I/ITSEC 99 JOINT TRAINING EVENT: HLA FEDERATION PERSPECTIVE

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Abstract

The US Army, Air Force, Navy, and Marines, joined by a number of contractors and representatives from academia, conducted a Joint Training Event (JTE) on the floor of the Orange County Convention Center during I/ITSEC 99. The JTE involved approximately 30 High Level Architecture (HLA) federates including virtual simulators, semi-automated forces (SAF), and HLA tools. To our knowledge this was the largest number of diverse HLA federates ever called upon to operate together. There was a significant amount of technical planning and preparation conducted by knowledgeable engineers prior to the event, to try to ensure its success. The event, conducted as a series of four 30-minute vignettes over three days, involved warfighters supervising training, warfighters being trained, plus technical operation of the simulators and simulations by a variety of contractors and government personnel. The JTE was managed to balance the dual objectives of pioneering technical achievements and warfighter training effectiveness. The event is considered to have been a significant success.

This paper conveys the experiences gained from the perspective of federation buildup and control. The story begins with a description of the complex federation we wanted to establish, the steps we took to try to accomplish it, and what we achieved. The federate test strategy we used is presented along with influencing factors, problems encountered and lessons learned. Establishment of the federation on the I/ITSEC floor and management of the federation execution are similarly presented.

Author Biographies

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INTRODUCTION

For I/ITSEC 99 the US Army Simulation, Training and Instrumentation Command (STRICOM) led a 24-organization Military, Industry, and Academia coalition in the conduct of a Joint Training Event (JTE) code-named *Operation Desert Rats*. The JTE consisted of a Joint Task Force (JTF) defending a fictitious nation (Westland) against an attacking neighbor designated Eastland. The actual area of operations was the National Training Center (NTC) in Southeast California extending westward 200 miles into the Pacific and southward to San Diego. The deployed JTF included air, sea, and ground forces in action against Eastland opposing forces (OPFOR) utilizing former Soviet equipment. Actual military Warfighters controlled each of the simulators and simulations replicating the battlefield on the I/ITSEC exhibit floor. A Joint Exercise Control Group (JECG), assisted by the U.S. Joint Forces Command (USJFCOM), was established in the Army booth and directed the exercise. The exercise was conducted in four 30-minute "Battle Vignettes" over three days designated as Counter-Recon/Combat Air Patrol (CAP), Defend in Sector, Movement to Contact, and Meeting Engagement. Post Event Debriefs were held after each vignette to discuss lessons learned and share information with conference attendees.

The JTE achieved its three declared objectives:

Demonstrate that selective technology can increase realism in a Joint Training Exercise (JTX) using multi-service virtual as well as constructive simulations to enhance future training and mission rehearsals for Warfighters.

Demonstrate that Joint distributed training and mission rehearsal can be achieved through the application of existing Distributed Interactive Simulation (DIS) and emerging High Level Architecture (HLA) simulation interoperability standards.

Demonstrate that multiple organizations can work together in a collaborative developmental environment to achieve interoperability.

The JTE also fulfilled the Commander's Intent:

Demonstrate that I/ITSEC is an environment that can be leveraged by the military-industrial coalition to evaluate new simulations and Warfighting applications, improve interoperability knowledge, and conduct limited Joint training and mission rehearsals for participating Warfighters.

FEDERATION CONCEPTION AND PLANNING

The lead responsibility for the joint Army/Air Force/Marine/Navy booth at I/ITSEC for 1999 fell upon the U.S. Army. Under the leadership of STRICOM, a number of interservice meetings and discussions were held that led to the idea of an HLA-centric Joint Training Event. By early April 1999 an initial set of simulators and simulations to be showcased had been identified by each of the four services. To mitigate integration risks, most of the simulators and simulations proposed were either already HLA operational, or expected to be by mid-summer of 1999. Participation was on a voluntary basis, with simulation sponsors providing the necessary funds, logistics and manpower required for preparation and operation.

