTI to see how the federate reacts. The federate may react by changing its human-machine interface (displays, audio, etc.), or may respond by sending data back through the RTI. In the latter case, the FTS can also be used to capture and analyze the resulting output.

The FTS has scripting tools, which are used to insert functions, such as RTI service calls and associated parameters, into a script (See Figure 2). For function parameters that require Object Model input, a FOM navigator is provided to select object attributes or interaction parameters and to assign appropriate values. In this manner, the user can simply point and click, creating Federate Scripts, without the need for a programmer.

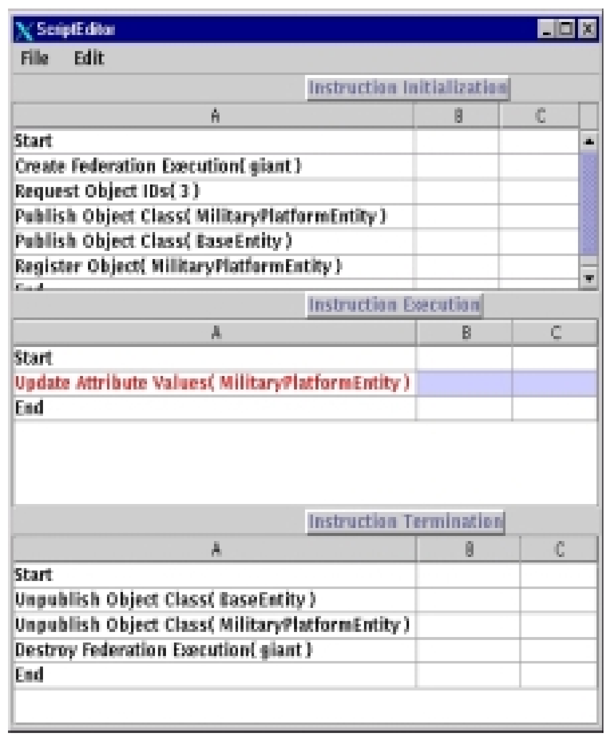

Figure 2 - FTS Script Editor

FEDERATION INTEGRATION & TEST

The goal of the Integration & Test phase is to ensure that all Federation implementation activities have been performed and that Federation interoperability requirements are being met. During Execution Planning, all information required to support Federation Execution is captured, including performance requirements for the hosts computers and network. In the Integration & Test phase, all federation participants are brought together, into a common operating environment, to test that federates can interoperate to the degree necessary to meet federation objectives.

Federation Execution Planning

The Federation Execution Planning Workbook (FEPW) provides a common structure to capture essential performance and implementation requirements of the RTI and individual federates. The FEPW Editor is currently being used mainly for capturing the FOM responsibilities of each individual federate, which can then be monitored during integration with the Federation Verification Tool (FVT). In the future, as the federation grows larger and more complex, the FEPW can be used to capture computer and network resource requirements. In addition to the FEPW, the RTI Initialization Data (RID) file, FOM, and the Federation Execution Details (FED) file provide the Federation Developer with all the execution-specific information needed to operate and monitor the federation and must be strictly configuration managed.

Federation Integration and Test

The FEDEP defines three levels of testing: Compliance, Integration and Federation testing. Compliance testing is performed on the individual federates and ensures that the Federate can properly use the RTI services and has documented its SOM, in accordance with the Object Model Template. Integration Testing brings federates together as a whole to determine if they can exchange data as described in the Federation Object Model. And finally, Federation testing determines if the federation can interoperate to the degree necessary to execute the federation scenario and meet all federation objectives.

HLA Compliance Testing. During Compliance Certification Testing, Federates are tested to the HLA Specifications, including the RTI Interface Specification, the Object Model Template, and the HLA Rules. The Certification testing process is supported by automated tools to reduce time and cost associated with testing. The Federate Under Test (FUT) submits a description of its capabilities via a SOM and a Conformance Statement (CS) to the Certification Agent. The Certification Agent then tests the SOM for compliance with the Object Model Template. Also a sample of the SOM is selected for demonstration by the Federate during Interface Testing. During this test, the Federate will go on-line with the Certification Center and demonstrate that it can properly use the RTI services for the selected SOM data. The Certification agent verifies that the federate conforms to the specifications by analyzing logged test data [4].

