Construction of HLA Compliant Federates/Federations for the Special Operations Forces

William Garbacz
Lockheed Martin Information Systems
Orlando, FL

Ivan Carbia, Gilbert Gonzalez, Gene Lowe, Glenn Valentine, John Bray, Jason Walker
Science Applications International Corporation
Orlando, FL

Robert Miller
U.S. Army Simulation Training and Instrumentation Command
Orlando, FL

Víctor Colón
Naval Air Warfare Center Training Division
Orlando, FL

Abstract

The U.S. Special Operations Forces (SOF) have recognized the need and benefit of the DoD High Level Architecture (HLA), and have taken a proactive role in pursuing HLA Compliance for their Distributed Interactive Simulation (DIS) legacy devices. The SOF have teamed up with the U.S. Army Simulation Training and Instrumentation Command (STRICOM) and the Advanced Distributed Simulation Technology (ADST II) program to migrate these devices to HLA, and have begun paving the way to leverage this new technology to advance their distributed simulation capabilities.

This paper highlights the SOF migration strategy to HLA compliance for each of the following five SOF training devices: the AC-130U Navigator/Fire Control Officer Testbed, the MC-130E and MC-130H Combat Talon simulators, and the MH-47E and MH-60K Combat Mission Simulators. In addition, the migration strategy for other supporting federation components such as stealths, computer generated forces, simulated radios, etc. will also be presented. The paper also includes HLA implementation issues such as the use of middleware and gateways to achieve RTI connectivity, development of Simulation and Federation Object Models, and HLA compliance testing. Lessons learned with regard to federate development, as well as the construction of the SOF federation, will be presented.

Author Biographies

William Garbacz is a Senior Simulation Systems Engineer for Lockheed Martin and a member of the ADST II HLA Team. He has been involved in simulator development and distributed simulation technologies since 1993. Mr. Garbacz received a BS degree in Electrical Engineering from SUNY Buffalo and an MS degree in Computer Engineering from the University of Central Florida.

Ivan Carbia, Gilbert Gonzalez, and Gene Lowe are employed by SAIC and are members of the ADST II HLA Team. Mr. Carbia is a Senior Software Engineer, and holds a BS degree in Computer Science and a BA degree in Organizational Communication from the University of Central Florida. He has been involved in distributed simulation technologies since 1997. Mr. Gonzalez is a Project Engineer, and holds a BS degree in Computer Engineering from the University of Central Florida. He has been working in the simulation industry since 1987. Dr. Lowe is a Project Director, and holds a Ph.D. in Electrical Engineering from Georgia Tech. He has over 28 years of experience in systems engineering and project management.

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INTRODUCTION

The U.S. Special Operations Command (USSOCOM) has embraced the DoD's HLA mandate, and is pursuing HLA compliance for their training devices. In 1998, USSOCOM tasked STRICOM to implement an HLA solution for their AC-130U Navigator/Fire Control Officer Testbed located at Hurlburt Field, FL. STRICOM, as the procurement agent, formed an Integrated Product Team (IPT) consisting of STRICOM, USSOCOM, and the Advanced Distributed Simulation Technology (ADST II) Team to achieve this goal. The IPT achieved HLA Compliance for the AC-130U device in late 1998, and the program was deemed a success. As a result, USSOCOM began pursuing HLA compliance for their other training devices. Along with upgrading the AC-130U to utilize the most current RTI version, the team was awarded follow-on contracts to migrate the MC-130E and MC-130H Combat Talon simulators, and the MH-47E and MH-60K Combat Mission Simulators, from DIS to HLA.

This paper presents the HLA migration strategy for the AC-130U Testbed, including the AC-130U NAV/FCO training device, as well as the supporting DIS exercise tools at this site, including stealths, computer generated forces, plan view displays, data loggers, and simulated radios. The paper addresses the different approaches to achieving an HLA solution, and also includes such topics as the development of Simulation Object Models (SOMs) and Federation Object Models (FOMs), HLA Compliance testing, and HLA federation execution. The migration strategy and implementation of the follow-on projects, including the AC-130U upgrade and the MC-130E, MC-130H, MH-47E, and MH-60K HLA migrations are also presented. The paper also highlights the lessons learned throughout the migration process of all five training devices.

HLA MIGRATION TASKS

To achieve an HLA solution for a simulator, there are fundamentally two core tasks that must be completed. One of these tasks is the development of a Runtime Infrastructure (RTI) connectivity solution for the simulator. This allows the simulator to communicate to the RTI and thus, to other members of the federation.

