SUPPRESSOR AND THE B-2 AIRCREW TRAINING DEVICE (ATD): THE ENHANCEMENT OF A LEGACY MANY VERSUS MANY WARGAMING MODEL AND A LEGACY VIRTUAL SIMULATOR TO HLA AND DMT

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Abstract

Due to the changing training requirements of the B-2 Aircrew Training Device (ATD), the US Air Force has been upgrading their existing, legacy virtual simulator to be HLA compliant. These devices provide individual and crew training, but do not provide interoperability with other devices to satisfy full mission rehearsal requirements. Executing a strategic plan established in the late 1990 s to meet the Department of Defense (DoD) directive to become High Level Architecture (HLA) compliant, these devices are being upgraded to interoperate with other devices, both virtual and constructive. The devices will then be usable for team training in a Distributed Mission Training (DMT) environment to support full mission rehearsal.

The B-2 Weapon Systems Trainers (WST) and Mission Trainers (MT) were created to support the individual and crew training of B-2 pilots. They are large, high fidelity, multi-platform systems that simulate systems associated with the B-2 aircraft. These devices all provide a simulation of the synthetic environment (friendly, hostile, and neutral forces). The many versus many synthetic environment employed on the B-2 devices is Suppressor, a DoD, analytical, event-stepped, many-versus-many, threat model. Its traditional use has been in the analytical world to support Analysis of Alternatives (AOA), weapon effectiveness, and survivability analysis. It simulates human behavior, sensors (infrared, electro-optical, radar, and radar warning receivers), radios, jammers, weapon systems, and movement systems. The Suppressor model in place on the B-2 devices has been enhanced to run at a real time rate, interact with virtual devices, run under the simulator executive, handle Instructor requests to control/modify the environment and use no wait input/output (IO) mechanisms for file access during real time.

This paper will detail the stand-alone approach used to transform Suppressor into an HLA compliant federate. This carefully planned approach will allow the HLA compliant Suppressor model to be used in a similar manner on other virtual simulation devices to provide a many versus many synthetic environment for simulation based acquisition (SBA), wargaming analysis and full mission rehearsals. This paper also presents information detailing the modifications made to the existing B-2 devices to allow interoperability with the HLA compliant Suppressor model. All of the stand-alone capabilities were retained with this approach for an HLA federation. This federation can consist of one synthetic environment, Suppressor, and multiple HLA compliant B-2 devices.

About The Authors

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INTRODUCTION

In the late 1980’s, L3 Communications, Link Simulation and Training (Link) began implementing distributed simulation programs under our internal MULTISIM research programs. These programs began to address the interactions needed between full fidelity simulation devices and the time critical nature of these events. In the summer of 1989 a network of existing devices was installed at Ft. Rucker, Alabama that provided four helicopter training devices networked in a real-time psuedo-synchronous network. This was a custom network solution but proved that training could be performed in a networked environment. This network design was limited by it’s structure and thus Link began to address many of the bandwidth problems that exist with today s networks.

In 1990, Link began investigating the use of reflective memory products to provide real-time networking. SCRAMNET was selected for the local area networks (LAN) due to its high bandwidth ability to send only changed data. Determination of which data needing be transmission is performed on the hardware thus greatly decreasing the host CPU processing required.

Although the SCRAMNET system was simply reflective memory, the MULTISIM memory layout was designed in an object-oriented fashion, which was segmented for individual entities and events along with a common global control area for simulation control.

Throughout the 1990’s Link continued to design networks for full fidelity simulations which addressed real-time problems such as shipboard landing, formation flight, air refueling and weapon designation. These distributed simulations consisted of both custom and Distributed Interactive Simulation (DIS) networks and were used as a foundation to the initial development of the B-2 HLA distributed simulation in the late 1990 s.

This initial effort was a first cut at transforming the B-2 Aircrew Training Devices (ATDs) into an HLA federation, an effort that developed a proof of concept of an HLA compliant B-2 ATD. Beginning in 2001, the initial functionality was used as foundation to create a total training capability across an HLA federation.

B-2 ATD BACKGROUND

There are currently five B-2 Aircrew Training Devices (ATDs), three Weapon System Trainers (WSTs) and two Mission Trainers (MTs). Each WST provides complete training for the two member B-2 crew and consists of a full cockpit simulation including a significant amount of actual aircraft hardware and software. In addition, each WST has a Digital Radar Landmass System (DRLMS) used to simulate the aircraft s Synthetic Aperture Radar with a 20 million nautical mile database, a six degree of freedom (6-DOF) motion system and a 150 x 40 degree out-the-window visual system. The MT simulates the right seat of the B-2 used by the Mission Commander. The MT runs the identical software as the WST but does not contain the visual or motion systems. In addition, since only the right seat is simulated there are no pilot controls so flight is completely under computer control. All of these devices are full fidelity flight simulators consisting of over two million lines of real-time Ada code per device. In addition to the complexity of the large number of lines of code, these devices consist of several independent computer platforms that are connected by various means including reflective memory and direct memory access (DMA) devices. The major obstacle to overcome in order to make the devices HLA compliant was to break into the current architecture with the required hardware and software modifications without losing the stand-alone capabilities of the ATDs.