Both the ModSAF and RWA Certification testing were performed on-line at STRICOM. A compliance test scenario was developed for demonstrating the use of the RTI services and SOM data. The test scenario consisted of the federate actions required to invoke the RTI services under test. This test scenario greatly expedited the compliance test process and allowed the test team to replicate the test as needed. Each test session was completed in under two hours. Since the goal of the STRICOM Federation was to demonstrate HLA interoperability among the STRICOM simulations, actual certification testing can be done for the other federates as time allows.

Integration Testing. HLA Compliance is necessary but not sufficient to ensure interoperability among federates. Integration testing brings federates together as a whole to determine if they can exchange data as described in the Federation Object Model.

A testbed is being created at STRICOM to support federation integration, scheduled to begin in August, 1999. With the use of large man-in-the-loop simulators like CCTT, some of the federates can not be physically moved to the testbed but instead will be tied in over a Wide Area Network (WAN).

Federation Testing. Federation testing determines if the federation can interoperate to the degree necessary to execute the federation scenario and meet all federation objectives. The initial objectives for the STRICOM Federation are to demonstrate basic battlefield functionality including visual detection, movement, weapon fire/detonation, vehicle collisions, and damage assessment. As part of federation testing, technical issues such as network bandwidth and latency, terrain correlation, and support for the FOM will be examined.

FEDERATION EXECUTION

The objectives of the federation execution for the STRICOM Federation include a demonstration of the HLA concepts and interoperability among several STRICOM simulation programs. The real benefits of the HLA will be noticeable as additional functionality and a wider variety of simulations are incorporated.

TOOL SUPPORT

As the HLA specifications have matured and are now being balloted by IEEE and the RTI software baseline has stabilized, commercial and government-sponsored tools are now being released to support the use of HLA. While implementation packages were discussed above, there are now several tools that can help support federation integration and execution.

Federation Verification Tool (FVT)

As the scenario and FOM are developed, each federate developer must agree on which attributes of which objects his federate will update, which attributes of which objects it will reflect, which interactions it will send, and which interactions the federate will receive. These federate responsibilities can be documented using the FEPW Editor. The Federation Verification Tool (FVT) can then be used during the Federation Integration and Test phase of the FEDEP to verify that federates properly fulfill their update/reflect and send/receive responsibilities.

Federation Management Tool (FMT)

During a typical HLA federation execution, federates can be geographically dispersed making coordination and control among the federates difficult. The FMT helps to visualize the federation execution, providing information such as which federates have currently joined the federation execution, what information they are subscribed to and what information they are publishing. The FMT can also be used to control federates, such as scheduling saves and restores, requesting object updates, and causing a federate to resign. For the STRICOM Federation, the FMT will be used mainly to monitor federates during the execution.

Data Collection Tool (DCT)

The DCT can be used for collection, playback, and analysis of HLA federation execution data. The DCT supports data management planning, identifying data to be collected; data management during the federation execution; and exporting the data to a standard database format for analysis using commercial tools. The DCT can be very useful during integration, federation execution, and after action review.

LESSONS LEARNED

While this migration was performed primarily to satisfy the HLA mandate, special emphasis was placed on development from a federation perspective rather than the individual federates, to coordinate HLA migration efforts among several major STRICOM programs and to share lessons-learned.

Having the simulations and team members in the same local area where team members could meet face to face and see the other simulations first hand is very beneficial. Configuration management during development and implementation is also critically important. The ability of each application to interface with versions of the RTI and RPR FOM was a key issue during the federation development process. Also, the emergence of HLA tools and their support of the FEDEP process promises to facilitate Federation development and integration. Most of the tool s are PC-based and are therefore affordable to include in a software development lab.

SUMMARY

This paper examined many design issues and tradeoffs associated with the development of an HLA Federation for real-time, platform-level simulations. The real advantage of the HLA is the way it lends itself to composing a training system to meet the training need. After the completion of this first phase of the STRICOM Federation, STRICOM intends to continue to enhance the federation to completely exploit many aspects of the HLA. In the near term, the STRICOM Federation will become part of a larger multi-service federation for an interoperability demonstration at this year's Interservice/Industry Training, Simulation, and Education (I/ITSEC) Conference.

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