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GLOBAL INFORMATION ENTERPRISE SIMULATION (GIESIM)

Prediction Systems Incorporated

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ROME, NEW YORK

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13. ABSTRACT *(Maximum 200 Words)*
The GIESim project was a simulation development program to define, design and implement a Modeling and Simulation (M&S) framework for the Global Information Enterprise (GIE). Within the GIESim framework users will be able to execute, via a common interface, multiple communications and network M&S tools to most effectively and efficiently analyze candidate communications architectures and technologies. GIESim can interface with other M&S tools (e.g., force-level simulations and detailed hardware system models) to provide the appropriate level of M&S fidelity and processing speed for the broad spectrum of M&S tasks. The GIESim user base will span from advanced technology researchers to communications network architects to mission planners. In FY04, the GIESim capabilities were merged into the Joint Semi-Automated Forces (JSAF) simulation in AFRL Rome in conjunction with the JSB-RD team. The central theme for the FY04 GIESim/JSB-RD merger was to add communications modeling capabilities to JSAF by interfacing GIESim communication modeling capabilities for faster and easier design, development and execution of GIESim simulations. This work resulted in the successful merger of GIESim/JSB-RD software, and the team can now demonstrate the addition of JTIDS tactical communications to JSAF using a modified version of the JTIDS simulation built by PSI. With the advent of this merger, JSAF now has tactical communications to support critical Network Centric Operations (NCO) and Warfare (NCW) needed for the future evolution of the Joint Enterprise including the AF C2 Constellation Net, Army/USMC LandWarNet, and the Navy/USMC FORCENet.

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Table of Contents

List of Figures

List of Tables

1.0 EXECUTIVE SUMMARY

The vision of the Global Information Enterprise (GIE) is to move, process, manage, and protect the C2ISR information that supports the functions of Global Awareness and Dynamic Planning and Execution. The mission of GIE is to link aerospace assets in-theater and globally, to integrate C2 & ISR networks, to defend critical information systems from cyber attack, and to develop new information processing and management techniques. Most large-scale force level simulations assume perfect communications. This can lead to significant limitations in the results obtained from running these simulations. Tools are needed to bridge these communications modeling gaps.

The GIESim project is a simulation development program to define, design and implement a Modeling and Simulation (M&S) framework for the Global Information Enterprise (GIE). Within the GIESim framework users will be able to execute, via a common interface, multiple communications and network M&S tools to most effectively and efficiently analyze candidate communications architectures and technologies. The GIESim can interface with other M&S tools (e.g., force-level simulations and detailed hardware system models) to provide the appropriate level of M&S fidelity and processing speed for the broad spectrum of M&S tasks. The GIESim user base will span from advanced technology researchers to communications network architects to mission planners.

In FY 2004, the GIESim AFRL/IFGC leadership team set the goal of expanding on and drawing upon the expertise and lessons learned in building the DTIG Multi-Simulation Demonstration (DMSD) built for the 2003 SAB Review. In FY04, the GIESim capabilities were merged into the Joint Semi-Automated Forces (JSAF) simulation in AFRL Rome in conjunction with the JSB-RD team. The central themes for the FY04 GIESim/JSB-RD merger were:

- The merger of the GIESim/JSB-RD software to add communications modeling capabilities to JSAF by interfacing GIESim JTIDS modeling capabilities. JSAF is a JFCOM program that is used extensively for war gaming and large, man-in-the loop exercises. However, JSAF does not include any communications modeling, and simply assumed that communications always worked.

- Faster and Easier design, development and execution of GIESim simulations.

Maintenance of a standing version of the GIESim SAB Demo was also a goal for FY04.

This work resulted in the successful merger of GIESim/JSB-RD software, and the team can now demonstrate the addition of JTIDS tactical communications to JSAF using a modified version of the JTIDS simulation built by PSI. With the advent of this merger, JSAF now has tactical communications to support critical Network Centric Operations (NCO) and Warfare (NCW) needed for the future evolution of the Joint Enterprise including the AF C2 Constellation Net, Army/USMC LandWarNet, and the Navy/USMC FORCENet. By virtue of the PSI Link-16 Network Management Tool Suite that our JTIDS is part of, JSAF can now participate in network operational planning in addition to tactical operations training and exercises.

2.0 INTRODUCTION

This final report reviews the work done by PSI in FY04 for AFRL Rome, NY. Accompanying this final report is User Simulation Documentation for the PSI portion of the GIESim/JSB-RD merger software.

2.1 Scope of Work

The scope of this report covers three GIESim work areas in FY04:

1) Integration of the modifications to the updated GIESim SAB Demonstration. This was a small, though significant, effort to update the GIESim SAB Demo that was built in FY03. The effort resulted in a standing demonstration of the GIESim capabilities within the AFRL Rome labs.

2) Preliminary work and study associated with potential integration of the GIESim SAB Demo with the DARPA/SAIC NMS and OSC. This effort was never funded, and ultimately dropped at the direction of Jon Valente.

3) The merger of the GIESim/JSB-RD software. This is the most substantial and meaningful work that was completed in FY04, and is the primary focus of this final report.

2.2 GEISim SAB Demo

The primary requirement for the GIESim SAB Demo was to maintain a version in the GIESim Lab that could be demonstrated on short notice. This demo was to use a new driver from SAIC as a substitute for the JBISim component. The basic functionality for the SAB Demo needed to be retained. Ultimately the team agreed to the move to RTI-S. In addition, PSI recommended the migration to a newer version of the underlying JTIDS simulation and a newer version of GSS. Both changes enabled better on-going support for the GEISim SAB Demo, and more flexibility if AFRL decided that additional features were needed in the Demo.

2.3 NMS Integration Exploration

The FY03 GIESim SAB Demo was quite successful. After some reflection, the AFRL GIESim leadership felt that additional instrumentation might help the demo, and thought that the demo might benefit from a more centralized control interface. Therefore, the GIESim team was asked to explore integration with the Network Management System (NMS) and Online Simulation and Control (OSC) functionality based on work done by DARPA and SAIC. NMS and OCS provided C-based APIs for monitoring distributed simulations and for controlling their start-up and shut down. The GIESim team determined that additional funding was required to support this effort, and ultimately Jon Valente requested that all further work stop on integration with NMS and OSC.

2.4 GIESim/JSB-RD Software Merger

The primary effort and top priority for GIESim in FY04 became the merger of GIESim and JSB-RD software, with the primary goal of adding Link-16 communications support to JSAF. JSAF (Joint Semi-Automated Forces) is a large and important simulation under Joint Forces Command (JFCOM). The JSB-RD has their own branch of JSAF in Rome for the purposes of adding Air Force behaviors to JSAF. JSAF is used for frequent war-gaming exercises, however, JSAF currently does not model communications – communications "simply" happens. The GIESim Leadership saw a great opportunity for applying the capabilities of GIESim to JSAF. The majority of this final report is focused on the GIESim/JSB-RD software merger.

It is important to note that the PSI Link-16 Network Management System shown in Figure 1 was, and continues to be, critically important to the success of the GIESim/JSB-RD software merger. The Link-16 Planning Tool was used to define all the scenarios and Link-16 Networks used in the merger, and a modified version of the Link-16/JTIDS Simulation was the tactical communications component that we added to JSAF.

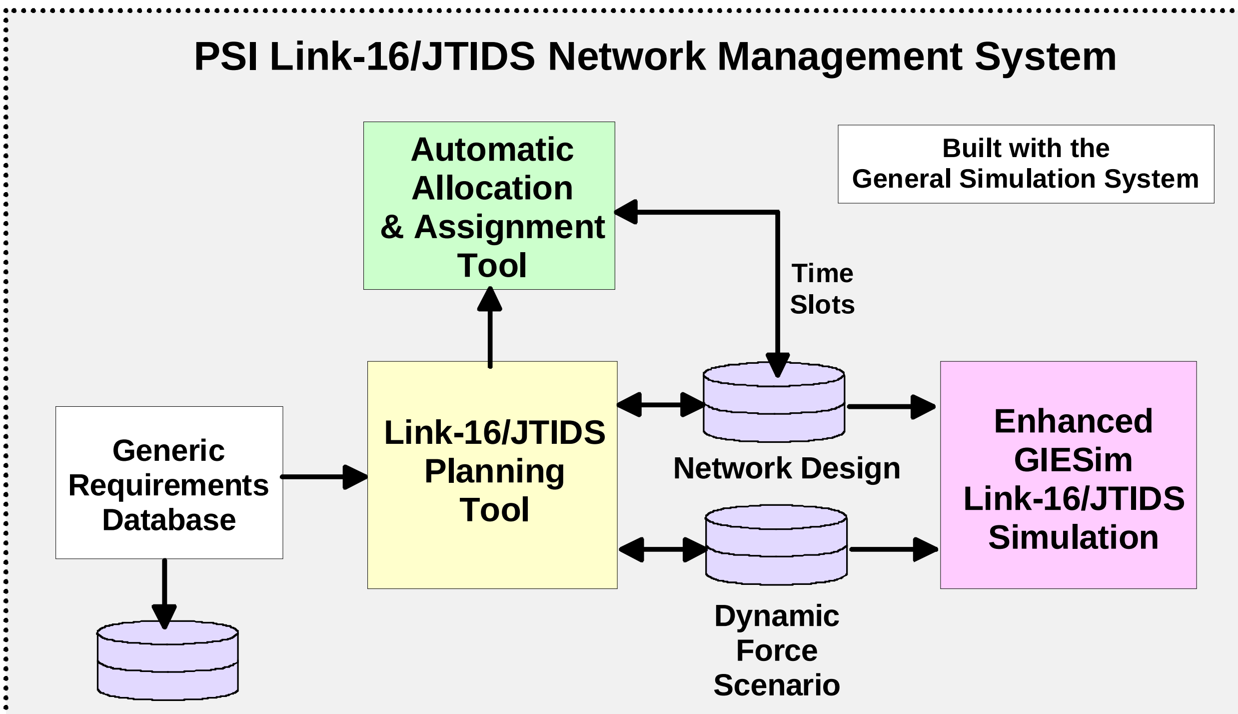


Figure 1 - PSI Link-16 Network Management System

3.0 UPDATED GIESIM SAB DEMO

3.1 Requirements

The primary requirements for the GIESim SAB Demo in FY04 were as follows:

1. Update the GIESim SAB Demo so that it could be maintained and would be available at any time for demonstration.
2. Move to RTI-S. While this was not an initial requirement, since the PSI JTIDS simulation was moving to RTI-S (since JSAF uses RTI-S versus DMSO RTI NG), the team chose to go with RTI-S. Also, since RTI-S does not use a centralized RTI server, there is one less component to start, therefore RTI-S it simplifies the demo.
3. Test with new driver from SAIC that replaces JBISim.
4. Retain the physical structure and scenario for the demo.

All of these requirements were met, and the fully operational demo was installed in the GIESim Lab in Rome. The sections that follow, describe the design, developments, and testing that were accomplished to meet the above requirements.

3.2 Changes to the GIESim SAB Demo Design

The primary design changes to the PSI simulation components in the GIESim SAB Demo were:

1. Move to RTI-S
2. Upgrade of JTIDS to the newer version available
3. Upgrade JTIDS and SAT_COM to the most recent release of GSS (Release 10.3.7).

In addition, these design changes preserved the SAB Demo functionality including interoperability with STK 5.0, and interworking with the new GIESim driver tool that replaced the JBISim component of the demo.

Furthermore, to support testing, the PSI GIESim HLA TEST_DRV was also moved to RTI-S and the newest version of GSS**.**

3.3 PSI Developments for GIESim SAB Demo

Developments associated with maintaining the GIESim SAB Demo are covered in this section. Figure 2 shows the new architecture for the Demo. The primary change is the use of RTI-S rather than the DMSO RTI. This change eliminated the centralized DMSO RTI server.

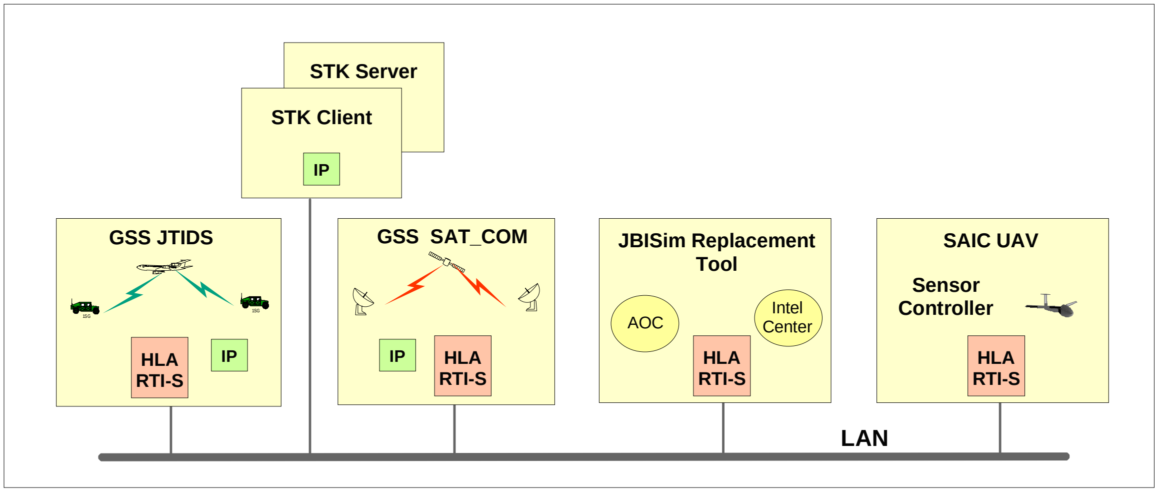


Figure 2 - New Architecture of GIESim SAB Demo

3.3.1 Migration to Newer Version of GSS

The GSS JTIDS and GSS SAT_COMM components of the GIESim SAB Demo were migrated to Version 10.3.7 of GSS. All processes and resources of each simulation were re-prepared with the new version of GSS, and then each simulation was prepared.

PSI has an agreement to migrate the GIESim SAB Demo to newer versions of GSS when they become available. Release 10.3.7 of GSS supports enhanced 2D and 3D visualization. Both PSI and GIESim ordered and installed newer graphics cards to use this capability.

3.3.2 Migration to Newer Version of JTIDS

The GIESIM_INTERFACES model that was developed for the GIESim SAB Demo, see Figure 3, provides the HLA interface to the other HLA connected GIESim SAB Demo simulation components, the TCP/IP interface to the GSS SAT_COM simulation, and the AOC and SAT Gateways used for transporting the demo images through JTIDS. The GIESIM_INTERFACES model was exported from the earlier version of JTIDS that was used for the Demo, and was then imported into the latest, more capable version of the JTIDS. After import, the appropriate process and resource changes were made to JTIDS, and the GIESim specific icons were added to functionally incorporate the GIESim SAB Demo functions. Finally the Control Specification of the newer JTIDS was modified to activate the GIESim Demo components.

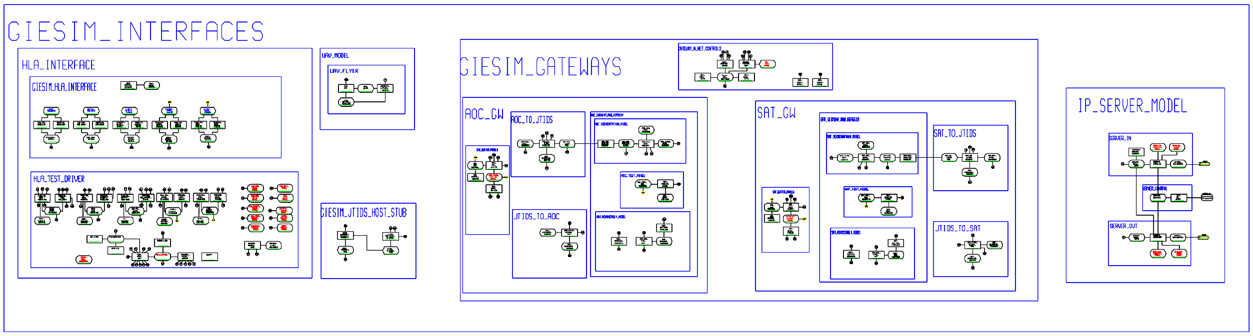


Figure 3 - GIESim SAB Demo Model

3.3.3 Migration to RTI-S

Once GSS had been modified to support RTI-S, migration of the GIESim SAB Demo to RTI-S was relatively easy. See Section 5.6.1 of this report for further details on migration to RTI-S.

3.3.3.1 TEST_DRV

The first step in the migration to RTI-S was to convert the PSI HLA TEST_DRV program to RTI-S. This involved re-preparing it with the version of GSS that was modified to support RTI-S. The default RTI-S rid file replaced the rid file that was used with the DMSO RTI.

3.3.3.2 JTIDS and SAT_COM

The steps that were used to migrate JTIDS and SAT_COM were exactly the same for the TEST_DRV program. Also, since the other GIESim SAB Demo simulation components used the FOM that is generated by GSS for JTIDS and SAT_COM, the FOM did not need to change, and the existing GIESIM.fed file could simply be re-used.

Figure 4 shows a picture of the PSI simulation components for the GIESim SAB Demo. Note we have retained the existing functionality throughout the migration to RTI-S and to a newer version of JTIDS. Note that RTI-S appears to start faster, and is far more robust to federates leaving the federation abnormally.

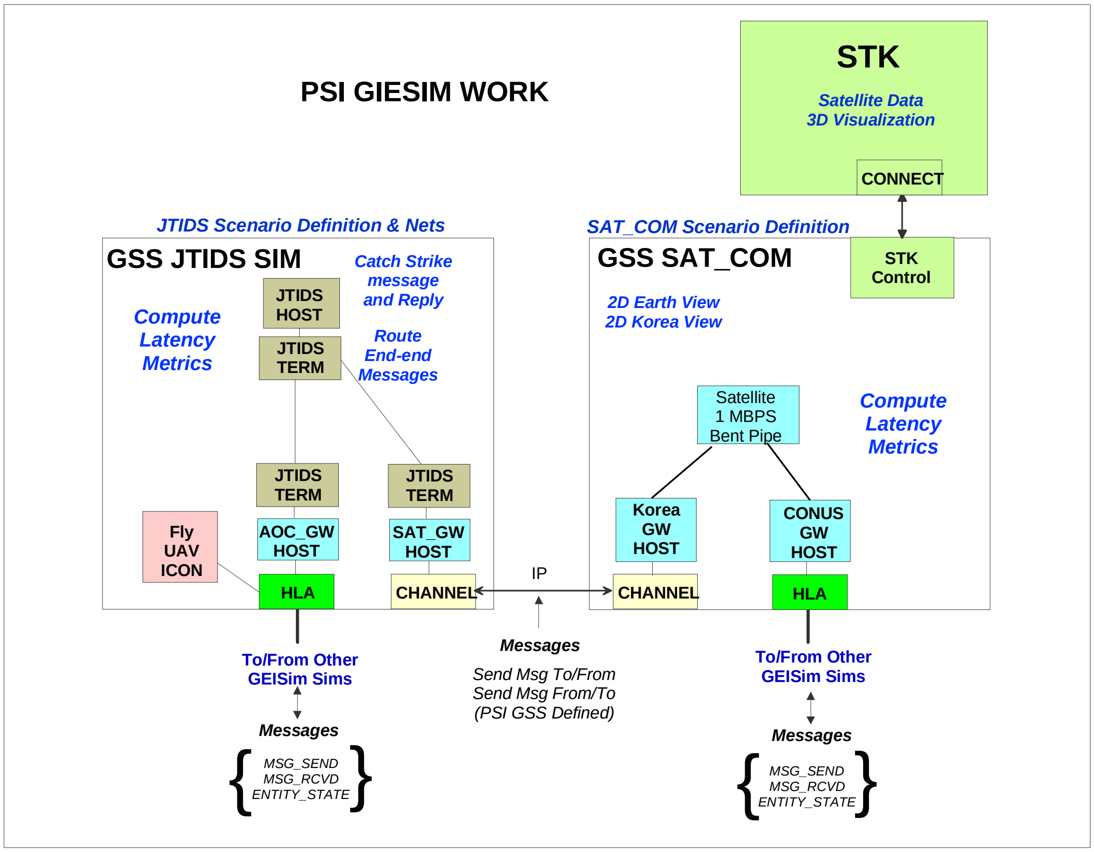


Figure 4 - PSI Simulation Components for GIESim SAB Demo

3.4 GEISim SAB Demo Testing

The updated PSI components for the GIESim SAB Demo were tested in-house using several PCs as shown in Figure 5. Proper operation was verified by first sending messages into JTIDS over HLA, and then by following successful transmission through JTIDS, and message flow into and through the SAT_COM simulation. Successful message transmission was also verified in the opposite direction – from HLA into SAT_COM, through SAT_COM into JTIDS and then through JTIDS ultimately resulting in a new HLA message coming out of JTIDS.

Over August 18th and 19th, PSI installed a new version of GSS and upgraded versions of JTIDS, SAT_COM and TEST_DRV that use RTI-S in both the JSAF and GIESim labs. In both labs, operation was successfully verified between simulations and with STK by using our HLA test driver TEST_DRV. In the JSAF lab, our simulation components were also successfully tested with the new test driver built by SAIC for the upgraded GIESim SAB Demo.

The architecture of the new GIESim SAB Demo, which was our test configuration, is shown in Figure 2

Tom Parisi of the AFRL GIESim team was given training on the upgraded GIESim SAB Demo, and Tom expressed his satisfaction with the updated components.

The updated GIESim SAB Demo is stable and in a form that is much more easily maintained. Mostly importantly the GIESim SAB Demo is ready to demonstrate at any time.

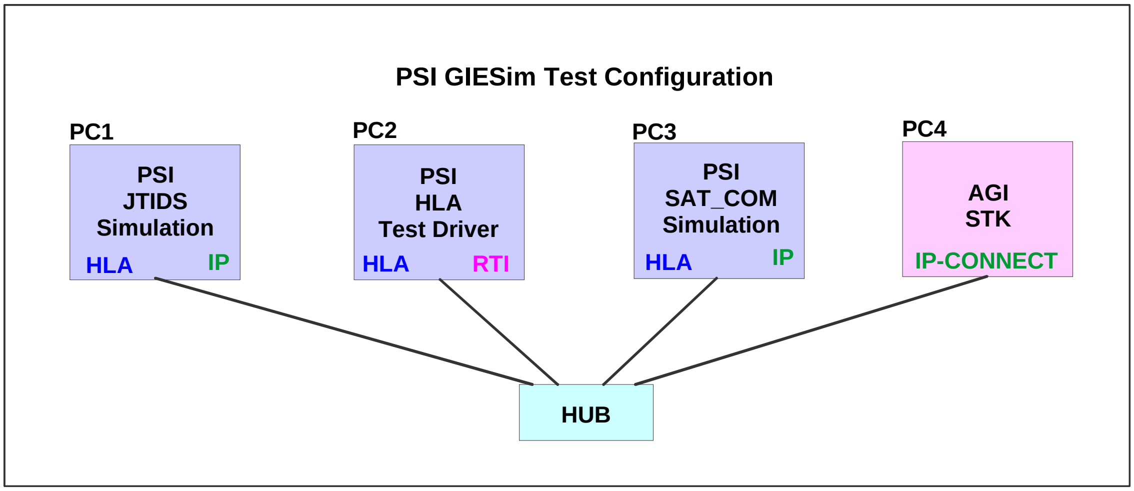


Figure 5 - PSI GIESim In-House Test Configuration

4.0 EXPLORATION OF NMS/OSC INTEGRATION

Two interests of the GIESim AFRL leadership drove this exploratory work:

1. The desire to have central control of the GIESim SAB Demo.
2. The desire to have additional monitoring of the performance of the GIESim SAB Demo.

Central control was a potential need in light of the somewhat complex start-up sequence of the original GIESim SAB Demo as shown in Figure 6. PSI developed Figure 6 and shared this with the team and with the SAIC representative, Gary Warren, in discussions on NMS and OSC.

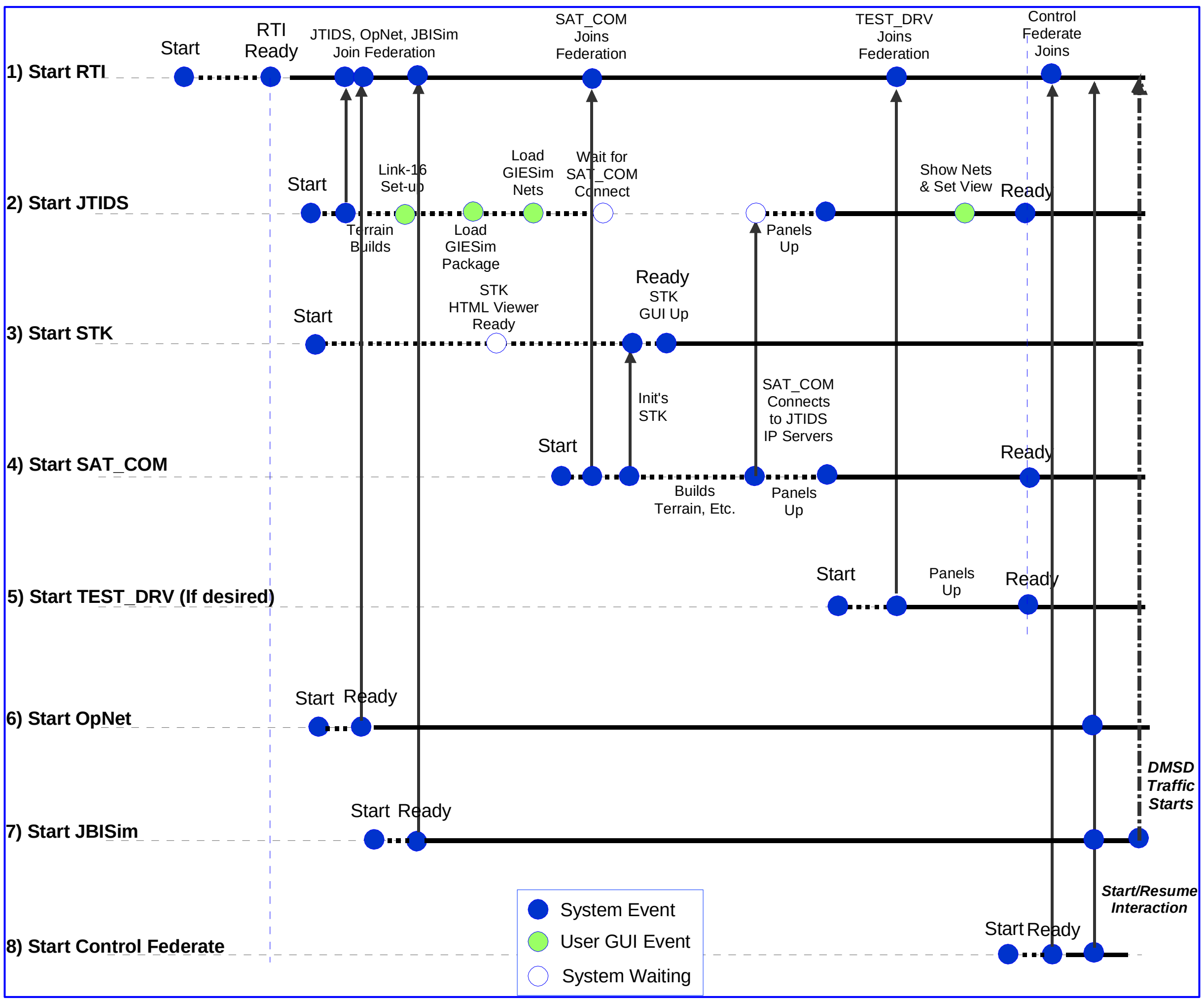


Figure 6 - GIESim SAB Demo Start-up Sequence

In May 04, PSI reviewed several sets of materials on the NMS and Online Simulation and Control (OSC) work that SAIC did for DARPA. This material included descriptions of the SAIC Real-Time Network Monitoring functions. PSI formulated initial impressions – particularly on Remote Start and Monitoring functions – and identified the need for additional technical information to determine stronger applicability to GIESim and to size the effort. Later in May, PSI received and reviewed a draft proposal from SAIC on GIESim that was targeted for DARPA funding. The proposal also raised several questions about the relationship of the SAIC/DARPA work to the parallel work with JSAF, and also further raised the need for additional technical details to size the work. Furthermore, the presentation material that had been received earlier helped PSI formulate some earlier impact statements. These were included in our response to Jon Valente. For example, the OSC remote start capability requires either command line arguments or an initialization file to start a simulation. The JTIDS simulation used in the GIESim SAB Demo presents three GUI panels for user choices on start-up. These panels will need to be replaced with a file initialization capability.