Information is shared between the major components of the ATDs (Figure 1) is done through shared memory and contain the following functions:

B-2 Cockpit — This component consists of simulations of the aircraft aerodynamics, avionics, sensors and weapons systems. Each cockpit also contains an Instructor Station (IS) which allows an Instructor to initiate, modify and monitor a training exercise. Among some of the unique monitoring capabilities provided by the IS are the ability:

- Platforms (players) currently in the scenario and their locations in the world
- Weapon events (fire and detonation)
- A God s eye view of who sees who
- Player movement plans
- Player command and control (C2) chains

The IS capabilities on each ATD include the capability to add players on the fly, take control of player movement, initiate/abort attacks, force weapon fire events, and control the mode of various equipment (force them into search, track, etc.).

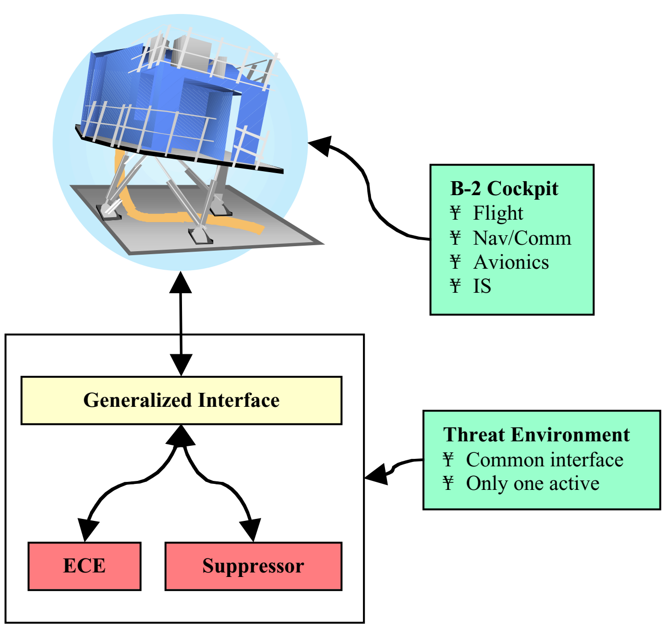


Figure 1 -- B-2 ATD Stand-alone System

Threat Environment — This component consists of the threat environment, including the movement and tactics of the various threat laydowns. Each ATD is equipped with two possible threat environments (Electronic Combat Environment (ECE) and Suppressor). Each communicate with the B-2 systems via shared memory called the generalized interface that contains all data exchanged between the B-2 cockpit and the players within the threat environment. The ATD can run with one threat environment or the other, but not both simultaneously. ECE is a many-versus-one, legacy product that has been used for normal school house training on the ATD and supports worldwide flight. Suppressor, just implemented in 2000, has not been fully utilized on the ATD at this point but will be the primary threat environment used during HLA exercises. Suppressor and the networking aspect of the ATD will be the basis of this paper.

SUPPRESSOR BACKGROUND

Suppressor is a DoD, analytical, event-stepped, many-versus-many threat simulation system. Its traditional use has been by the analytical community to perform Measure of Effectiveness (MOE) and Analysis of Alternative (AOA) studies. It simulates human behavior, sensors (infrared, electro-optical, radar, and radar warning receivers), radios, jammers, weapon systems, and movement systems. The human behavior algorithms are separate from the physical systems. They execute database-defined tactics for resource allocation and movement evaluation. Resource allocation entails selecting a target and associating it with specific sensor and weapon systems to form an engagement. Movement evaluation involves selecting the appropriate movement plan as well as determining whether or not to perform terrain maneuvering and/or threat avoidance. After the desired movement is determined, a separate set of route planning algorithms, which take into account physical limits such as minimum and maximum speed, minimum and maximum altitude, and minimum turn radius, combine the desired avoidance technique to determine the actual path that will be followed.

The human behavior algorithms do not make decisions based on ground truth, but on perceived truth. A player s perceived truth is obtained by noticing and mentally digesting what is detected by the player s sensors or what has been communicated to that player from another. Command and control structures, as well as a player s tactics, help define what will be communicated and to whom. Subordinates can communicate, to their commander(s), targets or players they detect. Subordinates may also have, in their database, logic to act autonomously if communication to their commander continues to fail after a certain number of tries. Commanders can assign a target to a subordinate, control whether a subordinate is allowed to fire a weapon or not, and launch a subordinate, i.e., tell it to start movement.

