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JLINK - JANUS FAST MOVERS

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ABSTRACT

This paper summarizes a two year project, called JLINK, which enables the Janus, Army constructive interactive simulation to be connected to manned land and air combat vehicle simulators, using Distributed Interactive Simulation (DIS) Protocol Data Units (PDU). The JLINK project was one of the first to demonstrate that a constructive simulation can be connected to and realistically interact with DIS compliant virtual combat vehicle and aircraft simulators. This paper discusses how this was accomplished, highlights the major considerations involved, and describes the interface model that was developed to connect Janus to the DIS world. The paper concludes with a discussion of the Janus Fast Movers Project which connected Janus to an Air Force F-16C manned virtual aircraft simulator.

1 INTRODUCTION

JLINK, the name chosen for the new distributed interactive Janus, was conceived to support the Anti-Armor Advanced Technology Demonstration (A2 ATD) directed by the Army Material Systems Analysis Agency (AMSSA). The A2 ATD is charged with developing and demonstrating the use of Distributed Interactive Simulations (DIS) to assess and evaluate anti-armor weapon systems and concepts on a combined arms battalion task force level within a synthetic environment. The JLINK effort was significantly expanded and enhanced with a follow on project called Janus Fast Movers, which involved connecting Janus to an Air Force F-16C manned virtual simulator. Throughout the project, tests were conducted which demonstrated the potential and realism of the connection. These tests included local and wide area net trials and a demonstration conducted at the Mounted Warfare Test Bed (MWTB) at Fort Knox, Kentucky and at the Air Force's Armstrong Laboratory air crew research and training facility.

The DIS link with Janus was accomplished over a two year period with a diverse team consisting of members from the TRADOC Analysis Center-Monterey (TRAC-MTRY), the RAND Corporation, the MITRE Corporation, the Naval Postgraduate School (NPS) and ROLANDS & ASSOCIATES Corporation. TRAC-MTRY provided project management and functional area expertise. NPS developed the World Modeler interface model between Janus and DIS compliant simulators. RAND developed the interface code between Janus and the World Modeler, conducted terrain analysis and conversions, and added some specialized detection and attrition algorithms to Janus, that were used specifically for the A2 ATD study. ROLANDS & ASSOCIATES Corporation significantly enhanced JLINK for the Janus Fast Movers project and is responsible for JLINK maintenance and future enhancements.

1.1 Janus Description

Before discussing the details of the JLINK project a short description of Janus is in order. Janus is an interactive, two-sided, closed, stochastic, ground combat simulation with detailed 2-dimensional color graphics. Janus is "interactive" in that the command and control functions are entered on workstations by military analysts who decide what to do during the course of a combat simulation. "Two sided" refers to the two opposing forces directed simultaneously by two sets of players. "Closed" means that the disposition of opposing forces is unknown to the players in control of the other force. The model is stochastic in that it uses probability distributions in its detection and direct fire engagements. "Ground combat" means that the principal focus is on ground maneuver and artillery units, although Janus does model rotary and fixed wing aircraft. The graphics display shows the terrain elevation contours, forested areas, and cities, and super-imposes icons on the terrain to represent the individual combat vehicles. Janus is an event driven simulation that supports conflict from individual systems and company sized units through brigade/regimental sized units.

1.2 Organization of the Paper

In the remainder of this paper we will discuss the major considerations and challenges involved in taking a constructive combat 2-dimensional simulation and making it realistically interact with 3-dimensional manned virtual simulators. Then we will discuss the World Modeler interface model that was developed to allow this realistic interaction. A discussion of the enhancements made to connect Janus to an aircraft simulator in the Janus Fast Movers Project will follow. Lastly, some conclusions and final thoughts are presented.

2 CHALLENGES AND CONSIDERATIONS

In linking a constructive 2-dimensional simulation with a 3-dimensional virtual manned simulator there are many issues that have to be considered. Among the major considerations are battlefield scale, terrain resolution, object resolution and event timing.

Battlefield scale addresses the ability to play a large number of entities within a scenario. Janus is a battalion to brigade level model and in many instances battlefield scenarios may have a large number of individual vehicles in play. Janus is an event driven simulation and as the size of the scenario increases the load on workstations and the network may cause Janus to run slower than real-time. In order to interact with a real-time simulator, Janus must run at real time or faster. Adjusting parameters within Janus such as detection cycles and movement update intervals helped to maintain real-time. For scenarios (less than 100 entities) like those run for the A2 ATD and Janus Fast Movers this was not a problem. Phase II enhancements to JLINK will investigate solutions for larger scenarios.

Terrain resolution addresses the differences between representation and resolution of terrain in the virtual simulators and Janus. Simulator terrain is polygonal with high resolution features. Janus' terrain is at a fixed resolution with a polygonal overlay describing many, but not all, features. These terrain database differences may result in contrasting outcomes during line-of-sight and target acquisition calculations. This problem was addressed by a series of techniques to correlate Janus' terrain with the terrain used in the virtual simulators.

Object resolution concerns the representation of individual entities in the simulation. Each simulation represents objects at different resolutions. Janus, a 2-dimensional simulation, places the entity icon symbols on a map and provides vehicle direction and velocity. The simulators, operating in a 3-dimensional visual world, also maintain turret position, vehicle orientation, velocity, pitch roll and yaw. This additional information must be provided for Janus entities to give realistic representations in the simulators. This problem is addressed in the World Modeler and is discussed in more detail later.

Event timing mismatch addresses differences between Janus, an event driven simulation, and virtual simulators that run in real time. The clock time at which events occur in Janus is determined by factors like scenario size and computer system capability. A *heartbeat* interval is established in the World Modeler - Janus connection to serve as a method for information exchange between Janus and connected simulators. This heartbeat is used to limit the number of updates Janus receives and transmits because interrupting Janus too frequently causes it to fall behind real time. Four seconds appears to be a reasonable heartbeat for scenarios up to 200 Janus entities. As will be discussed later, the World Modeler, through an event queue, maintains the match between the event driven Janus and the continuous real time of the virtual simulators. Next, we'll introduce the JLINK system and the World Modeler Interface model.

3 JLINK SYSTEM AND THE WORLD MODELER

3.1 JLINK System Overview and Hardware Requirements

The JLINK system consists of the Janus constructive combat model, the World Modeler-Janus Protocol interface and the World Modeler. The JLINK system will interact with any DIS compliant application that is present on the LAN or that is connected via a Wide Area Net (WAN). Janus and the World Modeler-Janus Protocol interface run on a Hewlett Packard HP715 series computer. The World Modeler runs on a lower end Silicon Graphics machine such as the SGI Indigo, with Performer software. Figure 1 shows a schematic of the JLINK system. In the figure ModSAF is the DIS compliant Modular Semi-Automated Forces model.

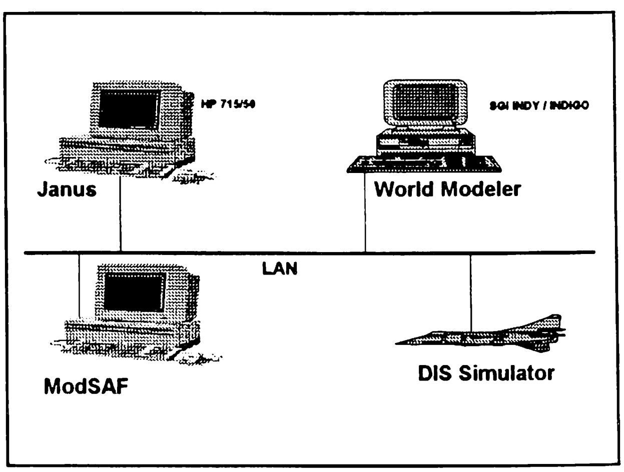

Figure 1: JLINK System

3.2 JLINK Overview Flowchart

An overview flowchart of the JLINK system is shown in Figure 2. Janus and the World Modeler-Janus Protocol interface are on the HP machine and the World Modeler is on an SGI. Janus and the World Modeler communicate via a Transmission Control Protocol/Internet Protocol (TCP/IP) point to point connection using the WM-Janus message protocol code. The World Modeler communicates with all DIS applications present (on the net) using User Datagram Protocol/Internet Protocol (UDP/IP) to send out and receive DIS PDUs. The JLINK system receives and accepts Entity State, Fire, Detonation and Radar Emission PDUs.

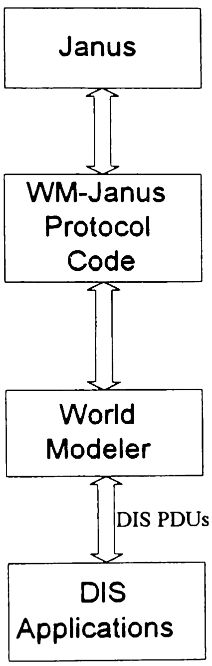

Figure 2: JLINK Overview Flowchart

3.3 World Modeler

3.3.1 World Modeler Overview

The World Modeler performs five major functions: network management, dead reckoning, entity/terrain reconciliation, engagement arbitration, and aircraft engagement functions. The network management function processes message traffic between Janus and DIS applications and codes/decodes DIS PDUs that are transmitted over the network. The dead reckoning function updates entity positions between receipt of entity state PDU updates, and accomplishes turn smoothing for a more realistic visual display of Janus entity movement for the manned simulator. The entity/terrain reconciliation determines (for the manned simulator visual display) the Janus entity orientation and velocity. The engagement arbitration function determines and transmits engagement results between Janus and DIS entities. The aircraft engagement function, added during the Janus Fast Movers project, consists of processing radar emissions, aircraft evasive maneuver logic and missile fly out models. These functions are summarized in Figure 3.

WORLD MODELER				
NETWORK MANAGEMENT	DEAD RECKONING	ENTITY/TERRAIN RECONCILIATION	ENGAGEMENT ARBITRATION	FAST MOVER FUNCTIONS
- Processes Janus Message Traffic - Codes/Decodes DIS PDUs	- Intermediate PDU Updates - Turn Smoothing	- Determine Janus Orientation - Calculate Janus Velocity	- Done by Janus - Done by WM	- Radar Emission - Aircraft Evasion - Missile Flyout

Figure 3: World Modeler Functions

3.3.2 World Modeler Initialization

The World Modeler initialization process is shown in Figure 4.

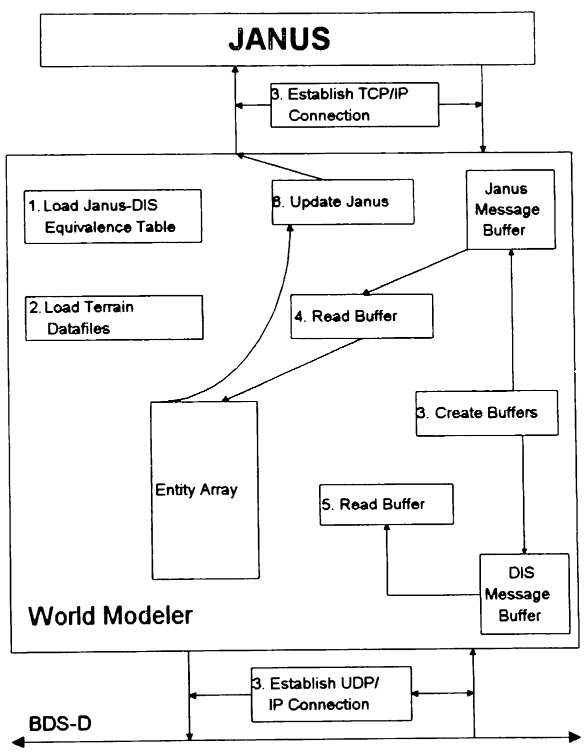

Figure 4: Initialization of the World Modeler

This initialization process includes the following actions:

1. Load the DIS-Janus entity equivalence table. This enables World Modeler to match DIS and Janus entities so they are correctly represented in each model.

2. Load terrain data file. The World Modeler maintains a copy of the terrain. The terrain is needed in World Modeler because Janus does not explicitly keep track of entity elevation values, so World Modeler determines elevation and orientation values for Janus entity positions and munition effects.
3. Establish a TCP/IP connection to Janus and a UDP/IP connection to DIS. Once these connections are established, the associated message buffers begin to fill with Janus and DIS entity information.
4. Read the Janus message buffer and load the Janus entities into the World Modeler entity array. This array stores information on all Janus and DIS entities.
5. Read the DIS message buffer and load the entity array with the entities currently active in the DIS world.
6. Send Janus the current DIS entity dispositions. Janus acknowledges the receipt of these data with a synchronization message which signifies the completion of the World Modeler initialization. The World Modeler clock starts and the main application loop starts.

3.3.3 World Modeler Application Loop

The main application loop continuously executes the primary functions of the World Modeler. This loop continues until the simulation is terminated. When the simulation starts the Janus clock runs a *heartbeat* faster than the World Modeler clock. This *heartbeat* corresponds to the time interval for which Janus is updated on DIS entities. This interval is necessary because Janus algorithms involve a large number of calculations. Four seconds has been found to be a reasonable value for scenarios with up to 200 Janus entities.

The application loop includes the following actions.

1. Janus - World Modeler
   - Read Janus message buffer
   - Update vehicle array
   - Create PDUs for fire/detonation messages, load them in the event queue unless time has already passed (if already passed, send directly to DIS.)
   - Send out DIS PDUs as appropriate (fire & detonations) from the event queue (i.e. if event time >= clock time) and send entity update information if appropriate.
2. World Modeler - DIS
   - Read DIS PDU message buffer
   - Update vehicle array
   - Dead reckon vehicles
   - Arbitrate DIS fire/detonation PDUs: if Janus entity affected then immediately send detonation message to Janus
   - Update Janus on DIS entities if heartbeat exceeded

An overview flow chart the World Modeler Application Loop is shown in Figure 5.

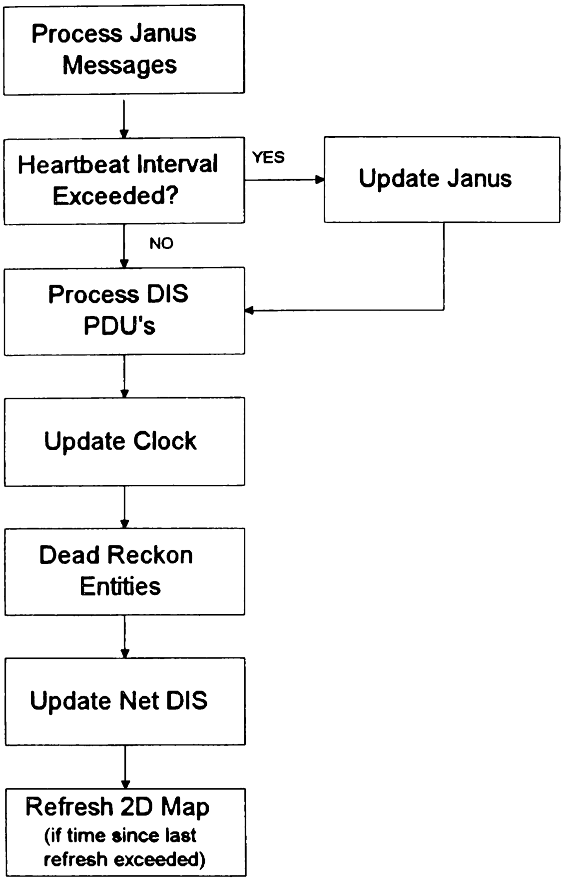

Figure 5: World Modeler Main Application Loop

4 JANUS FAST MOVERS PROJECT

The Janus Fast Movers Project was a follow on project to the originally conceived JLINK support for A2 ATD and resulted in a significantly enhanced JLINK system. The purpose of the Janus Fast Movers project was to seamlessly connect a virtual fixed-wing aircraft simulator (fast mover) with Janus using real-time Distributed Interactive Simulation Protocols (DIS PDUs). The project was accomplished with Armstrong Laboratory's aircrew research and training facility, Mesa Arizona, using their Multi-Ship Training Research and Development (MULTIRAD) aircraft simulator system. MULTIRAD is fully DIS compliant and included two F-16C aircraft simulators.

4.1 Challenges in Achieving Realistic Interaction

We knew that with the existing JLINK system we could establish a connection to the DIS compliant MULTIRAD system. The challenge was achieving a realistic interaction between Janus and the F-16C simulators, since Janus represented aircraft in a very rudimentary manner.

To achieve a realistic interaction, significant changes were needed in three major functional areas. First, when a Janus radar/missile site acquires, tracks and launches a missile, the aircraft should get the proper indications on its radar warning receiver. This was accomplished by adding a radar emission PDU to the World Modeler. Second, given that the pilot received the indication that he was being tracked or a missile fired, the effect of the evasive maneuver he takes to break that radar lock had to be modeled. This was accomplished by adding evasive maneuver algorithms to the World Modeler. And finally, if Janus launches a missile at the aircraft, a missile flyout model was needed, so the visual cue would be present for the pilot. This was also accomplished in the World Modeler by adding missile flyout algorithms.

4.1.1 Radar Emissions

A Janus radar is considered to be on and radiating unless it is in "hold fire", and can be turned on and off by toggling the hold fire selection on the Janus Menu. When the simulation starts, if a radar unit is not in hold fire, an initial Emission PDU is transmitted (by the World Modeler) with a beam parameter index (state) indicating that it is radiating. An update emission PDU is subsequently sent if there is a change in state or every 5 seconds if there is no state change. State changes occur when a radar is turned on or off, goes from acquisition to track, or launches a missile. The Janus radar model is built around three events: acquire, track and launch. When each of these events occur, Janus sends a message to the World Modeler; the World Modeler then sends out an update emission PDU with the identity of the radar, the affected aircraft(s) and the status (acquire, track or missile launch).

The MULTIRAD Network Interface Unit (NIU) reads and interprets the emission PDUs and sends the appropriate messages to the F-16C simulator to trigger the cockpit radar warning receiver, which displays the appropriate track or launch indication.

4.1.2 Aircraft Evasive Modeling

Given that the pilot receives an indication of when his aircraft is being tracked and/or when a missile is launched, the next task is to model the effect of his evasive maneuver to break a radar lock and/or defeat a missile in flight.

The modeling of radar tracking and aircraft evasion to breaklock is jointly handled by Janus and the World Modeler. Janus does the radar acquire, track and launch of missiles against aircraft and breaks lock if one of the following happens:

- Line of sight between the radar and the aircraft is lost;
- The aircraft flies out of range of the radar;
- The aircraft or radar unit is killed.

If any of these happen, Janus sends a breaklock message to World Modeler, then starts the acquire/track sequence all over again. World Modeler sends an update emission PDU on the DIS net indicating breaklock and the information is transmitted to the F-16C radar warning receiver.

The World Modeler can also determine if an aircraft breaks radar lock. It does so through its evasive maneuver algorithm that evaluates the aircraft movement against the parameters of the tracking radar. If the World Modeler determines that an aircraft breaks lock due to its maneuver, it sends an appropriate message to Janus and sends an emission PDU (indicating breaklock) out on the DIS net.

4.1.3 Evasive Maneuver Algorithm

The intent of this algorithm was to capture the essence of a pilot maneuvering rather than to create a detailed flight dynamics engineering model. The goal was to cause the Janus radar to breaklock if a pilot executed a maneuver that would realistically cause a breaklock in combat. