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JOINT SYNTHETIC BATTLESPACE FOR RESEARCH AND DEVELOPMENT

Northrop Grumman Mission Systems

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12a. DISTRIBUTION / AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.				12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 Words) The Joint Synthetic Battlespace for Research and Development (JSB-RD) is a distributed simulation environment that is intended to facilitate research into both advanced Air Force command and control concepts and simulation science. The JSB-RD environment includes a computer generated forces (CGF) system, the JSB-RD Viewer, which provides theater-level situation awareness and mission status information in multiple formats, weather and environment simulations, a collection of sensor simulations, and a gateway(s) to C4ISR systems. A variety of AFRL/IF programs require a flexible, multi-purpose, modeling and simulation environment in order to represent various aspects of the joint battlespace, and to stimulate and react to prototype C4ISR systems and components. The JSB-RD system forms the starting point for such an environment. This effort focused on Visualization, System Integration and Modeling and Simulation Facility Planning. NG developed improvements and enhancements to the existing JSB-RD Viewer application to allow it to more effectively be used to evaluate and demonstrate advanced visualization and GUI techniques for theater-level situation awareness, integrated the enhanced JSB-RD Viewer application with the other major components of the JSB-RD federation, developed test and demonstration scenarios, and assessed how the existing JSB-RD system, and its individual components, could be used as the starting point for the development of a more complete C4ISR modeling and simulation environment.				
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1. INTRODUCTION

This final technical report summarizes the accomplishments and lessons learned under the Joint Synthetic Battlespace for Research and Development (JSB-RD) contract. JSB-RD is a distributed simulation environment that is intended to support advanced research and development of Air Force C4ISR systems at the Air Force Research Laboratory (AFRL), Rome Research Site (RRS). This work was performed by Northrop Grumman Mission Systems (NGMS) for the AFRL, C4ISR Modeling and Simulation Branch (IFSB), under Contract F30602-98-D-0318/0045. This report addresses CLIN 0002, CDRL A002 of that contract.

The overall goal of this effort was to develop a flexible Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) distributed modeling and simulation environment at the AFRL Rome Research Site. The JSB-RD synthetic battlespace addresses three objectives:

1. To provide a testbed for C4ISR research, experimentation, and evaluation, supporting AFRL C4ISR concepts and programs such as Predictive Battlespace Awareness (PBA), the Commander's Predictive Environment (CPE), Effects Based Operations (EBO), and the Advanced Technology Air Operations Center (ATAOC), and using communications infrastructures being developed by AFRL, such as the Joint Battlespace Infosphere (JBI).
2. To explore the synchronization of simulations to real-world situation data in order to predict future events, supporting concepts such as Dynamic Situation Awareness and Prediction (DSAP) and Course of Action (COA) Analysis.
3. To support research into simulation science, particularly in the areas of adversarial modeling, information management, and visualization.

The JSB-RD distributed simulation environment was constructed primarily by integrating existing simulations and tools. The JSB-RD environment is centered around the Joint Semi-Automated Forces (JSAF) simulation software. JSAF is a computer generated forces (CGF) system that is used by the U.S. Joint Forces Command for joint experimentation. The JSB-RD environment also includes the Ocean, Atmosphere, and Space Environmental Services (OASES) system, which models weather, and the Dynamic Terrain Simulation (DT-SIM), which models changes to the environment such as bomb craters, damage to buildings, and the creation and destruction of obstacles, as well as a clutter simulation, which models civilian traffic. The environment also includes tools for creating scenarios from existing Air Battle Plans, extracted from the Air Operations Data Base (AODB) with the Theater Battle Management Core System (TBMCS), as well as gateways for connecting simulations communicating using DMSO's High Level Architecture (HLA) and/or the earlier Distributed Interactive Simulation (DIS) protocol, with C4ISR systems, using AFRL's JBI.

Section 2 describes the JSB-RD environment in more detail. Section 3 summarizes the lessons learned in the course of performing this effort, including recommendations for subsequent related work. Section 4 contains a list of acronyms.

2. JSB-RD DISTRIBUTED SIMULATION ENVIRONMENT

As noted above, the JSB-RD distributed simulation environment consists of a number of components, which are connected together using several different mechanisms. Fundamentally, the environment is an HLA federation made up of simulations that communicate using a variation of the Millenium Challenge 2002 (MC02) Federation Object Model (FOM). Simulations that still use the DIS protocol can be connected through a DIS-HLA gateway federate. Similarly, an HLA-JBI gateway allows the federation to communicate with C4ISR system component prototypes being developed at AFRL.

2.1 Overall Architecture

The overall architecture of the JSB-RD distributed simulation environment is shown in Figure 2.1. It consists of three primary components, addressing each of the three primary aspects of any simulation environment. At the bottom, the Preparation component addresses experiment planning, scenario preparation, and all other aspects of preparing a simulation experiment. This includes accessing, extracting, and manipulating various kinds of source data, including Air Battle Plan (ABP) and Friendly Air Order of Battle information contained in the AODB, and Enemy Order of Battle (EOB) information contained in the MIDB, as well as geospatial data.

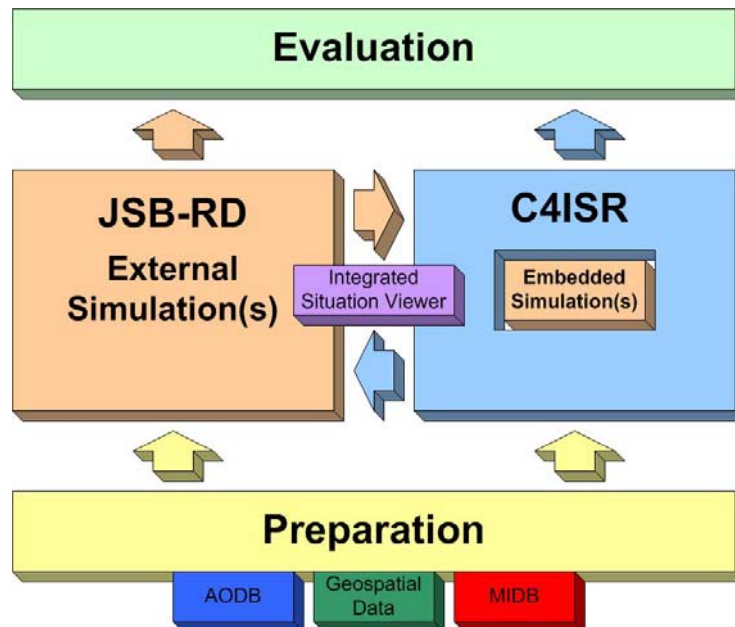


Figure 2.1. JSB-RD Overall Architecture

In the middle are the components that address the execution phase of a simulation experiment. These consist of the various simulations that make up the JSB-RD environment, as well as real C4ISR systems, system components, or prototypes. Note that the C4ISR component can also include an embedded simulation within it, used for COA analysis or other forms of prediction. The simulation and C4ISR components communicate with one another in both directions. The

status of friendly entities, and of visible opposing entities, and the effects of any relevant scenario events, are reported by the simulation to the C4ISR system, via various modeled sensor and communication systems. As the C4ISR system issues commands, they are passed back to the simulated entities that are to carry them out. In the center, visualizing both the simulation and C4ISR information, either separately or together, is the Integrated Situation Viewer application.