One of Suppressor s most important features is its data capture capability. Via a model input file, the user can choose which types of situations are captured during the run. The captured data can be stored as an American Standard Code for Information Interchange (ASCII) text file and/or as a Suppressor binary file. An analysis process can be run, using the captured data as input, to further filter the output for specific situations, specific players, or a combination of the two. An analyst can view this data to gain a better understanding of the scenario. Although it is not included in the government furnished Suppressor, there are graphical utilities that have been developed to read the captured data back into Suppressor for a replay or playback option. Both of these unique capabilities provide the user with a flexible and analytical option to compliment the threat model.

Suppressor, as delivered from the government, operates in a non-real-time, analytical environment. In order to support real time and running on virtual devices, Link has developed a real-time shell to Suppressor that has been used on several projects. The Suppressor real time shell includes numerous offline tools to support scenario generation, modifications to the Suppressor Fortran code to support real time, numerous Ada interfaces to support virtual devices (exporting data from Suppressor to be seen by the ATD and importing data into Suppressor from external simulations), and implementing a no wait input/output (IO) procedure for Suppressor.

INITIAL HLA DEVELOPMENT AND OVERVIEW

The initial HLA effort on the B-2 has served both as a proof of concept exercise as well as a training enhancement. This initial effort included the capability for each B-2 WST to see other cockpit federates in their visual system and for the ATD s to communicate via radios across the HLA network. For this effort, the Real-time Platform Reference Federation Object Model (RPR-FOM) was used as a basis to develop the Federation Object Model. The actual objects and interactions defined, however, were specific for the B-2 applications. Vehicle objects were published and received from each cockpit to provide the state of the WST to the other federates. Objects and interactions were defined for each of the radio types in the B-2 cockpit and published and subscribed to by each of the federates. The objects contained the state of the radio and the interactions contained the data to be transmitted between the B-2 crew members. Voice transmissions were digitizied and packed into the radio interactions and sent to the other federates. Upon receipt, each federate determines if its radio is properly configured to receive the message and if so unpacks the interaction into the required radio format.

The DMSO Run-time Infrastructure software version 1.0.3 for the DEC Alpha platform was used as part of this effort. Not all of the RTI services and callbacks were required and therefore were not implemented. Ownership Management, Time Management and Data Distribution Management (DDM) services were not used at this time. It was determined that these functions would be added as the need developed.

An additional computer was added to the ATD configuration to host the RTI software and a reflective memory interface from the RTI to one of the existing host computers was added to provide the means of communicating to/from the host and the RTI computer. Various networking software utilities were added to move the necessary gather and move the data as well as provide a layer of software between the application code and the RTI, so as to minimize the code modifications necessary in each of the existing host applications on the ATD.

B-2/SUPPRESSOR STAND-ALONE CAPABILITIES

As part of Link's effort to expand the HLA functionality of the B-2 ATDs and to transform Suppressor into an HLA compliant federate, the team first needed to fully understand the current capabilities of the ATD, Suppressor, and the two functioning together. It was important not to lose any of the existing capability when Suppressor was pulled out of the ATD computer architecture and hosted on its own platform.

Currently, a Suppressor mission is built offline on the scenario development system (SDS). This Suppressor mission is built to include a B-2 and any other moving platforms that the mission developer wishes the ATD to supply, as well as all desired Suppressor entities. This Suppressor mission is processed through various offline tools and the Suppressor threat laydown is processed through AFMSS as the basis to create a B-2 ATD mission.

Additionally, a supplemental data generator (SDG) program is run against the scenario where the user is prompted for data about each player, equipment, etc. This data is used by the various real time interfaces on the B-2 ATD, but is not part of Suppressor. Once SDG has been run, an Ic_Create tool is run for the scenario. This tool provides the capability to develop Initial Conditions used to initialize the ATD when running Suppressor (see Figure 2).

The scenario real-time input (SRTI) CD is taken to the trainer to run the real-time mission (see Figure 3). Once on the trainer, scenario data is accessed from the CD and the mission can begin. All Suppressor players and their activities appear on the Instructor Situation (IS) displays and the local avionics equipment responds to changes in the modes of various equipment. Suppressor movers are passed off to a high fidelity 6-DOF movement program created on the B-2 program, called the Targets Computer Program Component (CPC). Suppressor provides the planned waypoints of moving targets and the Targets CPC flies the platform(s) to the given points using 6-DOF fidelity.