The other required core task is the development of HLA object models, namely the SOM and FOM. The SOM, required as part of the HLA Rules [1], describes the intrinsic capabilities that the simulator can offer to the HLA federation. The FOM, also required as part of the HLA Rules, provides the information model contract for all members of the federation.

RTI CONNECTIVITY SOLUTION

The IPT was tasked with implementing an HLA RTI connectivity solution for the AC-130U training device and the other native DIS Tools of the AC-130U Testbed, including ModSAF, a Stealth, a PVD/Exercise Manager, Data Logger, and simulated radios (see Figure 1). Some of these devices were Commercial-Off-The-Shelf (COTS), while others such as the AC-130U were developed for the government (and thus source code was available).

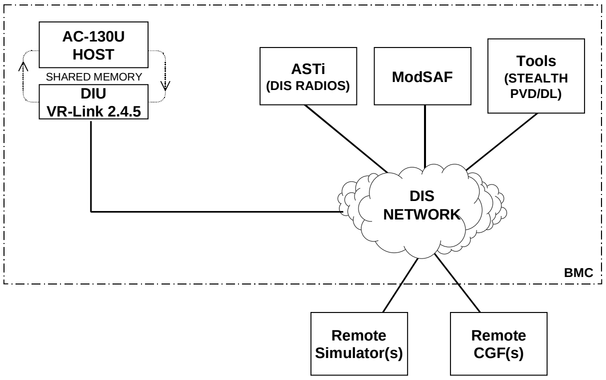

Figure 1. AC-130U Testbed DIS Configuration

The IPT performed an analysis of the different approaches that may be used to transition each simulator application from DIS to HLA. These approaches primarily included a DIS-HLA gateway approach, a middleware approach, and a native approach.

The gateway approach involves adding a device between the DIS and HLA networks to convert or translate DIS PDUs into coresponding HLA service calls and data. The gateway device also performs the reverse operation and converts HLA data into corresponding PDUs. This method permits the use of unmodified DIS devices to interact with HLA devices. While the gateway approach can be very cost effective, it does have limitations. These include the addition of latency, limited scalability, and that the gateway also does not take full advantage of the features of HLA (such as Data Distribution Management or Ownership Management).

The middleware approach involves the integration of a commercially available software product into a simulation device. The middleware handles all interfaces to the RTI and network, and typically comes with an API that the software developer uses in linking the simulator application to the middleware solution. The middleware solution offers low latency, scalability, and potentially full HLA capability. In addition, the middleware product can ease the integration of new releases of RTIs and FOMs, particularly if the middleware product maintains a consistent API between versions. As HLA continues to mature, this can be an important consideration.

The native HLA solution involves the implementation of a direct RTI interface to the simulator device. While this approach offers the least latency and can take full advantage of HLA, it often involves extensive rework of the application, development of new software, and significant integration and test time. This approach is also the most costly and poses the highest engineering risk.

Results of RTI Connectivity Analysis

Following the analysis of the different approaches to achieving RTI connectivity, the IPT developed a migration strategy for each DIS device of the AC-130U Testbed. This strategy included the integration of a middleware product into the AC-130U, replacing its DIS Interface Unit (DIU) with an HLA Interface Unit (HLAIU). The solution was the most cost effective HLA-based solution, and was also achievable within the time-frame of the contract.

The IPT evaluated the available COTS middleware products, and chose MäK Technologies' VR-Link (version 3.2) product as the best solution. VR-Link 3.2 supported RTI 1.0.3 and RPR-FOM 0.3. A key reason for choosing VR-Link was that the AC-130U DIU utilized a previous version of VR-Link (2.4.5), thus facilitating an easier integration approach. Also, MäK offers a maintenance agreement with the VR-Link product that provides technical support and software upgrades for newer versions of the RTI and FOMs as they are released.

For the other devices of the AC-130U Testbed, the IPT decided to utilize a gateway to translate between DIS and HLA. The other RTI connectivity approaches were considered for these devices, but since these were COTS products, an HLA solution was either presently unavailable or would require significant development. As the gateway approach does have some limitations, it is recognized as being an interim approach to HLA interoperability for these products until a native HLA solution is available. As such, the on-going HLA migration strategy includes replacement of the DIS devices (such as simulated radios) with HLA native devices.

The HLA IPT evaluated the available HLA Gateway products, and chose the STRICOM Gateway as the best solution. This gateway, developed and maintained by IST, utilized RTI 1.0.3 and a slight variation of RPR-FOM version 0.3.