At the top, the Evaluation component provides a collection of tools for analyzing data produced by both the simulation and C4ISR systems. This component addresses the post-execution aspects of a simulation experiment. It is currently the least developed part of the JSB-RD environment.

2.2 JSB-RD Components

The components of the JSB-RD distributed simulation environment are shown in Figure 2.2. JSAF, OASES, and several supporting simulations make up an HLA federation. The HLA/XML Gateway translates the federation message traffic into an XML stream that can be easily read by a variety of applications. One such application is the Integrated Situation Viewer, which receives and displays entity state and interaction information. The Simulation Preparation tool extracts Air Battle Plan and Friendly Order of Battle information from the AODB, and Enemy Order of Battle information from the MIDB, which it then uses to generate a scenario input spreadsheet that can be read by JSAF to create and task the necessary simulation entities. The Simulation Preparation tool also interfaces with an aircraft route-planning tool created at AFRL to generate more realistic air mission flight paths that avoid known threats.

2.2.1 JSAF

JSAF is currently the primary simulation used within the JSB-RD environment. As noted above, JSAF is an entity-level, computer generated forces (CGF) simulation system that is used by the U.S. Joint Forces Command for joint experimentation, by the U.S. Navy for Fleet Battle Experiments, and by the AFRL Human Effectiveness Directorate (AFRL/HE) in support of the Distributed Mission Training (DMT) program. JSAF provides entity-level simulation of ground, air, and naval forces. In support of the joint experiment Urban Resolve, it has been used by JFCOM to simulate more than 100,000 entities within a single distributed simulation. It has also been used to support a variety of experiments with environment simulation, including dynamic terrain (i.e., craters, trenches, etc.), weather, and chemical/biological warfare defense, as part of DMSO's EnviroFed program. JSAF was originally developed by DARPA as part of its Synthetic Theater of War (STOW) program, and is descended from ModSAF. It is currently maintained by the Joint Forces Command (JFCOM). It incorporates intelligent agents, due to the Soar program, that autonomously control simulated fixed wing aircraft.

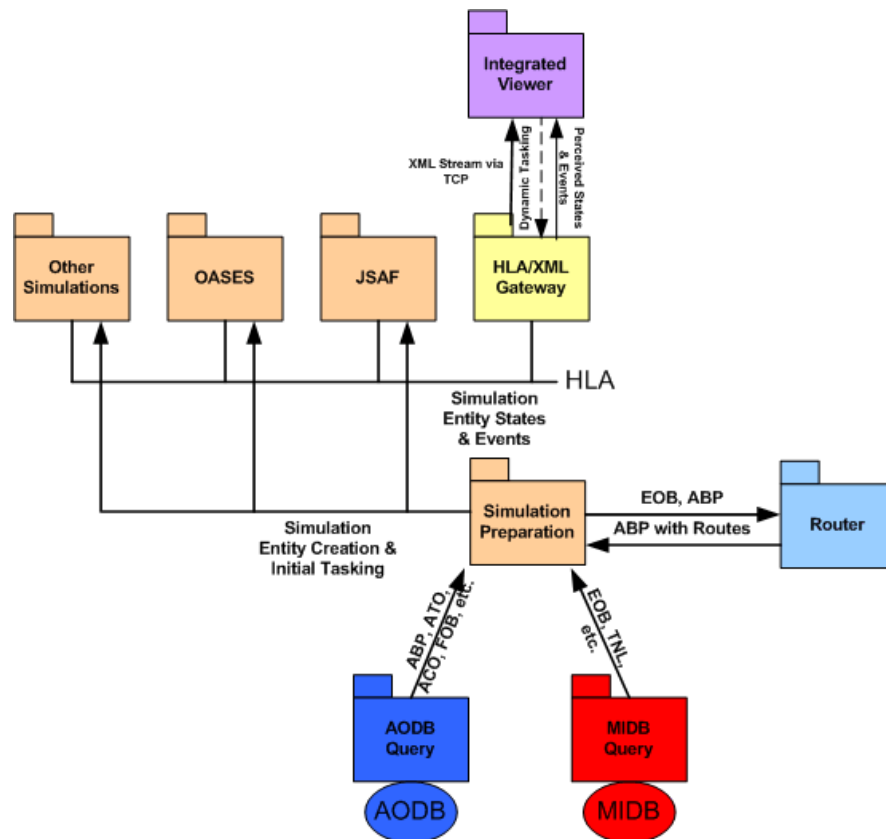


Figure 2.2. JSB-RD Components

JSAF is an extremely large software application. It was originally developed more than 15 years ago, in C, and has been extensively modified and extended. As a result, its original architecture has been almost completely obscured. It now consists of more than 1000 object libraries that model different types of platforms, weapons, sensors, etc. While it contains a great deal of powerful simulation functionality, it is difficult to use, and even more difficult to modify. Documentation and support are both extremely limited.

JSAF runs under the Linux operating system. In the JSB-RD environment, JSAF can be run on multiple (currently up to nine) Linux systems simultaneously. The individual copies function together as a single HLA federate, keeping their separate internal database copies in synchronization, and sharing the computational load.

The primary input to JSAF is a spreadsheet file that defines a collection of entities, both friendly and enemy, to be created, and specifies how each entity is to be tasked. Entity types, initial locations, call signs, and assigned tasks are identified. Such spreadsheets can be prepared by hand. However, they can also be automatically generated from Air Battle Plan information, supported by Friendly and Enemy Order of Battle information, extracted from the AODB and MIDB within TBMCS.

JSAF scenarios can also be created interactively, using its integral Unit Editor. Individual entities and small units can be created, placed on the Plan View Display, and assigned tasks to perform. Interactively created scenarios can be saved and (re)loaded. However, such scenarios and the scenario spreadsheets are two separate mechanisms, and cannot be readily combined. There is currently no mechanism that allows JSAF entities to be tasked by other federates.

JSAF is capable of receiving and processing several types of information via HLA. This includes entity state information output by other simulations within the federation. For example, JSAF reads the states of civilian vehicles and pedestrians that are modeled by the clutter simulation, and displays them on the JSAF Plan View Display. Any such external entities are visible to the JSAF-controlled entities; they can be detected, fired at, collided with, etc. JSAF also reads the weather state information output by OASES, although most platform and equipment models within JSAF do not make use of such information. JSAF also reads messages describing changes to the terrain that are output by DT-SIM. Such dynamic terrain changes (e.g., the appearance of a bomb crater) can affect the movement of ground vehicles in JSAF.