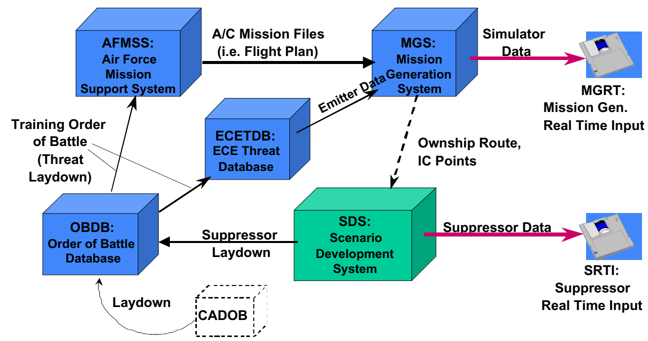
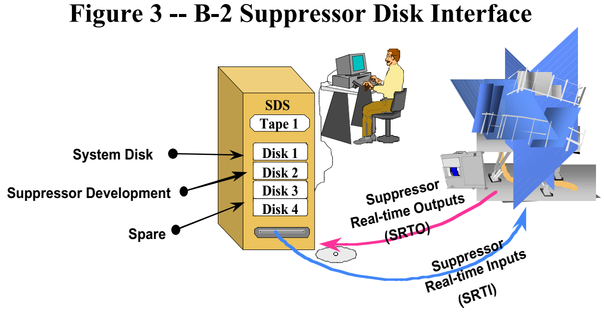


Figure 2 -- B-2 ATD Scenario Development Process

The Instructor also has the capability to take manual control of Suppressor moving platforms to designate various movement characteristics (speed, altitude, etc.) to control. Once under manual control, the platform will continue to fly the waypoint route under the given Instructor supplied criteria. If the Instructor releases manual control, Suppressor will once again resume normal flight duties for the platform.

Figure 3 -- B-2 Suppressor Disk Interface



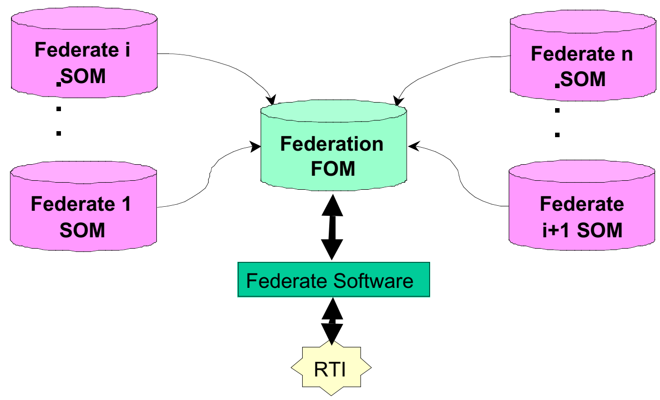
Other key Instructor capabilities (see Table 1) include adding a player, deleting or moving players, player suppression/restore, attacks, weapon fires, equipment mode changes, enhance/unenhance detection of ownship, and snap/reset capability.

As the real-time processing occurs, Suppressor continuously saves off mission data to the scenario real-time output (SRTO) disk. Once the mission is terminated, the SRTO disk is taken to the SDS machine where standard Suppressor post-analysis steps can be executed (see Figure 3).

B-2 FEDERATION AND SIMULATION OBJECT MODELS

The normal Federation Object Model (FOM) generation process (see Figure 4) requires all federates in the federation to define the objects and interactions it will be publishing and subscribing to in their respective Simulation Object Model (SOM). The sum total of the federates' published and subscribed objects and interactions is analyzed and the resulting union is represented in the FOM. In developing the B-2 Federation, a slightly different approach was used. The Suppressor threat environment that was already in place on the B-2 and embedded deep within the cockpit computer architecture was the starting point for the FOM generation. The design goal for this project was to pull the Suppressor software out of the cockpit, host it on a stand-alone PC, make it HLA compliant, and plug it into the B-2 Federation. The objective was to maintain the existing capability of Suppressor on the B-2 when this was done.

Figure 4 -- Normal FOM Generation Process



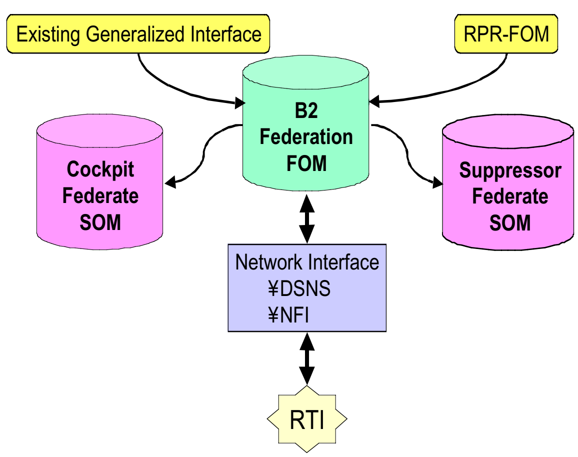
Sitting down to develop a full blown SOM of all of Suppressor s capabilities would not only be very time consuming, but would not benefit the current task since Suppressor has far more capabilities than those that are utilized on the B-2 ATD. The goal was not to bring these forth under this HLA effort, but to supply, via HLA, the data that the B-2 simulation was already capable of handling. The existing generalized interface discussed previously provided the basis for defining objects and interactions necessary to maintain the current functionality. In addition, the radio communications that were provided under the initial proof of concept effort also needed to be maintained. Since the objects and interactions used to perform these functions were independent of the data required for Suppressor, those classes and the accompanying software were retained.