In late May the team received the User's Manual for Version 2.5 of the OSC Framework. The manual provided a lot of useful information and generated several questions relative to GIESim. PSI identified the need for a technical discussion to clarify how GIESim and OSC would best fit together. Part of this discussion would compare the current GIESim architecture and networking with respect to OSC needs and capabilities.

On June 2 PSI took part in a conference call that took place between AFRL, SAIC and DARPA. The purpose of the conference call was to review the proposed technical transition plan for applying the SAIC components that were generated for DARPA to GIESim. There was general agreement to couple the OSC Framework and Network QoS Monitoring with GIESim components. The team also agreed to explore the possible addition of the SAIC/DARPA JTRS model to the GIESim Framework.

PSI conducted a further, deeper review of the User's Manual for the OSC Framework, and formulated a number of insights into potential modifications needed to the PSI JTIDS and SAT_COM simulation components in the GIESim SAB Demo. This review also helped us prepare for the meeting between the GIESim team and SAIC held on June 9.

In preparation for the planned June 9 meetings with SAIC on OSC and with the JSB-RD team for JSAF, PSI took the initiative to prepare a series of viewgraphs to overview the GIESim SAB Demo scenario, the demo architecture, the demo start-up sequence, and GSS-based GIESim components provided by PSI. These slides proved to be very useful in focusing discussion in the meetings.

PSI participated in this meeting, and used our overview slides to provide some background on the GIESim SAB Demo to Gary Warren from SAIC. Based on these slides and other material presented at the meeting SAIC developed a better understanding of the GIESim SAB Demo.

The scenario overview, Figure 7, helped SAIC understand the conceptual operation and purpose of the demo scenario. The Physical Architecture, see Figure 2, of the Demo helped in delineating all the simulation components, their functional roles, and their simulation network connectivity by virtue of HLA and TCP/IP sockets. This view also showed all the components that the OSC remote start capabilities would need to "manage".

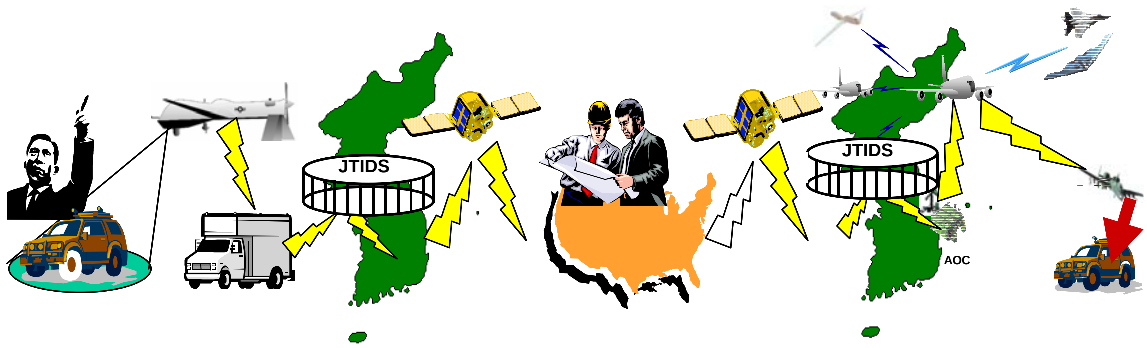


Figure 7 - GIESim SAB Demo Scenario Overview

The start-up sequence, Figure 6, showed the dependencies between the GIESim multi-simulation components, including points where simulations were waiting for user inputs to GUIs, and were waiting for connections from other simulations. This particular slide was highly useful in focusing the meeting, and the team reviewed the slide line by line to understand the sequence and what was going on behind the scenes. This slide helped to identify and capture information that was needed to support the demo components, e.g., IP addresses and ports, location of DTED and contour files, and needed changes to the user interfaces and file and directory structures of the GIESim components to permit OSC to handle remote start and shut-down.

The final slide, Figure 8, illustrated some of the file interfaces on the JTIDS and SAT_COM simulations provided by PSI, and served to stimulate additional discussions.

At this time, the GIESim team ultimately concluded, partly based on inputs from PSI, to retain the functional behavior and scenario of the GIESim SAB Demo while applying the OSC Framework to automate the remote start/stop of the Demo, and to add in the SAIC Network QoS Monitoring functions to the current set of GIESim simulations. PSI viewed this as a wise decision since it retains the current scenario that took a long time to define, and since it minimizes the number of changes needed to work with OSC and the Network QoS Monitoring. The team also agreed to explore the addition of the SAIC/DARPA JTRS model into the GIESim Framework and scenario, as a second step in working with SAIC following completion of the OSC work.

On mid-June, PSI received some details and files associated with the software for the OSC Framework and for the API for the Network QoS Monitor. It rapidly became clear that a Windows based (versus Linux-based) library was needed to support the API. This fact was communicated to SAIC and to the GIESim team. The team received a commitment from SAIC to build and provide a Windows library for the QoS API. Review of the header files, example of the API calls, and file structure required for the OSC remote start/stop helped PSI to size the work effort required to support these functions.

On June 15 PSI received a request from Jon Valente, AFRL, to provide a statement of work (SOW) and costs for modifying the JTIDS and SAT_COM simulations to work with the OSC remote start/stop and to support the QoS API, and to add the SAIC/DARPA JTRS model to the GIESim Demo scenario. PSI provided the SOW on June 15 and our cost statement on June 16.

In July, PSI and the other GIESim team members received direction from Jon Valente to stop all work on the integration of GIESim components with the SAIC/DARPA OCS APIs.

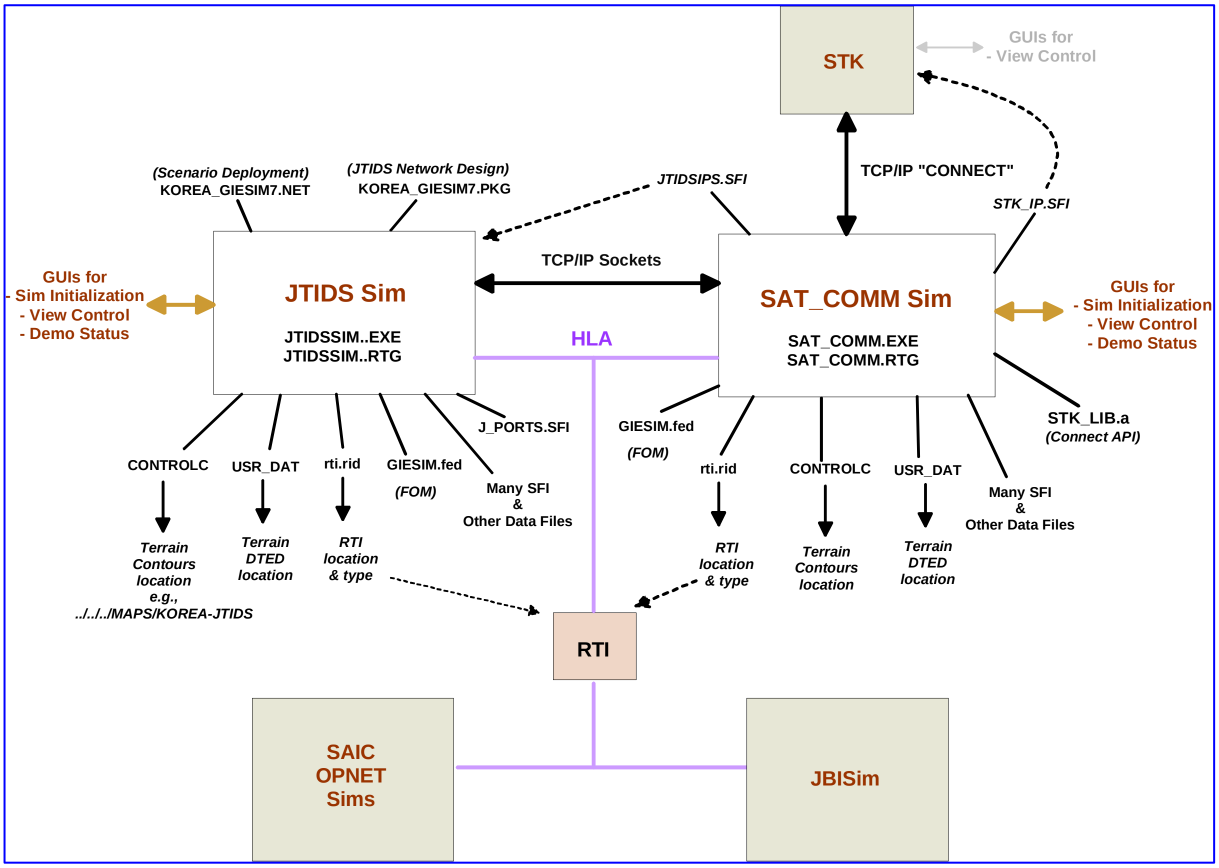


Figure 8 - PSI GIESim Simulation Components and Interfaces

5.0 GIESIM/JSB-RD MERGER

This section of the Final Report describes the work PSI undertook and the accomplishments completed with respect to the GIESim/JSB-RD software merger.

5.1 Merger Requirements

Figure 9 shows the steps that PSI and the GIESim/JSB-RD team took in merging the GIESim and JSB-RD software. This diagram was created by PSI to assist the team maintaining focus on the steps that we had to follow. The merger requirements were determined over several meetings and email exchanges. In most cases, PSI encouraged a Keep-It-Simple (KIS) approach. The sections that follow in this report largely follow the sequence in this diagram.

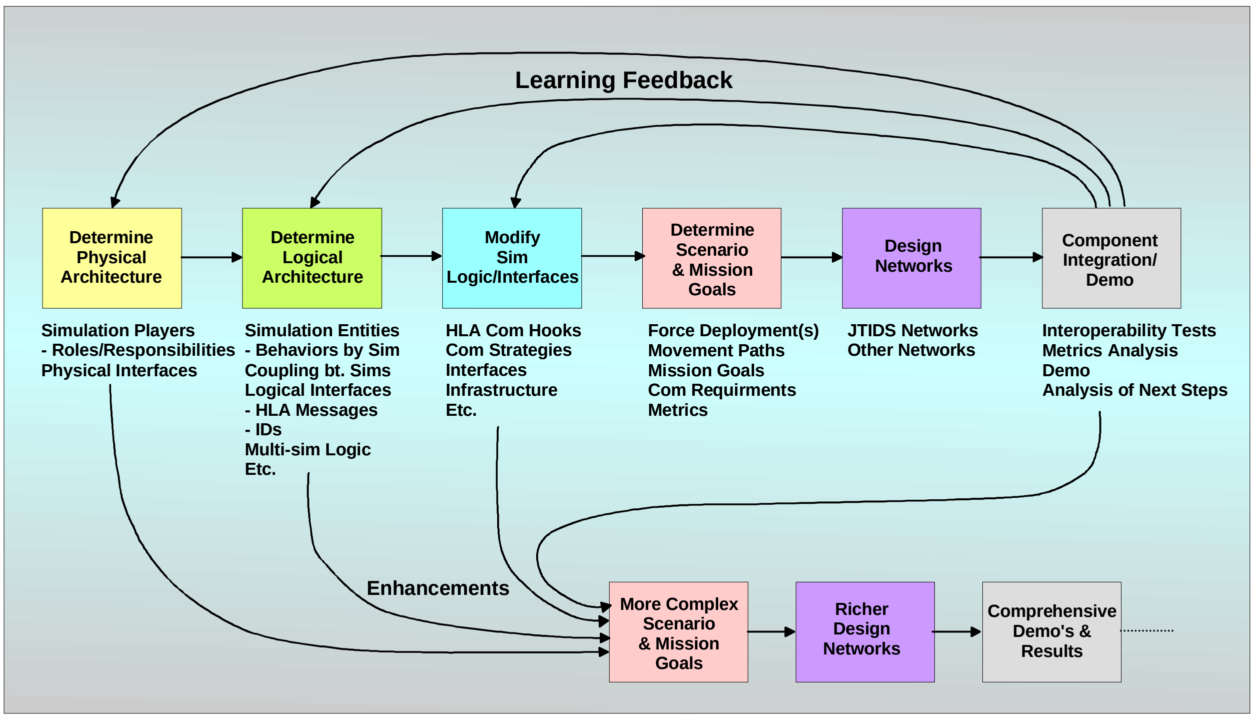


Figure 9 - Steps for GIESim/JSB-RD Software Merger

Early in the program PSI produced a white paper entitled “Technical Considerations for GIESim-JSAF Merger” that was formative in mapping out many of the considerations and recommendations that were later used in the merger. The paper provided background material on JTIDS and Link-16 that were intended to aid the team in understanding tactical communications better, particularly the Link-16 message set and addressing capabilities. Figure 9 first presented in this paper.

Figure 10 shows the various architectural layers that were considered when building requirements for the GIESim-JSAF communications scenario and subsequent simulation enhancements.

Dynamic Mission Events
Trigger the Flow of Mission Thread Comm
At Specific Times/Places
E.g., Pop-up Threats

Mission Threads
Define Flow of Comm Messages Associated with a particular Mission
Threads consist of multiple ***Links***
Example Threads: TCT and SAR

Network Design
Allocation of Time Slots and Protocols to support all Mission and Comm's IERs within a Scenario
Example: NEA 2010 (Korea)

Dynamic Scenario
Equipment Deployments
Mission Deployments
Movement Paths
Example: NEA 2010 (Korea)

Geography/Terrain

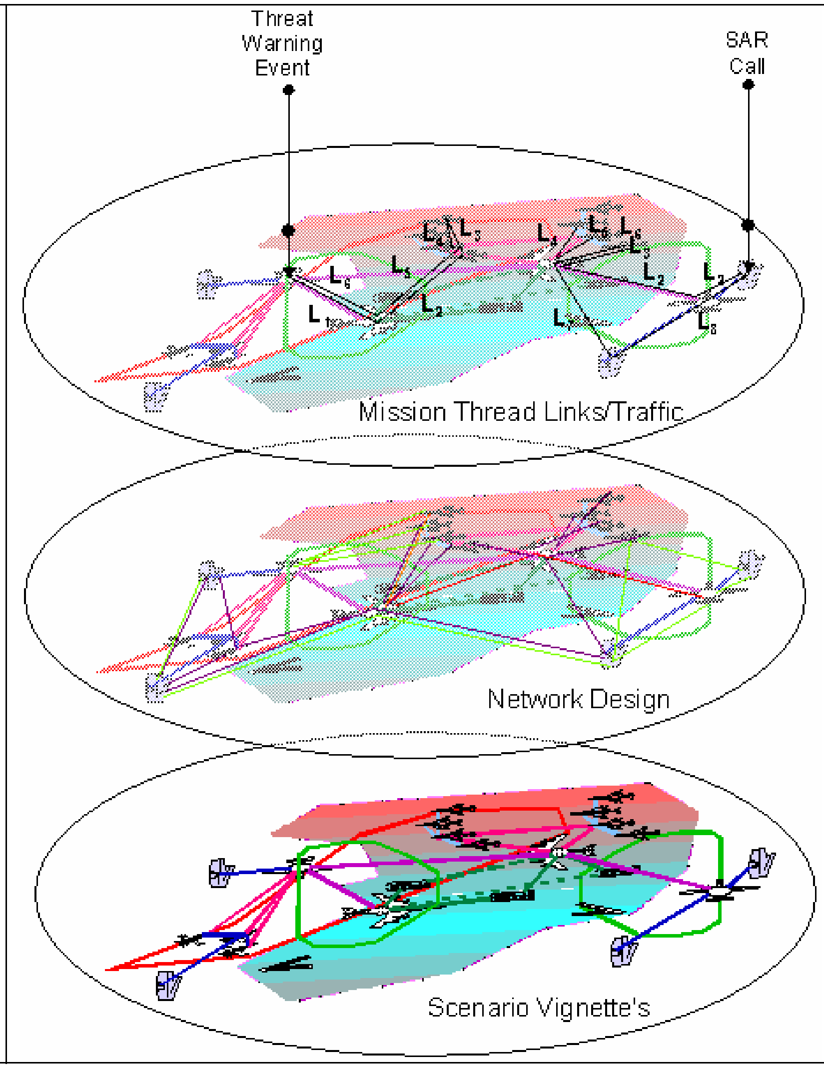


Figure 10 - Communications Scenario Architectural Layers

At the bottom is the geography of the area of interest (AOI). Next is the force deployment and associated dynamics – the scenario vignettes. A Network Design is needed for the force deployment that supports the communications needs of the operational missions including expected traffic levels, required response times, and expected events and surprise events, e.g., pop-up targets. A communications scenario, or mission threads, drives traffic over the networks as the scenario vignettes unfold, and in response to dynamic mission events.

After several GIESim and JSB-RD team discussions on whether to use the PACIFIA or Korean terrain, the team ultimately agreed to use Korea as the theater of interest. This allowed for great reuse of the work done by the GIESim team for the SAB Demo, and had minimal impact of the JSB-RD team.

5.2 Physical Architecture

The physical architecture of the GIESim-JSAF merger is shown in Figure 11. JSAF and the GIESim JTIDS simulation from PSI are the two main components. There is no longer an RTI Server since RTI-S is nodeless.

Entities that need to communicate in JSAF via JTIDS need to have counterparts in JTIDS. These are indicated by the three platforms shown in each simulation in Figure 11. JSAF and JTIDS each agreed to use a common force deployment scenario of JTIDS platforms.

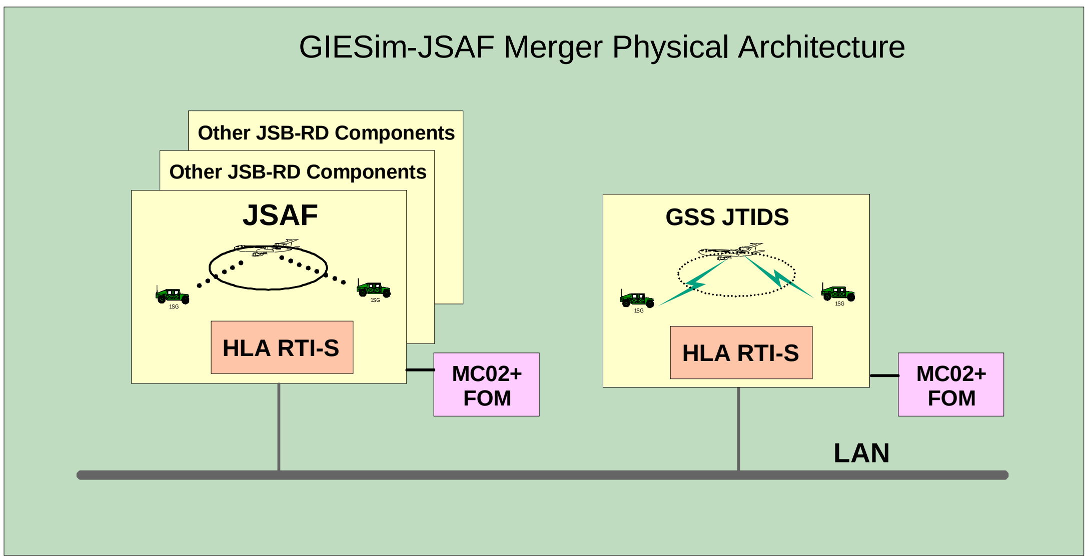


Figure 11 - GIESim-JSAF Physical Architecture

5.3 Logical Architecture

The GIESim/JSB-RD merger team agreed to use the GIESim HLA Interactions that were defined for the GIESim SAB Demo for the merger. These HLA interactions, with minor modifications, were merged with the Millennium Challenge 02 (MC02) FOM. The HLA interactions are discussed further in Section 5.3.2.

JSAF has flight (movement) paths to dynamically move aircraft, and sends position updates to JTIDS when platforms change position. A flight path is shown as a solid ellipse within JSAF in Figure 11 and as a dotted ellipse in JTIDS. The enhancements to JTIDS to support these operations are detailed in a later section of this report.

JTIDS exercises a network designed to support the tactical communication needs of the entities in JSAF, and sends messages between selected pairs of JTIDS platforms. This is shown notionally in right side of Figure 11 as green radio "links." JSAF, on the other hand, was given new software to support an abstract representation of JTIDS communications that is shown in

Figure 11 as dotted lines. Enhancements to the JTIDS simulation to support external network transmission requests will be detailed in a later section of this report.

PSI worked with the GIESim and JSAF teams to ensure that entity behaviors were operationally correct relative to the scenario and multi-simulation environment being built. Work accomplishments in this area included:

- PSI worked with SAIC to investigate platform (entity) behaviors in response to communications and communications outages (lost messages). Figure 12 illustrates communications message strategies.

5.3.1 Inter-simulation Communications Message Handling

A major challenge in defining inter-simulation communications between JSAF and JTIDS, was that JSAF essentially had no communications models or concepts built into it. This resulted in the need to define entity behaviors that had to must deal with the vagaries of tactical radio communications.

It was agreed that the GIESim-JSAF merger would follow Strategy B. Messages lost in JTIDS would simply not be reported to JSAF. JSAF would introduce a message "time out" that would handle lost messages.

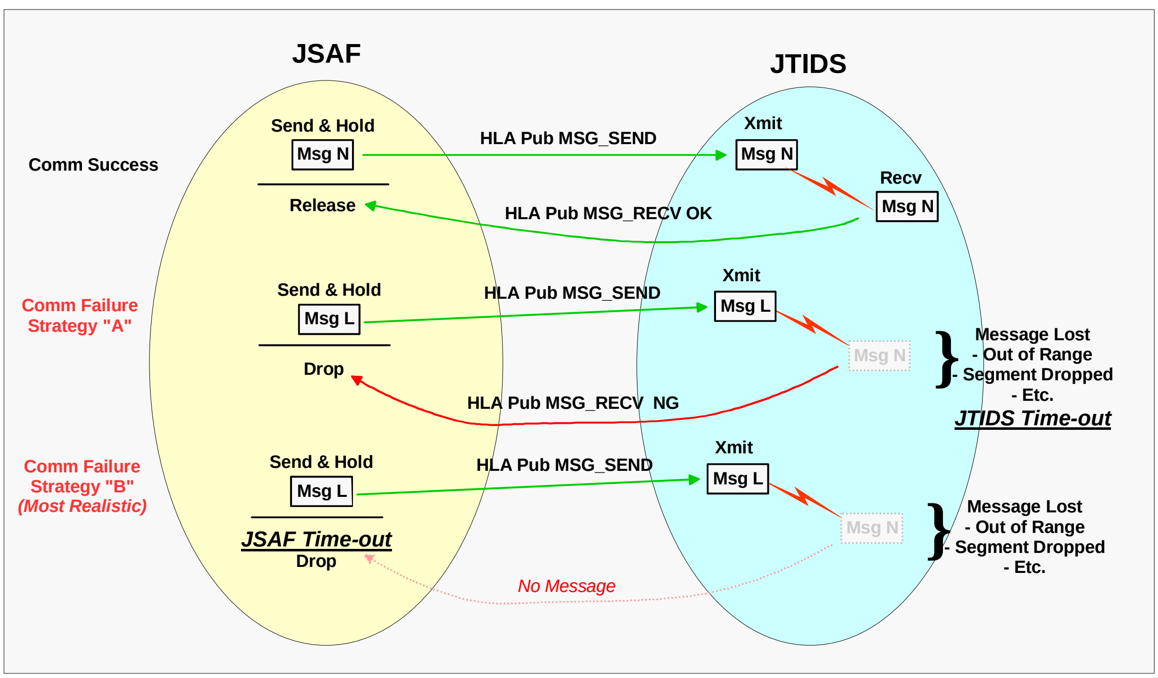


Figure 12 - Inter-simulation Messaging Strategies

JSAF holds the "actual" message to be transmitted, and provides message characteristic to JTIDS via HLA. Message characteristics include message size, and accumulated latency. When JTIDS reports that a particular message is received, then JSAF processes it.

Details on transmission requests and message receipt between JTIDS and JSAF are covered in another section of this report.

Changes to the simulation interface and the internal, logical architecture of the PSI JTIDS simulation were designed, developed and then tested to support the physical and logical architecture of the GIESim/JSB-RD software merger. These are discussed in subsequent sections of this Final Report.

5.3.2 GIESim HLA Interactions

The team agreed to use three GIESim HLA Interactions that were defined for the GIESim SAB Demo. These were:

1. GIESIM_MSG_SEND: For sending Link-16 message transmission requests from JSAF to JTIDS.
2. GIESIM_MSG_RCVD: For JTIDS to report successful reception of a message to JSAF.
3. GIESIM_ENTITY_STATE: For JSAF to send platform position updates to JTIDS.

The PSI GSS model for handling these HLA interactions is shown in Figure 13.

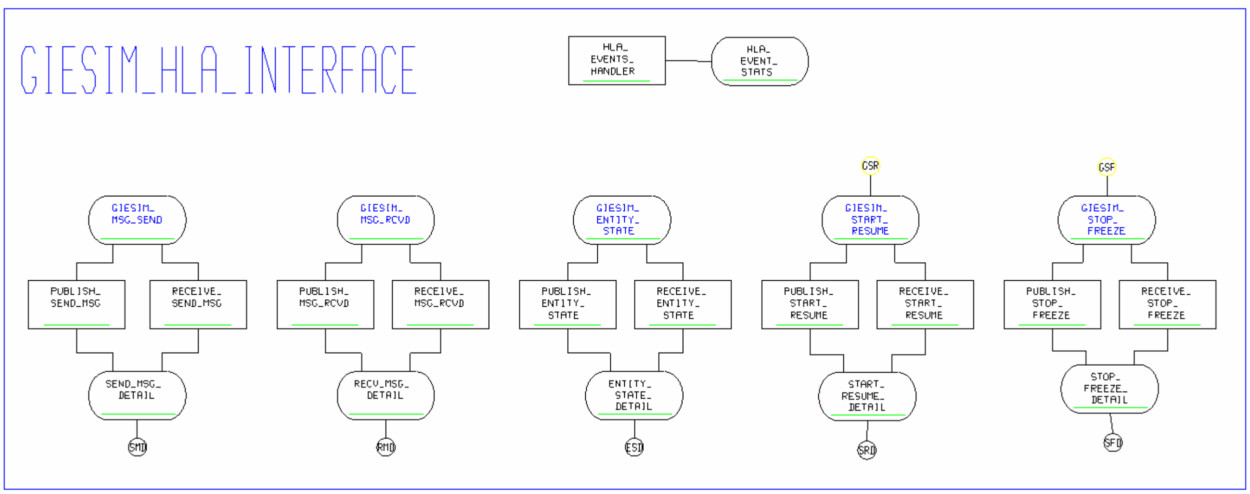


Figure 13 - GSS Model to Handle GIESim HLA Interactions

The resources in the top layer of five are labeled with blue text to indicate that they are HLA Resources. This means that GSS automatically "subscribes" to these five HLA interactions. For each HLA resource, there is companion resource, e.g., SEND_MSG_DETAIL below GIESIM_MSG_SEND. The HLA resources are in the "public" HLA interface, and the companion resources are used to expand fields in the public HLA resource.

Table 1 - GIESIM_MSG_SEND Interaction Resources.

```
***GIESIM_MSG_SEND************************************

ORIGINATING_ENTITY       CHAR    4   *** TWO INTEGERS
RECEIVING_ENTITY         CHAR    4   *** TWO INTEGERS
MESSAGE_ID               INTEGER     *** UNSIGNED LONG
MESSAGE_LENGTH           INTEGER     *** UNSIGNED LONG
CUMULATIVE_LATENCY       REAL        *** FLOAT
NET_TYPE_NUMBER          INTEGER     *** New for JSAF ****
-------------------------------------------------------------
***SEND_MSG_DETAIL************************************

SEND_ORIG_ENTITY
    1   SEND_FED_ID      INDEX
    1   SEND_ENTITY_ID   INDEX

SEND_RECV_ENTITY
    1   RECV_FED_ID      INDEX
    1   RECV_ENTITY_ID   INDEX

SEND_MSG_ID              INTEGER
SEND_MSG_LENGTH          INTEGER
SEND_CUM_LATENCY         REAL
SEND_NET_TYPE            INTEGER      *** New for JSAF ****
```

Table 2 - GIESIM_MSG_RCVD HLA Interaction Resources

```
***GIESIM_MSG_RCVD*************************************

RECEIVING_ENTITY         CHAR    4   *** TWO INTEGERS
MESSAGE_ID               INTEGER
CUMULATIVE_LATENCY       REAL
NET_ID                   INTEGER     *** New for JSAF ****
-------------------------------------------------------------
***RECV_MSG_DETAIL*************************************

ENTITY_RECEIVED
    1   FED_ID           INDEX
    1   ENTITY_ID        INDEX

RECV_MSG_ID              INTEGER
RECV_SUM_LATENCY         REAL
RECV_NET_ID              INTEGER     *** New for JSAF ****
```

Table 1 through Table 3 list the contents of the HLA Resources and their companions. The companion resources show the detailed breakout of all HLA interaction parameters and their sizes. New parameters that were added to the GIESIM_MSG_SEND and GIESIM-MSG_RCVD HLA interactions are noted with comments.

This specific breakout of resources was sent to SAIC to help resolve interoperability problems. The new field in the GIESIM_MSG_SEND interaction was named NET_TYPE_NUMBER rather than simply NET_TYPE, so the team agreed to change the FOM to match. Also, the NET_ID field was added to the GIESIM_MSG_RCVD interaction so the FOM also was changed to reflect this parameter.

All other parameters and their types remained the same. Explicit sharing of these tables served too clear-up a number of interoperability problems.

Table 3 - GIESIM_ENTITY_STATE HLA Interaction Resources

```
***GIESIM_ENTITY_STATE***********************************

ENTITY_TYPE               CHAR    6
ENTITY_IDENTIFIER         INDEX
HEADING                   REAL
WORLD_LOCATION            CHAR    12
SPECIAL_EFFECT            INTEGER
```

```
***ENTITY_STATE_DETAIL***********************************

ENTITY_TYPE_DETAIL              *** 6 CHARS
    1   ENTITY_TYPE       CHAR
    1   DOMAINX           CHAR
    1   COUNTRY_CODE      INDEX
    1   CATEGORY          CHAR
    1   SUBCATEGORY       CHAR

ENTITY_ID_DETAIL          INDEX
HEADING_DETAIL            REAL

WORLD_LOCATION_DATA
    1   LAT               REAL
    1   LON               REAL
    1   ALT               REAL

SPECIAL_EFFECTS_DATA      INTEGER
```

Additional discussion on design, development and testing of these HLA interactions and associated processing is presented in subsequent sections of this report.

5.4 Scenario Development

Once the combined GIESim JSB-RD team agreed to use Korea as the theater of interest, a Korean-based scenario was needed. PSI volunteered use of its Korona scenario that was developed to support testing of our Link-16 Network Management System (NMS) under contract with another AFRL Group. A complete description and a full set of deployment data for Korona and Korona-WDL (a Weapons Data Link variant) were sent to the team in July 04.

5.4.1 PSI Korona Scenario

The composition of Korona is based upon the Blue force disposition of the NEA III 2010 ATO Excursion described in the "TECHNICAL REPORT 2003, Single Integrated Air Picture (SIAP), Link 16 Networking/Throughput, Network Design Analysis, November 2003, Joint SIAP System Engineering Organization (JSSEO)". Rather than use the classified platform deployments of the SIAP reference scenario, PSI created an unclassified deployment called Korona. Figures 1 and 2 show full views of Korona platforms and movement profiles.

The force composition of the Korona scenario is listed in Table 4. The Korona scenario includes 87 profiles. A large part of building Korona was the creation of operationally meaningful profiles, i.e., movement paths. A high percentage of the platforms are assigned to individual profiles.

Korona has 3 Areas of Operation (AO) as shown in Figure 16. In each AO, there is a target "protected" by four ground threats, e.g., SAM sites. Icons indicate the targets and ground threats and provided a focus for developing mission profiles.

Each AO has several missions. Suppression of Enemy Air Defense (SEAD) missions were supported by F15s that go in first to take out air defenses and then STRIKER missions were assigned to F18s to go in to hit ground targets. One SEAD aircraft was assigned to each air defense target and four Strikers were assigned to each main target. Combat Air Patrol (CAP) and Escort/Reserve aircraft supported the SEAD and Striker missions. Aircraft assigned to the AO's followed Ingress and Egress routes as illustrated in Figure 16.

Ultimately, a subset of the PSI Korona scenario was chosen as one part of the scenario for the merger.

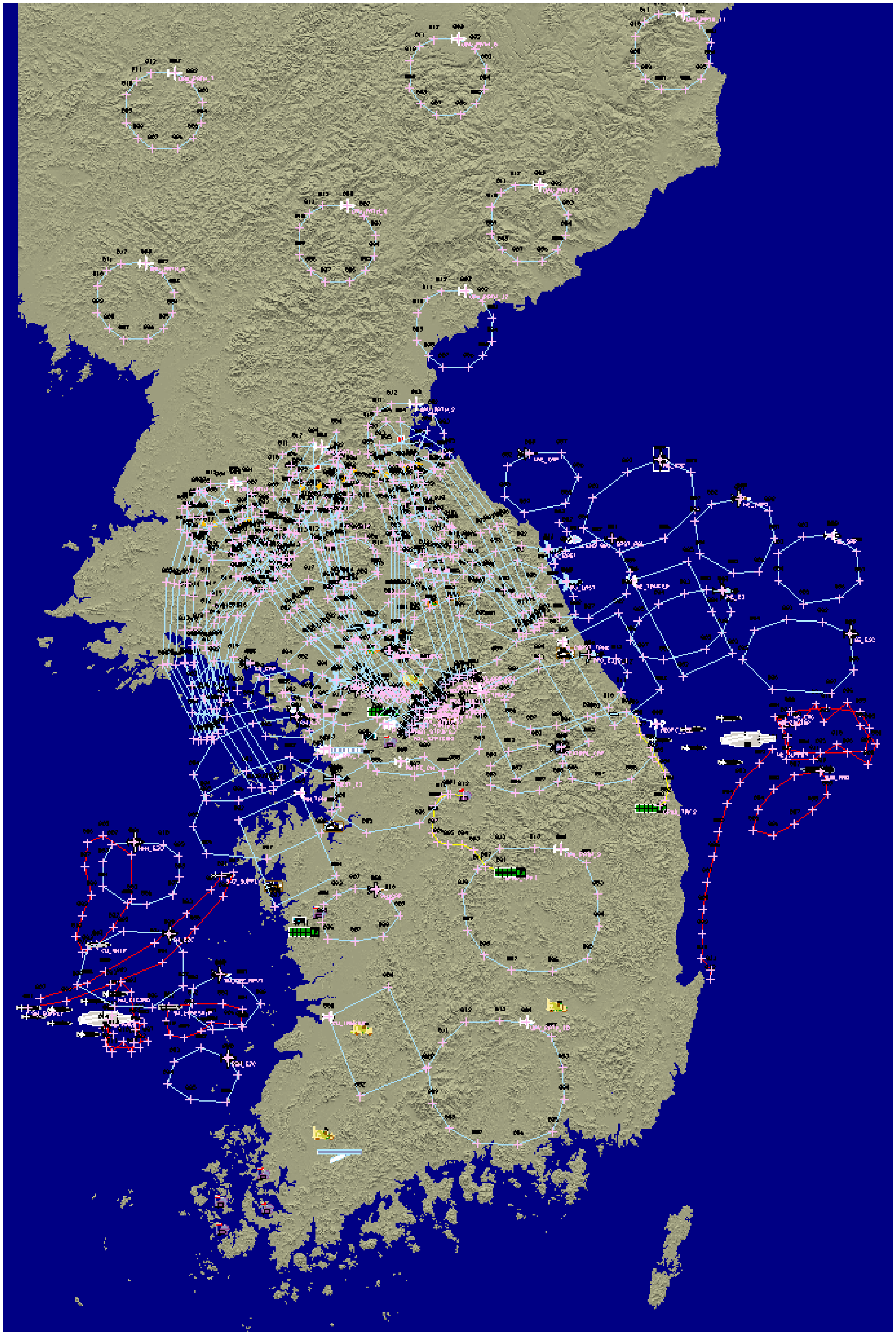


Figure 14 - Full View of PSI Korona Scenario over Korean Terrain

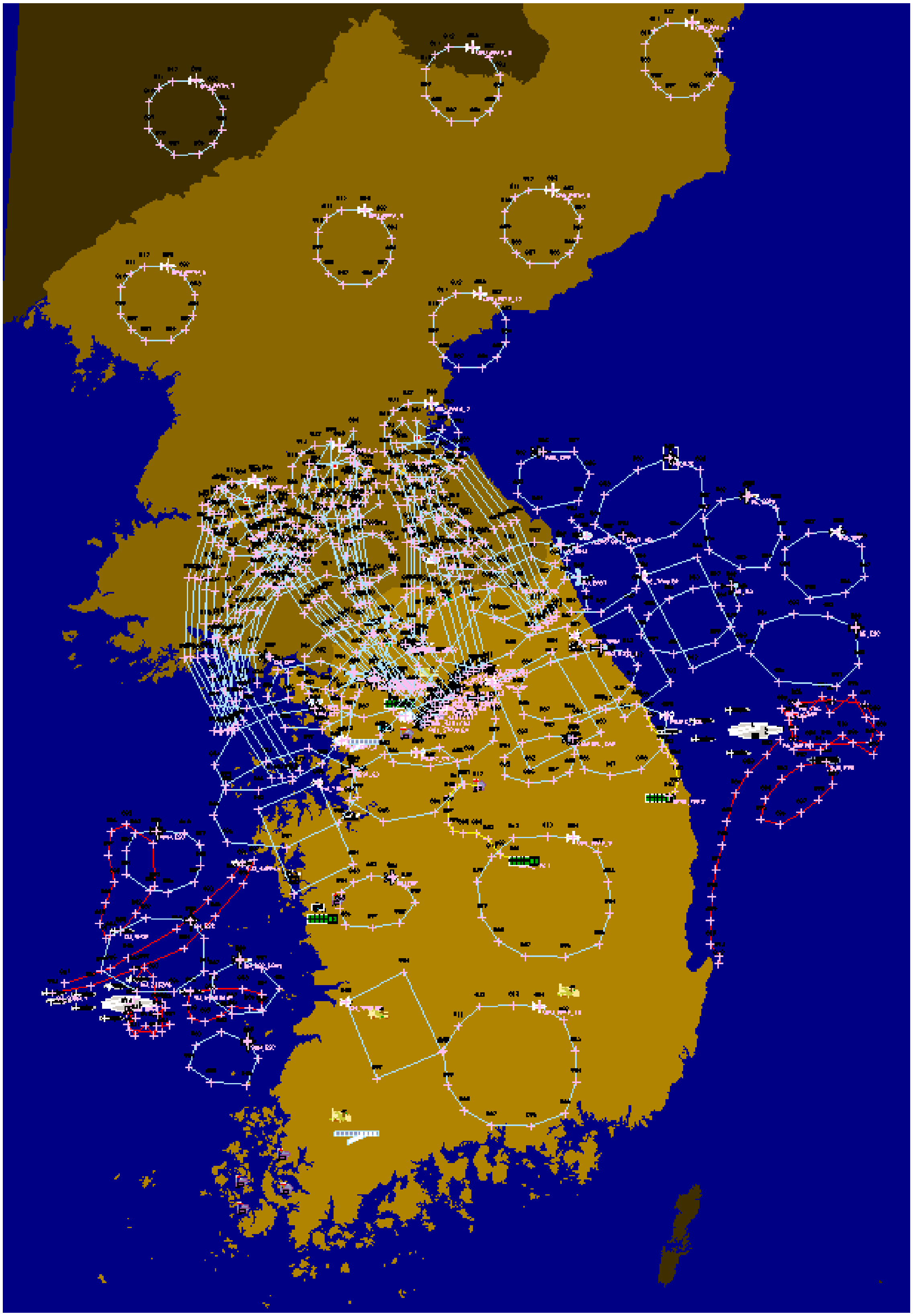


Figure 15 - Full View of PSI Korona Scenario over Political Boundaries

Table 4 - Force Composition of the PSI Korona Scenario

Category	Platform	Count
Air Platforms	AB IFC Sensor	2
	ABL	4
	KC 135	5
	Air Cav Helo	2
	E2C	6
	E3	1
	F15F	24
	F18	24
	JLENS	3
	JSTARS	2
	Rivet Joint	2
	Global Hawk UAV	12
	Total Air	*87*
Sea	Carriers	2
	Cruisers	15
	Submarine	1
	Total Sea	*18*
	Total Moving	*105*
Ground	CAC2S	6
	CRC	2
	JTAGS	4
	Patriot ICC	4
	SHORAD	2
	TOAM	2
	THAAD TOC	4
	UAV Grnd Station	1
	Total Ground	*25*
	Total Stationary	*25*
	Total Link-16 Platforms	***130***
	Movement Paths	87
	Reference Icons	18
	Navy Carrier Groups	2

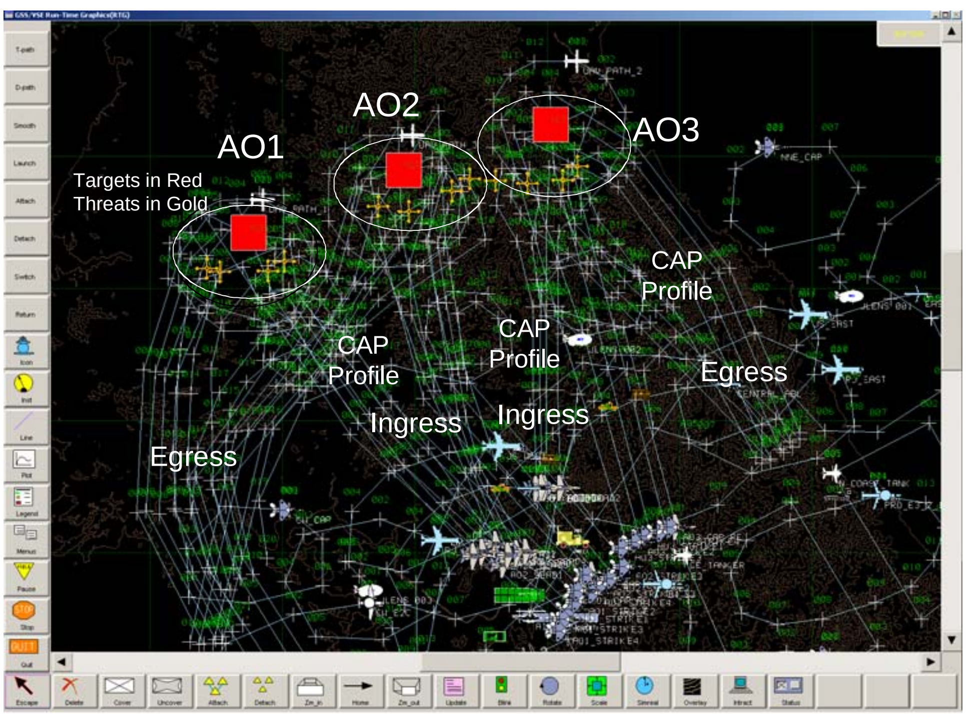


Figure 16 - Areas of Operation (AOs) in basic Korona Scenario.

Scenario planning involved an analysis of the platforms available and their missions. For example, a KC-135 tanker might support both in-air refueling and also serve as a relay platform. Scenario planning also involved assignments of speeds, which can (and may likely), vary throughout the scenario, altitudes, and timing. Altitudes along movement profiles were "deconflicted" and reflect platform capabilities in addition to their missions. Expert input on missions and tactical considerations was used to build realistic scenarios.

The "basic" Korona scenario has an altitude plan that is shown in Figure 17, which reflects research and expert inputs on altitudes typically associated with the platform types in the scenario. Figure 18 shows typical speeds for these platforms. The altitude and speed values differ for the SEAD, STRIKER, and Escort/CAP aircraft.

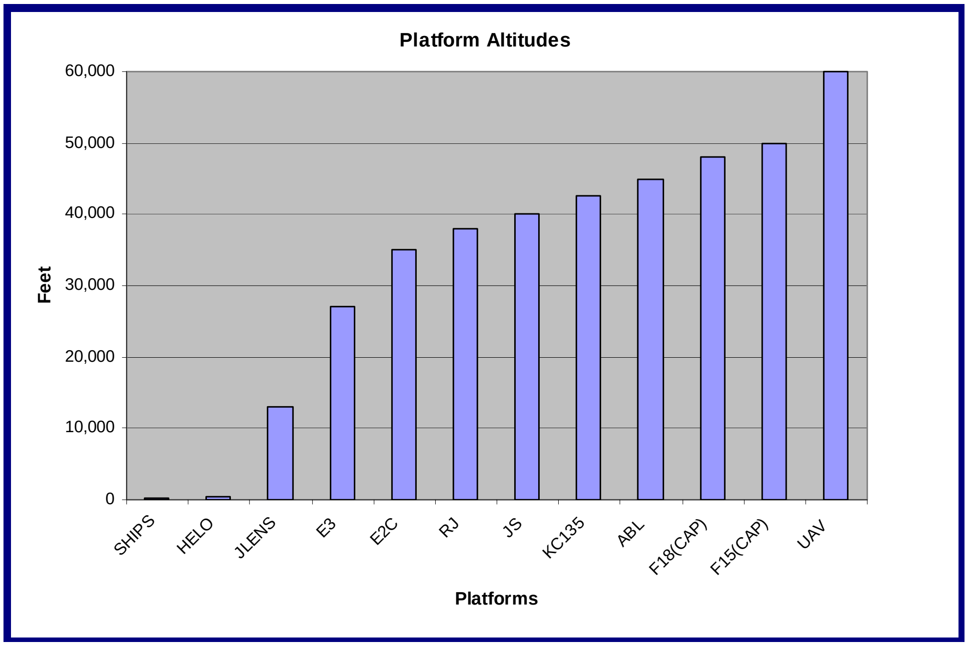


Figure 17 - Altitude Plan for Korona.

The Korona scenario assumes that the campaign is many days or weeks old, and several hours into the current scenario. This implies that all support missions, e.g., tankers, surveillance, etc. are "on station" and therefore traveling stationary orbits. The scenario starts with the fast-mover SEAD, Striker and their CAP support already past launch time and well into ingress and pushing towards their targets.

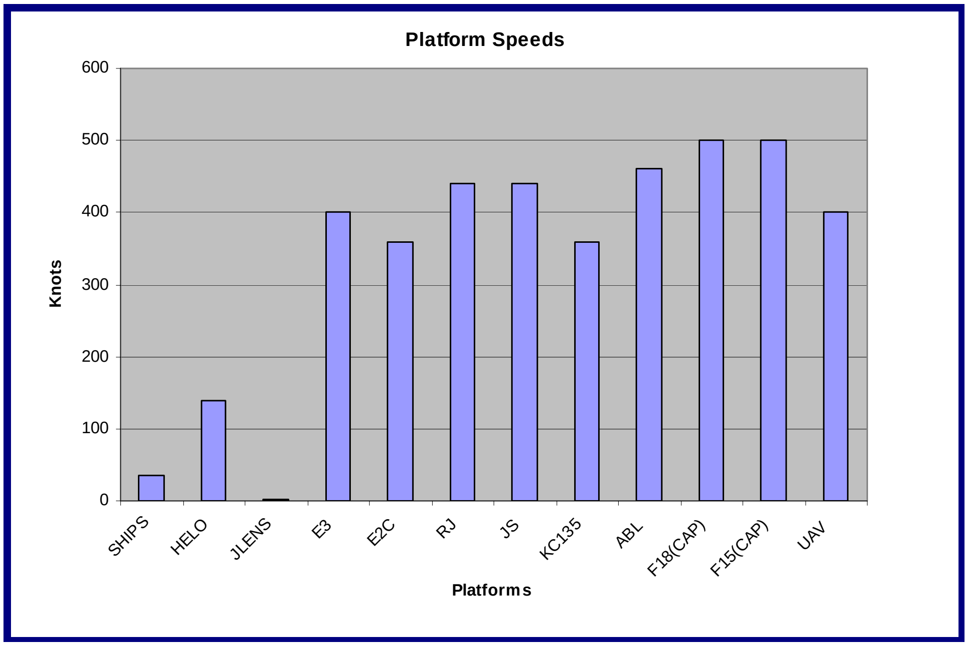


Figure 18 - Platform Speeds in Korona.

When deploying the land, air and sea platforms, the scenario takes into account how each should be deployed based on the current "time" of the scenario and their characteristics. For instance, F15s can serve both CAP and Strike missions, and F18s can serve CAP and SEAD missions. E2Cs handle surveillance and relaying in the vicinity of naval task groups. E3s handle surveillance at a standoff distance from the action. KC-135 tankers need to be located near ingress and egress routes for refueling and can also act as relays. Global Hawk UAVs fly up at 60,000 feet to transmit video and other surveillance information. Movement profiles reflect the platform assignments in terms of speeds, altitudes, locations and timing.

Tactical Aircraft Deployment

The Korona scenario includes 24 F15s and 24 F18s. These aircraft had to be allocated to different missions across the scenario. Table 5 shows how these aircraft were deployed. Figure 19 shows the SEAD profiles with respect to the 3 Areas of Operation (AO) and Figure 20 shows the Striker missions over the main target in each AO.

Table 5 - Deployment of F15 and F18 Fighter Aircraft.

	CAP Locations					AO1 (West)				AO2 (Central)				AO2 (East)				
	CEN CAP	CW CAP	SW CAP	NE CAP	SW_N CAP	SEAD	STRIKER	CAP	R/E	SEAD	STRIKER	CAP	R/E	SEAD	STRIKER	CAP	R/E	Total
F15	2	2	2				4	2			4	2			4	2		**24**
F18			2	2	2	4			2	4			2	4			2	**24**
Total			**12**				**12**				**12**				**12**			**48**

CAP	Combat Air Patrol
STRIKER	Strike Aircraft associated with a Target
SEAD	Suppression of Enemy Air Defenses
R/E	Reserve/Escort

In the basic Korona scenario, the SEAD and Striker mission profiles were directed over their associated targets. Flight paths were designed for SEAD missions to ensure that ground threats were attacked in close synchronization. Similarly, the flight paths for the STRIKER missions were designed for close synchronization of attacks that took place from different directions. Flight path waypoint positions, altitudes and segment speeds were adjusted to reflect the mission profile and capabilities of each aircraft.

Figure 19 - Korona F18 SEAD Mission Profiles.

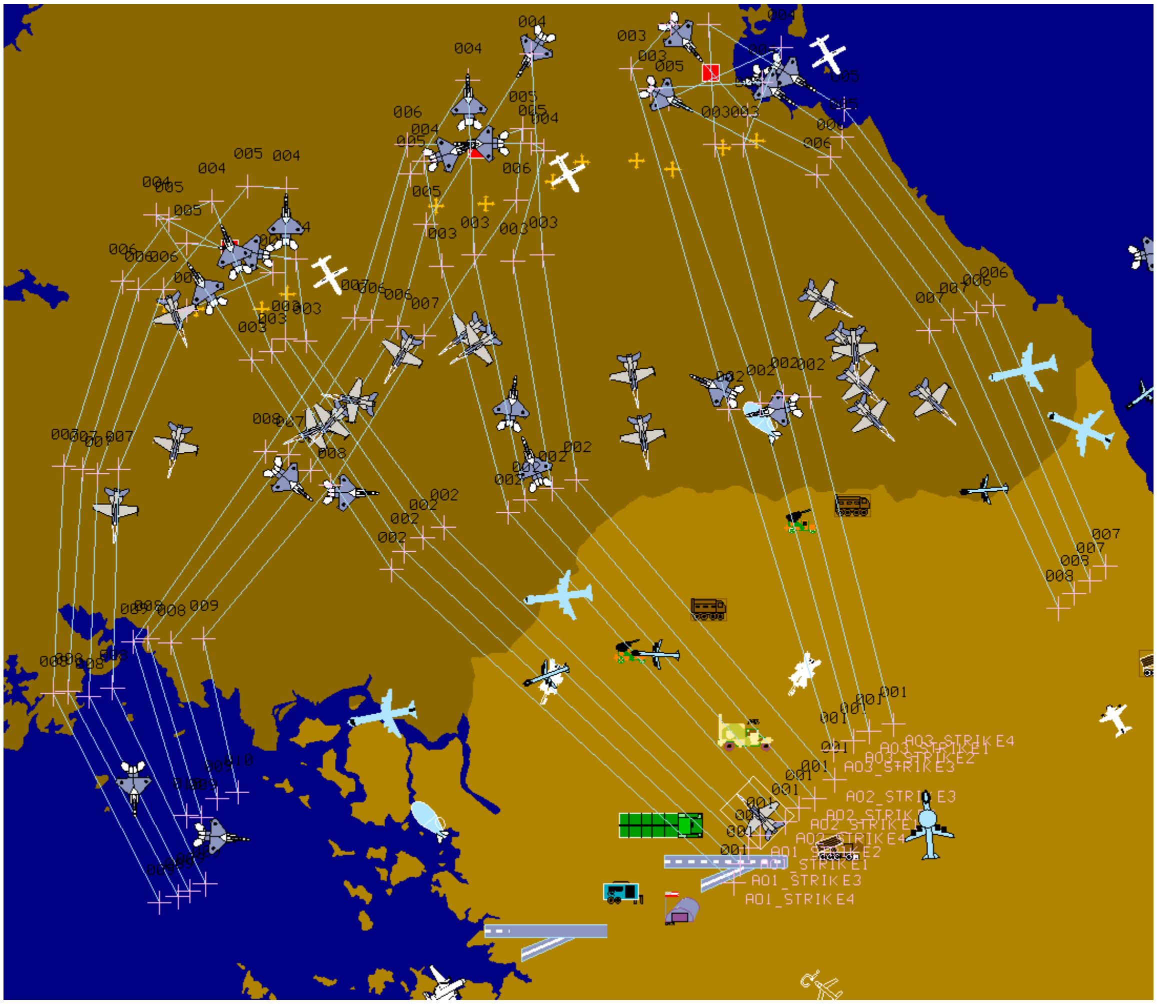


Figure 20 - Korona F15 STRIKER Missions.

Since the team wanted to have a simple scenario to demonstrate, and one that had visual (and emotional) impact, PSI proposed and finally built a simple though operationally relevant and timely scenario, that came to be called the “Wow” scenario. This scenario was selected by the team, and is described in the next section of this report.