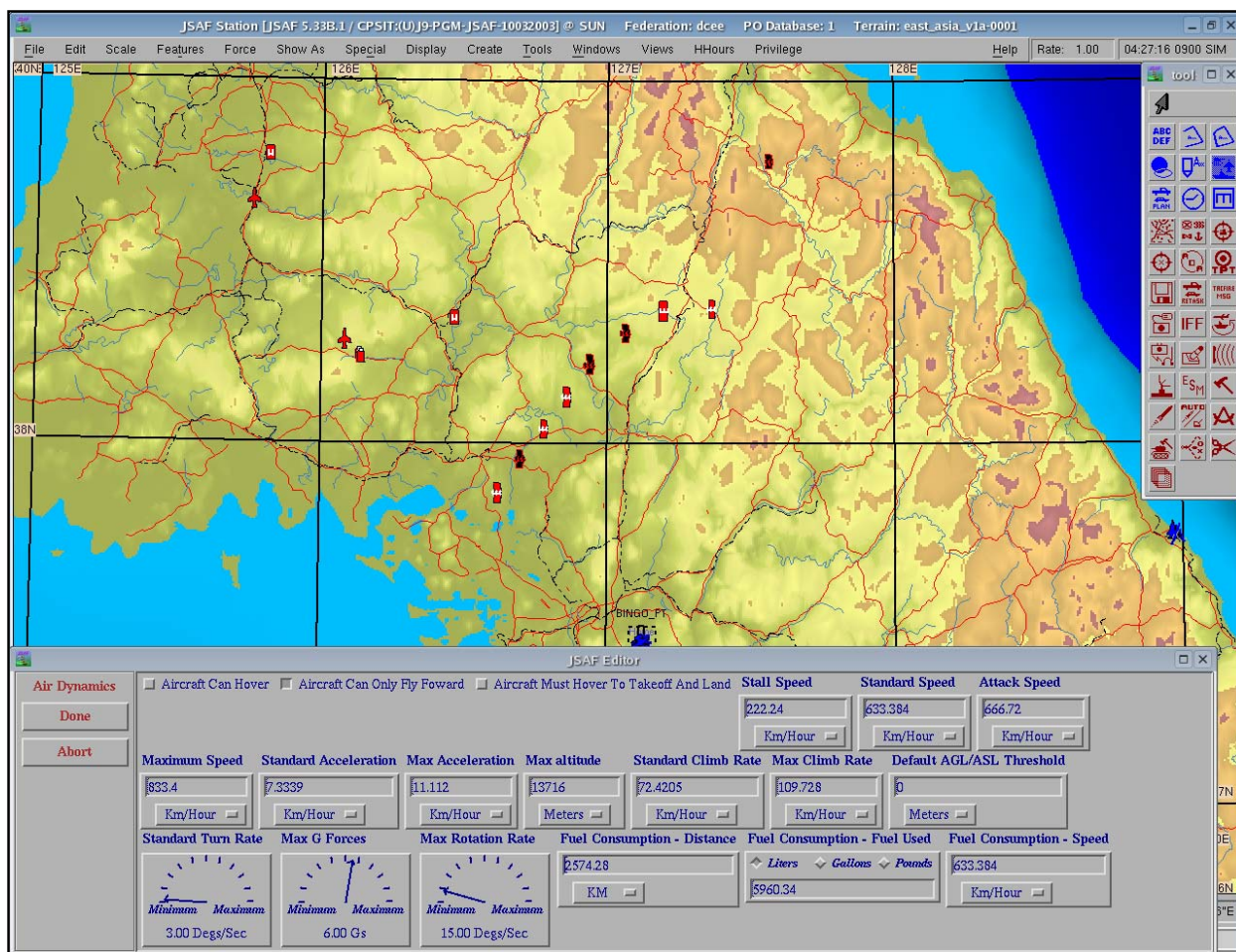


Figure 2.3. JSAF Plan View Display with Air Dynamics Editor

The primary output of JSAF is entity state information for all of the entities that it models. It also outputs various types of interactions, including weapons fire and detonation, collision, etc. In support of various exercises and experiments, JSAF has been extensively modified to support additional FOMs. It includes an extensive FOM agility layer. Many of its outputs are platform- or weapon-system specific.

Figure 2.3 shows the JSAF Plan View Display (PVD), with a map background (in this case showing terrain elevation and roads) and various platform-level icons. The toolbar at the upper right provides access to a variety of tools for creating, tasking, and otherwise manipulating the simulated entities. The window at the bottom shows the Aircraft Dynamic control panel, which can be used to manipulate the flight and fuel consumption characteristics of a particular aircraft. Multiple copies of the JSAF PVD can be run simultaneously. Commonly, some JSAF GUIs are configured as controller workstations, which see and can manipulate all entities, while others are configured as “player” workstations, which can see only their own forces, as well as any enemy forces that have been detected.

2.2.2 OASES

The OASES system is a suite of applications for creating and managing a three-dimensional, time-varying, digital representation of the natural environment. OASES has been used primarily to provide natural environments (SNEs) to systems of networked military training simulations running on the Department of Defense’s (DoD) High Level Architecture (HLA). The simulated natural environments created by OASES are based on authoritative, validated numerical models, typically the same models that are used by METeorological/OCeanographic (METOC) personnel in support of real-world military operations. OASES provides tools for converting authoritative model outputs to a data format recognized by all of the OASES applications. This format supports the data access requirements of distributed simulations that integrate virtual and/or live entities and which must operate in real-time. Additionally, OASES provides tools for tailoring the SNE, either before the simulation begins or while it is running, to meet exercise-specific requirements for environmental phenomena.

The original development of the OASES system was sponsored by the Defense Advanced Research Project Agency (DARPA), under the name TAOS (Total Atmosphere Ocean Services), in support of the Synthetic Theater of War (STOW) 1997 Program. In 1998, DARPA funded the development of a low-resolution worldwide atmospheric and oceanographic database, also known as the *Global-98* database, for use by the JSIMS program. In 1999, the United States Space Command’s (USSPACECOM) Space Warfare Center funded extensions to TAOS to support the space environment, specifically ionospheric effects on precision-guided missiles, as part of the PSM+ (extended Portable Space Model) project. More recently, funding for continued development and integration with the HLA, under the name OASES, has been provided primarily by DMSO through the Environment Federation (EnviroFed) projects.

Figure 2.4 shows the OASES subsystems and the data flows among them. OASES converts current and forecast environmental data, provided by physics-based operational and research models, into a form that can be used by distributed simulations running on the HLA.

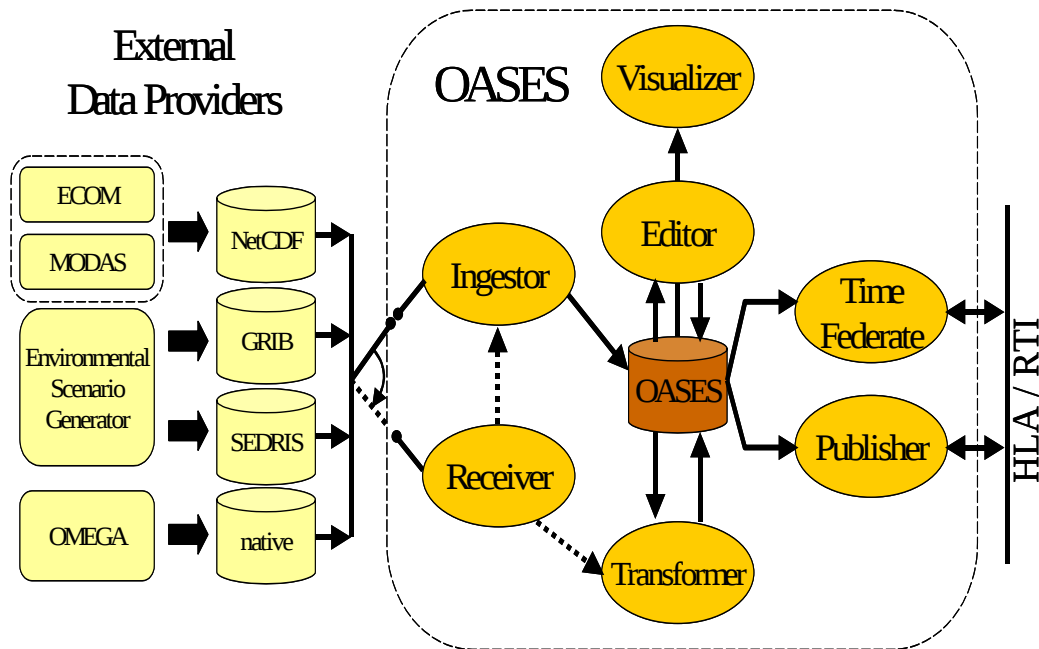


Figure 2.4. OASES Organization

The OASES system consists of five primary subsystems. The OASES Ingestor converts all input model data to a common run-time format that is recognized by all OASES subsystems. The external data providers are identified in the rounded-rectangles on the left side of the figure. The OASES Transformer uses a set of transformation algorithms to augment existing OASES databases with various environmental parameters that are not provided directly by an external data source, but that are required by the simulations served by OASES. The OASES Editor allows users to tailor the contents of an OASES database. The Editor provides three editing algorithms: 1) replacement at a point with gaussian spatial and temporal blending, 2) a Pressure Field Modification (PFM) algorithm for editing atmospheric environments while preserving correlation between temperature, pressure, wind and relative humidity, and 3) a precipitation editing algorithm. The Editor can be used to prepare scripted changes to an existing METOC scenario, or it can be used at run-time to modify the SNE during a simulation exercise. The OASES Time Federate and Publisher are the subsystems that interface directly to the HLA Federation; that is, they are the OASES *Federates*. They create and update the objects that encapsulate the state of the simulated natural environment via services provided by the RTI. The Time Federate creates objects that establish the time-dependence of the SNE while the Publisher manages objects that encapsulate its spatial-dependence.

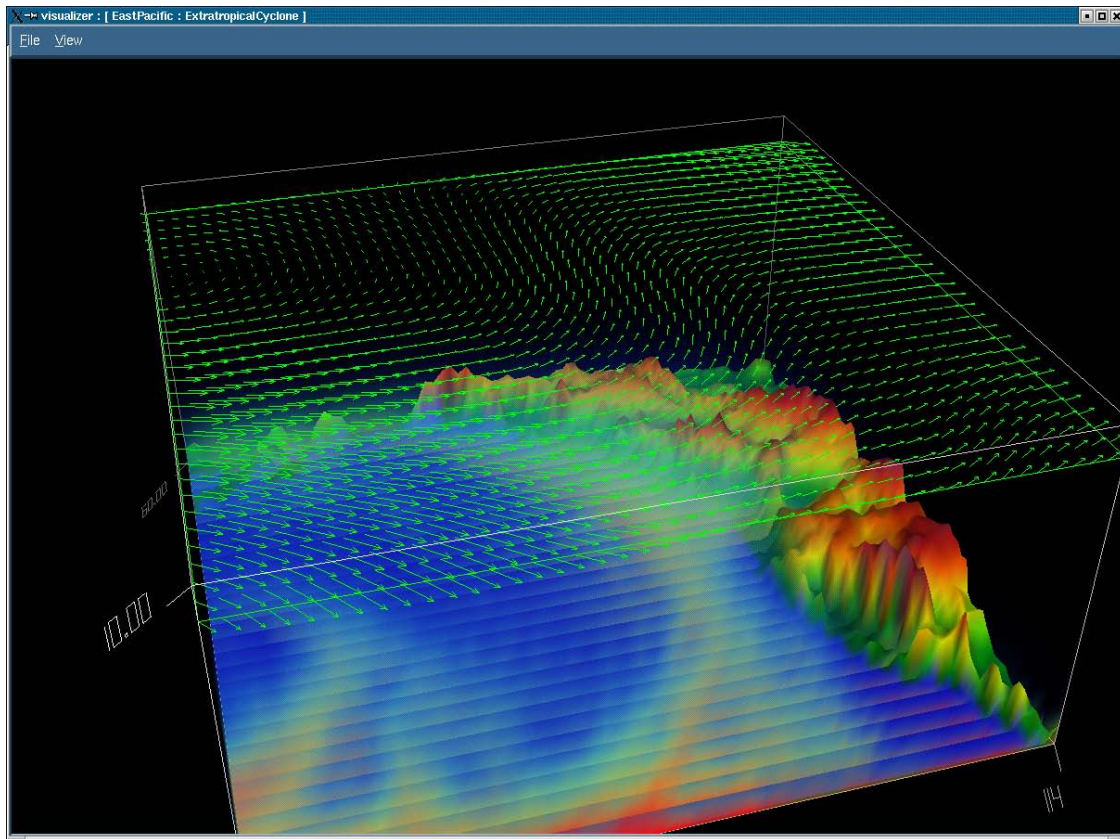


Figure 2.5. OASES Weather Visualization

The OASES Visualizer is a tool for visualizing the contents of an OASES database. It is used to validate databases built by the Ingestor and/or extended by the Transformer, to review the results of edits applied by the OASES Editor, to monitor the current state of the SNE created by the Publisher, and/or to monitor the current state of the SNE as received by the OASES Subscriber. An example of an OASES Visualizer display is shown in Figure 2.5.

Finally, the OASES Receiver is responsible for polling local or remote data sources, using the Internet File Transfer Protocol (FTP), for environmental data transmittals matching a user-specified file-naming pattern. The Receiver is the subsystem that supports the “Live Mode” of OASES, in which the simulated natural environment is continuously updated based on the data received from current and forecast environmental models running in real-time.

Within the JSB-RD environment, OASES is used to bring in weather information from Air Force and Navy sources. OASES outputs weather state information, including temperature, pressure, and precipitation information, in one-dimensional (profile), two-dimensional (surface), and three-dimensional forms, over HLA. This information is read by JSAF and DT-SIM, which use it to modify some military operations, and to implement changes to the terrain database, respectively.

2.2.3 DT-SIM

The Dynamic Terrain Simulation (DT-SIM) models changes to the terrain component of the environment. The changes result from various types of simulation events, including weapon detonations, movement, weather effects, and military engineering operations, such as the creation and destruction obstacles. DT-SIM receives interaction events from JSAF, and determines what effect, if any, they have on the geometry or attributes of the terrain at the location event. For example, when DT-SIM receives a weapon detonation interaction from JSAF, it may, depending on the type of the weapon and its proximity to the terrain surface, or a specific terrain feature, determine that a crater should be created, or that a building should be damaged. DT-SIM updates its internal terrain representation, and publishes messages over HLA describing how the terrain has changed. These messages are used by JSAF to update its terrain representation, which in turn affects how some activities are carried out. For example, the appearance of a new crater may change the movement of vehicles to avoid it. Weather effects, such as prolonged rain, may also change the characteristics of the terrain, restricting the speed of cross-country movement.

2.2.4 Clutter Simulation

The clutter simulation, which is part of the JSAF distribution, models the movements of civilian vehicles and pedestrians. The amount and type of clutter is specified using clutter templates. Each template specifies a list of entity types with associated relative weights, as well as a collection of control points. Each control point specifies a center location, a radius (defining a circular area), and a number of clutter entities. Each control point is identified as defining a static clutter area, a mobile clutter area, a clutter source, or a clutter sink. Clutter entities move randomly within a static clutter area. Sources and sinks allow dynamic traffic flows to be created. Clutter entities are randomly created in the source areas, and move to random locations within a sink area. When they arrive, they are destroyed and replaced with a new entity in one of the source areas. The clutter simulation publishes entity state information for each of the clutter entities as they move.

2.2.5 MC02 Federation Object Model

The JSB-RD simulation environment currently uses a version of the Millenium Challenge 2002 (MC02) federation object model (FOM). The MC02 FOM is based on the Realtime Platform Reference (RPR) FOM, which was designed to map the original DIS protocols into an HLA environment. The MC02 FOM includes a number of objects and interactions that were added to support specific aspects of the Millenium Challenge 2002 exercise. Most of these are not used within the JSB-RD environment. The elements of the MC02 FOM that are currently used include:

- the BaseEntity/PhysicalEntity/Platform class, primarily the GroundVehicle and Aircraft subclasses,
- the Atmosphere, SurfaceWeather, and Weather classes, and their various subclasses, and
- the Collision, Weapon Fire, and Munition Detonation interactions.

The JSB-RD environment conforms to the MC02 Federation Agreements, Spiral 3-10, May 2002.

2.2.6 Integrated Situation Viewer

The Integrated Situation Viewer, commonly referred to simply as “the Viewer”, is intended to support experimentation with theater-level air mission situation awareness and dynamic retasking. The Viewer displays simulation state information describing air missions, which is, in effect, ground truth, and the corresponding Air Battle Plan information, as well as any information (derived from the simulation) that reflects the reported or perceived current situation, as output by various sensor models. In its current form, the Viewer consists of a number of loosely coupled components. Figure 2.6 shows the architecture for the Viewer, which is based on the classic Model-View-Controller paradigm.

The back-end portion of the Viewer consists of a collection of components that are capable of reading data from various sources. Simulation entity state and event data output by JSAF, OASES, DT-SIM, and other simulations is read via an HLA-to-XML gateway. This gateway converts entity state information received over HLA into a stream of XML messages. It also performs coordinate conversion (from the geocentric coordinates used by the MC02 FOM to geodetic coordinates), and partial translation of the DIS Entity Bit Vector (EBV) fields that are used to hierarchically identify entities by nationality, domain, type, subtype, etc. Other data sources, including JSAF input spreadsheets, are read directly from the appropriate files.

The “heart” of the Viewer consists of an integrated domain model that stores and maintains information on air mission plans, individual aircraft, and their targets. The data read from the various back-end sources is used to populate and update this model.

The front-end of the Viewer consists of multiple views of the information that the domain model contains. Several types of views are supporting, including:

- Map views – displaying the locations of aircraft and targets, planned and actual flight paths, etc., overlaid on a map background, at multiple scales and resolutions, using the JView visualization toolkit developed by AFRL/IFSB (see Figure 2.7),
- Tabular views – listing entities of various types (aircraft, targets, missions, etc.) and their relevant characteristics, and capable of being sorted and ordered in various ways,
- Text views – displaying a streaming list of text messages, generated by the Simulation Network News (SNN) utility, which is part of the JSAF distribution.

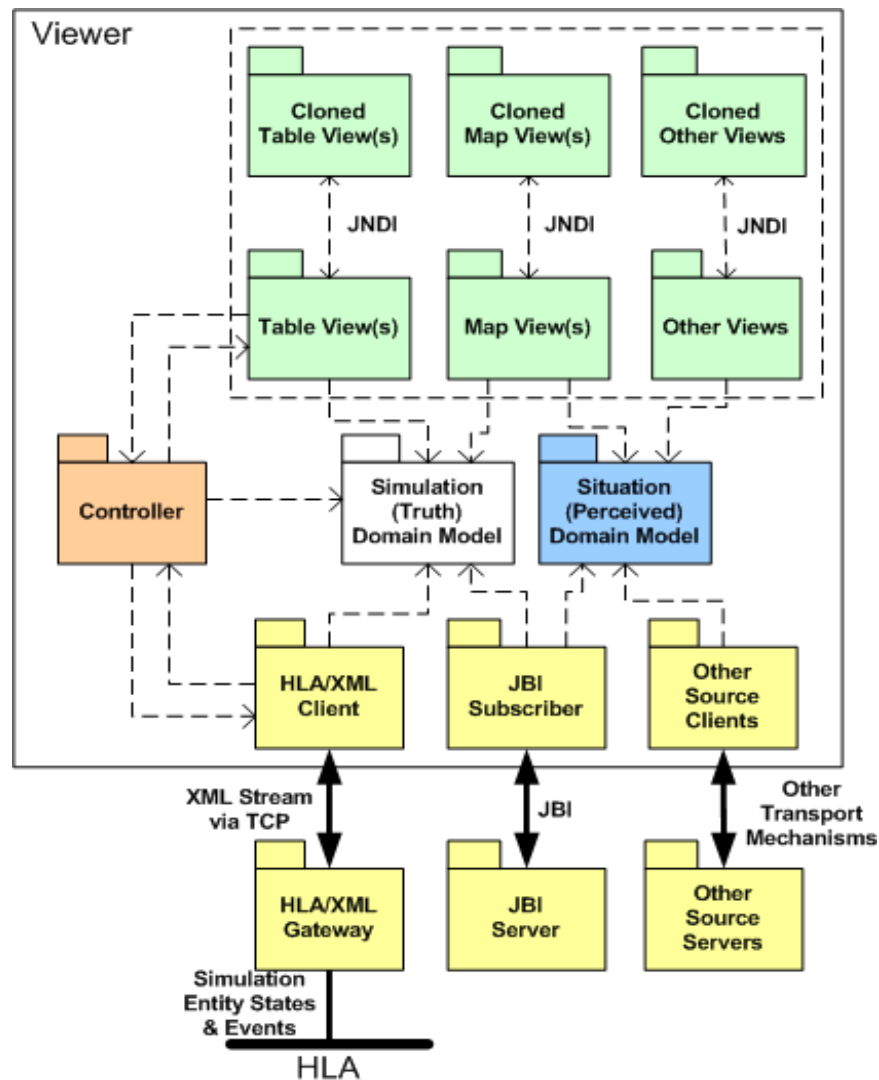


Figure 2.6. Viewer Architecture

The Controller is the “brain” of the Viewer, coordinating all of the other components. When new information arrives from one of the sources, the Controller triggers the updating of the domain model, and then the updating of all views that are affected by the change. Similarly, when the interactively changes a piece of information in one of the views, the Controller triggers the updating of the domain model, and then the updating of any other views that are affected by the change. The Controller also coordinates the selection of entities and locations across all of the views, so that an entity that is selected in one of the views is also highlighted in all other views in which it appears. A Controller GUI allows the user to select which types of views should be displayed, and what the content of each should include.

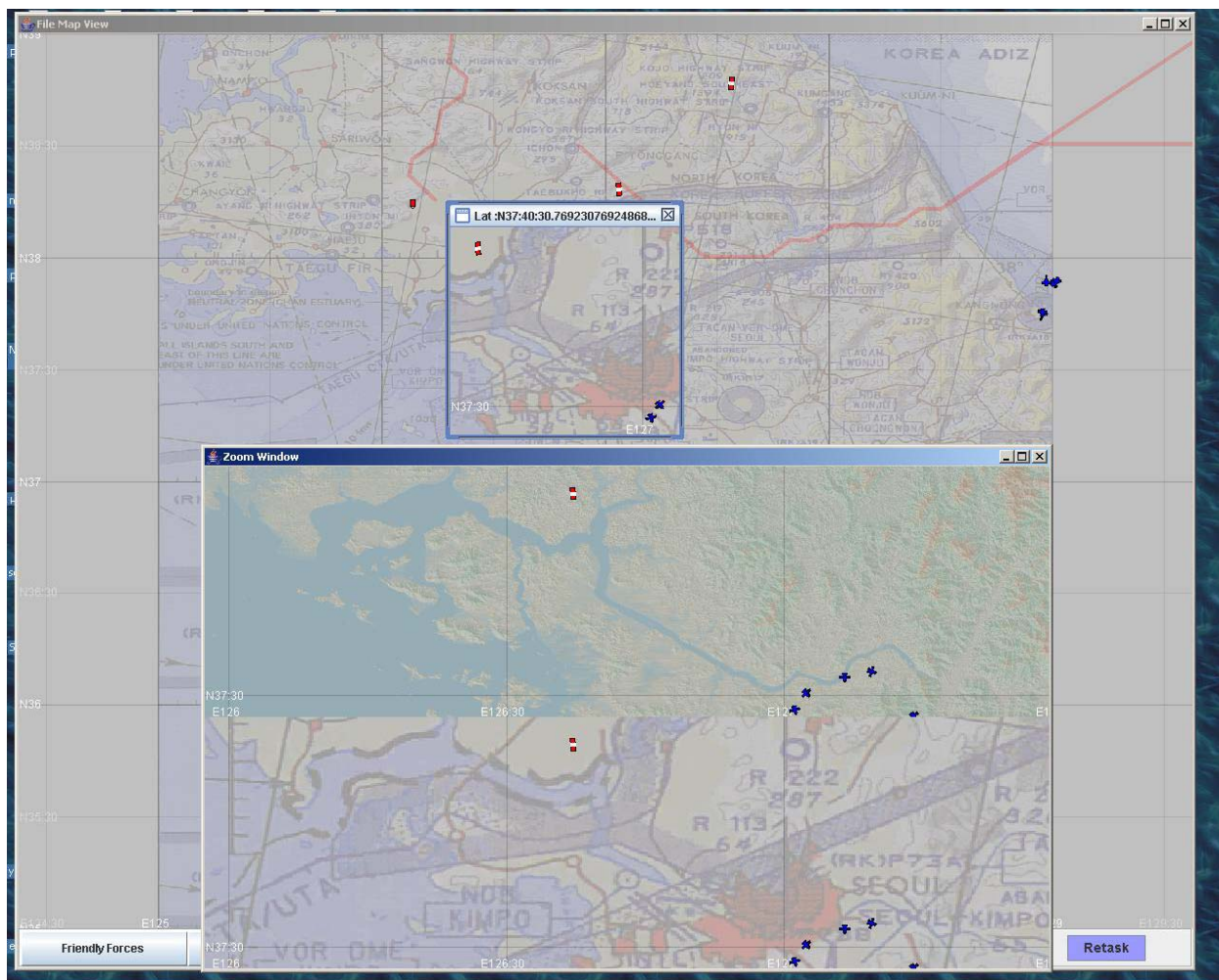


Figure 2.7. Viewer Map View

A planned enhancement to the Viewer will make use of a custom implementation of the Java Naming and Directory Interface (JNDI), developed by AFRL/IFSB, to allow views to be “cloned” across multiple workstations and monitors.

2.2.7 Simulation Preparation

The Simulation Preparation component of the JSB-RD environment allows existing Air Battle Plans (ABPs) contained within the Air Operations Data Base (AODB) of the Theater Battle Management Core System (TBMCS) to be converted into sets of JSAF input spreadsheets that can be executed using JSAF. This component extracts a specified ABP from the AODB, which contains specifications of multiple air missions of various types. Each mission specification includes the numbers and types of aircraft involved in the mission, their takeoff and return times and bases, and a sequence of key mission events. These mission events include takeoff, refueling (start and end), time on target (start and end), and landing. Ground attack missions

also identify their targets. Supporting information describing the mission targets is extracted from the MIDB.

The basic mission information, along with a list of the air defense threats in the area, can be fed to a separate Routing application, which determines the “best” route for each mission to and from its assigned target while avoiding air defense threats. The returned route contains a number of intermediate waypoints that the aircraft should pass through on the way to and from their target.

This information is then used to generate a JSAF input spreadsheet. The spreadsheet contains two entries for each scheduled air mission, one describing the ingressing leg of the mission, and the other describing the return leg. Each entry specifies, in JSAF terms, the number and type of aircraft, the call sign(s) of the aircraft, the type of task to be performed, the take off and return times, and the base and target locations. A second spreadsheet contains the intermediate route points, linked via the call signs.

3. LESSONS LEARNED

This section summarizes the lessons learned during this effort. The key accomplishments achieved under this effort include:

- development of limited capabilities to extend and modify JSAF,
- development of a capability to use JSAF to execute Air Battle Plans extracted from the TBMCS Air Operations Data Base,
- development of the HLA-to-XML gateway to translate distributed simulation message traffic over HLA into a stream of XML messages,
- separation of the Viewer into a collection of loosely coupled components using the classic Model-View-Controller paradigm.

Each of these discussed in the subsections below. Finally, conclusions and recommendations are given.

3.1 JSAF Modification

JSAF is not a packaged software product. There does not appear to be an active JSAF user/developer community, with mailing lists, news groups, and other such resources, where newer users can go to find answers to their questions. There is no JSAF help desk, or any other similar type of support mechanisms. JFCOM J9 maintains a staff of more than 30 developers who are constantly modifying and extend JSAF to meet the requirements of an ongoing series of simulation experiments. Although the JSAF development staff has been helpful in finding answers to some questions, supporting external users of JSAF is not a high priority.

With help from the JSAF developers, we have learned to make several minor types of additions. These include:

- Adding a new type of platform/vehicle,

- Adding new components to an existing platform/vehicle,
- Adding a new type of military unit,
- Adding a new high-level taskframe for an air mission,
- Changing the values of parameters associated with a platform/vehicle or high-level task frame.

The JSAF software appears to contain an impressive degree of functionality. However, closer examination reveals that much of the functionality that appears to be present is difficult or impossible to access. JSAF has been modified extensively over the years to meet specific needs of particular exercises and experiments. It appears that many of these modifications were never completed, or never worked successfully, but they remain in the JSAF software distribution. In some cases, it appears that capabilities were added at one point, but were later incompletely removed, leaving unused entries in data files, etc. For example, under this effort the existing Link-16/TADIL-J communications functionality within JSAF was investigated. JSAF contains a number of software libraries that appear to support this functionality, as well as data elements. The MC02 FOM includes messages that describe Link-16 radios and TADIL-J messages. We ran several experiments attempting to use aircraft, as well as surface ships, equipped with Link-16 components. However, we were never able to observe any communication between these platforms, or any sharing of the awareness of targets being detected by other platforms within a Link-16 network.

JSAF does a reasonable job of simulating the movement of physical entities from one location to another. It also does a reasonable job of simulating many types of individual weapons and the related combat activities. It can model tactical aircraft and simple air missions adequately. Although it does model some types of sensors, including the detection of targets, it does not model the tracking or reporting or dissemination of information resulting from sensor detections to other entities. It does not model most ISR assets (e.g., AWACS, JSTARS, UAVs) with useful realism. It should be noted that for the current Urban Resolve experiment, JFCOM J9 did not use JSAF for sensor modeling, but instead relied on the expensive COTS software package SLAMEMTM (Simulation of the Locations and Attack of Mobile Enemy Missiles) from Toyon Research Corporation.

The JSAF software distribution is extremely large and complex. It now consists of more than 1000 individual object libraries. A complex web of dependencies connects these libraries to one another. The JSAF software is primarily written in ANSI C, but has a complex object-based structure that simulates inheritance and aggregation relationships among libraries. Extensive configuration script and reader (i.e., data) files further add to this complexity. This complexity makes the JSAF software extremely difficult to understand. JSAF documentation is extremely limited. Many of the libraries have no documentation whatsoever.

JSAF has two interfaces for creating scenarios. One is the interactive Unit Editor, which allows military units and platforms to be created, placed on the Plan View Display, and given tasks. Once created, scenarios can be saved to files, for reloading later. The second interface is the Spreadsheet mechanism, which allows spreadsheets specifying air mission information to be

read in, from which the necessary aircraft are created and then tasked. Spreadsheets can also be written out, but without any tasking information. Oddly, there is very little overlap between the aircraft tasks that can be assigned using these two mechanisms. Tasks that can be assigned interactively using the Unit Editor generally cannot be assigned using the Spreadsheet mechanism, while the mission types that can be assigned using the Spreadsheet mechanism cannot be assigned using the Unit Editor. The Unit Editor also offers a number of interactive commands (e.g., Fly Higher/Fly Lower) that cannot be accessed through other mechanisms. In particular, there is no mechanism that allows military units to be tasked via an HLA message from another federate.

3.2 JSAF Scenario Preparation

The ability to extract an Air Battle Plan from the TBMCS Air Operations Data Base, along with supporting target information from the MIDB, and generate a JSAF input spreadsheet that can be used to execute those air missions, is a very powerful tool. When used in conjunction with a realistic mission route generator that takes into account known air defense threats, it provides an even more important capability.

However, there are currently several limitations to this capability. Currently, this requires multiple queries of AODB and MIDB tables, followed by the joining of these tables. It would be convenient if this information could be easily queried via JBI by specifying an Air Battle Plan name. It would also be nice if a list of the Air Battle Plans contained within the AODB was easily accessible.

There are also several issues concerning the translation of ABP information into JSAF input. AODB aircraft types must be translated into corresponding JSAF entity types. The necessary JSAF entities are created for each specified air mission. This makes it difficult for a particular aircraft to fly multiple missions in sequence. ABP mission numbers are not used by JSAF. Instead, the call signs for each mission in the ABP are augmented with unique numeric IDs, and are inserted into the “markings” field of the JSAF entities. These call signs are not always unique. The mission types specified in the ABP must be translated into JSAF air mission task frames. Currently, the task frames used are Interdiction/Attack Ground for strike missions, FWA Hold for orbiting (including CAP, tankers, etc.), and Return to Base. Finally, the route points that can be entered into JSAF are two-dimensional (latitude-longitude). Altitude is specified indirectly, as a parameter of the top-level task frame. This makes it difficult to specify mission profiles that depend on variations in altitude.

3.3 HLA-to-XML Gateway

The HLA-to-XML gateway allows multiple applications, such as the Viewer, to access the stream of information coming out of the simulations without having to deal with the complexities of HLA. However, the HLA-to-XML gateway currently has several limitations. It currently provides only entity state information. It does not currently publish MC02 FOM interactions, such as collisions, weapon fire, and munition detonation events. The entity state information is published as a simple sequence of entity states. However, these are not time stamped; they are simply provided “in real-time” as they are received. Also, the translation of

entity state fields is currently limited to coordinates, force identifier, and damage state, leaving the application to deal with the more difficult translation of the seven EBV fields that identify the type of the entity. Finally, the HLA-to-XML gateway currently operates in only one direction. Therefore, it only supports “receive-only” federates. Any HLA messages that an application needs to send back to the simulation to, for example, retask an aircraft, must use another mechanism.

3.4 Viewer Architecture

The reorganization of the Viewer into a collection of loosely coupled components has significantly enhanced its long-term potential to incorporate a wide variety of visualization and interaction techniques. However, in the short term, this reorganization has resulted in the loss of some capabilities that previously existed within the Viewer. Three-dimensional views are no longer included, though they could be easily restored. Support for retasking has also been lost, though this is primarily due to the replacement of Interactive Suppressor with JSAF as the primary simulation component within the JSB-RD simulation environment.

Also, the current Scenario Preparation implementation, which extracts data from the AODB and MIDB and generates a JSAF input spreadsheet in a single integrated step, makes it difficult for the Viewer to access the original source data without re-extracting it from the AODB and MIDB.

3.5 Conclusions and Recommendations

The conclusions and recommendations resulting from this effort are summarized below:

1. JSAF has been used successfully by a number of large programs, including Joint Strike Fighter (JSF), EnviroFed, and Distributed Mission Training (DMT), and the use of JSAF facilitates the development of a closer relationship between AFRL and JFCOM. However, JSAF is not very suitable for use within a small, dynamic laboratory environment. It requires a large, highly trained, and highly skilled staff to maintain, to operate, and especially to modify or extend it. Extending or modifying the JSAF software in support of a specific simulation experiment is difficult and time-consuming. Although it can be integrated with other existing tools and C4ISR systems, this is not easy to accomplish. Continued use of JSAF within the AFRL/IFSB modeling and simulation laboratory will require a significant commitment to develop and maintain a skilled and experienced staff.
 - a) Obtain and install the current version of JSAF (Version 6). In this new version, aircraft of all types have been converted to a new, more realistic flight dynamics model. The clutter simulation has also been significantly improved in support of the Urban Resolve exercise.
 - b) Continue to investigate the JSAF software and to learn how to modify and extend it. This includes:
 - i) Extending the spreadsheet input mechanism to support additional types of air missions.

- ii) Learning to create new air mission task frames, and to modify existing air mission task frames.
 - iii) Learning how to extend the existing interactive tasking interface to support the tasking and retasking of entities from external applications, such as the Viewer.
 - iv) Learning how to define new object and interaction messages to be output by JSAF, and to modify existing output messages.
- c) Consider augmenting the use of JSAF with other, more modern entity level simulations, such as JIMM and/or EADSIM. Copies of these simulations should be obtained, installed, and evaluated with respect to their usability and flexibility.
- 2. Extend the Scenario Preparation software to publish the Air Battle Plan and associated order of battle information in XML form, unless this information can be obtained directly in XML form using TBMCS version 1.1.3. This information can then be input by the Viewer, allowing the planned missions to be compared with the actual execution of those missions.
- 3. Improve the XML-to-HLA gateway to support MC02 FOM interactions including weapon fire and munition detonation, takeoff and landing, and entity removal, and to add a time stamp to the XML representation of each published HLA message.
- 4. Enhance the Viewer to display additional air mission-related information, and to display information in additional forms. This includes:
 - a) Display of MC02 FOM interactions, including weapon fire and munition detonation, and takeoff and landing, as well as entity removal.
 - b) Display of planned mission information from the Air Battle Plan, and graphical comparison of planned mission states with actual mission states.
 - c) Three-dimensional views that can be attached to a specific aircraft or group of aircraft.
 - d) Vector map data (e.g., VMap Level 0, 1, or 2) overlaid on terrain elevation data.
 - e) Time line/Gantt chart type displays showing planned and actual mission event (takeoff, on target, return, etc.) times.
 - f) Addition of improved controls for customizing individual views, as well as creating, naming, storing, and retrieving collections of views including view configuration (i.e., window size and placement) information.
- 5. Publish simulation events that correspond to planned mission events, including takeoff and landing, weapon fire and munition detonation, start and end of refueling, etc., via the HLA-to-JBI gateway, so that they may be accessed by CAOC-21 applications.

4. ACRONYMS

This section provides a listing of acronyms and their meanings as used in this document.

ABP	Air Battle Plan
AFRL	Air Force Research Laboratory
AOC	Air Operations Center
AODB	Air Operations Data Base
ATO	Air Tasking Order
ATAOC	Advanced Technology Air Operations Center
AWACS	Airborne Warning and Control System
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CADRG	Compressed ARC Digital Raster Graphics
CDRL	Contract Data Requirements List
CGF	Computer Generated Forces
COA	Course of Action
COTS	Commercial Off The Shelf
CPE	Commander's Predictive Environment
CRC	Control and Reporting Center
CSE	Common Simulation Environment
DARPA	Defense Advanced Research Projects Agency
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DMT	Distributed Mission Training
DoD	Department of Defense
DSAP	Dynamic Situation Awareness and Prediction
DTED	Digital Terrain Elevation Data
DT-SIM	Dynamic Terrain Simulation
EBO	Effects Based Operations
EBV	Entity Bit Vector
EOB	Enemy Order of Battle
ESC	Electronic Systems Command
FOM	Federation Object Model
FWAEE	Fixed Wing Aircraft Exercise Editor
GUI	Graphical User Interface
HE	Human Effectiveness Directorate (of AFRL)
HLA	High Level Architecture
IFSB	C4ISR Modeling & Simulation Branch
IF	Information Directorate (of AFRL)
IFT	Technology Division
JB	Joint Battlespace Infosphere

JEFX	Joint Expeditionary Force exercise
JFCOM	Joint Forces Command
JIMM	Joint Integrated Mission Model
JIPTL	Joint Integrated Prioritized Target List
JNDI	Java Naming and Directory Interface
JSAF	Joint Semi-Automated Forces
JSB	Joint Synthetic Battlespace
JSB-DS	Joint Synthetic Battlespace – Decision Support
JSB-RD	Joint Synthetic Battlespace for Research and Development
JSIMS	Joint Simulation System
JSTARS	Joint Surveillance and Target Attack Radar System
MAAP	Master Air Attack Plan
MARCI	Multi-system Automated Remote Control and Instrumentation
MC02	Millenium Challenge 2002
METOC	Meteorological/Oceanographic
MIDB	Modern Integrated Data Base
ModSAF	Modular Semi Automated Forces
NGMS	Northrop Grumman Mission Systems
NIMA	National Imagery and Mapping Agency
OASES	Ocean, Atmosphere, and Space Environmental Services
OPFOR	Opposing Force
PBA	Predictive Battlespace Awareness
PFM	Pressure Field Modification
PSM	Portable Space Model
PVD	Plan View Display
RPR	Realtime Platform Reference
RRS	Rome Research Site
RTI	Run Time Infrastructure
SAA	Situation Awareness and Analysis
SAM	Surface to Air Missile
SEDRIS	Synthetic Environment Data Representation and Interchange Specification
SNE	Synthetic Natural Environment
SNN	Simulation Network News
STF	SEDRIS Transmittal Format
STOW	Synthetic Theater of War
SWEG	Simulated Warfare Environment Generator
TAOS	Total Atmosphere Ocean Services
TBMCS	Theater Battle Management Core System

UAV	Unmanned Aerial Vehicle
USATEC	U.S. Army Topographic Engineering Center
USSPACECOM	U.S. Space Command
VMap	Vector Smart Map
VPF	Vector Product Format
XML	eXtensible Markup Language