CONTROL	DESCRIPTION
Add Player	The Instructor is supplied with a list of player types that may be added on the fly. The list of player types may be different for each mission. The Instructor has the capability to view attributes (equipment) that are associated with the added player. Once a player is selected, the Instructor must supply initial data for the player. For non-moving platforms, the latitude/longitude (map selected) and the heading must be entered. For movers, the inital latitude/longitude, heading, speed, and altitude are required. This request is sent to Suppressor and the requested player is added. A status of the request message (success/failure) is returned to the Instructor.
Delete Player	Supplies the Instructor with the capability to delete a player and its associated attributes. Once the delete is selected, a confirmation window appears to ensure the delete is really desired. This request is sent to Suppressor and the requested player is deleted. Similar to the add player request, a success/failure message is returned to the Instructors.
Move Player	Supplies the Instructor with the capability to move a player (and all of its associated locations) to a new position on the map. The Instructor selects the new desired position via a map selection and the request is sent to Suppressor where the requested player is then moved. The success/failure of this request is returned from Suppressor to the Instructor.
Suppress or Restore Player	One of the widely used features on the B-2 ATD (for engineering purposes) is the Suppress/Restore feature associated with the threat environment. Player suppression makes a player invisible to the simulation. The player is still in the scenario, but its turn is skipped in regards to all activity. The suppressed player does not move and does not interact. Once the restore is selected, all activity for the given player returns to normal. The instructional feature for player suppression/restoring allows the Instructor to affect a single player, a particular force (red, gray, blue), a category of players (bombers, fighters, etc.), or all players in the scenario. Again, the request is sent to Suppressor and the given player(s) is suppressed/restored and the status of the request is returned to the Instructor.
Attacks	The Instructor also has the ability to affect attacks in the threat environment. A request can be sent to Suppressor to inhibit or enable player attacks. If a player s attacks have been inhibited, the Suppressor player will not initiate an attack on any other player. Likewise, enabling a players attack capability restores the player to its normal state where the Suppressor database logic will be followed and attack may be initiated. In addition, the Instructor can force an attack to begin. If the given player was modeled in the Suppressor database with engagement ability, the IOS will display an attack button when the Instructor views the capabilities of the player. If attacks are chosen, the Instructor then chooses a player to be attacked (via a map selection). When Suppressor receives this request, its database tactics are ignored and the player begins to pursue the targeted player. This pursuit will continue until the attacking player runs out of ammunition, a successful hit is noticed, or until the Instructor requests to abandon the attack.
Weapon fires	Weapon fire events can also be initiated at the Instructor station. Again, the targeted player is selected from the IOS map and the command is sent to Suppressor. Suppressor will then bypass all of its weapon firing criteria and will force the firing event to occur (regardless of range, target type, etc). The weapon will be launched and will either detonate or abort (if the weapon is incapable of reaching its destination). As with all of the Instructor events, a status message will be returned indicating the success/failure of the request.
Weapon Reload	The Instructor is also presented with the capability to reload any weapon on any Suppressor player. Once the reload is requested, the selected weapon will be reloaded to have the number of rounds it had at the start of the exercise.
Mode changes	Forcing selected equipment into a desired mode (on, off, search, track, launch) is another key instructional feature of the B-2 ATD. This capability presents the Instructor with the current mode of the equipment and a pull down menu provides all of the modes the selected equipment is capable of operating in. The Instructor simply selects the desired mode and the request is sent to Suppressor. Suppressor will then force the equipment into the requested mode and will not allow a mode change due to Suppressor tactics until the Instructor selects to resume normal equipment operations. Again, status messages will be returned indicating the success/failure of the requests.
Enhance detection	During testing phases, it is sometimes desired to force a player to gain a detection of the B-2 aircraft. With the low observable features of the B-2, this is not always easy to do. Therefore, the enhanced detection feature was added to the simulation. This feature allows the Instructor to force a given player to process a much larger than normal radar signature for the B-2. This enhanced signature is used only by the designated player and has no affect on the rest of the threat environment. It is also used by the designated player until a request is received from the Instructor to once again use the normal signature values.
Snap/Reset	Provides the ability to go back in time and do the exact same thing over again. The Instructor must initiate a snap to occur which causes a background task to store off all data necessary to restore the simulation to that point in time. When the reset is selected, all data is restored to the value at the point of the snap. The Suppressor environment fully supports the snap/reset function on the ATD.

Table 1 -- Suppressor Controls at the B-2 Instructor Station

So the approach taken was to take the FOM from the initial HLA effort in the late 1990 s and the existing B-2/Suppressor interfaces to create the new B-2 FOM. From there, the individual federate SOMs (Cockpit and Suppressor) were generated (see Figure 5). After analyzing all of the current interfaces, the task was to develop the HLA objects and interactions that would enable required data to be passed around the network. With plans of joining Distributed Mission Training (DMT) exercises in the near future, close attention was paid to the RPR-FOM so as to align with it as closely as possible. The obvious RPR-FOM objects have been used (Platform, Radio Transmitter, RRB objects, and Weaponfire and MunitionDetonation interactions). The Instructor commands to Suppressor were mapped to the RPR-FOM interactions CreateEntity, RemoveEntity, Acknowledge, ActionRequest and ActionResponse and SetData and Data.

Figure 5 -- B-2 FOM Generation Process



All of these RPR-FOM objects and interactions allow handling of all normal simulation activities. However, due to the internal design constraints on the B-2 IS, there was still additional data needed from Suppressor. In particular, specific data about each player, location and equipment was needed for the IS to draw its icons. A list of available players to be added was also needed for the add player feature via the IS. Additionally, specific data for the IS to draw waypoints, command and control (C-2) networks, and detection/perception lines was needed. Creating our own objects and interactions to send/receive this data solved all of these IS specific needs.

Below is a list of all object and interaction classes used in the B-2 Federation and defined in the B-2 FOM. The classes in *Italics* indicate a class that was created to support B-2 specific information between B-2 Cockpit Federates or a B-2 Cockpit and the Suppressor Federates. The classes in the normal font are the RPR-FOM v2.0 draft 5 classes that are used.

Objects:

PlatformEntity	RadioTransmitter
Player_Status	*Location_Status*
Equipment_Status	*Federate_Conditions*
Player_Prototype	*Location_Prototype*
Equipment_Prototype	*Satcom Uhf_Vhf*
Hf	*Instructor_Communication*
Federate_State	

Interactions:

MunitionDetonation	WeaponFire
SetData	Data
ActionRequest	ActionResponse
CreateEntity	RemoveEntity
Acknowledge	
C2_Link	*Waypoint_Link*
Perception_Link	*Detection_Link*
Comm_AudioHf_Voice	*Instructor_Voice*
UHF_VHF_Voice	*SATCOM_Data*
AFSATCOM_Message	*MILSTAR_Message*
Timing	

NETWORK INTERFACE ARCHITECTURE AND PORTABILITY

The B-2 Federation consists of one or more Cockpit Federates running the legacy B-2 ATD software as well as the new networking code, a Suppressor Federate with the same functionality Suppressor had when it was embedded within the B-2, and an Exercise Manager PC (see Figure 6). This Exercise Manager is not a federate, but is the controller of the Federation and is where the RTI Executive (RTIExec) and RTI Federation Executive (FEDEX) processes run. A graphical user interface (GUI) was developed for the Exercise Manager to allow the creation and destruction of the Federation.

The DMSO Run-time Infrastructure (RTI) software 1.3NGv.4.0 for Linux was used as part of this effort. Not all of the RTI services and callbacks were required and therefore were not used at this time. As the Federation expands, more services will likely be added.

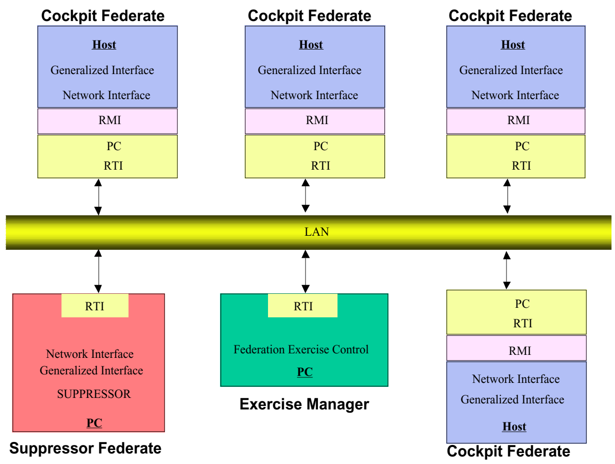


Figure 6 — B-2 Federation Architecture

Once the FOM was defined and the RTI software in place, one of the largest design tasks was to determine how the information should be passed between the RTI and the Host. The original HLA effort done on the B-2 divided the network interface software into three pieces:

- Network Federate Interface (NFI) to handle the conversion between the FOM object and interactions
- Distributed Simulation Network Support (DSNS) to manage the objects and interactions
- RTI Interface Manager (RIM) that provides the Federate Ambassador callback and the RTI Ambassador methods.

The NFI and DSNS software are Ada routines while the RIM is written in C++ and all three pieces reside on each of the federates, Cockpit and Suppressor. Although similar in nature, the software is based on each of the federate s SOM and therefore needs to written accordingly. It was determined early on in the program to develop a parser of the SOM to automatically generate the types and declaration of the RTI objects and interactions as well as the routines used to manage these items. The parser is also used to generate the object arrays and interaction rings used as the interface between the federate s application and the RTI software.

Each federate s application calls NFI routines to read the outgoing data generated and stored in the generalized interface by the federate, create the appropriate object or interaction and call the DSNS routine to transfer the data to the appropriate outgoing array. The RIM, a separate task running within the federate, calls DSNS routines to monitor each of the object and interaction arrays looking for updates. Upon receipt of an update, the RIM invokes the appropriate RTI Ambassador method, sending the object or interaction to the rest of the Federation. After processing all of the outgoing objects and interactions, the RIM will invoke the RTI tick routine, requesting any updates from the RTI. If an update is received, the appropriate Federate Ambassador callback method is invoked by the RTI. The RIM handles the update and calls the DSNS routine to transfer the update to the respective object or interaction array. The federate s application will call NFI routines to process incoming object and interaction arrays. Upon receipt of an update, the NFI software will perform the required conversions and store the data into the generalized interface for processing by the rest of the federate application.

A Linux PC was added to each B-2 ATD as the Local RTI Component (LRC). Although each B-2 Host consists of many processors, only one will have an interface to the RTI computer. This interface via reflective memory is managed by the DSNS routines. The NFI and DSNS executes on the Host platform while the DSNS and RIM execute on the Linux PC. The Suppressor Federate is a quad processor Linux PC and one of the processors on this machine is reserved for the interface to the RTI, i.e., to be the LRC for this federate. This processor runs the same RIM executable as the Cockpit Federate to handle communication with the RTI. The NFI and DSNS routines are called by the real-time Suppressor executable to handle the object and interaction updates.

SUPPRESSOR FEDERATE CAPABILITIES

Within the Suppressor Federate, Suppressor functionality has been totally separated from the B-2 ATD. Suppressor, as a stand-alone federate, maintains the same functional capabilities that it had when it was embedded within the B-2 ATD computer systems. It can run the same type of scenarios, send out data reflecting the state of all of the Suppressor entities, receive data about external entities and ghost them into Suppressor. The same no-wait I/O procedures are used and Suppressor can still accept the same Instructor commands. The only difference functionally is that the data is transferred to/from Suppressor via HLA instead of the internal B-2 communication methods.

While operating in the B-2 Federation, control of the Suppressor scenario has changed. Previously, when the B-2 mission was initiated or terminated, Suppressor did the same. Likewise, when the B-2 ATD performed an initial condition (IC), a snap/reset or change in freeze state, Suppressor did so as well. As an HLA federate, the closely coupled connection has been removed. Since scenario control at the ATD and the Suppressor Federate are now separate, Suppressor must now be commanded to perform these functions on its own.

SUPPRESSOR GUI SYSTEM DISPLAYS	
Reference Times	The day of year and GMT for scenario begin and end times.
IC Information	Information about each available initial condition in the given mission, including a brief description of the IC and the day of year and GMT that it begins.
Selected IC	The initial condition chosen for execution.
Scenario Duration	The scheduled length of the Suppressor mission.
Phase	The phase of the Suppressor software including the following choices: 1. Wait - Suppressor software is not executing any portion of any mission. It is waiting for a user input. 2. Mission Init - Suppressor is reading mission specific information from the input disk. 3. Exercise Init - Suppressor is initializing the scenario specific data and will begin publishing and subscribing. 4. Real Time - Suppressor is executing its scenario. Suppressor scheduled events are being processed and network data is being processed within Suppressor. 5. Mission Terminate - Suppressor is closing down the mission. Binary files containing information about what happened in the scenario is being written to the output disk.
Current Day of Year	The current day of year of the Suppressor scenario.
Current GMT	Current Greenwich Mean Time (GMT) of the Suppressor scenario.
Fed Status	Displays whether or not a federation exists.
Federation Members	A list of every federate that is currently part of the existing federation.
Current Rate	The rate (multiple of real time) at which the Suppressor software is currently running.

SUPPRESSOR GUI USER INPUTS	
IC Select	Provides the selection of which Suppressor IC will be executed upon the start of real time.
IC Insert	Starts the processing of loading the selected IC.
Join	Causes Suppressor to join the HLA Federation (only available if a federation exists).
Resign	Causes Suppressor to resign from the HLA Federate (only available if already joined).
Freeze	Puts the Suppressor Federate in a freeze mode or releases it from a freeze mode.
Mission Init	Starts the process of loading mission specific data from the Scenario Real Time Input Disk (only available if not already executing a mission or IC).
Mission Terminate	Causes Suppressor to terminate the execution of the current mission (only available if running real time).
Commanded Rate	Provides the Suppressor Federate with the requested execution rate. This will be a real number between 0.01 and 1000.0, with 1.0 indicating the real-time rate. If Suppressor is part of an HLA Federation, this rate will default to 1.0 and cannot be altered. For all other rates, Suppressor will achieve the rate to the best of its ability, dependent upon the scenario.
Start	Provides the capability to start Suppressor executables after they have quit. Allows for restart without a reboot of the machine.
Quit	Causes all Suppressor executables to return to an initialization state. Suppressor will not be able to be run again without first issuing a start command.
OS Shutdown	Causes a shutdown of the Suppressor Federate PC. If any executables are currently running, they will be terminated prior to PC shutdown.

Table 2 -- Suppressor GUI Display Features

To perform this scenario control, two choices were explored. First, a request for various Federation control commands could to be sent via HLA from the Cockpit Federate IS. However, this was beyond the scope for the current task. Instead, the solution implemented was to use a graphical user interface (GUI) on the Suppressor Federate. This GUI (see Figure 7) serves as the scenario controller for Suppressor and is broken into two sections — system displays and user inputs (see Table 2).

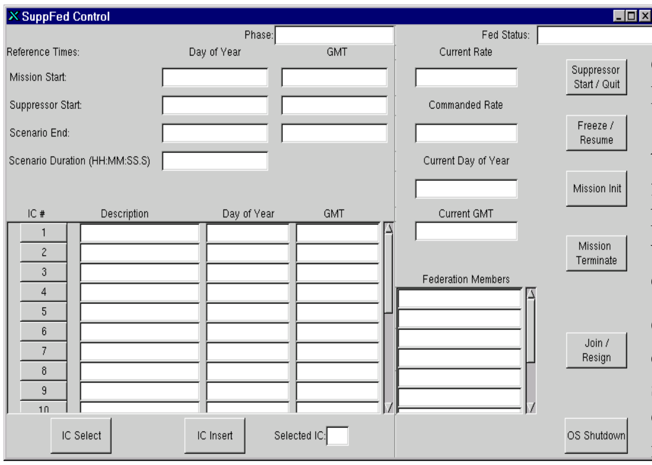


Figure 7 — Suppressor GUI

FEDERATION TRAINING CAPABILITIES

The implementation of a B-2 HLA Federation will prove highly beneficial to the B-2 community by providing greatly improved mission rehearsal capabilities. A common threat environment supporting all B-2 ATDs will provide more realistic effects within the Federation. The ability to view, from any ATD, how the battle is progressing is a much needed ability. Also, the ability for B-2 ATD to B-2 ATD interaction will allow the aircrews to rehearse such things as air-to-air TACAN rendezvous and radar beacon station keeping before entering the actual aircraft.

Additionally, Suppressor s analytical capability will add infrastructure components for improved mission planning and debrief capability. Real missions can be built and rehearsed on the ATD using Suppressor to help determine the effectiveness of the mission. Post analysis steps can be run with Suppressor to view desired statistics. This analysis feature will provide the mission planners valuable information to support what if scenarios and test them using Suppressor. Concrete data will also be captured as pilots are trained on the ATD that can be analyzed and fed back to the aircrews to show cause and affect of different actions.

FUTURE OPPORUNITIES

A major goal of this program was to provide the foundation for the B-2 ATDs to participate in Distributive Mission Training (DMT) exercises. Care was taken throughout the program to align, as much as possible, with the RPR-FOM. With joining DMT exercises just around the corner, only minor modifications appear necessary for success. One possible solution will be to simply install a gateway into the B-2 Federation to perform the necessary conversions to other federations.

Care was taken in the development of the Suppressor Federate so it would not be tied to the B-2 ATD. The Suppressor Federate can easily be connected to another training device via HLA. With its wide range of functionality, coupled with the government backing and history of analytical success, the Suppressor Federate will be a viable candidate for a DMT threat environment.

One major opportunity for future development is creating a graphical display on the Suppressor Federate, similar to the B-2 IS display. This display will show a God s eye view of the entire scenario and allow for user interaction similar to the B-2 Instructor capability. Another is a rapid development database environment to automate the population of model parametrics from intelligence sources and a user interface that provides easy manipulation and modification of data files.

SUMMARY

The implementation of HLA technology into the legacy B-2 ATD and the complex Suppressor environment has demonstrated that large, full fidelity, flight simulators and other complex systems can be modified to form HLA Federations. These modifications only allow the federates to operate in distributed exercises and provide for easy system enhancements in the future. Developing our SOMs and FOM from RPR-FOM objects and interactions have made the ability to join other federations and exercises much easier. We have created a B-2 Federate capable of joining DMT exercises and a Suppressor Federate that could prove highly useful to the DMT community.

REFERENCES

Sardella, J. and Schwalm, S. (1999). The B-2 Aircrew Training Device (ATD) Federation: The Enhancement of Large, High Fidelity, Legacy Virtual Simulations with HLA. *Simulation Interoperability Workshop, Spring 1999*, paper number 99S-SIW-165.

Douglas, G. L. (2000). A Case Study on Model Integration, Using Suppressor. *Interservice/Industry Training, Simulation & Education Conference (I/ITSEC) 2000*, paper number MS-017.