An Integrated Product Team (IPT) was formed and led by the STRICOM JTE Project Director. The IPT was

composed of military operational and technical personnel from all four services as well at technical personnel from the participating contractors. IPT members attended working meetings and made the final decisions on JTE technical and operational issues. The military operational IPT members made the decisions on the military objectives of each vignette, including the following key decisions:

- The general location of the scenario
- Refined list of participants
- Number, duration, and proposed schedule for the vignettes

The technical IPT members made final decisions on implementation issues based upon risk, technical capability and cost factors. Key decisions included:

- Basing the I/ITSEC Federation Object Model (FOM) on the Real-time Platform Reference FOM (RPR-FOM) version 0.5
- Using the Defense Modeling and Simulation Office (DMSO) Run-Time Infrastructure (RTI) version 1.3v6
- Using the Close Combat Tactical Trainer (CCTT) entity and munitions enumerations
- Limiting interactions to fire, detonate, and collision
- No Electronic Warfare (EW) capabilities due to federation development time constraints
- Separate network for the simulated tactical radios, all of which were using DIS protocol
- Use of the National Training Center (NTC) as the scenario location due to widespread use of existing NTC terrain databases and cost considerations

The military operations IPT members defined a series of vignettes within the limitations of these technical decisions and the pool of available simulators and simulations. Feedback from technical IPT members helped keep the vignettes achievable with low-to-moderate technical risk.

The Joint Training Event Federation

The JTE federation was planned to encompass over 30 federates in a complex federation topography involving four networks. The I/ITSEC HLA federation ran on one network and the CCTT HLA federation ran on a second network. A DIS "federation" of DIS simulators and simulations ran on the third network. The fourth network was utilized for DIS tactical radio implementation and was isolated from the other networks. These four networks collectively made up the JTE federation.

The CCTT HLA federation contained federates using the CCTT Primary2 (P2) version of the NTC database while the I/ITSEC HLA federation contained federates using all other NTC database versions. These two federations were established in an attempt to resolve database correlation issues between the CCTT and the I/ITSEC federates. Separate Federation Executives (FEDEXs) were established for the CCTT and I/ITSEC federations. The same RTI_MESSAGE_NUMBER was used by both federations which were managed by the same RTI. The CCTT and I/ITSEC federation utilized the same Federation (Fed) file defining object and interaction classes.

The DIS tactical radio network utilized three types of simulated radios: the ASTi Digital Audio & Communication System (DACS), the Battle Force Tactical Trainer (BFTT) radio, and the Motorola ModIOS radio. These radios provided tactical communication among JTE federation members participating in the vignettes.

Interoperability among the networks of the JTE federation was accomplished in the following manner.

STRICOM Gateway

A STRICOM Gateway which translates between DIS and HLA protocols was used to link the DIS and I/ITSEC networks. Gateway filtering was utilized to allow only entity state, fire, detonate and collision information to pass between these networks.

Bridge Federate

Communication was accomplished between the CCTT and I/ITSEC federation networks using Bridge federates. A Bridge federate joined both the CCTT and IITSEC federations. The CCTT Bridge federate utilized the P2 version of the NTC database while the I/ITSEC Bridge federate utilized an OpenFlight version of the NTC database. Both Bridge federates ran from the same host and utilized shared memory for inter-process communications. The purpose of the Bridge federates were to modify and repack positional data between the CCTT and I/ITSEC federations to compensate for terrain offsets in the two database representations.

CONSTRUCTING THE FEDERATION

Due to the geographic dispersion of the federate members during federation development, it was not possible to accomplish full federation testing prior to federation establishment at I/ITSEC. Therefore, federation construction prior to I/ITSEC relied on information coordination and pair-wise testing to identify and eliminate as many interoperability and runtime issues as possible.

Planning and Communications

Several methods were used to facilitate information coordination. A JTE Controller's Handbook specifying procedures, relationships, and information was maintained and distributed. Monthly federation meetings were conducted in Orlando and a JTE web site was established to facilitate document downloads and information updates.

Pair-Wise Testing

The objectives of pair-wise tests were to verify proper Fed and RTI Initialization Data (RID) file configuration, entity enumerations and test basic interoperability. The federation join process was monitored and data publication and subscription capabilities were confirmed. In order to accomplish this, a JTE test federation was established at the Advanced Distributed Simulation Technology (ADST) II HLA Testbed in Orlando, Florida. The JTE test federation consisted of a MäK Technologies HLA Stealth Viewer, F-18 and Data Logger federates, a STRICOM (now Mäk) Gateway and DIS ModSAF 5.0.

Pair-wise testing was facilitated in one of two ways: Either the JTE federates were installed and tested in the ADST II HLA Testbed or the JTE test federation was shipped to the federate host location. Most, but not all, federates underwent pair-wise testing at some point prior to I/ITSEC. Pair-wise testing resolved some issues such as object class publication levels and the need for Gateway filtering. Pair-wise testing also identified missing object attributes and interaction parameters as well as enumeration inconsistencies. It had originally been intended to log the pair-wise tests and distribute the log files to other federates for replay and utilization during their pair-wise testing. These logs would have exposed the federates to the output of as many other federates as possible prior to integration testing on the I/ITSEC floor. While some logging took place, distribution ended up being very limited and the practice was not consistently employed.

ESTABLISHING THE FEDERATION

Due to time constraints at the I/ITSEC conference, the federation needed to progress from bare network drops to a functioning federation in less than two days. This entailed assembling booths, unpacking, installing and checking out over 30 federate systems as well as federation integration, testing and checkout.

Federation control was divided into two areas: Technical Control and Exercise Control. Technical Control was responsible for federation establishment and federation management during vignette rehearsals and execution. Exercise Control was responsible for vignette operational considerations such as timing, execution and management.

Each federate provided a technical expert and development environment in order to facilitate any modifications that might be required. This capability was regarded as essential to support JTR integration and test, as well as vignette execution.

Floor Technical Radio Communications

To facilitate federation and execution management, Motorola two-way radios were employed. An engineering point-of-contact for each federate was identified and assigned a radio. The radios were extremely useful and functioned without problems throughout the entire event.

Floor Network Implementations

The JTE federation included two HLA networks and two DIS networks, each with its own hub. One hub connected the I/ITSEC HLA network, the second hub connected the CCTT HLA network and a third hub connected the DIS network. The dual ported STRICOM Gateway federate utilized one ethernet connection running to the I/ITSEC HLA network with the other connection running to the DIS network. A dual ported PC laptop host ran a CCTT Bridge federate application and an I/ITSEC Bridge federate application. The DIS tactical radio communication network remained isolated from all other networks. Figure 1 shows the three interconnected networks of the JTE federation minus the isolated DIS tactical radio network.

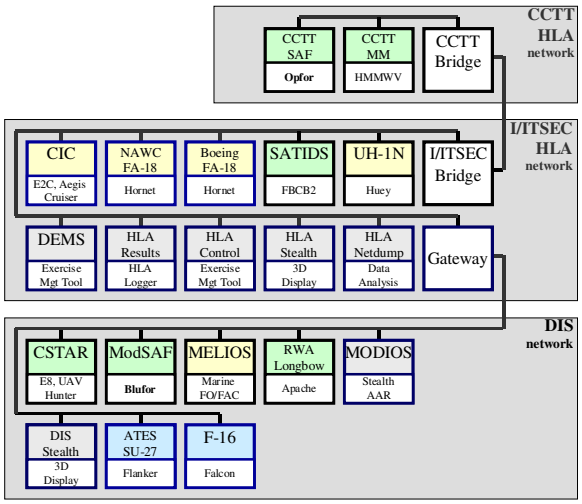

Figure 1. Network Diagram of the JTE Federation

Network drops originating from the STRICOM booth hubs extended to all the federate booths. At the federate booth the network drop was plugged directly into the federate host computer or federate network hub, depending upon the composition of the federate(s) located at that booth. Network hub depth was restricted to be no more than two deep.

Individual Federate and RTI Testing

When federates were ready to join the federation, the following preliminary tests were performed. First, technical radio communication was established between Technical Control and the federate. Federate IP address and netmask settings were verified and ping tests were conducted to verify network connectivity with the RTI/FEDEX host. Once network connectivity was verified, federate join and remove capabilities were confirmed.

Federation Network Problems

Initial multiple federate join attempts met with inconsistent results. With assistance from DMSO HLA personnel, it was determined that the JTE network did not have full multicast connectivity among all the federates. During the federation join process, the joining federate attempts to establish multicast connectivity with each federate that has already joined. Figure 2 illustrates the Internet Protocol (IP) multicast network connectivity required to support successful federation
joining.

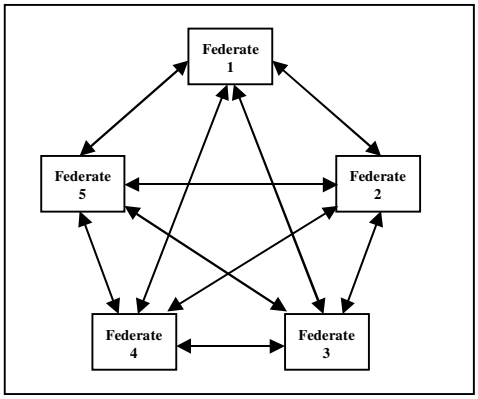

Figure 2. Required IP Multicast Connectivity

The join process proceeded smoothly as long as federates able to establish multicast connectivity between each other were the only ones in the federation. The problem arose when a federate attempted to join which could not establish communications with one of the federates present in the federation. The federate would "hang" attempting to establish a multicast connection and the FEDEX would "hang" waiting for the federate to complete its join process handshaking. Once this condition occurred, the FEDEX would not respond to any further join or remove requests.

Due to delays in establishing the federation and the pressing need to begin vignette rehearsals, the quickest solution was to change the mode of communication among the federates. Since all federates could communicate with the RTI/FEDEX host, the RTI.RID file of each federate was modified to use the RTI/FEDEX host as the network reliable distributor. This modification directed each federate's Local Runtime Component (LRC) to use a specific IP address for FOM data marked for reliable distribution. In this case, all reliable data was sent to the RTI/FEDEX host. The RTI/FEDEX host in turn sent the data to federates interested, or subscribed to, that data (see Figure 3).

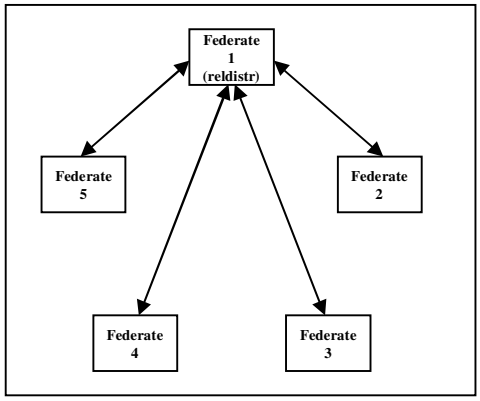

Figure 3. Reliable Distributor IP Unicast

This immediately resolved the multicast network connectivity problem that had been preventing full federation membership joining.

MANAGING THE FEDERATION

Managing the Join Process

During the JTE, management of the federate join process was required. The decision to do this was made in order to mitigate problems and conditions that could adversely affect federation establishment and execution. The primary factors that influenced this decision were the strict scenario start times, the federation size and the design constraints of the RTI.

JTE Scenario Start Time Requirements

The JTE vignettes were all tightly time managed. Start times were published in the I/ITSEC schedule and "news coverage" media presentations were coordinated to broadcast "live" immediately prior to the scheduled start time of each vignette. At the conclusion of the media presentation, all participating federates were required to be joined and ready to operate. Federation control then transitioned from Technical Control to Exercise Control who would issue a verbal command to start the exercise (STARTEX).

JTE Federation Size

While each federate will attempt to join the federation for some period of time before timing out, there was concern about the ability of the FEDEX to effectively service the uncoordinated join requests from a federation as large as the JTE. It was also expected that any join problems encountered would have a cascade effect on the other federates "waiting in line", causing additional problems and delay.

RTI1.3v6 Single Theaded FEDEX Design

The implementation design of the RTI 1.3v6 FEDEX process does not allow for parallel processing of multiple join requests. The FEDEX will sequentially process all join requests starting with the federate join and ending when the federate tick is received. During the period between join and tick, the FEDEX conducts a series of handshakes, and will effectively ignore all other federate join and remove requests.

Problems Associated with Federation Joining

It was our concern that the following types of problems would either cause the FEDEX to hang or make it unavailable for unacceptable periods of time, thus preventing the timely joining of all the federation members:

- Delays due to federate join process implementation
- Unstable federate requiring FEDEX intervention
- Federation join order dependencies

Delays due to Federate Join Process Implementation
Efficient implementation of the join process is the responsibility of each federate. Each federate should seek to complete the join process as quickly as possible once initiated. Once the joinFederationExecution service completes the handshakes required for successful invocation, the federate must consistently tick the LRC. It was found that some of the JTE federates took an inordinate amount of time between the join and tick commencement. In some cases several minutes were required before the federate would begin ticking. During this time, the FEDEX would not process any other join requests. Ideally, federation service requests should begin after all federate startup and initialization processes have completed and the federate application is ready to begin cycling.

Unstable Federates Requiring FEDEX Intervention
A federate that abruptly exits the federation without the appropriate service calls (i.e. crashes) must be manually removed from the FEDEX. When a federate does not tick the FEDEX, the FEDEX hangs and blocks federation join and remove requests until the next tick is received. This behavior was also observed when federates were paused. Ticking of the LRC should continue in a pause mode to prevent this from happening. If the federate has crashed then the federate must be manually removed from the FEDEX as quickly as possible.

Federation Join Order Dependencies
Following resolution of the network connectivity issue, join order dependencies among certain federates were still observed and required management. Due to time constraints, little analysis was made to determine the cause of these dependencies other than to determine that the CCTT HMMWV federate must join before the CCTT SAF federate. Should the CCTT HMMWV federate have to leave the federation, it could not rejoin unless the CCTT SAF was first removed.

Managing Federation Joining

Federation joining was conducted in the following manner:

- Exercise Control coordinated with Technical Control to produce a list of required systems prior to the start of each vignette. Not all systems participated in every vignette and within each vignette different systems had varying degrees of importance to the mission scenario. This checklist was used by Technical Control to ensure the proper systems were successfully established in the federation prior to inclusion of less critical tool and ancillary federates.
- Technical Control established the RTI, I/ITSEC FEDEX and CCTT FEDEX.
- Technical Control would then contact a required federate system via two-way radio and request they join the federation. Technical Control would verify the FEDEX join message and then wait for the federate to indicate that the system was cycling. Sequential joining of the CCTT federation was managed in parallel with I/ITSEC federation joining.

- Technical Control then proceeded to the next federate on the list and repeated the joining steps.
- When both the I/ITSEC and CCTT federations were established, the Bridge federates were joined to link the CCTT and I/ITSEC federations.
- Approximately five minutes before anticipated STARTEX, Technical and Exercise Control jointly evaluated the system list for completeness to determine if STARTEX delay was necessary.
- Immediately prior to STARTEX, Technical and Exercise Control jointly reviewed the federation status. Exercise Control then declared STARTEX to initiate vignette execution.
- Technical Control would then declare the federation "locked" and began monitoring and advisory duties.

Managing Federation Execution

During federation execution, Technical Control performed monitoring and advisory duties. Technical Control monitored the RTI and FEDEX windows as well as the Gateway and Bridge interface federates. Once the federation was declared "locked", federates were required to obtain approval from Technical Control prior to initiation of join or remove requests. Technical Control would in turn advise Exercise Control. Permission or denial of the federate request was based upon Exercise Control decision with Technical Control input.

Once federation join up had occurred and STARTEX was declared, the entire JTE federation was found to be extremely stable. At no time during normal vignette execution did the RTI or FEDEX indicate any errors or exhibit any instability.

Following vignette three, it was speculated that not all federates could "see" all the other federates. Since the Fed file had not been modified, only the MOM data was being sent via the reliable distributor. Non-MOM data was still being sent via the incomplete multicast pathways. Given that no mission critical interoperability problems were being reported and no time existed for federation testing using a Fed file converted to full reliable distributor for all data, no changes were made.

JTE vignette federations typically contained 14 to 17 federates with the largest federation composition depicted in Table 1.

Number of Federates	JTE Federation
10	I/ITSEC HLA federates
3	CCTT HLA federates
4	DIS federates
17	JTE federates

Table 1. JTE Federation Composition

Actual JTE federation size was much smaller than anticipated due to several factors. Not all federates were scheduled to participate in every vignette. Many participants had indicated they would be utilizing additional observation federates which were not realized. STRICOM's Stealth and Logger federates were installed in the DIS ring during set up and never transitioned to HLA. Three HLA federates (which had not undergone pair-wise testing) were unable to join and remain in the federation and consequently reverted to DIS.

At the end of two vignettes, instead of announcing the end of the scheduled exercise (ENDEX), Exercise Control announced unrestricted free play. This meant that all forces could interact and engage at operator discretion. During free play, entities and munitions that had not been part of the federation development and test plan were utilized. In both instances of free play, all problems observed were attributed to the negative effects of untested enumeration and attribute data on individual federate members.

Within a few minutes of the first free play several federates stopped cycling and presumably crashed. Technical and tactical radio traffic indicated many lost contacts among the federation members. Also reported were many (primarily munitions) entities exhibiting strange behavior. This was attributed to "orphan" objects left by crashed federates which did not exit the federation gracefully and remove their published objects. At this point, Technical Control advised Exercise Control to call ENDEX. The second free play resulted in only a couple of federates crashing and these were removed without incident from the federation via FEDEX operator commands. Orphan objects were still left on the network but no problems were reported. Federation free play continued for some time until Exercise Control called ENDEX.

CONCLUSIONS

Inter-service and industry cooperation was a key factor in the successful conduct of Joint Training Event (JTE), Operation Desert Rats.

It is believed that JTE Operation Desert Rats was the first time:

- Real-time Close Air Support (CAS) operations between the Army, Air Force, Navy and Marines were conducted using virtual simulators from all services
- Joint deployed Air Operations were conducted using virtual simulators
- A Navy Combat Information Center (CIC) was linked to Army, Air Force and Marine simulators in the conduct of multiple operations.

JTE Desert Rats was a success and met all of its declared objectives as well as the commander's intent.

The JTE also provided an example of the complex federation topographies which will become more prevalent as joint simulation requirements drive legacy DIS and heterogeneous HLA federations to interoperate.

JTE Federation Problems and Issues

Pair-wise testing was effective and productive. This type of federation test strategy, however, falls short in one critical area: representing the complete federation network topography and related connectivity.

During the JTE the most difficult technical issue faced was network connectivity. This emphasizes the importance of understanding the HLA RTI network implementation.

Obvious concerns remain regarding the federation join process. It is hoped that future RTI implementations will eliminate current RTI 1.3v6 design constraints which do not allow for graceful management of federate join problems.

It is recommended that DMSO consider sponsoring an HLA networking course covering such issues as HLA network implementation, network analysis and troubleshooting and RID file manipulation. Hands-on training in FEDEX diagnostics capabilities and RTI Test Federate utilization would also be desirable.

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