AC-130U Testbed HLA Configuration

Figure 2 illustrates the HLA configuration for the AC-130U Testbed following the implementation of the HLA migration plan. In this configuration there are only two federates, namely the AC-130U and the STRICOM Gateway, as these are the only devices that communicate using the RTI.

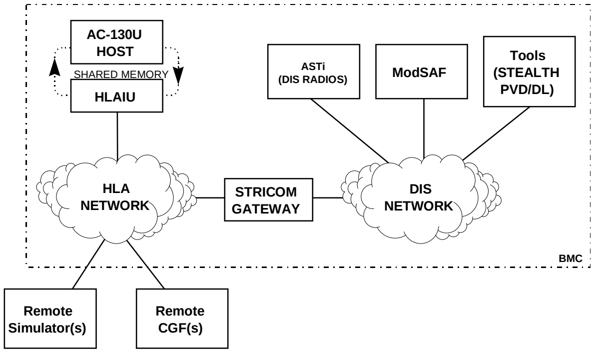

Figure 2. AC-130U Testbed HLA Configuration

HLA OBJECT MODEL DEVELOPMENT

The IPT was also tasked to develop a SOM and FOM for the AC-130U Testbed. The IPT chose the RPR-FOM [2] version 0.3 as the target reference FOM to develop these object models. The RPR-FOM is a reference FOM developed to meet the needs of the Real-time Platform (and former DIS) community. Although the long-term migration plan for the AC-130U Testbed involves the development of a Special Operations Forces FOM, the RPR-FOM was initially selected because it was the only FOM supported by the STRICOM gateway and VR-Link. Also, being a DIS legacy simulator, the use of the RPR-FOM was recognized as the quickest approach to achieving an HLA compliant solution.

As a Common Foundation Reference FOM, the RPR-FOM contains a foundation set of interoperable objects, attributes, and interactions in Object Model Template (OMT) compliant format [3,4]. The RPR-FOM also contains an associated guidance document referred to as the Guidance, Rationale, and Interoperability Modalities (GRIM) for the RPR-FOM [5]. The set of object model data provided by the RPR-FOM, along with its associated guidance document, eases the task of developing HLA compliant, interoperable federates for both legacy simulators and new simulators. In particular, the effort involved in developing SOMs and FOMs for a federate/federation is shortened considerably.

SOM Development

The SOM development process used for the AC-130U utilized a process originally outlined by Robert Lutz [6], which was later refined by William Garbacz [7] for the case of using Reference FOMs in the SOM/FOM development process. The process utilizes a combination of the Lutz Object Model development guidance, the RPR-FOM, the GRIM, and the AC-130U simulator system documentation.

The Lutz Object Model development guide provided a step by step process to SOM and FOM development. The process includes determining the publication and subscription capabilities for object and interaction classes, as well as their respective attributes and parameters. Once these capabilities are determined, the Object Model Template can be populated with this information.

The process was simplified by the use of the RPR-FOM, which already defined all object and interaction class names, along with their respective attributes and parameters. In addition, all abstract classes and the class subscription hierarchy are defined by the RPR-FOM, as are all enumerated and complex datatypes and object model lexicon. The process simplified down to identifying the elements of the RPR-FOM that were supported by the AC-130U simulator, and mapping the simulator's internal data definitions to the RPR-FOM. This mapping was greatly facilitated by the GRIM and the AC-130U system documentation.

The GRIM provides a mapping between DIS PDUs and the components of the RPR-FOM. Since the AC-130U was a DIS simulator, the data model of the simulator's network interface closely matched that of DIS. Using the AC-130U system documentation and the GRIM, a mapping was made between the data (variables) within the DIU and the RPR-FOM elements. The AC-130U system documentation included the PDUs transmitted/sent (or published) by the AC-130U, received and utilized (or subscribed to) by the AC-130U, and the respective PDU fields that were supported by the AC-130U. This system documentation was used extensively throughout the SOM development process to determine the SOM publication and subscription capabilities.

Once the mapping was completed, the OMT was populated using the DMSO provided Object Model Development Tool (OMDT). This was accomplished by beginning with the complete RPR-FOM (v0.3) loaded into the OMDT, and removing the unsupported object classes, interaction classes, attributes, parameters, and enumerated/complex datatypes. The publication and subscription capabilities were then assigned to the remaining elements.

FOM Development

The long-term goal of the IPT is to develop a SOF FOM which will extend the RPR-FOM to include SOF unique object model elements not contained within the

RPR-FOM. However, during the duration of this program, the gateway and middleware products only supported the use of the RPR-FOM, thus limiting us to use this Reference FOM as the basis for our FOM.

Since the federation consists of only the AC-130U and Gateway federates, the FOM assumed the same elements as the AC-130U SOM. This is referred to as the single SOM approach. In this case, the FOM was developed by beginning with the AC-130U SOM and changing the publication and subscription designations. The publishable or subscribable leaf classes of the SOM were now designated as PS, the updatable or reflectable attributes of the SOM were now identified as UR, and the interaction classes of the SOM were now defined as IR (Initiates-Reacts).

HLA COMPLIANCE TESTING

The HLA compliance testing process has been established as the means to ensure that DoD simulations are, in fact, HLA-compliant in accordance with DoD policy. The HLA certification process is facilitated through an on-line web-based interface and includes four steps, culminating with the receipt of the HLA compliance certificate. These four steps include the following: 1) Submit a Test Application, 2) Provide a Conformance Notebook, 3) Provide Test Environment Information, 4) Perform Interface Test and Certification Summary Report.

The AC-130U test application was submitted, and the conformance notebook data was provided to the DMSO HLA certification agents. This included the SOM, conformance statement, and scenario data. The conformance statement included a list of all RTI services supported by the simulator. Since the VR-Link middleware product was used exclusively to interface with the RTI, the RTI services were verified with MäK.

A scenario SOM was generated to be used as the RepSOM for generating the compliance test sequence. This SOM included the set of object classes, attributes, and interactions necessary to demonstrate the services listed in the conformance statement. The objects and interactions in the scenario SOM were chosen such that they could be easily stimulated during the compliance test.

The test environment information was furnished to the DMSO compliance test agents, and the compliance test agents generated a testable sequence file. The testable sequence file contains a list of services with required object classes, interaction classes, and/or attributes that are required to be implemented as part of the interface test. From the testable sequence file, a procedure was developed to conduct the test. The procedure consisted of a step by step process to invoke the required RTI services and parameters. The required RTI services include two varieties – calls made by the AC-130U application to the RTI, and RTI callbacks to the AC-130U. The procedure utilized the STRICOM Gateway (in conjunction with ModSAF) as the test federate to invoke the required service calls (see figure 3).

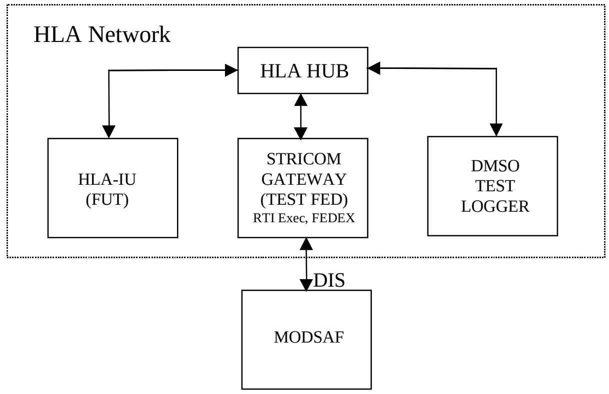

Figure 3. HLA Compliance Test Configuration

The interface test was conducted on November 4, 1998. All service calls were handled properly by the AC-130U federate, and HLA compliance was achieved.

AC-130U HLA UPGRADE

Following the successful HLA implementation of RTI 1.0.3, the ADST II HLA Team was awarded a follow-on Delivery Order to upgrade the AC-130U to utilize RTI 1.3 and RPR-FOM version 0.5. This was accomplished in a fraction of the time it took to perform the initial upgrade, as the new version of VR-Link (3.4) was easily integrated. Even though the FOM was upgraded to use the OMT 1.3 Specification, it did not need to change significantly. The AC-130U SOM process was repeated using RPR-FOM 0.5, retaining most of the same objects, attributes, interactions, etc. Also, the STRICOM Gateway was upgraded to utilize the current FOM and RTI versions, and the system underwent HLA compliance testing once again for the new HLA Interface Specification. The AC-130U federate passed compliance testing on June 22, 1999.

In addition to upgrading the RTI and FOM, the IPT continued the implementation of the AC-130U migration strategy by replacing the DIS Stealth with a MetaVR Stealth, a native HLA distributed exercise tool. As the other devices within the testbed (such as ModSAF, radios, data loggers, etc.) become available in HLA native versions, they will replace their respective DIS systems.

MC-130E and MC-130H HLA MIGRATION

The ADST II HLA Team was also awarded a Delivery Order to migrate the MC-130E and MC-130H Combat Talon simulators, also located at Hurlburt Field. This upgrade involved the integration of VR-Link 3.4 (and RTI 1.3) into the simulator's DIU, similar to the AC-130U effort. A SOM was generated for the simulator following the same process used for the AC-130U, with slight deviation from the RPR-FOM.

The largest effort associated with this migration was the implementation of IFF. The Combat Talon simulators have the capability (under DIS) to send/transmit (publish) IFF information, but this capability had not yet been incorporated into the RPR-FOM. In collaboration with IST, new IFF classes and attributes were developed and incorporated into the STRICOM gateway. They were likewise added to the simulator SOM and FOM. Using the flexibility provided by the VR-Link middleware, the IFF classes were also implemented within the simulator HLA Interface Unit.

The Combat Talons underwent successful HLA Compliance Testing on June 23, 1999. A test configuration similar to the AC-130U was used to conduct the test, with the STRICOM Gateway and ModSAF functioning as the test federate. This test was also conducted on-site, as the Combat Talons run in a classified environment. This required the compliance test agents to utilize a test logging system with a removable, classified hard drive.

MH-47E and MH-60K HLA MIGRATION

The ADST II HLA Team was later awarded a contract to migrate the MH-47E and MH-60K Combat Mission Simulators located at Ft. Campbell, KY from DIS to HLA. This upgrade proved similar to that of the AC-130U and MC-130E/H simulators. A SOM was generated for these two devices, again based on the RPR-FOM version 0.5.

The only modification to the SOM/FOM implementation was the addition of light state attributes. Under RPR-FOM 0.5, light states were implemented as an enumerated attribute, but these enumerations were not yet defined. In collaboration with IST and the RPR-FOM Standards Development Group, it was decided to remove the light state attribute from the Physical Entity class of the RPR-FOM, and add attributes to the respective (leaf) platform classes of the RPR-FOM. For example, the MilitaryAirLandPlatform class now includes such attributes as NavigationLights and FormationLights, and the MilitaryLandPlatform class now includes attributes such as HeadLights and BrakeLights. The SOM and FOM were updated to include the above changes, and the simulator interfaces were developed to support this implementation.

The Combat Mission Simulators passed HLA Compliance Testing on August 13, 1999. The Interface Test was conducted on site at Ft. Campbell, as the federates run in a classified environment. A configuration similar to the previous Compliance Test configurations was used to conduct the test.

SOF FEDERATION

The current configuration of the SOF federation is illustrated in Figure 4. Each HLA local area network is connected to the others through a router, and in the case of the Ft. Campbell devices, the communication is conducted over a T-1 line. All federates utilize RTI version 1.3V6. Only one of these devices can run the

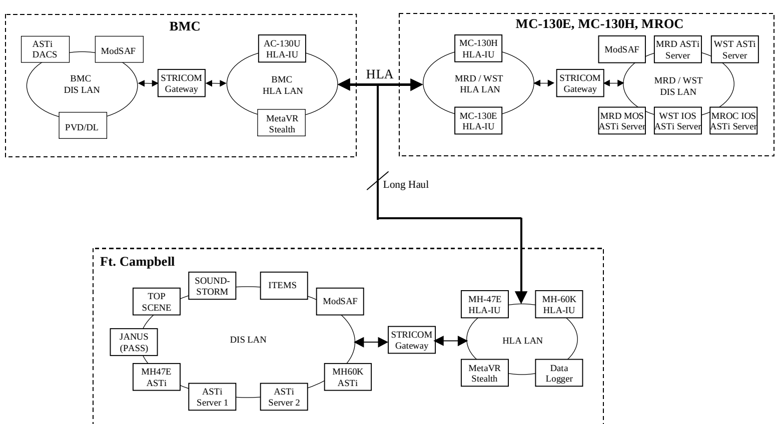

Figure 4. SOF HLA Federation

RTI Exec and RTI Fedex, and each HLA simulator application must also maintain an identical .fed file and RTI .rid file.

Each of these HLA simulator applications has been demonstrated to operate functionally with no apparent performance problems while in a stand-alone or local area network mode. The simulators are currently undergoing testing in long-haul modes, where we hope to verify proper data communication between all federates and achieve a successful federation execution. Also, we are currently conducting experiments with other sites that are still operating in DIS by using the STRICOM Gateway.

LESSONS LEARNED/CHALLENGES

Versions

One of the biggest challenges in constructing HLA federates and federations is the identification of a set of GOTS and COTS products that are interoperable. This includes middleware products, gateways, and HLA native simulation applications. All products must utilize the same version of the RTI and must also be able to operate with the desired FOM. In addition, as the RTI is government furnished software, the user is limited to using the operating systems and compilers that are specified for the RTI. This can pose significant design issues, as it may impact the choice of platforms with which to run a simulator host computer and other simulation applications.

HLA Object Models

While the HLA facilitates the development of new object models to implement unique simulator capabilities, this flexibility can cause the simulator to become less interoperable as the SOM becomes more unique. The closer a federate's SOM is to a "standard" FOM such as the RPR-FOM, the more the simulator will be inherently interoperable with other simulator applications that were developed to this standard. There is currently, however, promise of FOM flexibility being incorporated into many of the simulator applications that serves to address this problem.

Another issue worth noting lies in the development of FOMs and .fed files. A FOM is supposed to describe only those elements within a federation (with the exception of abstract classes) that may be communicated between two or more federates. However, if a participating federate cannot turn off a particular capability that the federation is not interested in (as is currently the case with most federates), then the data must still be defined within the .fed file (and likewise, the FOM) for proper federation execution. Thus, while it is desirable to include only the applicable data elements within a FOM (and .fed file), the federation developer is currently forced to include every possible functionality of every federate within the federation.

Simulated Radios

Simulated radios pose a significant challenge for the HLA real-time community, as they can at times demand/require a large amount of bandwidth usage. This bandwidth usage is caused by multiple, simultaneous, continuous voice streams that can push the limits of RTI processing ability. There are many factors to consider concerning this issue, including throughput, latency, packet overhead, dropped network packets, and CPU load on the radio federate.

There are currently no HLA native COTS simulated radios available. Research is currently being conducted to address RTI requirements for processing large bandwidth needs such as those needed for voice streams. For now, developers are limited to continue running the simulated radios in DIS or using a gateway to translate to HLA. In the latter case, however, only a limited number of voice streams can be supported concurrently. Our experiments using this configuration confirmed a limit of approximately 12 simultaneous voice streams through a gateway/RTI before significant break-up occurred.

HLA Compliance Testing/Acceptance Testing

Our initial submittal of the scenario SOM data (as part of the HLA compliance test procedures) utilized our entire AC-130U SOM, including all of its objects and interactions. When the compliance test sequence file was generated, we were required to demonstrate publication and subscription of all object classes along with some of their respective attributes. These included objects such as emitters, which were very difficult to stimulate during an interface test, and furthermore, were not necessary to demonstrate. The purpose of the Interface Test is to test the simulator's interface and not it's data elements. Thus, it is recommended to only include easily stimulated objects and interactions within the scenario SOM to be able to demonstrate the simulator's proper handling of the RTI service calls.

While the HLA compliance testing process tests the simulator's ability to interface with the RTI and also tests the simulator's SOM against the rules of the OMT Specification, it should not be construed as a complete system acceptance test. The compliance test does not test the data elements defined within the simulator's SOM, nor does it test that the simulator is interoperating properly with other simulators. For this reason, a formal acceptance test should not only include the Interface Test, but should also include a unit test to verify the simulator's SOM, as well as a functional test with other simulators or test federates to verify the simulator's ability to properly execute in an HLA federation. In addition, if compliance to a particular standard FOM such as the RPR-FOM is desired, this should also be included as part of the acceptance test.

FUTURE WORK

As HLA continues to mature and the capabilities of the SOF training devices continue to grow, additional HLA upgrades will be required for these systems. While all of the SOF's HLA compliant federates currently utilize RTI 1.3V6, they will likely be upgraded in the near future to newer releases of the RTI. Newer versions of the RPR-FOM are also likely to be incorporated. In addition, if any of the simulator's future developments require the extension of the FOM, this will also be incorporated. Finally, DIS native devices such as ModSAF will be replaced by HLA native devices when they become available.

CONCLUSIONS

The Special Operations Forces have achieved important milestones in the HLA Compliance of five training devices. As other SOF simulators are migrated to HLA, and supporting federation components such as ModSAF and simulated radios become HLA native, the SOF will be able to fully realize the benefits of HLA. Once HLA is fully incorporated, the SOF will be able to construct highly unique, complex, and realistic training simulations.

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