5.4.2 "Wow" Scenario

The GIESim/JSB-RD team was looking for a demonstration scenario that was simple, had a short run time, was operationally viable, and that had emotional and visual impact and that demonstrated the value of GIESim communications modeling to JSAF. PSI proposed the scenario shown in Table 6 in late August that eventually became known as the "Wow" scenario.

Table 6 - Initial "Wow" Scenario Description from PSI

Scenario Set-up:

A tactical STRIKER aircraft is following terrain during ingress to a strategic target. Some ways ahead, a SOF guy on the ground in range of the target suddenly detects a mobile SAM site. The SOF guy is separated from the STRIKER by a mountain ridge.

JSAF w/o Comms:

The SOF guy "notifies" the STRIKER who evades the SAM. Everybody is happy, but the simulation is unrealistic, and worse, it erroneously predicts the good guy gets away.

JSAF w/ Comms but no relay:

The SOF guy uses JTIDS to send a threat warning to the STRIKER but the mountain range blocks direct radio contact. The STRIKER gets hit. Explosion. Good guy buys it. <u>Lesson</u>: We need to account for distance and terrain in realistic mission planning.

Add Relay: Based on the results of the prior run, we turn on a JTIDS relay – maybe a UAV. Now the STRIKER gets the relayed threat warning and evades!!
<u>Lesson</u>: Communications modeling and advanced communications planning in support of operations is critically important. JSAF needs GIESim for communications modeling.

After some discussion, the team embraced the "Wow" scenario, and PSI was asked to build it. PSI sent its first version of the "wow" scenario to the team on October 11. The scenario was shown in a series of screen shots plus data for the flight paths and ground positions.

Building the "wow" scenario required some searching for an appropriate area. A long valley was needed, and the SOF had to be positioned carefully to attain the desired terrain masking for the scenario. The new 2D terrain and contours available with the PSI Link-16 Planning Tool made the job tractable and easy to accomplish.

Screen shots of the "Wow" scenario follow along with brief explanations.

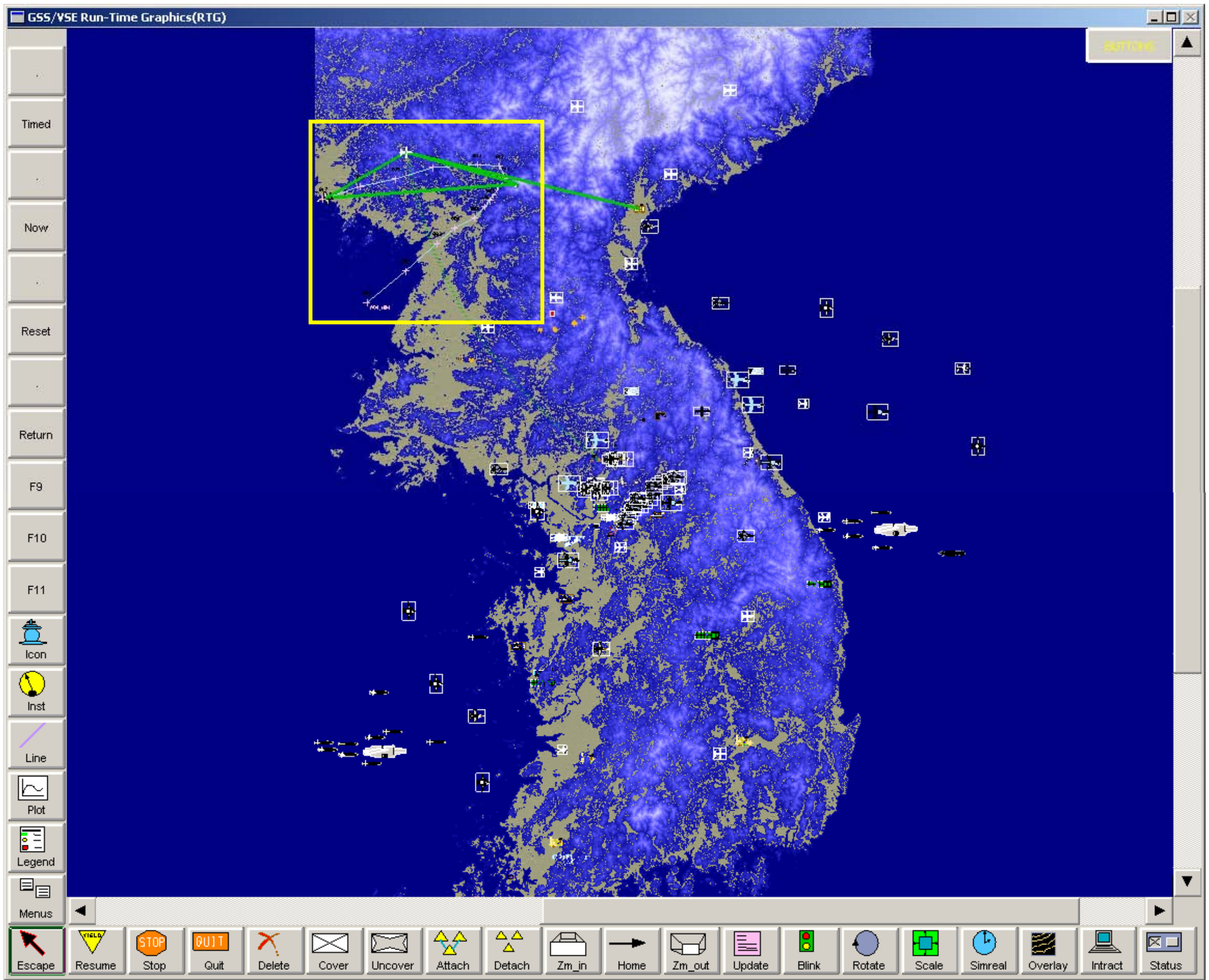


Figure 21 - Wow Scenario (yellow rectangle) addition to Korona

Figure 21 shows the wow scenario that was added to the Korona. The figure shows the new 2D terrain and contours that are available in GSS as of Release 10.3.6.

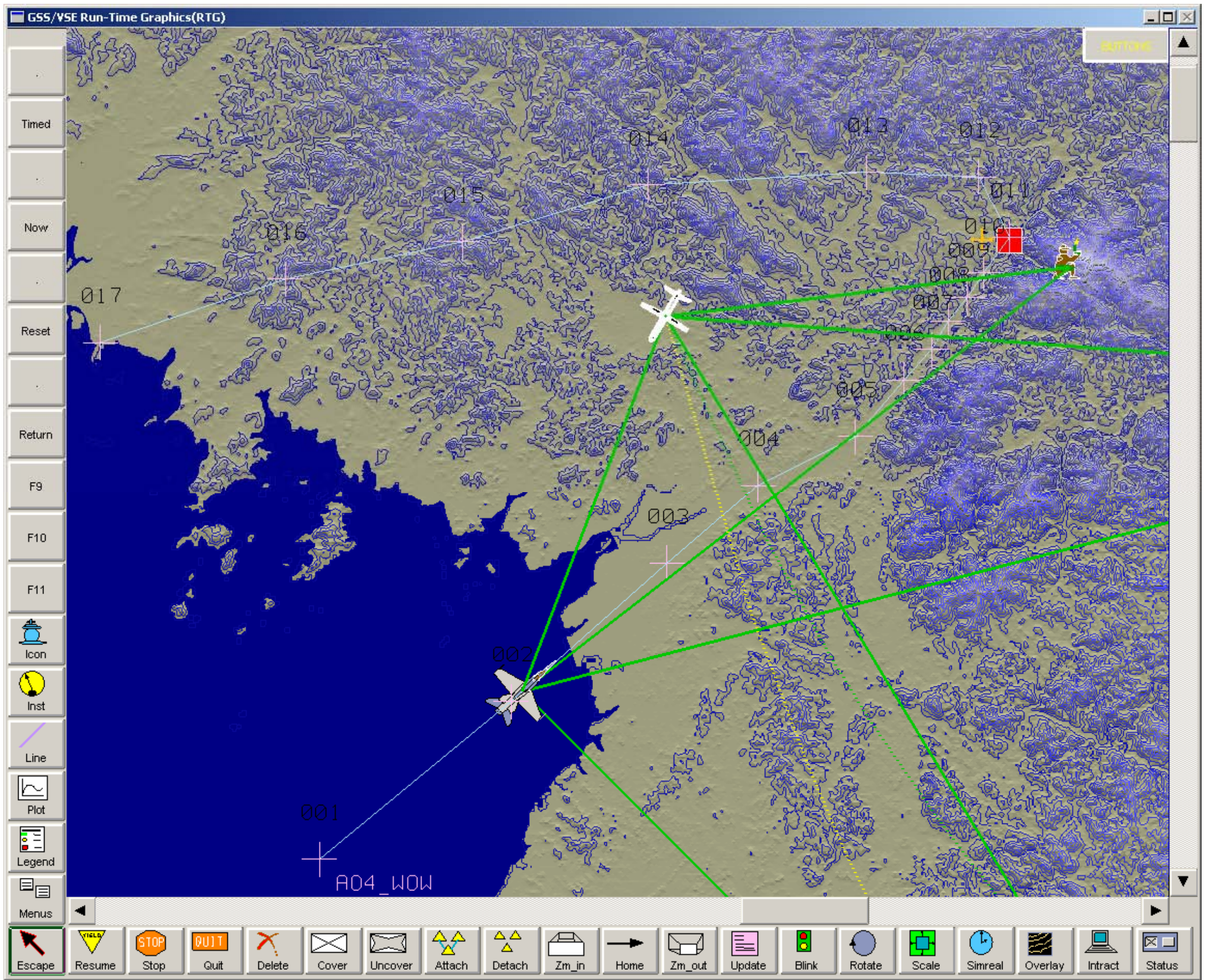


Figure 22 - Close-up of "Wow" Scenario

Figure 22 shows a close-up of the "wow" scenario that shows the F15 STRIKER, Global Hawk UAV relay, SOF, target (red square), and pop-up threat (gold cross). Green lines indicate good Link-16 radio connectivity. Note that the F15 has good connectivity with the SOF at the start of its attack run, while it is still at a high altitude.

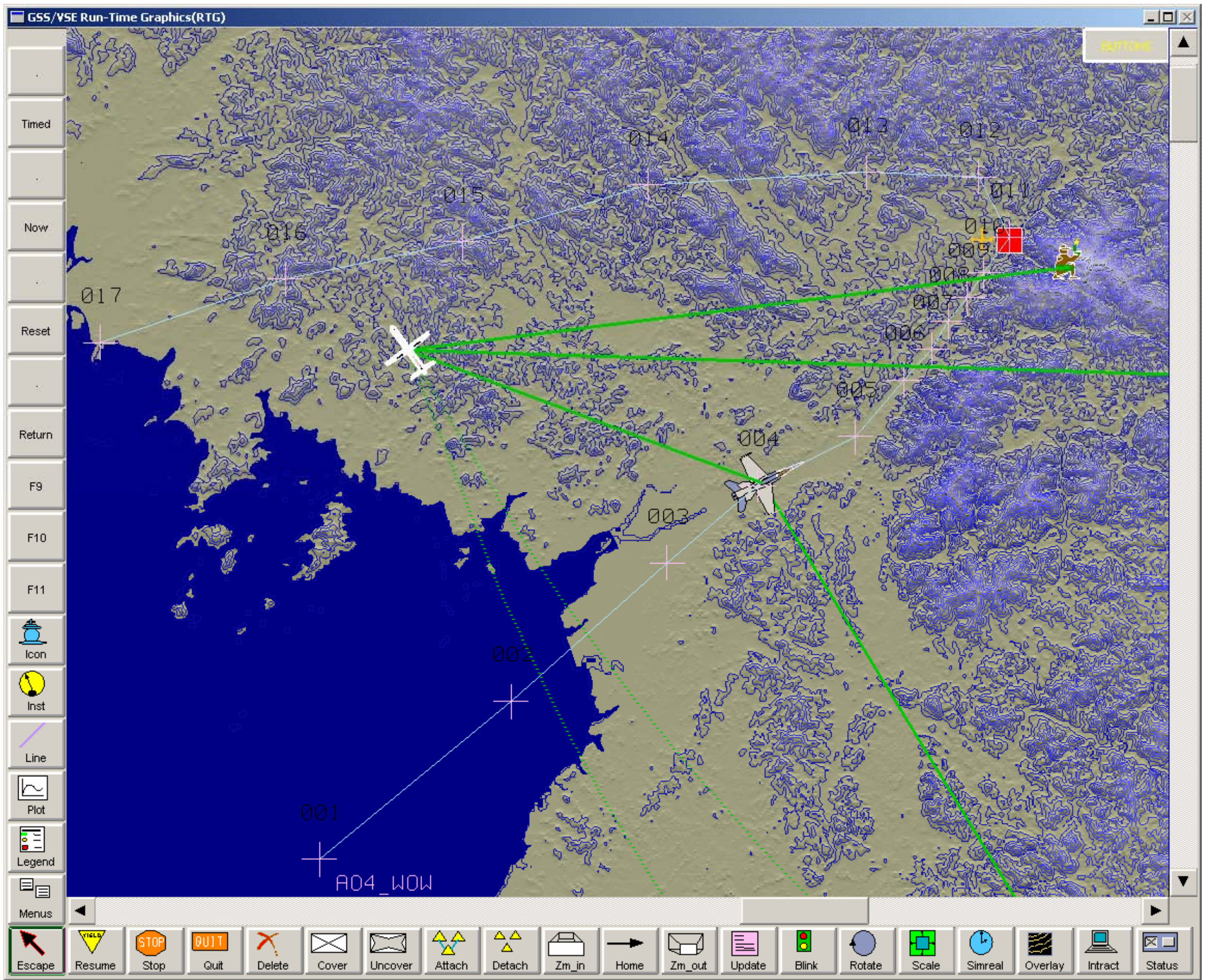


Figure 23 - Lost connectivity between the F15 and SOF due to terrain

As the F15 drops altitude to start following the terrain, RF connectivity between the F15 and the SOF is lost due to the mountainous terrain. This is shown in Figure 23. Note that there is still good connectivity between the F15 and UAV, and between the UAV and the SOF. This makes the UAV an excellent candidate for being a relay.

Once the F15 has completed its attack run, and begins to climb, connectivity with the SOF begins to reestablish as shown in Figure 23. The dotted yellow line indicates unidirectional connectivity. In this case since the F15 is transmitting at 100 watts and the SOF at 25 watts, the SOF can hear the F15 transmissions. When the F15 gains more altitude then full connectivity is restored as shown in Figure 25.

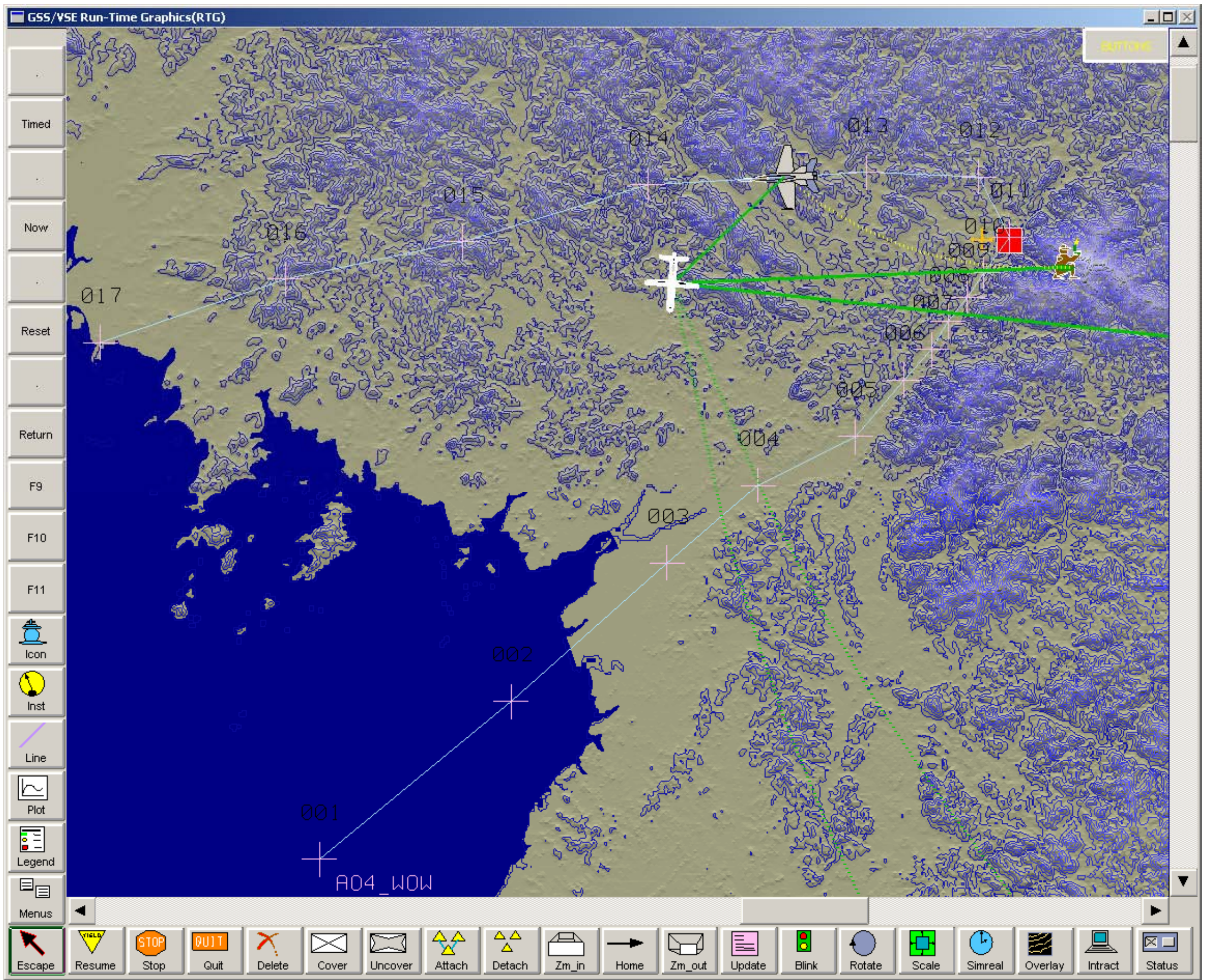


Figure 24 - F15-SOF connectivity starts to reestablish

Ultimately the team selected the PSI "Wow" scenario for it simplicity, and for its operational relevance and timeliness. The data for the "Wow" Scenario is provided in this report as Appendix A.

The next section of this report describes the specific JTIDS networks that were defined by PSI to support the "Wow" scenario. Whereas the original plans called for two scenarios, one scenario with and another scenario without the UAV relay, we ultimately built a single scenario (and single associated network design) that included the UAV. JSAF can simply move the UAV out of position whenever we chose to demonstrate lack of RF Link connectivity and the associated importance of the UAV relay.

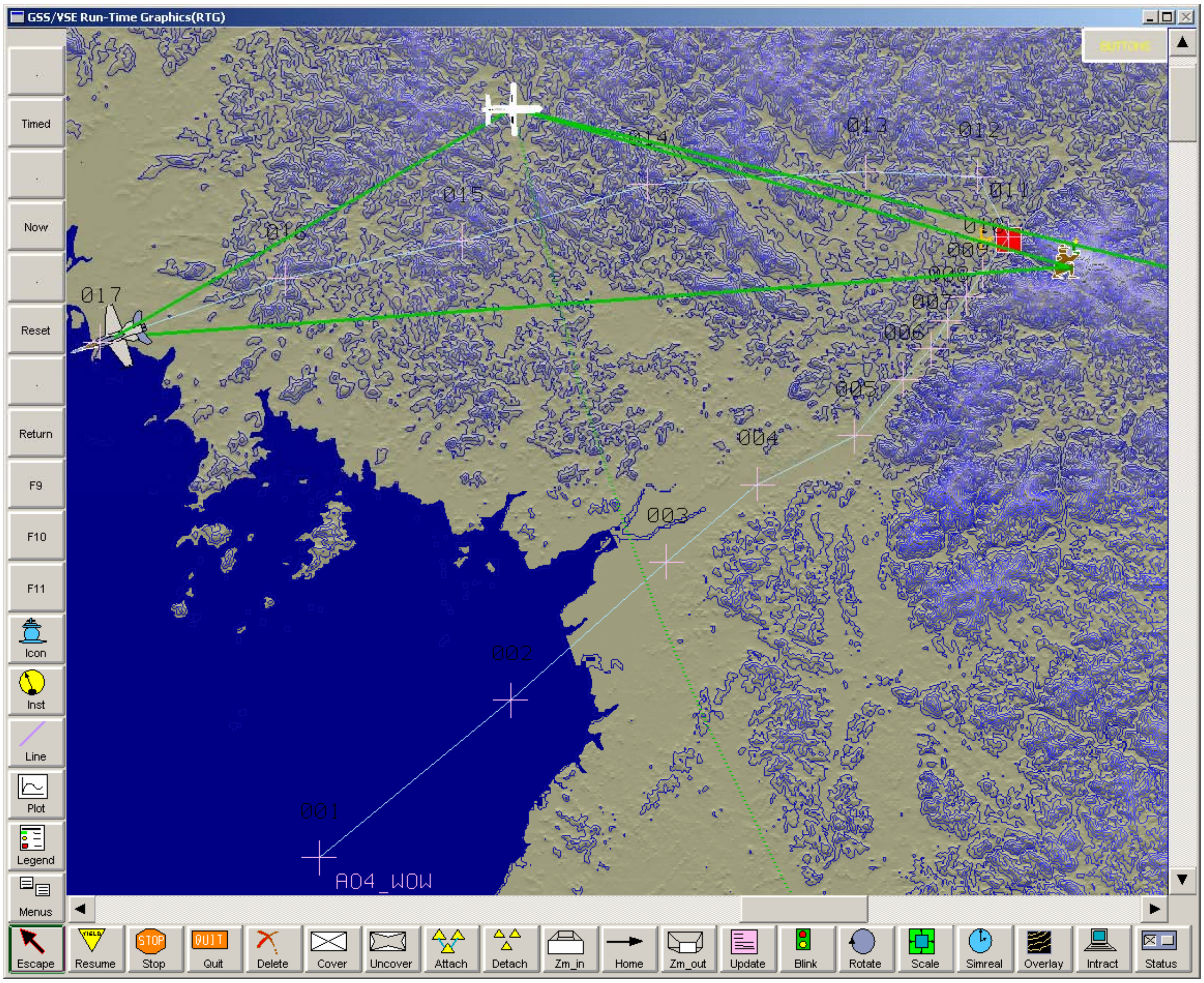


Figure 25 - SOF-F15 connectivity restored at end of mission

5.5 JTIDS Network Definition and Design

The ***"definition"*** of a JTIDS network refers to capturing or defining the requirements of the network, also referred to as the Information Exchange Requirements (IERs). The ***"design"*** of a JTIDS network refers to the process of allocating appropriate time slots and assigning them to JTIDS platforms based on the needs of the network definition. A network definition includes what platforms have to communicate, which TADIL-J messages to use, response time needs, type of network access required, etc.

For the "Wow" scenario, the three networks shown in
Table 7 were defined. The Threat Warning operational net was given a very fast response time of 1 second, uses a J15.0 message, and is intended for the SOF to warn the F15(s). The Mission Control Operational Net is intended for the SOF to send the F15 a message to engage the pop-up target. The Engagement Status net is intended for the F15 to send mission status messages to the SOF.

Table 7 - "Wow" Scenario Network Requirements

Network File Name:	Korona-WOW-F15.NET								
Net Label	NET_TYPE #	Access Mode	TDL_J Message	Source	Destinations				Response Time (Sec)
THREAT WARNING	14	Dedicated	J15.0	SOF_1	F154_WAO4.Lead	F15_WAO4.2	F15_WAO4.2	F15_WAO4.4	1
MISSION CONTROL	15	Dedicated	J12.7	SOF_1	F15_WAO4.Lead	F15_WAO4.2	F15_WAO4.2	F15_WAO4.4	2
				Receiver	Contention Sources / Transmitters				
ENGAGEMENT STATUS	16	Contention	J12.6	SOF_1	F15_WAO4.Lead	F15_WAO4.2	F15_WAO4.2	F15_WAO4.4	2

The Planning Tool from the PSI Link-16 NMS was used to capture the network requirements definition. Before the Planning Tool could be used however, new **"generic"** nets had to be defined in support of the tactical elements in the "Wow" scenario. The Generic Operational Net Database Manager was used to define these new generic net types, e.g., SOF to F15 Threat Warning net. Then the PSI Link-16 Planning Tool was used to capture and refine the network requirements. The "Wow" network requirements were added to the networks previously defined for the Korona Scenario.

The Planning Tool was used to automatically launch the Automated Resource Allocation and Assignment Tool (TSA), which allocated the required time slots in a matter of minutes. Note that this process is typically manual, and can take hours or days to accomplish. The PSI Link-16 NMS has automated the entire Link-16 management process including time slot allocation, and is therefore both easy and fast to use.

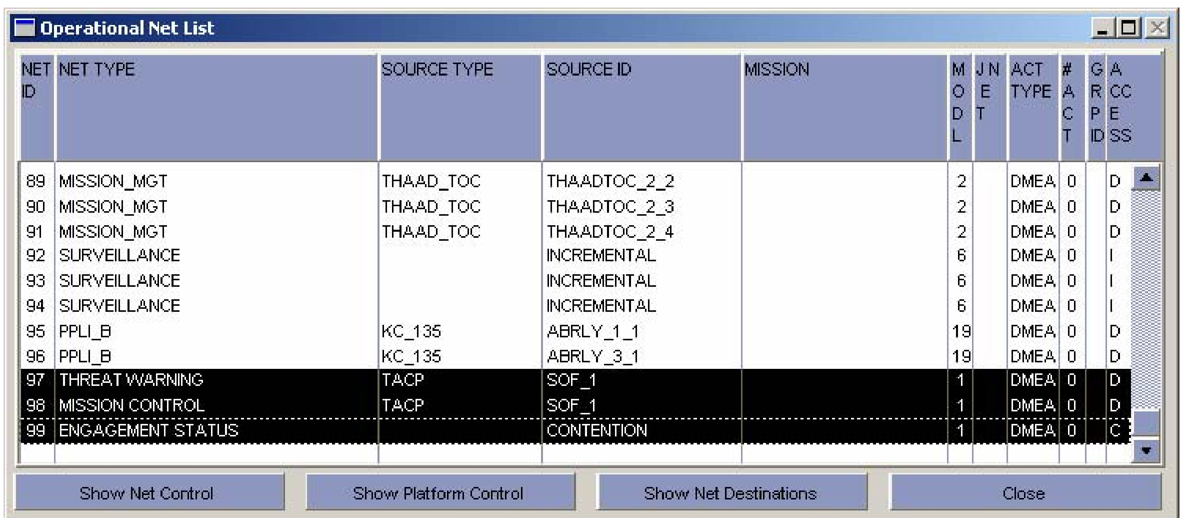
The resulting network file, Korona-WOW-F15.NET, contains both the network requirements and time slot allocations and assignments for the Korona-Wow scenario.

Note that the PSI Link-16 Planning Tool was modified to produce an ENTITY map file, ENTITY.OUT, and a file, NETMAPFILE.TXT, which contains a list of the NETTYPE numbers in the network. Table 8 shows the NET TYPE numbers for the combined Korona-Wow scenario and networks.

Table 8 - "Wow" Network NET TYPE Numbers

NET_TYPE #	Network Description Label	Designed for...	
1	RTT_B	Korona Network Types	
2	AIRCONTROL_UPLINK		
3	ELECTRONIC WARFARE		
4	FTR_TO_FTR_TARGET		
5	ENGAGEMENT_COORD		
6	RESIDUAL_MSG		
7	NEEDLINE		
8	PPLI_A		
9	VOICE_1		
10	VIDEO_DOWNLINK		
11	PPLI_B		
12	MISSION_MGT		
13	SURVEILLANCE		
			Purpose of Wow Net Type (See Wow Network tab for details)
14	**THREAT WARNING**	**Wow Scenario Network**	Used to send Threat Warning from SOF to any F15 in the net
15	**MISSION CONTROL**		Used to send Mission Assignment/Target information from SOF to F15s in the net
16	**ENGAGEMENT STATUS**		Any F15 can send engagement status to the SOF

Figure 26 shows a screen shot of the Operational Net List from the JTIDS Simulation that has loaded the new Korona-WOW-F15.NET file. The three highlighted networks show the new operational nets that were designed for the "Wow" scenario.



Operational Net List

NET ID	NET TYPE	SOURCE TYPE	SOURCE ID	MISSION	MODL	JNET	ACT TYPE	# ACT	GRP ID	ACCESS
89	MISSION_MGT	THAAD_TOC	THAADTOC_2_2		2		DMEA	0		D
90	MISSION_MGT	THAAD_TOC	THAADTOC_2_3		2		DMEA	0		D
91	MISSION_MGT	THAAD_TOC	THAADTOC_2_4		2		DMEA	0		D
92	SURVEILLANCE		INCREMENTAL		6		DMEA	0		I
93	SURVEILLANCE		INCREMENTAL		6		DMEA	0		I
94	SURVEILLANCE		INCREMENTAL		6		DMEA	0		I
95	PPLI_B	KC_135	ABRLY_1_1		19		DMEA	0		D
96	PPLI_B	KC_135	ABRLY_3_1		19		DMEA	0		D
97	THREAT WARNING	TACP	SOF_1		1		DMEA	0		D
98	MISSION CONTROL	TACP	SOF_1		1		DMEA	0		D
99	ENGAGEMENT STATUS		CONTENTION		1		DMEA	0		C

Show Net Control | Show Platform Control | Show Net Destinations | Close

Figure 26 - Operational Net List Showing New Nets for the "Wow" Scenario

It is worth noting that there was considerable team misunderstanding over how JTIDS relays work. At first the team thought that explicit message transmission requests had to be sent to and from JTIDS relays, a thought that greatly complicated code development in JSAF. In reality, any JTIDS radio can be configured to act as a transparent relay as in the case with the UAV in the "Wow" Scenario. Therefore, all JSAF had to do was to send position updates to JTIDS, and the JTIDS simulation would automatically handle message relaying through the UAV due to the design of the network. This clarification greatly simplified efforts within JSAF.

5.6 GIESim/JSB-RD Merger M&S Design

This section primarily covers the technical design changes associated with the PSI JTIDS simulation for the GIESim-JSAF merger.

5.6.1 RTI-S Design & MC02plus FOM

Since JSAF uses RTI-S rather than the DMSO RTI, PSI needed to move to its use. There was also a desire to move the GIESim SAB Demo to RTI-S, so that we only had to deal with a single RTI rather than two. This was ultimately accomplished.

A copy of the RTI-S was obtained in a release of JSAF that was provided by the AFRL JSB-RD group. Design changes required the replacement of the DMSO RTI with the nodeless RTI-S. This ultimately required minor changes to the PSI GSS development environment.

Use of RTI-S required use of a new rid file (RTI-s_1.3D9A.rid), which is supplied with the RTI-S distribution. In addition, since PSI is currently using MS VC++ 6.0, we needed to use the winnt_vc++6.0 version of the RTI-S library from the RTI-S distribution.

JSAF currently uses the Millennium Challenge 02 FOM, therefore a requirement of the merger was to use content of this FOM “merged” with the FOM that was developed by GIESim team.

Details on the development and testing with the merged MC02++ FOM are covered in Sections 5.7.1 and 5.8.1 respectively.

5.6.2 GIESim-JSAF JTIDS Design

The requirements analysis for the GIESim-JSAF merger led to the following requirements for the version of the PSI JTIDS simulation for the merger:

- Entity Mapping for Link-16 platform references exchanged between JSAF and JTIDS
- Creation of Entity map for use by JSAF based on a common force scenario.
- Update of Link-16 platforms based on position updates received from JSAF via GIESIM_ENTITY_STATE HLA interactions.
- Creation of a NetTypes file for use by JSAF based on the network that is designed to meet their requirements.
- Need to modify the GIESIM_MSG_SEND HLA interaction with the addition of a NET_TYPE field.
- Need to receive and act on Link-16 message transmission requests sent by JSAF in the form of modified GIESIM_MSG_SEND HLA interactions.
- Notify JSAF by sending a GIESIM_MSG_RCVD HLA interaction when a Link-16 message is received by the target destination

Since the PSI Link-16 Planning Tool would be used to design the common scenario and associated network requirements and design, its design was modified to output an Entity Map and an enumerated list of NetTypes. Both JSAF and the modified PSI JTIDS simulation use these output files. Figure 27 shows the modified PSI Planning Tool and output files.

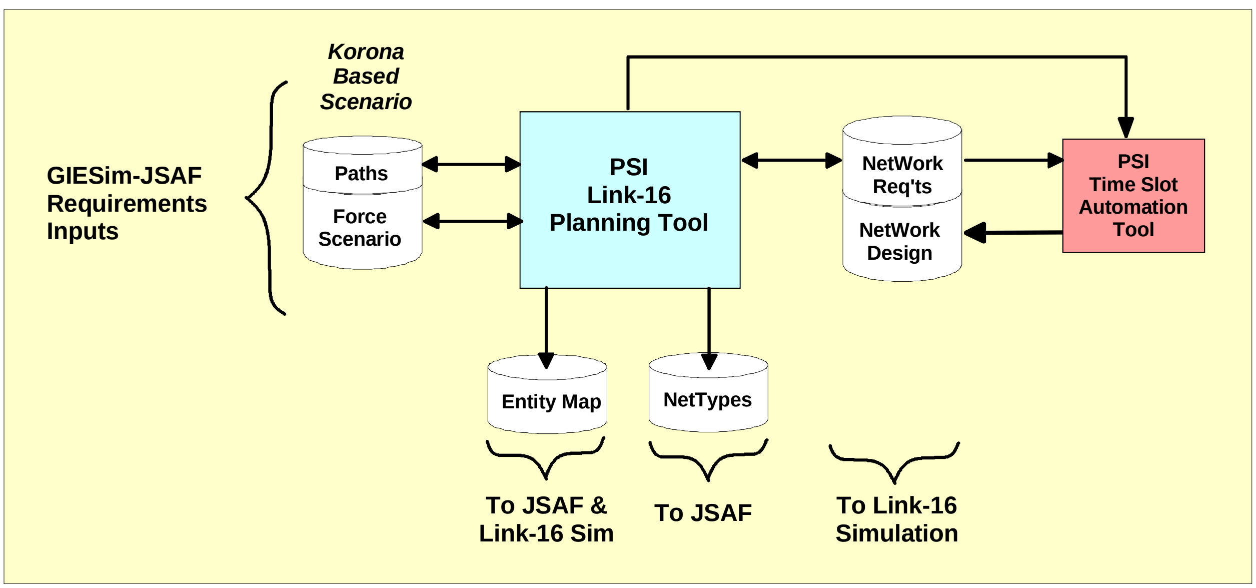


Figure 27 - Modified Link-16 Planning Tool for GIESim-JSAF Merger

Figure 28 shows the high-level design of JSAF and JTIDS with associated files and HLA interactions. Both JSAF and JTIDS need to use the same MC02plus FOM. JTIDS directly uses the Network Requirements and Designs output by the PSI Link-16 Planning Tool and automated

Time Slot Allocation and Assignment Tool. JSAF inputs and uses the contents of the NetType file for making Link-16 network transmission requests to JTIDS. Both JTIDS and JSAF input force composition elements from the common force scenario. Each simulation uses its own internal representation of Link-16 platform reference – hence the need for Entity mapping that is described in the next section. The movement paths from the common scenario are mapped into the internal representation in JSAF. Since JSAF drives position updates into JTIDS, JTIDS does not require movement paths.

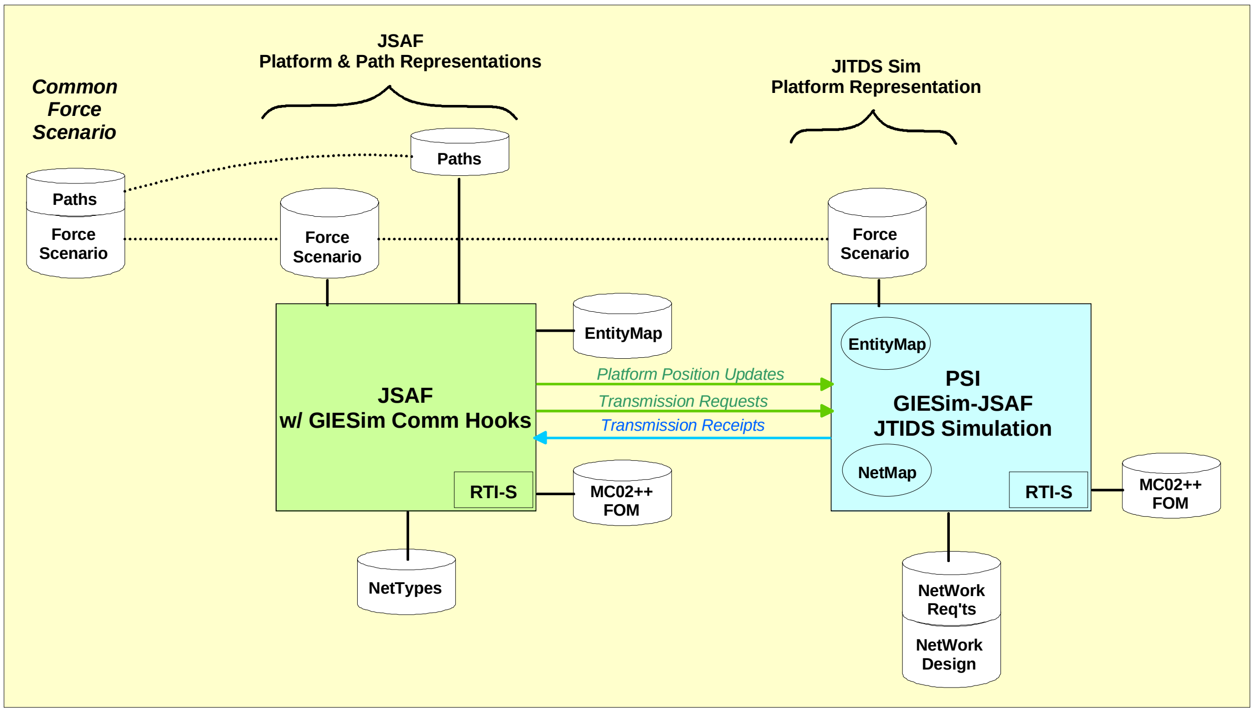


Figure 28 - High-level Design of JSAF-JTIDS Merger

The remainder of this section will address each specific design requirement in turn.

5.6.2.1 Entity Mapping Design

As discussed earlier and as shown in Figure 28, HLA interactions are used to send position updates and to make transmission requests and to report reception of messages from a particular platform; GIESIM_ENTITY_STATE, GIESIM_MSG_SEND and GIESIM_MSG_RCVD HLA interactions are used for these respectively. Internal to each HLA interaction are one or more ENTITY_IDs. The simulations use these IDs to make specific platform references with respect to a common scenario.

For human readability, platforms are usually given specific names in the scenario, e.g., F15_1.1, and E3(1). Each simulation then maps these names to its own internal representation, usually numeric values or keys. Therefore, a mechanism was needed for simulations to exchange platform IDs in a way that simplified the interface fast exchange of HLA messages.

The GIESim/JSB-RD team agreed to use an Entity mapping provided by PSI. Our Entity mapping approach takes each platform label, i.e., string, in the common scenario file and runs it through a hashing function to produce a unique numeric value for each platform label. Each simulation then maps this hashed value to its own numeric representation for the platform.

As shown in Figure 27, the PSI Link-16 Planning Tool provides the Entity Map from the common scenario file.

5.6.2.2 Design of HLA Platform Position Updates

JSAF sends platform position updates from JTIDS. Figure 29 illustrates the operations. JSAF and JTIDS each load the same scenario of JTIDS platforms. In JSAF mobile platforms will navigate on flight paths. Many of these paths are similar or exactly the same as those PSI created in its Korona and "Wow" scenario. In JTIDS, mobile platforms follow "virtual" flight paths based on periodic position updates received from JSAF. GIESIM_ENTITY_STATE HLA interactions are sent from JSAF to JTIDS to update positions.

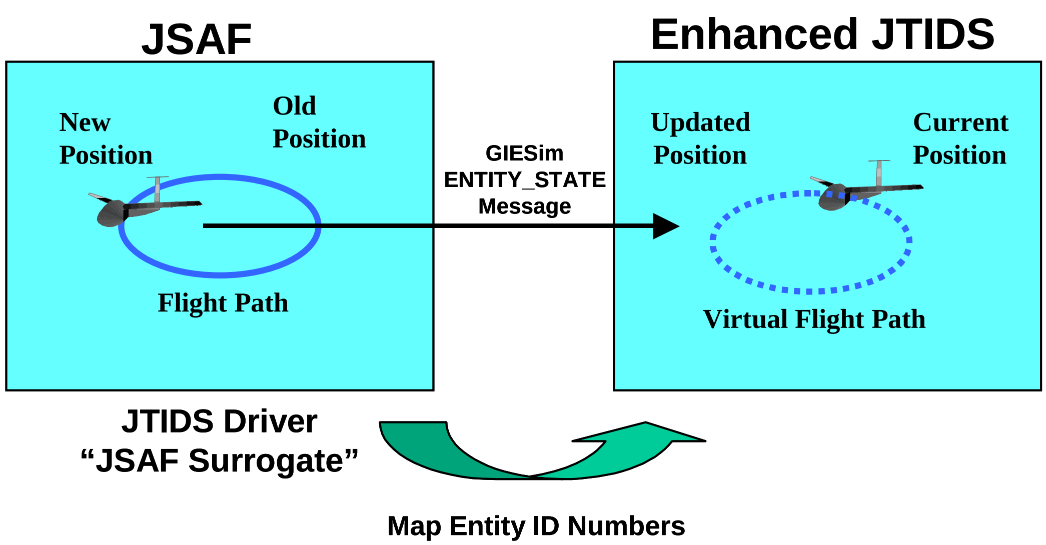


Figure 29 - JSAF Platform Position Updates into JTIDS

Therefore, a version of the PSI JTIDS simulation was created for the GIESim-JSAF merger to accept external position updates. In order to support early interoperability tests internal to PSI, enhancements were also designed into JTIDS to allow it to generate HLA position updates. This allowed us to test the interface using complex scenarios with different update rates typical of what was expected to come from JSAF.

5.6.2.3 JSAF-JTIDS Network Transmission Design

When the internal logic in JSAF determines that one platform needs to send a message to another platform via Link-16, it will:

a) Build the message with a unique ID number and determine its size
b) Obtain the mapped IDs of the sending and receiving platforms
c) Determine the type of Network to send the message on
d) Build a GIESIM_MSG_SEND message that encodes the above information, and then
e) Sends it over HLA to the JTIDS Simulation.

The JSAF simulation will hold the message until one of two things happens:

a) It receives a GIESIM_MSG_RCVD interaction from JTIDS for the receiving platform, or
b) A message receive time-out occurs.

SAIC is adding the appropriate logic to JSAF to support these operations.

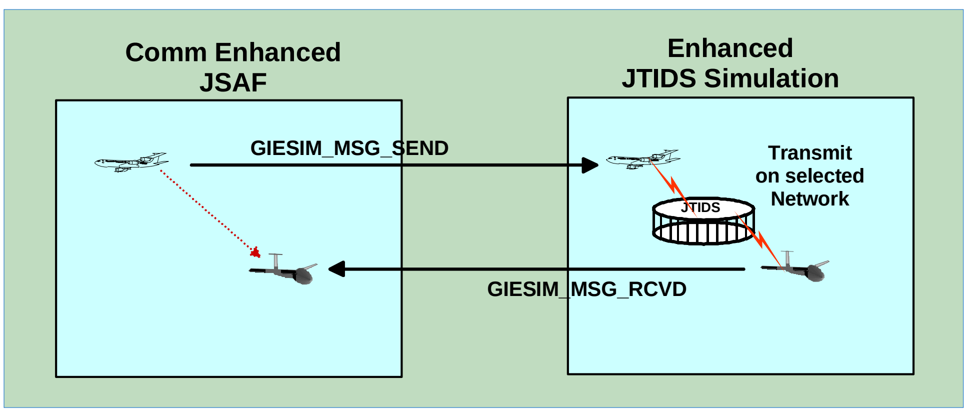


Figure 30 - JTIDS Sim Adding Communications to JSAF

Figure 30 and Figure 31 illustrate the simulation interfacing between JSAF and JTIDS, and the resulting Link-16 message transmission handling.

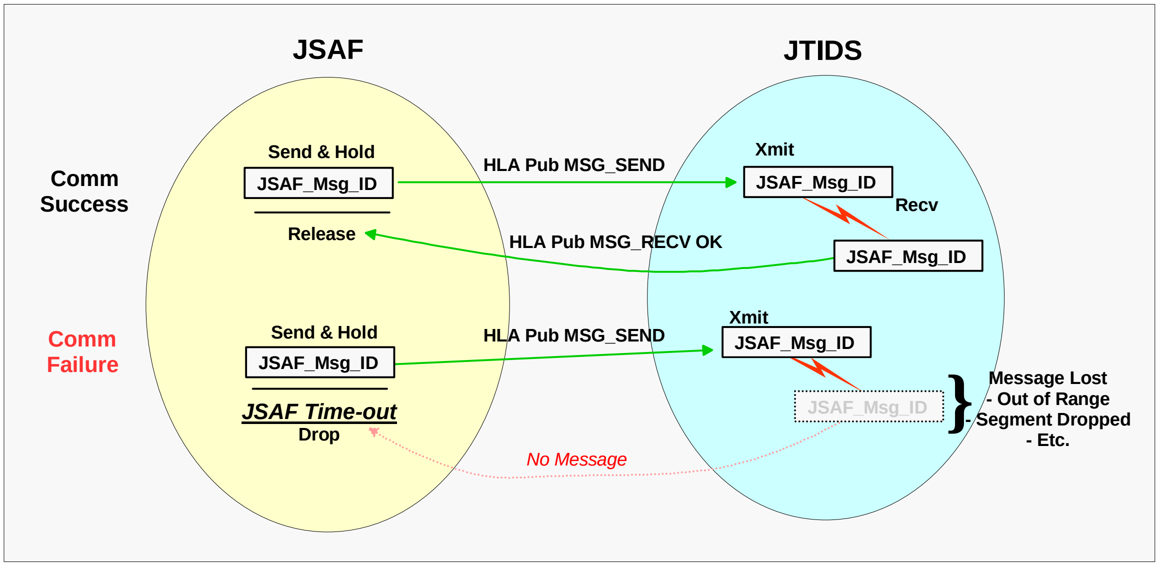


Figure 31 - Functional Messaging Relationship of JSAF and JTIDS

On the side of the JTIDS simulation, enhancements to JTIDS support several operations that take place when a GIESIM_MSG_SEND interaction is received:

a) JTIDS performs validity checks on the HLA message content received.
b) JTIDS uses the Source and Destination IDs to look-up these platforms in its internal database.
c) JTIDS uses the Net Type field (see next section) to set parameters that will be used to find an Operational Net to support the message transmission.
d) If JTIDS can find an Operational Net of the correct type and with the required source and destination platform, then it starts transmission of the message through the chosen JTIDS network, otherwise the request is dropped silently, e.g., no HLA message is sent to JSAF.

Note that JTIDS will perform message segmentation and reassembly (SAR) on messages that exceed the capacity of the operational net. More details on these operations are described shortly.

When all segments of a particular ID message are received within JTIDS, then JTIDS will:

a) Determine the additional latency that was added by the total transmission process, including SAR.
b) Build a GIESIM_MSG_RCVD interaction with the destination platform ID, JSAF message ID and latency.
c) Send the HLA interaction out over the HLA for the JSAF simulation to receive.

The JTIDS simulation interface was enhanced to support these operations.

5.6.2.4 Net Types & Network Design

Link-16 Operational Nets and their associated time slot allocations and assignments are required to support the communications requirements of the scenario running in JSAF.

PSI had previously designed several networks to support and test our Korona scenarios. These Korona-oriented networks served as the basis for the JSAF-JTIDS network that was described earlier in Section 5.5. Whereas network transmissions occur automatically in PSI's standard JTIDS simulation, enhancements were needed to allow transmissions between platforms to occur as a result of external HLA requests.

For this purpose the following design changes were introduced:

1. A NET_TYPE field was added to the GIESIM_MSG_SEND interaction. This allows JSAF to specify by type number, the nature of the communication. See Figure 32.
2. The PSI Link-16 Planning Tool was modified to create NetType maps from the network designed to support the common JSAF-JTIDS scenario. See Figure 27.
3. A NetType Map in JTIDS that maps the NET_TYPE number to a particular network type definition, e.g. "AIRCONTROL_UPLINK".

```
***SEND_MSG_DETAIL

SEND_ORIG_ENTITY
    1    SEND_FED_ID       INDEX
    1    SEND_ENTITY_ID    INDEX

SEND_RECV_ENTITY
    1    RECV_FED_ID       INDEX
    1    RECV_ENTITY_ID    INDEX

SEND_MSG_ID              INTEGER
SEND_MSG_LENGTH          INTEGER
SEND_CUM_LATENCY         REAL
SEND_NET_TYPE            INTEGER
```

Figure 32 - Added NET_TYPE Field

Table 8 lists the NetTypes that were defined for the PSI created Korona-WDL scenario, along with the actual NET_TYPE enumerations. Based on the type of message that a JSAF platform "wishes to send", e.g., Engagement Status – NET_TYPE 16, JSAF will choose the appropriate NET_TYPE. JSAF and JTIDS need to use this common net mapping produced by PSI.

Internal to JTIDS there is a database of operational nets, and each net has a field that lists its operational type. Therefore, when a message transmission request is received over HLA, the NET_TYPE number will be mapped to a particular net type description, and the combination of platform source, destination and net type will be used to find an operational net (if it exists).

Link-16 terminals support a variety of Access Modes. These are listed in Table 9 below. When Operational Nets are defined, their Access Mode must be specified. Dedicated Access means that a particular Operational Net has only one transmitter. In Contention Access, all Link-16 platforms are potentially transmitters, and "contend" for access to the net. Dedicated Slot Reuse supports pooled bandwidth capabilities.

Link-16 Access Modes
Dedicated Access
Contention Access
Dedicated Slot Reuse

Table 9 - JTIDS/MIDS Access Modes

Therefore, in order to handle general message transmissions requests from JSAF, the design of the enhanced JTIDS simulation will need to support each type of Access Mode whether the message goes directly through a net or through the SAR functions. This is a new design requirement on the JTIDS simulation for the GIESim-JSAF merger.

5.6.2.5 Design of HLA Transmission Request Handling

In the enhanced version of the PSI Link-16 JTIDS simulation for JSAF, most Link-16 message transmissions occur as a result of requests driven externally from JSAF[1]. Therefore, the existing JTIDS internal message generation logic was circumvented and replaced by routines to generate messages based on HLA stimuli.

In addition, new Operational Net selection logic was designed to select Operational Nets based on the platform source, destination and net type. Entity ID and net type mapping is required on message input, and Entity ID mapping is required on response to JSAF. Operational Nets typically have many destinations and the nets that are defined for JSAF required choices in this area. In order to simplify the interactions with JSAF and internal logic of JSAF, JSAF will provide a single destination address in the message transmission request. This meant that new logic had to be added to the JTIDS simulation to identify when the particular target destination platform specified by JSAF has received the message. Figure 33 illustrates many of these features.

In the event the teams decide to use broadcast Link-16 messages, e.g., for PPLI messages, or want all recipients on an Operational Net to report, JTIDS will support a destination field of '0'. This implies that all destinations in an operational net that receive the message will respond by the generation of GIESIM_MSG_RCVD interactions. This is illustrated in Figure 34.

[1] Some internally generated messages could be turned on in the driven JTIDS system to provide background traffic. Note that internal message traffic generation in the JTIDS simulation is currently turned OFF.

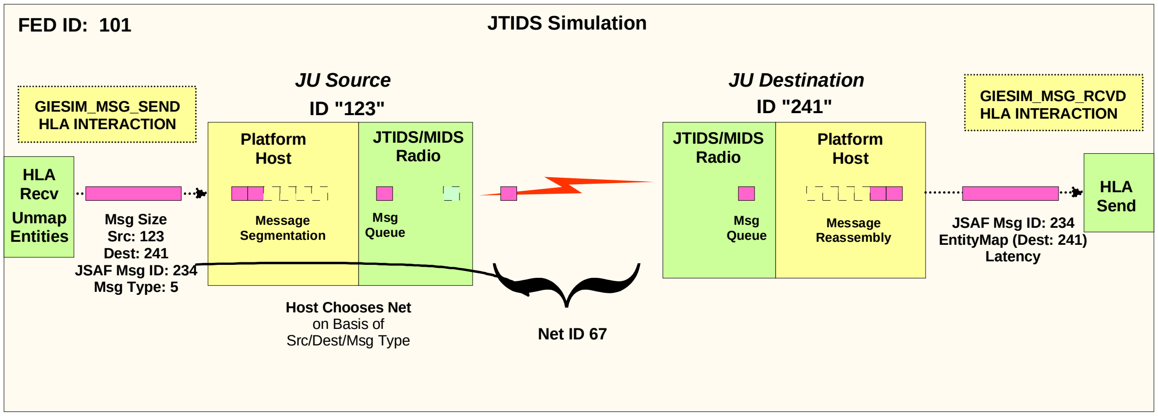


Figure 33 - JTIDS Internal Message Handling

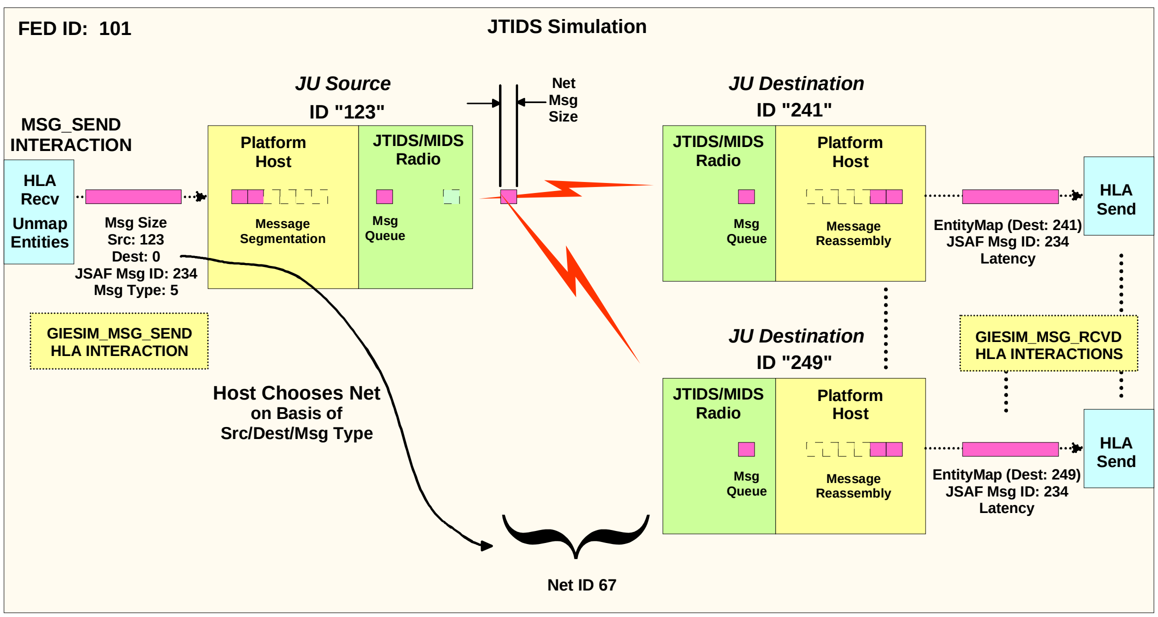


Figure 34 - Future Message Reporting Capability

Note that messages that can fit into the available capacity of the chosen Operational Net by-pass the SAR capability, whereas messages that will not fit into the capacity of the net are segmented by the JTIDS SAR capability.

5.6.2.6 JTIDS Message Payload and SAR Function Design

The combination of (1) the JSAF Message ID, (2) Destination Platform ID, and (3) Incoming Message Latency value comprise a payload of information that must be sent through the JTIDS simulation so that it can be reported back to JSAF on message reception, and must be preserved independently of whether or not the message passes through the SAR capability.

This JSAF-related payload must therefore be passed through the entire JTIDS simulation, and constituted a required design change to the PSI JTIDS simulation.

The version of the JTIDS that was used in the GIESim SAB Demo provided SAR capabilities that were designed specifically for the limited scenario that was being run in the demo. In order to support the more general nature of the communications modeling required for JSAF, a more robust and extensive SAR capability was required.

The design of the new SAR capability for the GIESim-JSAF merger was based on the assumption that only a small number of large, image-related messages would likely be in transit at any one time. The current SAR capability is therefore limited to ten outstanding large messages at any one time.

5.6.2.7 Design of HLA Reporting of Message Reception

In the JTIDS simulation, when a message is sent over a particular Operational Net, the message flows through the simulation and all platforms that are designated as destinations in the Operational Net are scheduled to receive the message. If conditions are appropriate for reception, e.g., strong enough signal and SNR is sufficient, at the scheduled time of arrival, then the message is "received".

In the enhanced JTIDS simulation, a receiving platform "host" will determine if its ID matches the platform destination ID sent by JSAF. If so, then a response HLA GIESIM_MSG_RCVD interaction is built for sending to JSAF. Note that a JSAF destination ID of '0' will cause all platforms to report reception of the message.

To build the response message, JTIDS moves the JSAF Message ID from the received message payload to the appropriate field in the GIESIM_MSG_RCVD interaction. JTIDS then puts the entity-mapped platform ID into the Destination ID field of the HLA interaction. Finally JTIDS determines the time required to pass the message through the simulation and adds it to the incoming latency from the message payload, and puts the updated latency value in the HLA interaction. Figure 33 and Figure 34 illustrate this.

5.7 GIESim-JSAF Merger M&S Development

This section provides details on the PSI developments required for the GIESim-JSAF merger.

5.7.1 RTI-S Development & Integration

Conversion of PSI GIESim GSS-based simulations, and testing GSS with the RTI-S used by JSAF proved to be rather difficult, and ultimately required some minor (though tricky) modifications to the environment of GSS itself. Testing was done with the HLA Test Driver (TEST_DRV) that PSI developed in 2003 in preparation for the GIESim SAB Demo.

5.7.1.1 Changes to GSS

Part of the difficulty in using RTI-S involved incorrect (or misleading) statements in the RTI-S read me file that implied the need to link RTI-S DLL files rather than library files (i.e., .lib files). Furthermore, the file naming conventions used in RTI-S are different than those used in the DMSO RTI. Ultimately, PSI took a very methodical approach to isolating factors required to make the RTI-S work with GSS. The current release of GSS relies on “private” system files at build time when a simulation is “prepared”. Modifications to one key GSS “internal” file were needed to get GSS to run with the RTI-S. The RTI_HOME and RTI_BUILD_TYPE environment variables used by GSS were modified to point to the location of the RTI-S directory that was built from the JSAF release.

5.7.1.2 RTI-S FOM Requirements

Once we had RTI-S working under GSS and in our test driver simulation, it was easy to modify our JTIDS and SAT_COM simulations to RTI-S. However, we did discover a new, unexpected characteristic of RTI-S.

With the DMSO RTI, each simulation could to use a subset of the largest, superset FOM in a multi-simulation system, and all that mattered was that the FOMs functionally matched. However, the RTI-S was much more demanding. Not only do the FOMs need to match functionally, they also need to match physically. RTI-S performs a check-sum on the FOMs and fails to connect if the FOMs do not have the same check-sum. Figure 35 illustrates this.

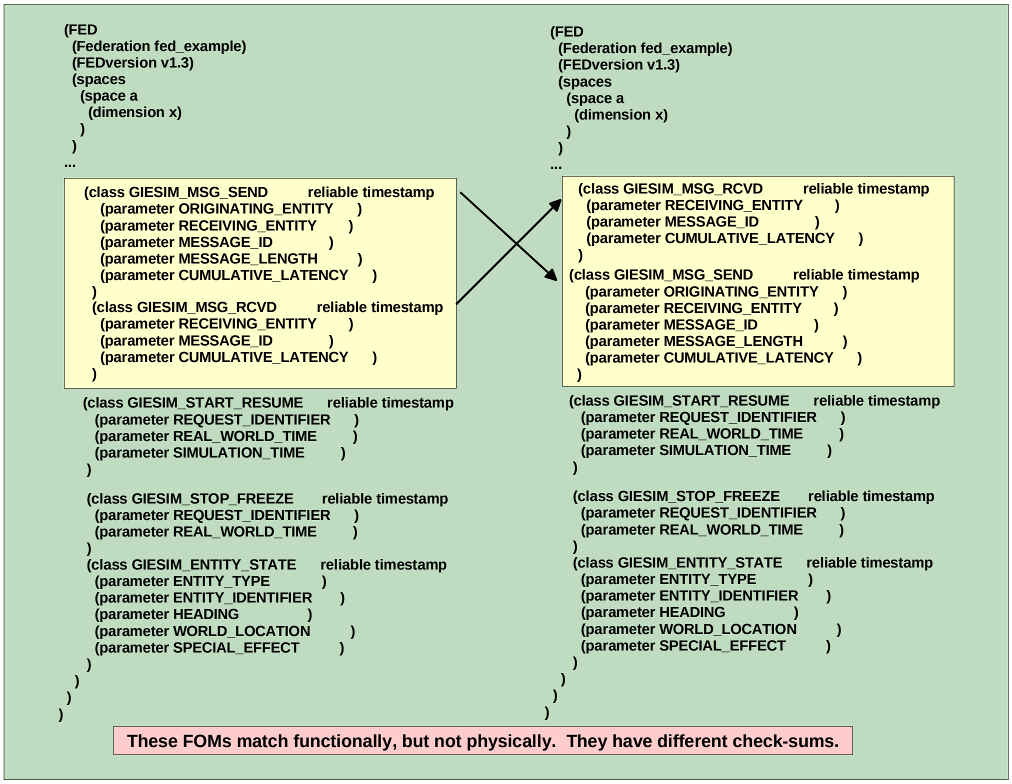


Figure 35 - Two FED files - Functionally though Physically Different

With the realization that all GIESim-JSAF simulations needed to run with the exact same FOM (.fed file), PSI determined that it needed to test with the same FOM that was planned for use with the GIESim-JSAF merger. This FOM used the Millennium Challenge 02 (MC02) FOM with the GIESim HLA Interactions added to it. This combined FOM, called MC02plus and built by SAIC, was converted by PSI to the required FED (Federation Execution Details File) format using the DMSO Object Model Development Tool. PSI then successfully tested the GIESim.fed FOM with our simulation components.

With this success, all the PSI GIESim SAB Demo components were modified for RTI-S and installed in the GIESim and JSAF labs in Rome.

Note that each time a GSS-based simulation using HLA is re-prepared, i.e., re-built, a new local FED file is generated. This FED file is based on all the HLA interactions used in the GSS simulation. Since RTI-S requires that all federates use the *same*, *super-set* FOM, the GSS generated FED file must be replaced by the full FOM, in this case, the MC02plus_v4.fed file. This is a minor nuisance, and requires that a copy of the target FED file be either kept in the simulation directory, or moved into the simulation directory and renamed GIESIM.fed.

5.7.2 JTIDS Development for GIESim-JSAF Merger

This section provides detailed descriptions of the developments in JTIDS that were accomplished for the GIESim-JSAF merger. An overview of these developments and changes to JTIDS is first provided, and the development of more discrete changes and new models are then described. Note that to realize operations with JSAF, the JTIDS simulation was designed to act either as a "driver" surrogate for JSAF to support testing, or as the JTIDS communications messaging "server" or "driven" JTIDS system for JSAF.

5.7.2.1 Overview of JTIDS Developments for JSAF

Figure 36 show the full GSS CAD drawing of the JTIDS simulation that will be used in the merger. Several parts of the simulation are highlighted and numbered in order to focus on key areas that were affected by the design requirements for the GIESim-JSAF merger.

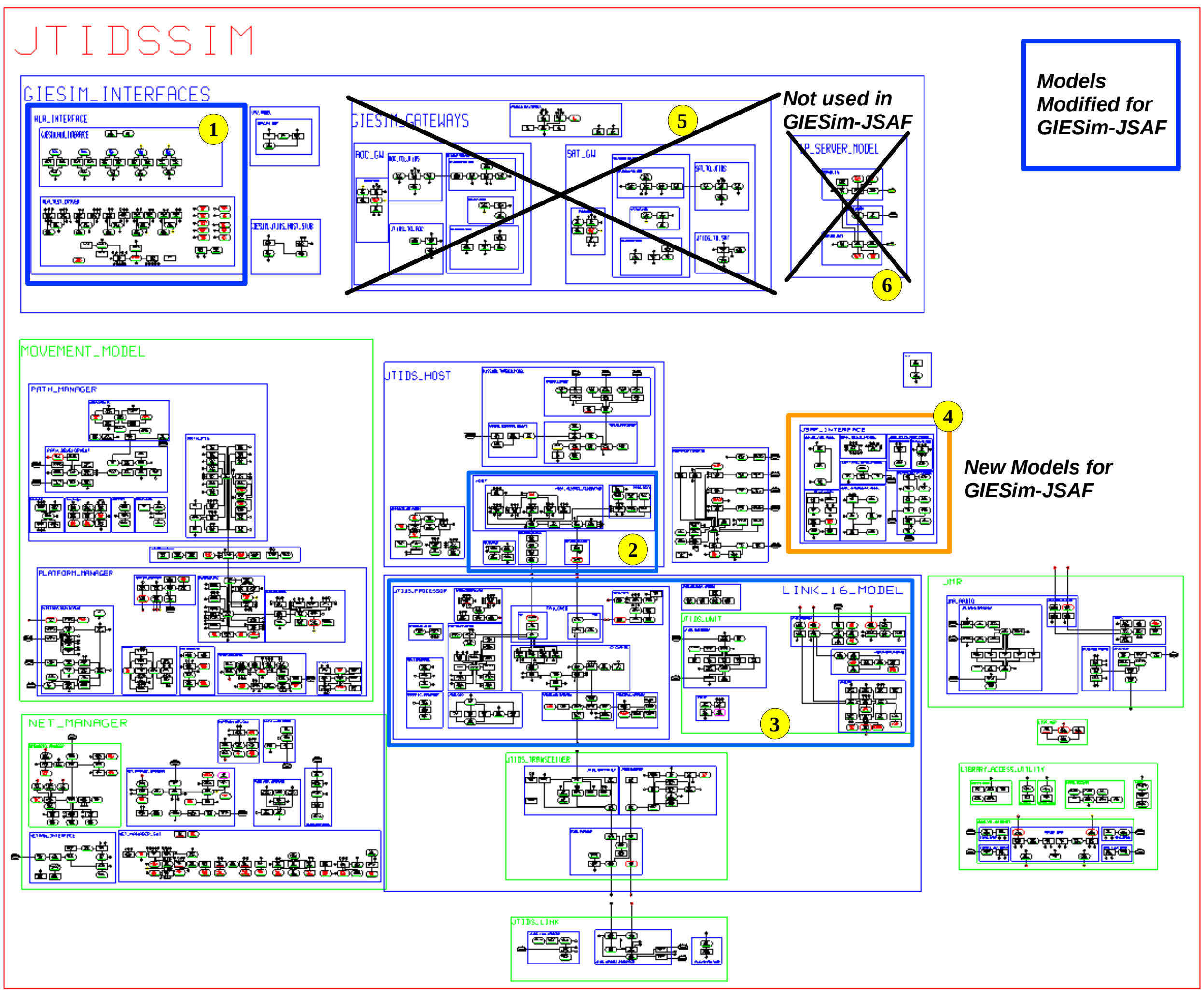


Figure 36 - Enhanced JTIDS Simulation for GIESim-JSAF Merger

Models that are outlined by heavy blue lines indicate hierarchical models that were modified to support the design requirements. The hierarchical model outlined in orange is a collection of new models that were developed specifically for the merger. Quite a number of design changes and developments were required for the merger. The changes to the numbered models are as follows:

1. The GIESim HLA Interface model was modified to support the addition of the NET_TYPE field to the GIESIM_MSG_SEND interaction. This modification is detailed in a subsequent section.

2. The HOST model of the JTIDS simulation required a number of modifications to support external transmission requests and to report receipt of a message over an Operational Net. In particular, the internal JTIDS message data structure had to be modified to support the payload of the JSAF Message ID, Destination Address and Latency values. This data structure change "percolated" through many parts of the simulation. More detail on these changes is provided further on in this report.

3. The JTIDS data structure changes for the JSAF message payload also required many changes within the JTIDS Terminal model.

4. The JSAF_INTERFACE is a new hierarchical model that handles many of the details of the simulation interface to JSAF and required hooks into the rest of the enhanced JTIDS simulation. This model development is detailed in a separate section.

5. The GIESIM_GATEWAY model was developed for the GIESim SAB Demo, and does not apply to the GIESim-JSAF merger. The Control Specification of the JTIDS simulation was modified such that this model is no longer exercised.

6. The IP_SERVER_MODEL was also developed to support the GIESim SAB Demo, and is no longer exercised in the JTIDS simulation.

5.7.2.2 HLA Interface Modifications

Figure 37 indicates changes to the models in the HLA_INTERFACE hierarchical model. The primary development was the addition of the NET_TYPE field to the GIESIM_MSG_SEND HLA interaction. Red stars in Figure 37 indicate GSS resources that were modified for the addition of this new field. Associated processes were also modified to support this change.

The processes PUBLISH_SEND_MESSAGES and PROCESS_REC_MSG_SEND were modified to support the ability of the JTIDS simulation to either act as a surrogate for JSAF or as a recipient of JSAF message transmission requests.

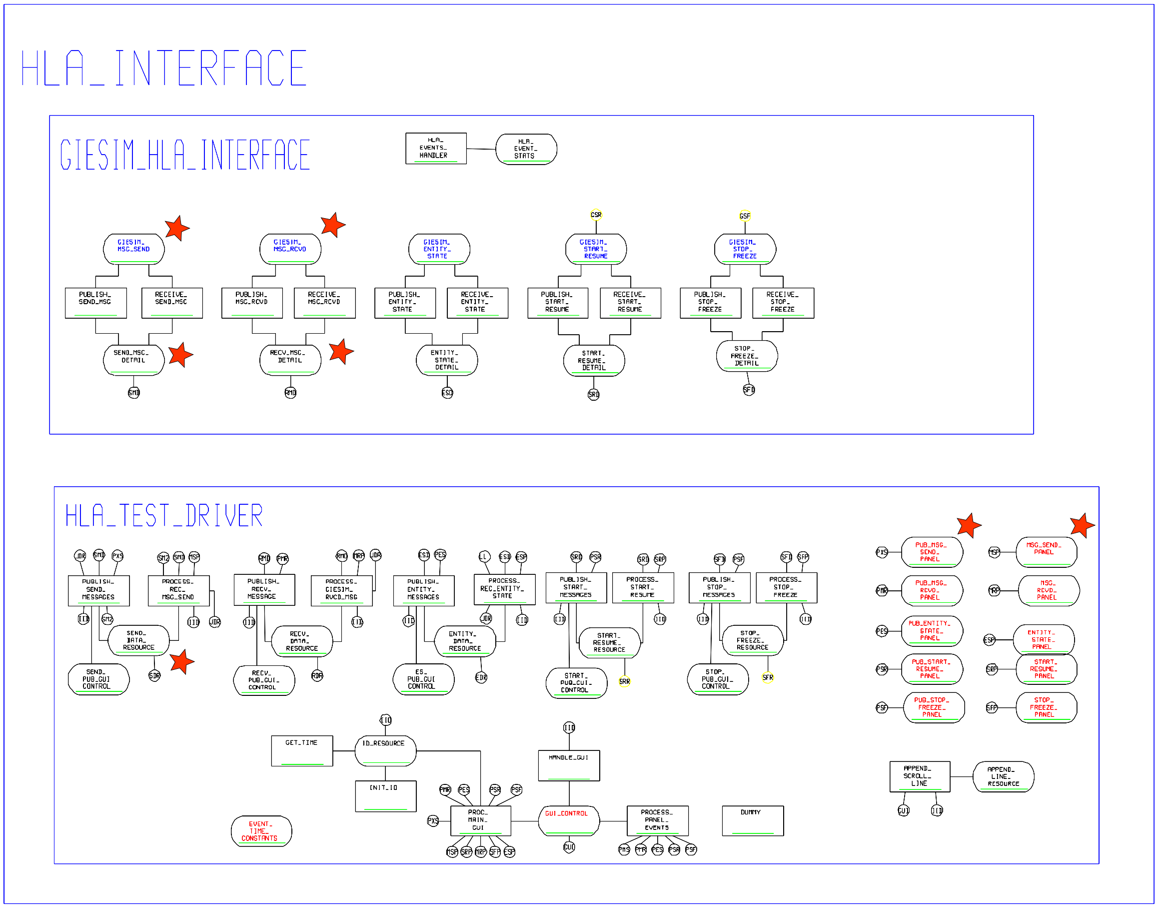


Figure 37 - Modification to HLA Interface

5.7.2.3 New JTIDS Model Development for JSAF

Figure 38 shows the detailed GSS drawing for the JSAF_INTERFACE model that was developed. This model "encapsulates" most of the simulation interfacing requirements for operation with JSAF, and for tying into the internals of the JTIDS simulation. The purpose and function of each of the models within the JSAF_INTERFACE model are as follows:

5.7.2.3.1 DRIVER_COM_MODEL

When the JTIDS simulation is in "driver" mode, Link-16 platforms are moved along movement paths that they are associated with in the scenario file. This model handles part of the JSAF surrogate functions, and is responsible for sending test HLA position updates for platforms when they move.

5.7.2.3.2 DRIVE_MODEL

This model provides functions for both the “driver” and “driven” modes of the enhanced JTIDS simulation.

In driver mode, it sets the HLA message rate for sending GIESIM_ENTITY_STATE position updates. A panel is provided to set the update rate. This capability was developed to test the expected range of position updates coming from JSAF to verify that the driven version of JTIDS could handle the update rate. Internal JTIDS simulation coordinates are mapped to LAT LON representation before being sent.

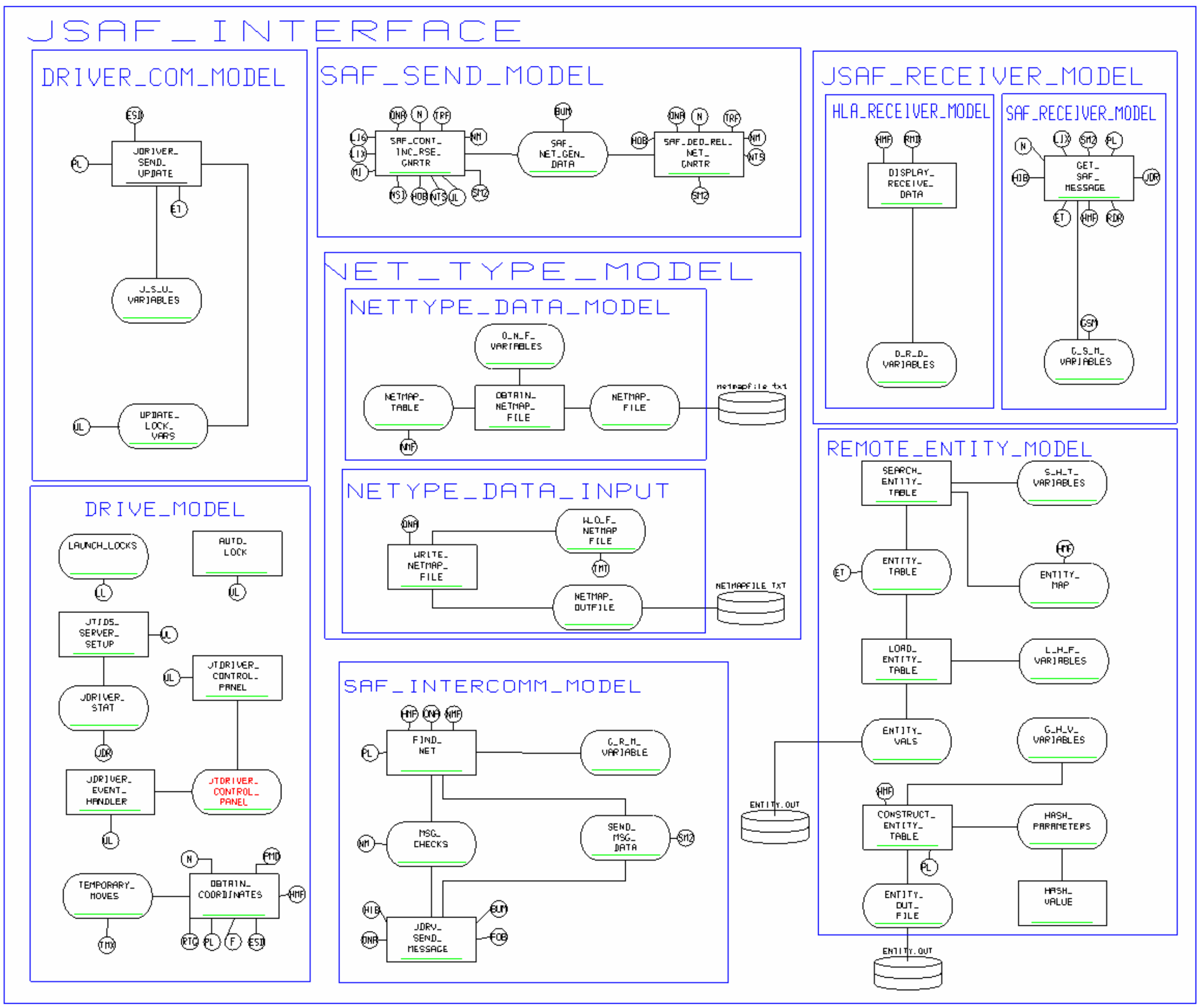


Figure 38 - New Models for Interface to JSAF

In both driver and driven modes, the DRIVER_MAPS between LAT LON coordinates and internal coordinates used within JTIDS.

5.7.2.3.3 REMOTE_ENTITY_MODEL

This model handles the mapping between internal JTIDS platform IDs and hashed values of platform IDs that are exchanged between JSAF and JTIDS. This model calls a hashing function on the platform names to create the hashed platform values.

5.7.2.3.4 NETTYPE_DATA_MODEL

This model reads the NETMAPFILE that was generated by the PSI Link-16 Planning Tool, and builds a table of net-type labels and their associated enumeration for use in other models.

5.7.2.3.5 SAF_INTERCOMM_MODEL

This is the main model for JTIDS when it is being driven by JSAF for JTIDS message transmission requests. The fields in the received GIESIM_MSG_SEND HLA interaction are interpreted by this model. Entity IDs are reversed mapped to internal sending and receiving platforms IDs, and the Net Type value is mapped to a net type label or string.

The sending and receiving platforms and the net type label are fed into the FIND_NET process to locate an Operational Net to send the message over. The JDRV_SEND_MESSAGE process sends the message to the appropriate process in the SAF_SEND_MODEL based on the Access Type of the Operational Net selected. If the size of the JSAF message is too big for the capacity of the chosen Operational Net, then the JSAF message is sent through the SAR functions in the JTIDS simulation. SAR functions are covered in the next section. If no Operational Net can be found, then the message transmission request is dropped.

5.7.2.3.6 SAF_SEND_MODEL

This model contains two processes that build and send JTIDS data structures through the JTIDS simulation. One process is used for Dedicated Access Mode, and the other is used for Contention Access and Dedicated Slot Reuse Access Mode.

Each process will build an internal JTIDS message transmission data structure that will include the JSAF data payload, i.e., destination platform, JSAF message ID, latency.

5.7.2.3.7 SAF_RECEIVER_MODEL

This model is used when a JSAF message has been successfully received over an Operational Net within the JTIDS simulation when it is being driven by JSAF. The model builds a GIESIM_MSG_RCVD HLA interaction that includes the entity-mapped platform ID of the receiving platform, JSAF message ID, and accumulated latency, i.e., the latency through the JTIDS transmission added to the incoming latency that was sent in the JSAF message request.

5.7.2.3.8 HLA_RECEIVER_MODEL

This model is used for debugging when the JTIDS simulation is being used as a driver. This model handles display of GIESIM_MSG_RCVD interactions from the driven system.

5.7.2.4 Internal Host and Terminal Models Changes to Support JSAF

Figure 39 shows some drawing details for parts of the JTIDS_HOST model, particularly the HOST model that contains the HOST_MESSAGE_GENERATOR and FREE_TEXT model, and HOST_OUTBOUND_QUEUE and HOST_INBOUND_QUEUE models. Figure 39 also indicates the connections between the HOST model and the LINK-16_MODEL. This section will describe the model developments that were required to support the GIESim-JSAF merger.

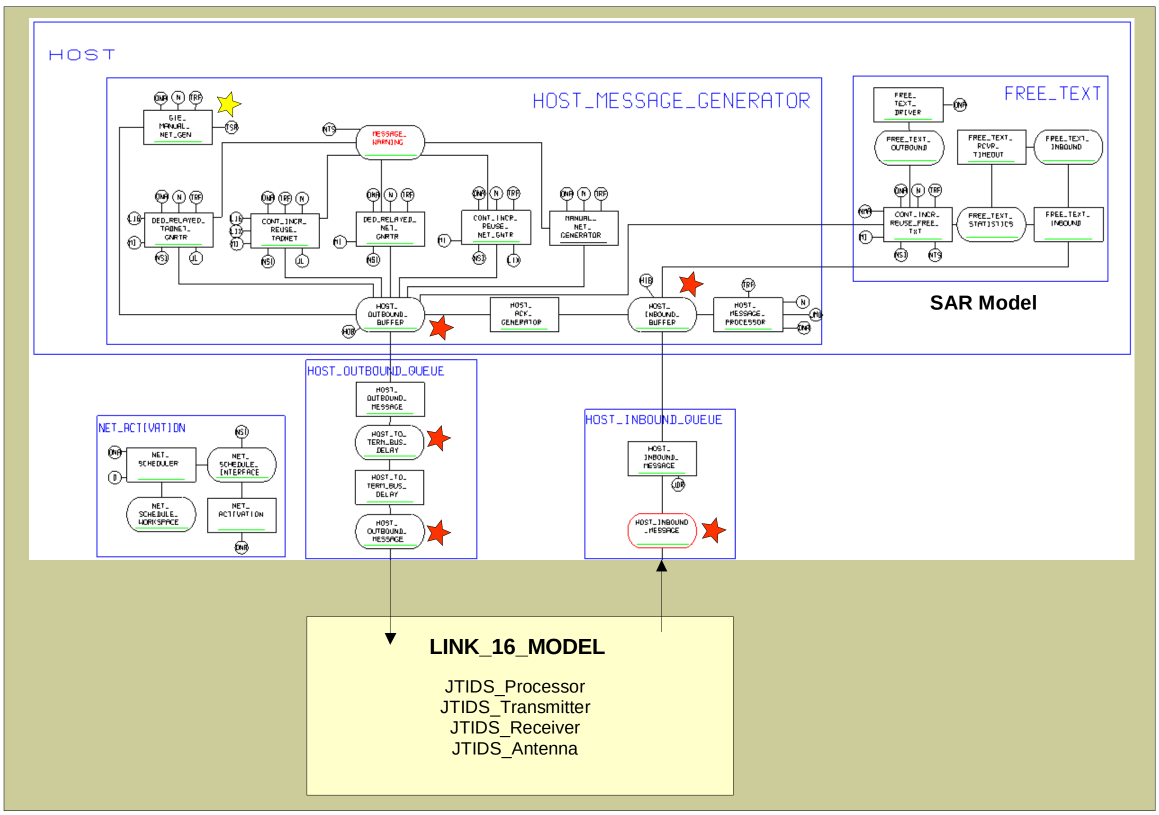


Figure 39 - Host Model Changes for JSAF Payload and SAR Functions

5.3.2.4.1 Additions to Outbound and Inbound Data Structures

The HOST_OUTBOUND_QUEUE resource contains a data structure that is sent through the Link-16 simulation, i.e. the LINK_16_MODEL. Fields in this data structure encode the sending platform, the Operational Net number and its Access Mode, a list of destination platforms, and other information required by the Link-16 model, and needed for measuring performance of the network. The HOST_INBOUND_QUEUE resource contains a similar data structure that is loaded whenever a message is received. In particular, the ID of the receiving platform is specified for use by the HOST_MESSAGE_PROCESSOR process that is called by the Link-16 Model whenever it receives a message.

For the operation of JTIDS with JSAF several fields were added to these data structures. As noted in an earlier section of this report, fields that were added to support the JSAF payload include: (1) JSAF Message ID, (2) Destination Platform ID, and (3) latency. Three additional, undedicated fields were also added for future use. In addition, an existing MESSAGE_SOURCE data attribute was modified to support a "SAF" tag so that JSAF related messages could get special handling.

The data structures from the inbound and outbound queues are replicated in many places throughout the JTIDS simulation. The red stars in Figure 39 indicate some of the resources that use these data structures. Over a dozen resources in the JTIDS simulation that use parts of these data structures were modified for the merger with JSAF.

5.7.2.4.2 Modifications to the HOST_MESSAGE_PROCESSOR

When a Link-16 message is received in the LINK_16_MODEL, the HOST_MESSAGE_PROCESSOR in the HOST model is called to handle it. This HOST model process was modified to look for the "SAF" tag in the received data structure in the HOST_INBOUND_QUEUE. If the message is tagged as a SAF message, then the GET_SAF_MESSAGE process in the SAF_RECEIVE_MODEL of the JSAF_INTERFACE is called for further handling. See Section 3.2.3.7.

5.7.2.4.3 New HOST_MESSAGE_GENERATOR Process

Processes within the HOST_MESSAGE_GENERATOR model are used to build various outbound messages. A new process, the GIE_MANUAL_NET_GEN, was added as an interface to the HOST_MESSAGE_GENERATOR process, and is called from the SAF_SEND_MODEL.

5.7.2.4.4 New FREE_TEXT SAR Model

For the GIESim SAB Demo, SAR models were added to JTIDS to support segmentation and reassembly of specific image related messages. For JTIDS operation with JSAF, a more generalized version of SAR was needed. The FREE_TEXT model shown in Figure 39 handles the JTIDS SAR functions for the GIESim-JSAF merger. This model is invoked for JSAF messages that will not fit as a whole into the capacity of the Operational Net. The model will use nets that are defined to use the Link-16 Free Text message type. If all segments of a message are not received within a time-out period by the FREE_TEXT model, it will drop the JSAF message. FREE_TEXT currently supports only Contention Access. This model will be enhanced to support the other Access Modes required for JSAF, particularly Dedicated Access mode.

5.8 M&S Testing

This section describes testing that was performed internal to PSI, and interoperability testing that was done to ensure proper operation of the PSI simulation components the GIESim-JSAF merger.

5.8.1 RTI-S Testing

Once the driver simulation, TEST_DRV, was built successfully, it could be tested. Testing disclosed the need to either relocate the RTI-S DLL files to the Windows directory or to modify the environment variables to include the RTI-S DLLs in the path. The latter approach is preferred and is the one that PSI ultimately adopted.

Figure 40 illustrates initial testing of the RTI-S with the GSS TEST_DRV simulation. Several instances of TEST_DRV were launched and we verified correct operation of the simulations.

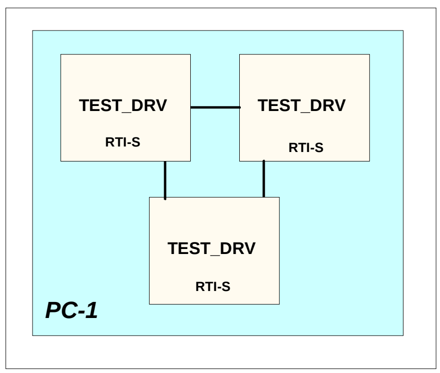


Figure 40 - Single PC Test of RTI-S with GSS

Figure 41 shows a multi-PC test case that was used to verify correct operation of the RTI-S and multiple instances of TEST_DRV running on two PCs over a local LAN connection.

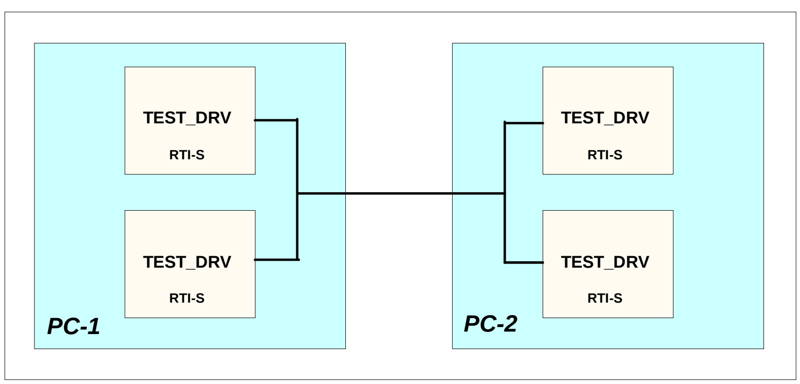


Figure 41 - Multiple PC Test of RTI-S with GSS

As each instance of the RTI-S simulation started, the RTI-S generated some diagnostic messages that were deemed to be benign. In each of the test cases shown above, PSI verified that messages were correctly published and subscribed to across instances of the TEST_DRV simulation. We also terminated instances of TEST_DRV abnormally to determine the impact on RTI-S and on the other running instances of TEST_DRV. Whereas the DMSO RTI became unstable when a Federate did not "resign" gracefully, the RTI-S continued to function flawlessly. This is likely due to the fact that RTI-S is nodeless, whereas the DMSO RTI requires and depends on a centralized RTI that supports all "connected" Federates.

PSI communicated success with RTI-S by email to the team on May 26. Future releases of GSS will support both the RTI-S and DMSO RTI conventions.

5.8.2 GIESim-JSAF JTIDS Testing

Recall that the enhanced JTIDS simulation that PSI built for the merger can be used either as a driver surrogate for JSAF or as the JTIDS communications modeling and simulation system being driven by JSAF. Initial testing of the enhanced JTIDS simulation was performed internal to PSI using both capabilities of the enhanced version of JTIDS. Figure 42 shows this test configuration.

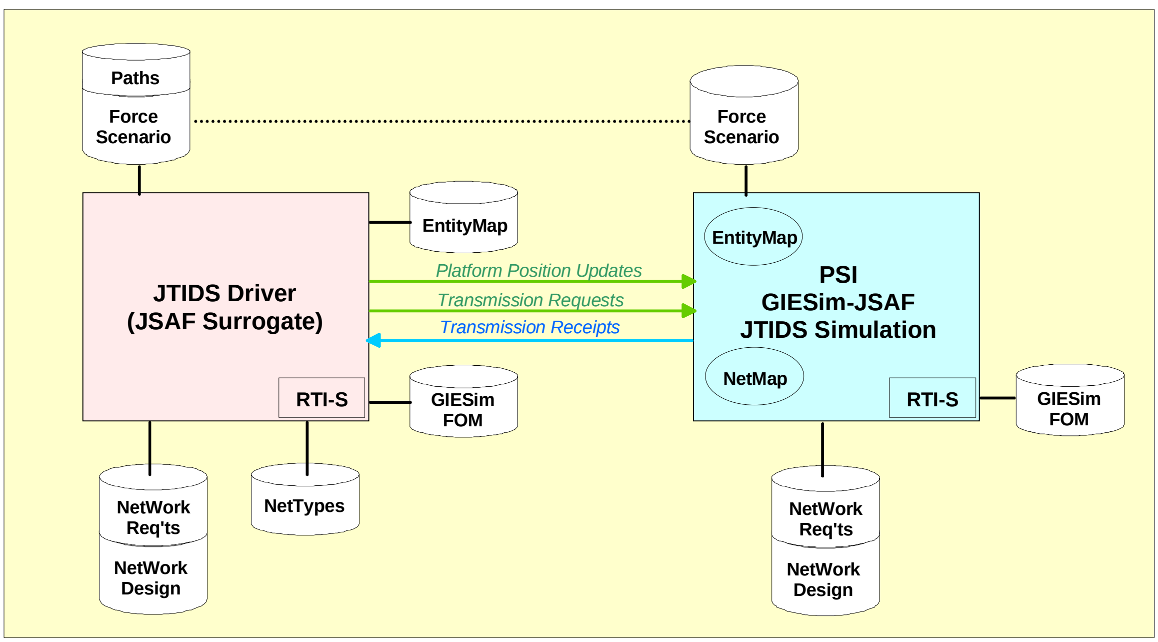


Figure 42 - Internal PSI Test Configuration for Testing the GIESim-JSAF JTIDS Simulation

Both the JTIDS test driver, and driven JTIDS simulation used the same network files, and force scenario. The JSAF surrogate system also had movement profiles or paths. Both systems used the same GIESim FOM (GIESIM.fed). In driver mode, JTIDS reads in the EntityMap and NetTypeMap files as JSAF is expected to do. The driven version of JTIDS performs the entity mapping hash functions internally, and maps the NET_TYPE field received from the HLA GIESIM_MSG_SEND interaction.

5.8.2.1 Position Updates

The PSI developed Korea_5 and Korona scenarios were used to verify correct operation of the Entity Mapping functions and position updates of platforms using various HLA position update rates from the JTIDS Driver. Correct operation was verified by visually observing position and movements of selected platforms in each version of JTIDS that was running. Aside from a slight delay in position, the driven JTIDS simulation performed as desired.

During inspection of platform positioning code, it was determined that the driver system was sending internal, relative XYZ coordinates rather than actual LAT LON values. This worked because the receiving JTIDS system was using these values directly instead of converting to internal coordinate from the received LAT LON value.

Therefore, the driver system was modified to convert output values to LAT LON and conversely, position updates received over HLA in the driven mode were converted from LAN LON to internal representations used in JTIDS. This demonstrates the value of building a test driver prior to interoperability testing with JSAF.

5.8.2.2 Message Transmission Testing

The PSI Korea_5 scenario and its associated network file were initially used to test the message transmission capabilities of JTIDS for the GIESim-JSAF merger.

Testing proceeded in stages and culminated in testing of messages from all “Wow” platforms in the Korona-Wow scenario.

In the driver system, HLA GIESIM_MSG_SEND interactions were manually constructed by using the internal test driver interface that was imported from the GIESim SAB Demo version of JTIDS. This approach provided a very controlled way of sending message transmission requests to the driven JTIDS system, and we could specify the message source, destination and net types to force transmission through selected Operational Nets. This allowed us to test the code that supported each type of Link-16 Access Modes. Messages using both valid and invalid data were sent to verify correct behavior in the Driven JTIDS simulation.

Initial testing was directed at nets that used Dedicated Access Mode, and verified correct operation, and correct response from the driven system, since we could view the HLA GIESIM_MSG_RCVD interaction in the JSAF surrogate that was sent by the driven JTIDS simulation when the message was received by the target JTIDS platform.

Initial testing used message sizes that did not require message segmentation and reassembly (SAR). Subsequent manual testing:

- Chose nets that use the other Access Modes.
- Use message sizes that require SAR support.

5.4.3.2.2 Auto-Generated Message Testing

When JTIDS is used with the actual JSAF system, message requests of different types and sizes are expected to occur at high volume. In order to test the expected mix and load of traffic in-house, PSI used the traffic generation capability built into JTIDS. This capability is enabled when JTIDS is being used in the driver mode, and disabled when JTIDS is being driven.

JTIDS auto-generation of messages can be enabled for all net type, i.e., access modes. Different modulation schemes can be used to vary message generation rates.

Testing of the driven JTIDS simulation for the GIESim-JSAF merger took place prior to the interoperability testing that occurred in AFRL Rome in November.

5.8.3 JSAF Interoperability Testing

Interoperability testing of the merged GIESim/JSB-RD software took place over an extended interval due to initial interoperability problems that are ultimately solved by the team, resulting in successful interoperability.

5.8.3.1 Interoperability Testing in AFRL Rome

Initial interoperability testing between JSAF and JTIDS took place on 16 and 17 Nov 2004 in the JSB-RD JSAF lab in AFRL Rome. The test configuration is shown in Figure 43. The Korona-Wow scenario was used in the interoperability tests.

JSAF used movement paths that were modified versions of the movement paths in the Korona scenario. The Link-16 platform force composition was the same. Operational Networks designed by PSI to meet the JSAF communications requirements for the scenario were used.

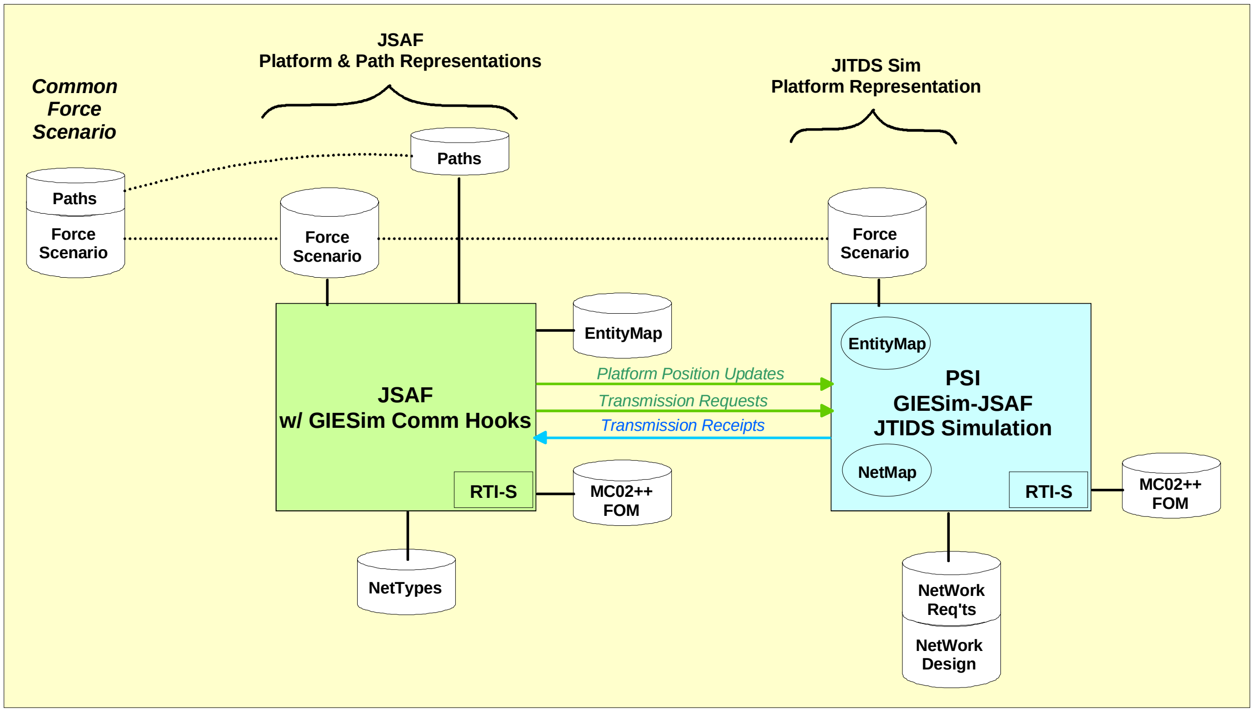


Figure 43 - JSAF-JTIDS Interoperability Test Configuration.

JSAF uses the EntityMap and NetType files provided by PSI.

PSI installed GSS Release 10.3.7 and the JTIDS Driver and Driven versions on one of the JSAF PCs assigned to PSI. While another team continued to work the modifications to JSAF, PSI:

- Modified GSS to support RTI-S
- Installed RTI-S on the target PC and modified the required environment variables:

    - RTI_HOME= C:\RTI-S\
    - RTI_BUILD_TYPE=Win2000-VC6
    - Added C:\RTI-S\Win2000-VC6\lib\ to the system PATH variable.
- Began testing the JTIDS systems (driver and driven) on the JSAF PC.

Initial testing disclosed a conflict between the PSI HLA Interactions and the MC02plus FOM that caused RTI-S to hang. The problems were found quickly and fixed. The MC02plus FOM had to be modified to support a new parameter field, NET_ID, at the end of the GIESIM_MSG_RCVD HLA interaction. Also, the name of the parameter field that the team had agreed to add to the GIESIM_MSG_SEND interaction differed between the PSI implementation and the MC02plus FOM. The FOM was modified to use NET_TYPE_NUMBER rather than NET_TYPE. These name changes were coordinated and agreed to by Jerry Reaper who was handling JSAF modifications.

The revised MC02plus.omt FOM was renamed to MC02plus_v4.omt, and the DMSO HLA tool was used to create a new fed file for use with JTIDS and JSAF – this file was named GIESIM.fed.

Ultimately, and for the sake of safety and reproducibility, PSI decided to re-prepare, i.e., rebuild or recompile, both JTIDS versions – driver and driven. Also, since JSAF was not ready for testing, PSI decided to test the newly built versions across two JSAF PCs.

Finally we had an exact copy of the same directory structure GIESIM-JSAF, shown in Figure 44, created on both PCs as.

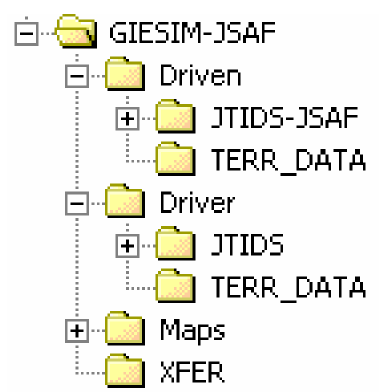


Figure 44 - GIESIM-JSAF Directory Structure

Executing JTIDSSIM2D.EXE in the GIESIM-JSAF/Driver/JTIDS directory launched the JTIDS driver, and executing JTIDSSIM2D.EXE in the GIESIM-JSAF\Driver\JTIDS-JSAF directory launched the driven version of JTIDS for use with JSAF.

The installation and operation was first tested using one PC to launch the driven JTIDS version and the other PC to launch the driver JTIDS version, then vice versa. Each case tested 100%. Platform position updates were sent from the driver system and received at and responded to correctly by the driven system. The graphic displays were used to compare platform positions to verify correct operation. The HLA GUI Control panel that is provided with each JTIDS simulation (shown below in Figure 45) was used to send an HLA interaction from the driver JTIDS system to the driven JTIDS system. This interaction was to request transmission from the SOF to the lead F15.

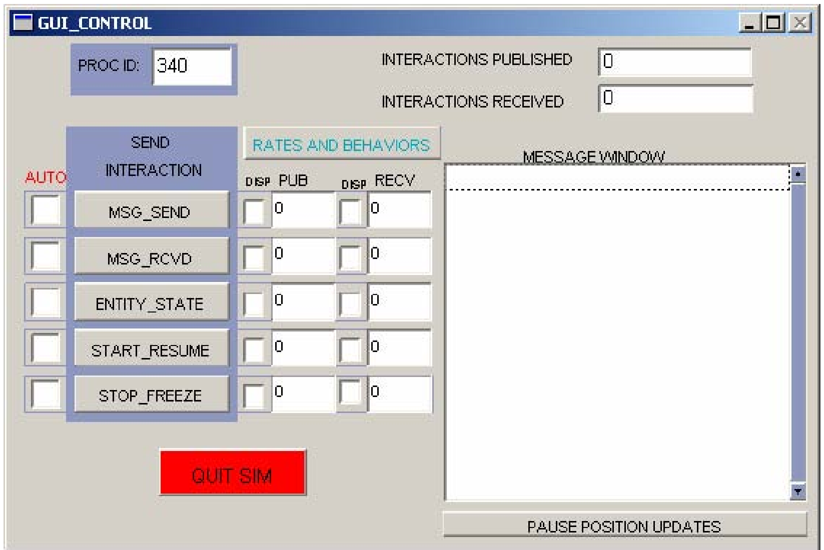


Figure 45 - HLA GUI Control Panel in JTIDS Simulations

Several more tests verified correction operation of both PSI JTIDS simulations on either PC.

Unfortunately, we were unable to exchange messages with the modified JSAF running on a Linux PC. The PSI simulations could not see any messages from JSAF, nor could JSAF see any messages from JTIDS. Another Linux workstation was able to see packets coming from JTIDS.

Several days later it was determined that JSAF was not actually publishing HLA interactions, nor was it responding to interactions. At the time (12/6/04), work was still underway to get the modifications on JSAF working to support communications handling by PSI JTIDS.

Over the next few weeks the JSAF modifications developed by SAIC enabled sending and receiving HLA messages by JSAF. However, since there was some uncertainty on how both systems, JSAF and PSI JTIDS, were handling messages associated with the FOM, PSI agreed to add additional diagnostic messages to the PSI JTIDS simulation to verify correct reception of, and generation of HLA messages.

5.8.3.2 Enhanced Diagnostics for Interoperability Testing

The initial versions of the PSI JTIDS simulation contained a certain number of diagnostic data printouts. These diagnostics had been removed to avoid any background overhead. Once PSI and SAIC had determined that some HLA messages might be scrambled, possibly due to different interpretations of the FOM, PSI agreed to heavily implement both the Driver and Driven JTIDS simulation with diagnostic messages. Diagnostics were added at the HLA receive and transmit points in both simulations. This allowed SAIC to examine received and sent HLA messages in detail. Furthermore, the internal logic for choosing platforms based on ENTITY_ID and networks via NET_TYPES was also instrumented so program flows in the simulations could be traced. In addition, the code was modified to ensure that the HLA GUIs reflected all HLA messages sent and received. Diagnostics were added in a manner that allows them to be easily turned off.

Also, further testing by PSI revealed that the hashing function used to generate ENTITY_IDs did not always give consistent values. Therefore, PSI rewrote the hashing code in GSS and verified correct and consistent operation.

The next few tables and figures illustrate some of the diagnostic changes PSI added to support interoperability testing. First, Table 10 shows the ENTITY_IDs for the "Wow" scenario components using the new hashing algorithms. Note that the numbers on the right side of Table 10 list the internal platform IDs within the PSI JTIDS simulations.

Table 10 - Wow Scenario Entity IDs in File ENTITY.OUT

018783	SOF_1	091
021052	Target-wow1	092
018721	SAM_POPUP	093
019691	SAM_POPUP2	094
019712	SAM_POPUP3	095
019733	SAM_POPUP4	096
029192	F15_WAO4.Lead	097
029768	F15_WAO4.2	098
029789	F15_WAO4.3	099
029810	F15_WAO4.4	100

Table 11 - NET_TYPES for the Korona-Wow JTIDS Network in File NETMAPFILE.TXT

001	RTT_B
002	AIRCONTROL_UPLINK
003	ELECTRONIC WARFARE
004	FTR_TO_FTR_TARGET
005	ENGAGEMENT_COORD
006	RESIDUAL_MSG
007	NEEDLINE
008	PPLI_A
009	VOICE_1
010	VIDEO_DOWNLINK
011	PPLI_B
012	MISSION_MGT
013	SURVEILLANCE
014	**THREAT WARNING**
015	**MISSION CONTROL**
016	**ENGAGEMENT STATUS**

The NET_TYPE numbers shown in bold in Table 11 list the new networks that PSI defined for the Korona-Wow scenario. The ENTITY IDs and NET_TYPEs are used in the examples that follow.

The left side of Figure 46 shows the GUI that was used to build a GIESIM_ENTITY_STATE HLA message in the JTIDS Driver simulation. After the message is published, i.e., sent over HLA, it was received by the PSI JTIDS Driven simulation. The right side of Figure 46 shows the details of the received interaction and diagnostics on the subsequent platform look-up in the Driven JTIDS simulation. The diagnostic message verified correct reception of this HLA message, and that the correct platform was found. Both valid and invalid Entity IDs were sent to verify correct operation of the driven JTIDS simulation.

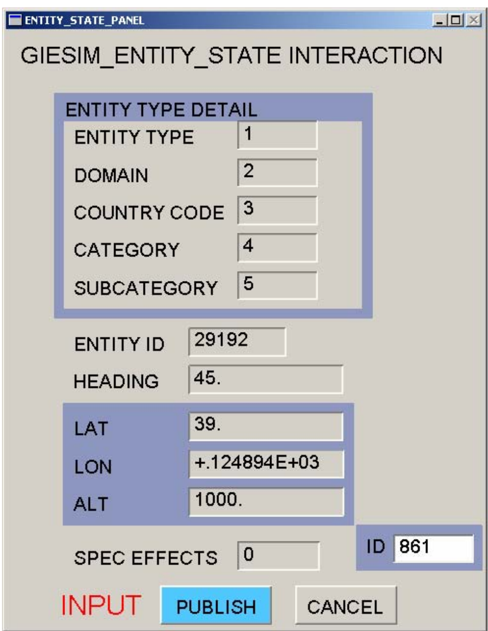
GIESIM_ENTITY_STATE **Sent by Driver Simulation GUI**	**GIESIM_ENTITY_STATE Diagnostics** **Displayed in Command Window of** **Receiving JTIDS Driven Simulation**
	RECEIVED GIESIM_ENTITY_STATE ENTTITY_TYPE= 1 DOMAIN= 2 COUNTRY CODE= 3 CATEGORY= 4 SUBCAT= 5 ENTITY_ID= 29192 HEADING= .4500000E+002 LAT= .3900000E+002 LON= .1248942E+003 ALT= .1000000E+004 EFFECTS= 0 ===================================== LOOKING UP KEY: 97 F15_WA04.Lead FOUND PLATFORM KEY: 97 F15_WA04.Lead PLATFORM_REL_X: .4247747E+005 PLATFORM_REL_Y: .5947803E+006 PLATFORM_REL_Z: .1000000E+004 PLAT_KEY BEFORE REPLACE: 97

Figure 46 - ENTITY_STATE Message Sent and Received

Next the JTIDS Driver GUI shown in Figure 47 was used to send a GIESIM_MSG_SEND interaction to the PSI JTIDS Driven simulation. Upon receipt, the diagnostics in the command window of the JTIDS Driven simulation show the diagnostic messages in Table 12.

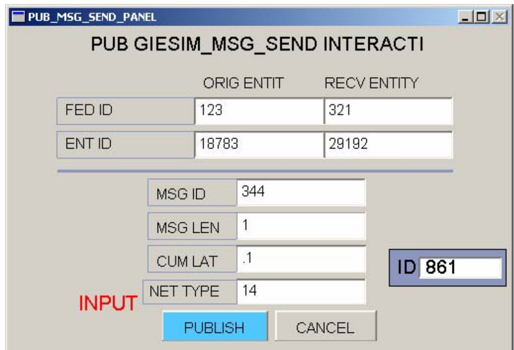


Figure 47 - GIESIM_MSG_SEND Send GUI Panel is Used to Build a Message

Table 12 - Received GIESIM_MSG_SEND, Transmission, and Publish Diagnostics

```
RECEIVED GIESIM_MSG_SEND INTERACTION FROM    123

RECV INTERACTION #         3  ***
GIESIM_MSG_SEND INTERACTION RECEIVED AT   12100106
SEND_FED_ID:         123
SEND_ENTITY_ID:    18783
RECV_FED_ID:         321
RECV_ENTITY_ID:    29192
SEND_MSG_ID:             344
MESSAGE LENGTH:            1
SEND_CUM_LATENCY:  .1000000E+000
SEND_NET_TYPE:            14
========================================
DRIVEN JTIDS RECEIVED REMOTE MESSAGE SEND REQUEST
FINDING NET...        14
GIESIM_MSG_SEND FOUND SENDER PLATFORM TO MATCH     18783  ->         91  SOF_1

GIESIM_MSG_SEND FOUND RECEIVER PLATFORM TO MATCH     29192  ->         97  F15_WA04.Lead
GHAWK_2_6                   19
F15_WA04.Lead               97
F15_WA04.2                  98
F15_WA04.3                  99
F15_WA04.4                 100
SENDING DED_REL MESSAGE TO     97
ACCUMTIME: -.1165899999998509E+004
GENTIME:  .1166000000000000E+004
DESTI:     97
SCHEDULE_TIME =  .8242733E-001
NUMBER_DESTS =      5
MSG_ID:         344
LATENCY:  .7289062514901161E+000
ACTUAL DESTINATION F15_WA04.2
    97
    98
EXITING
MSG_ID:         344
LATENCY:  .7289062514901161E+000
ACTUAL DESTINATION F15_WA04.3
    97
    99
EXITING
MSG_ID:         344
LATENCY:  .7289062514901161E+000
ACTUAL DESTINATION F15_WA04.4
    97
   100
EXITING
MSG_ID:         344
LATENCY:  .1291406251490116E+001
ACTUAL DESTINATION F15_WA04.Lead
COMENCING WITH RECEPTION
DESTINATION:     97
RECEIVED SAF MESSAGE!
EXPECTING COMMUNICATION WITH RECEIVER F15_WA04.Lead
FOUND RECEIVER IN ENTITY_TABLE
PUBLISHING MSG RECEIVED HLA INTERACTION
SEND_SIM PUB MSG_RCVD...
PUBLISHED GIESIM_MSG_RCVD INTERACTION
```

First the details of the received GIESIM_MSG_SEND HLA interaction are displayed. Then the platform look-up functions are displayed. In this case, Entity ID 18783 maps to SOF_1 and

Entity ID 29129 maps to the lead F15, i.e., F15_WAO4.Lead. The driven JTIDS system then determines if an Operational Net exists with (1) the SOF as transmitter, (2) the lead F15 as receiver, and (3) with Net Type 14. It finds Operational Net 97, and then sends the message over the simulated JTIDS Operational Net. When F15_WA04.Lead receives the message, the driven JTIDS simulation builds a GIESIM_MSG_RCVD HLA interaction, and sends it. (See area of Table 12 marked in blue.)

The left side of Figure 48 shows the command window diagnostics for the GIESIM_MSG_RCVD interaction that the JTIDS Driver simulation receives. The right side of Figure 48 shows the same received data in the JTIDS Driver GUI for this interaction.

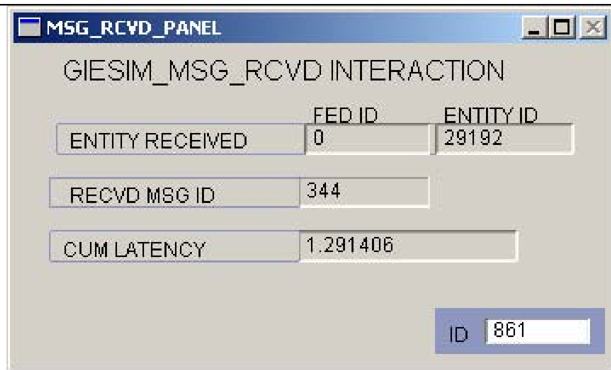
Command Window Diagnostics for Received GIESIM_MSG_RCVD Interaction in JTIDS Driver	**Received GIESIM_MSG_RCVD GUI in JTIDS Driver**
RECV INTERACTION # 1 *** GIESIM_MSG_RCVD INTERACTION RECEIVED AT 12100306 FED_ID:........... 0 ENTITY_ID:........ 29192 RECV_MSG_ID:...... 344 RECV_SUM_LATENCY: .1291406E+001 RECV NET_ID:...... 97 == A MESSAGE WAS SUCCESSFULLY SENT OVER NET: 97 MESSAGE ID: 344 LATENCY: .1291406E+001 MESSAGE WAS RECEIVED BY UNIT: F15_WAO4.Lead	

Figure 48 - Diagnostic for Received GIESIM_MSG_RCVD Interaction

5.8.3.3 Interoperability Testing Success

The enhanced diagnostic and refinement to the PSI JTIDS simulations ultimately helped to resolve some minor differences in FOM interpretation and platform referencing.

PSI sent updated versions of its JTIDS tools to both SAIC at WPAFB and to AFRL Rome, where, in conjunction with updates to JSAF made by SAIC, interoperability testing was finally completed to the satisfaction of all parties involved.

6.0 CONCLUSIONS

PSI contributed to many aspects and to the success of the GIESim/JSB-RD software merger, and was a consummate and proactive team player throughout the project. In particular, PSI defined requirements for many of the simulation enhancements that are required in JTIDS *and* in JSAF. PSI also designed and developed the scenarios used in the merger. As presented in this report, PSI performed requirements analysis, designed, developed and tested the JTIDS enhancements required for the merger of the GIESim JTIDS simulation with the enhanced version of JSAF. This effort heavily leveraged the PSI Link-16 NMS built for another AFRL team, and drew deeply from prior experience with the earlier GIESim projects.

PSI did extensive in-house testing, and participated in the extended interoperability tests with JSAF that took place over November and December. PSI also supported AFRL leadership by building a new, more robust, and supportable version of the GIESim SAB Demo, and worked with SAIC to ensure smooth, successful operation of the standing demo.

PSI looks forward to expanding on the GIESim/JSB-RD merger and working with the other team members and AFRL leadership in FY05 and beyond. The accomplishments of the merger software bring tactical communications modeling to JSAF, which is critically important for evolving Network Centric Operations (NCO) and Warfare (NCW).

The paper retroactively looks back over the FY04 effort and presents Appendix B on GIESim Contributions to GIESim/JSB-RD, and Appendix C lessons learned. The remainder of this paper looks forward to future work and includes appendices for potential near term (FY05) work (Appendix D) and further out work (Appendix E) associated with the merger.

PSI salutes AFRL leadership for their vision in merging the GIESim and JSB-RD efforts, and would like to express our appreciation for being involved in the 3rd year of the GIESim program. We look forward to a continued relationship and accomplishments with AFRL Rome programs and projects.

APPENDIX A - "WOW" SCENARIO DATA

The flight path data for the F15 in the "Wow" scenario is shown in Table 13 below. Since this data will be imported into JSAF, the segment speeds of 200 MPS shown in the table will be replaced by segment speeds generated by JSAF. A graph of the F15 flight path elevations is shown in Figure 49, and its profile is shown in Figure 50.

Table 13 - F15 "Wow" Scenario Flight Path Data

Profile Name	Point #	LAT	LON	ELEV (MASL)	Speed MPS
AO4_WOW	1	39.08282	124.89442	10000	200
	2	39.32995	125.24883	8000	200
	3	39.54504	125.53815	5000	200
	4	39.66636	125.70791	2000	200
	5	39.74417	125.89274	1000	200
	6	39.83144	125.98318	400	200
	7	39.87886	126.03476	250	200
	8	39.92084	126.06445	200	200
	9	39.95814	126.10066	200	200
	10	39.99526	126.13061	150	200
	11	40.0498	126.17883	250	200
	12	40.13797	126.11517	1000	200
	13	40.13961	125.8969	2000	200
	14	40.10811	125.47182	5000	200
	15	40.01192	125.117	8000	200
	16	39.9443	124.77702	10000	200
	17	39.83639	124.42457	10000	200

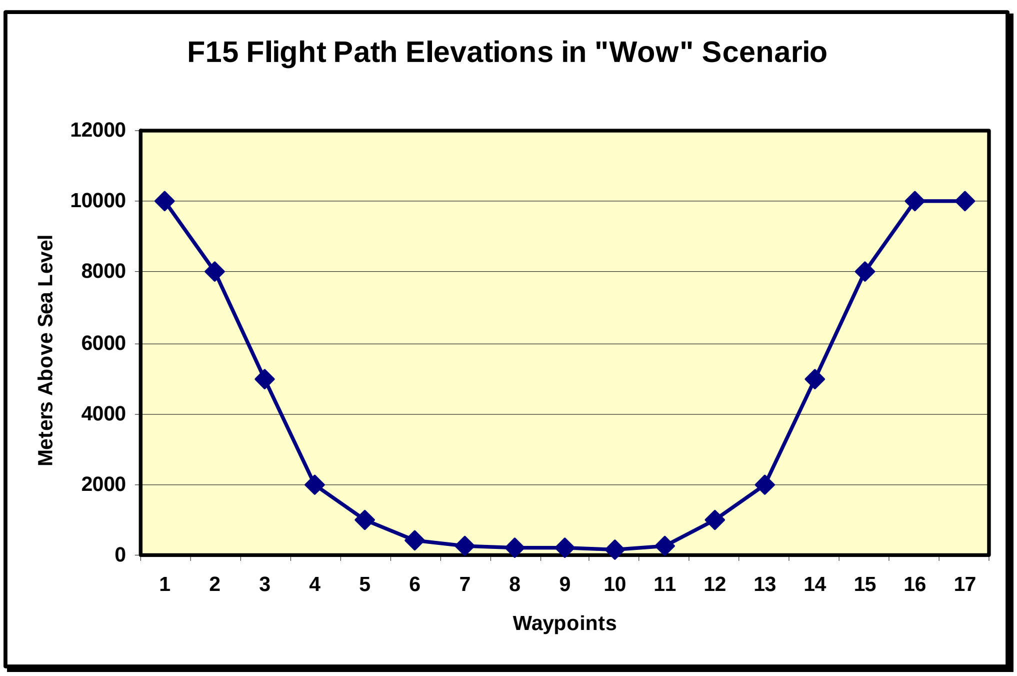


Figure 49 - Graph of F15 Flight Path Elevations in "Wow" Scenario

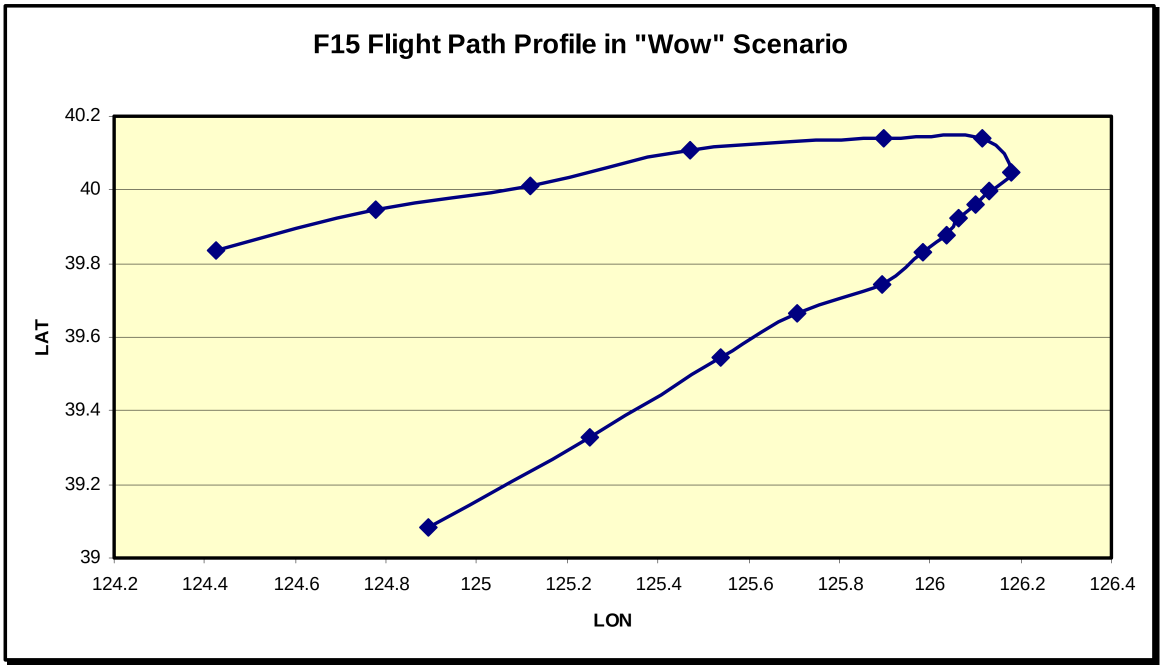


Figure 50 - F15 Flight Path Profile in "Wow" Scenario

Table 14 lists the data for the UAV flight path in the “Wow” Scenario.

Table 15 provides the data for the positions of the ground elements, i.e., SOF, Target and Ground Threats, in the “Wow” Scenario.

It is important that JSAF preserves the integrity of the F15 flight path waypoints and the position of the SOF, since they were strategically placed such that communications between the F15 and the SOF are masked by terrain when the F15 is in the valley leading up to the target.

Table 14 - UAV Flight Data for "Wow" Scenario

Profile Name	Point #	LAT	LON	LAT	ELEV (MASL)	Speed MPS
UAV_PATH_6	1	40.2177	125.30674	40.2177	18000	150
	2	40.16243	125.44003	40.16243	18000	150
	3	40.0505	125.53255	40.0505	18000	150
	4	39.92676	125.52621	39.92676	18000	150
	5	39.83817	125.46509	39.83817	18000	150
	6	39.77087	125.351	39.77087	18000	150
	7	39.76331	125.16041	39.76331	18000	150
	8	39.82309	125.04438	39.82309	18000	150
	9	39.91198	124.95177	39.91198	18000	150
	10	40.07389	124.94496	40.07389	18000	150
	11	40.16131	125.01364	40.16131	18000	150
	12	40.20947	125.11948	40.20947	18000	150
	13	40.21844	125.30767	40.21844	18000	150

Table 15 - Location of Ground Elements in "Wow" Scenario

Platform Name	MGR Coord	LAT	LON	ELEV (MAGL)	
SOF_1	52TBK6937832103	40.00764	126.29811	5	<- antenna height
Target-wow1	52TBK5934536515	40.04455	126.17906	0	
SAM_Popup	52TBK5479936686	40.04478	126.12577	0	

APPENDIX B - GIESIM CONTRIBUTIONS TO JSAF

Overarching Contribution:

Adds realistic, Link-16 tactical communication modeling to JSAF. Link-16 is the preeminent tactical data link in use today.

Motivations:

Today, tactical communications are critical to the success of any missions, either for speed of operations, control, situational awareness (SA), reach-back, and for prevention of fratricide. Joint and coalition operations and the modern nature and OPTEMPO of war today make the inclusion of communications modeling into any force-level simulation even more important. The rapid evolution of Network Centric Operations (NCO) and Warfare (NCW) make the inclusion of tactical communications model even more important to JSAF.

Attributes and Contributions of GIESim:

- Determination and visualization of radio connectivity including impacts of terrain.
- Determination and visualization of *network* connectivity including impacts of terrain and relays.
- Add realistic communications response times, throughput, and model communication failure cases.
- War game and train with realistic force deployment and communications scenarios.
- Measure the impact of communications on mission success.
- Include communications planning in scenario development (and operations planning).
- Determine points of failure and fix them.
- Perform what-if analyses on tactical networks.
- Allow collaboration between mission and communications planners.
- Optimize deployment of assets in support of communications.
- Explore communications oriented COAs and ECOAs, e.g., impact of enemy jamming on communications and operations.
- GIESim Team Expertise: The team has three years of experience in communications modeling in multi-simulation environments. We have experience with:
    - Force deployment scenario development
    - Communications scenario development
    - Multi-simulation interfacing and interoperability via HLA, and TCP/IP
    - Tactical radio communications, and ground network modeling
    - Rapid development and re-use of communications modeling
    - Mission Operations
    - Adding communications modeling to force-level simulations

APPENDIX C - LESSONS LEARNED

This section overviews some of the lessons learned from the merger of GIESim and JSB-RD software from a PSI perspective. There is value in having team collaboration on lessons learned.

- It is an order of magnitude (or more) less expensive (in time and dollars) to assemble a multi-simulation communications capability by drawing from existing models and simulations.

- The use of existing models and simulations ***does not*** eliminate the need for domain or subject matter experts. There is still a need for experts to define and develop the target analytical system:
    - Experts in the models and simulation environments and tools.
    - Experts in the systems being modeled.
    - Expertise in reducing system needs and requirements to the selection of appropriate models/simulations/environments.
    - Expertise in mission operations for scenario planning and development.

- While are is high value in the models and interfaces that were developed to realize the "merger", there is equal (perhaps even higher) value in the team itself. Members of the GIESim team have been together for three years, and have worked closely with the JSB-RD team for the past year. In addition to developing an excellent working relationship with high mutual respect, we have also fostered the building of expertise developed through living through building of the GIESim SAB Demo, and through resolving challenges with the GIESim/JSB-RD software merger.

- Large multi-forces simulations like JSAF are extraordinarily complex. This complexity, coupled to the fact that they do not inherently model communications, makes the addition of new software to add communications hooks and behaviors even more challenging. There were simply conceptual gulfs that the team had to overcome.

- Link-16 tactical communications is quite complex is its own right. In retrospect, the merger of GIESim and JSAF would have benefited from wider knowledge of Link-16 communications, particularly relay capabilities. As our software migrates into use (hopefully) by JFCOM, their "mission planners" will need to understand capabilities and limitations of Link-16 platforms, and JFCOM will need to learn about Network Planning and Design. This is particularly important since the network design will need to change as the force composition varies from experiment to experiment.

- Simulation interfacing always has challenges. For GIESim and JSAF, different operating systems (Windows and Linux) introduced some (suspected) added complexity and made interoperability testing more difficult, particularly since we couldn't run JSAF at all locations. Also, the use RTI-S made interoperability testing over the Internet essentially impossible, and necessitated testing of components at one or more locations. Because we "reused" HLA interactions from the GIESim SAB Demo, we were a little complacent even though we were making some “minor” changes to the interaction. In general, we need to:

- Map out the details of all HLA interactions very early and clearly in the project.
- Ensure that all parties are using the same FOM in a consistent matter.

- Track changes more carefully as system components evolve. For instance, NET TYPE NUMBERS changed from the early values specified and caused some minor delays..

- Model requirements and multi-simulation architecture must be defined based on requirements and needs of the target analysis that is to be accomplished. Validity should be looked at as a quality process with each simulation/model component impacting quality in a potentially multiplicative way.

- Existing models and simulations may (and probably will) need tailoring to meet the needs of the each experiment. Thus, a simulation environment that supports ease of use and understandability is essential. Good architectural designs are also needed.

- There is value in integrating GIESim and JSAF more tightly, particularly in the area of scenario development. The PSI Link-16 Planning Tool is excellent for building scenarios. JSAF has its own scenario building capabilities. A more effective means of exporting and importing scenarios between these tools would improve efficiency of scenario development and incorporation into the other simulation environment.

- Scenario development and equipment collections must be defined and developed for the multi-simulation environment based on mission needs and operations being planned. This will require:
    - A common definition of what is meant by “scenario”.
    - Import of terrain for area of interest.
    - Flight paths and other movement paths for dynamic communications.
    - Definition and implementation of network characteristics (connectivity, network capabilities, redundancies, etc.).
    - Traffic generators and other means to stimulate the simulation environment in realistic ways.
    - Many other variations and considerations are likely.

- Scenario trade-offs are made for the sake of a demonstration of appropriate length – typically 5-10 minutes. This “marketing” orientation is understandable, although it may shift attention from more operationally meaningful scenarios that might surface interoperability problems that should be worked. We should probably test robustness against a longer running, more complex scenario, in addition to a demonstration scenario targeted for an audience.

- Potential modifications of models and simulations may be needed as identified during testing and during analytical experiments, e.g., need to have the ability to change buffer sizes. Ease of use of the simulation environment is critical for this.

- Existing models and simulations may (and probably will) need tailoring to meet the needs of the each experiment. Thus, a simulation environment that supports ease of use and understandability is essential. Good architectural designs are also needed. Some points to consider include:
  - Definition and development of IP Interfaces, and HLA interfaces with associated Interactions, etc., with of IP Addresses and required simulation and entity IDs.
  - Definition and development of metrics and capabilities to collect them, e.g., latency. These metrics may require new models or tailoring of existing model to gather and report to the multi-simulation environment.
  - Definition and development of means to interact with a simulation to introduce controlled flaws, outages, etc. to explore overall impacts on the communications system being studied. Means might include real-time feeds, access to data files, user interaction with the running simulation, and multiple simulation runs.
  - Definition and development of appropriate visualization capabilities to support both testing and analytical experiments.

APPENDIX D - PROPOSED FY05 WORK

The success of the GIESim/JSB-RD software merger came very late in the program. As such there were limited opportunities to demonstrate our achievements and capabilities to audiences who would be interested in leveraging our accomplishments. Therefore, a rich and compelling demonstration could be developed to showcase our work and to solicit further developments.

Also, there are rich, currently untapped opportunities for further research from experiments with our system to explore scalability, more complex scenarios, tighter coupling between GIESim and JSAF, and perhaps new modalities for operations.

New Demonstration and Presentation Development

The FY05 Demonstration of the merged GIESim/JSB-RD software will capitalize on groundwork and capabilities developed in FY04. The demonstration will be aimed at audiences outside of AFRL and would have an operationally relevant, and high impact scenario that will show the full capabilities of the merged software. The demonstration will be easily adapted to the technical levels of the audience, ranging from no technical background to those working in the network modeling and simulation area.

This task will have several subcomponents:

- Develop a scenario for the demonstration.
- Implement the scenario.
- Develop a presentation for the demonstration.
- Document how to use the demonstration.
- Participate in the demonstration.

The demonstration will in part be based on the “Wow” scenario that was suggested and adopted by the team in FY04, and selected (and potentially expanded) aspects of the PSI Korona scenario that PSI shared with the team in FY04. Specific scenario details will be developed in conjunction with the GIESim/JSB-RD team.

A SOF deployed on the ground detects a high-value target, and sends a tasking message to the F15 that starts to ingress towards the target. As the F15 starts to follow terrain through the valley, the SOF sees pop-up threats, and sends a Threat Warning message to the F15. At this point, terrain blocks direct reception of the warning message. With the Global Hawk UAV acting as a Link-16 relay, the threat warning reaches the F15, otherwise the F15 continues on towards the target oblivious to the threat.

Experimentation on Merged Software & Assess Capabilities

An ultimate goal of the GIESim/JSB-RD merger is to add tactical communications to JSAF for large scenarios through distributed simulation with the PSI Link-16 Simulation handling the tactical data links. This addition to JSAF will allow the JSB-RD team to study Air Force platform behaviors they are adding. This task will involve:

- **Expanded scenarios**: Experiments will be performed as the scenario size increases. This will test scalability within JSAF, and within the PSI JTIDS simulation, and with respect to HLA RTI-S. It is expected that the PSI Korona force deployment scenario and its derivatives will play a key role in scenarios for experimentation. In addition, the JSB-RD team may desire to add specific force components and missions.

- **Additional Link-16 Network Designs**: As scenario sizes increase there will be a need to support additional Link-16 message traffic. Specific mission-related communications requirements for the GIESim/JSB-RD scenarios will be captured in the PSI Link-16 Planning Tool, and then the actual JTIDS/MIDS time slots will be allocated automatically by the PSI TSA tool. Communications requirements need to take into account the response times, addressability, and sizes of required TADIL-J messages. Increased inter-platform traffic will increase the load on the JTIDS simulation, and this is one focus of our experimentation.

- **Use of Multiple Simulation Configurations**: As the number of platforms and associated traffic builds, there may be a need to explore the use of multiple simulation configurations. It may be possible to separate platforms into isolated communications groups on different processors. However, the desire to potentially request transmission of PPLI messages between platforms may impose other considerations.

The PSI Korona will serve as part of the basis for the scenarios that evolve for the demonstration and experimentation.

APPENDIX E - POTENTIAL FUTURE WORK

This appendix is forward looking, and presents some ideas on future work.

Deeper integration of GIESim JTIDS and JSAF

There are ample opportunities to enrich and deepen the interface and integration between JSAF and the GIESim JTIDS simulation. Some ideas follow.

- **Additional interactions**: The current interactions are bare bones, and the minimal set required for JSAF to update platform positions and to request Link-16 network transmission. The existing HLA interactions could be enhanced to support platform health and other platform and communications related controls. Transmission requests are either for point-to-point or broadcast (although broadcast has not be used nor tested). We could enrich the HLA destination requests to make use of Link-16 message addressing capabilities.

- **Creation of and use JFCOM Mission Threads**: Real missions have a certain tempo, and dynamic relationships between participating platforms – this includes communications. JFCOM is building seven “standard” mission threads for use in training and war gaming. The team could acquire these threads, and incorporate them into our scenarios and network designs.

- **Use of platform PPLI and Status messages:** Link-16 platforms automatically transmit location and platform status messages to enhance situational awareness (SA) and to avoid fratricide. We could add this message traffic to GIESim/JSAF.

- **More integrated scenario planning:** Currently a scenario is built in either JTIDS or JSAF, then “imported” into the other simulation environment. This is somewhat awkward and time consuming. Greater use of Link-16 Planning and network design capabilities of the PSI Link-16 NMS, and tighter integration with JSAF would expedite faster and more comprehensive scenario development.

- **Investigate support for 24x7 operations:** JFCOM is moving towards 24x7 operations of large distributed simulations. We could explore how to do this in conjunction with required network designs.

Support for and Participation in one or more operational tests and/or events in 05/06

Now that the team has integrated GIESim and JSAF to support tactical data links, we could look to participate in one or more tests using JSAF. This would get us operationally connected, and assist us in better understanding how exercises are planned and conducted. It would also be an opportunity to input our requirements for tactical communications to influence future planning by users of JSAF.

Introduction of additional tactical data links and networking capabilities

Looking forward, there are many data links and capabilities that could be added to JSAF and similar large-forces simulations. Some potential candidates are listed below.

- Link-11 HF/UHF: After Link-16, Link-11 is the next most important tactical data link (TDL).
- JTRS WNW: Joint Tactical Radio System (JTRS) is evolving, and will offer software controlled versions of most current TDLs including Link-16 and Link-11. In addition, the highly touted Wide Band Networking Waveform (WNW) may become an important capability in future operations.
- Joint Range Extension (JRE): JRE is important for enabling beyond-line-of-site (BLOS) extension of Link-16 between separated areas of interest. JREs can bridge Link-16 network using IP networks and Satellite connections.
- Satellites: Satellite play and increasingly important part in both strategic and tactical communications, as well as intelligence.
- Ground Networks: All military operations rely on some form of ground network, and could be important additions to JSAF and similar systems.
- EW Threats (jammers, etc.): It is important to model EW threats since they still exist, and can greatly impact operations at critical times.

GIESim Communications modeling for other JSAF-like systems

The GIESim Team has developed considerable expertise in merging the GIESim JTIDS software with JSAF. Furthermore, we have built a sound operational framework in the PSI JTIDS simulation to easily support the addition of Link-16 tactical communications to other large multi-forces simulation. This is something the AFRL leadership should strongly consider.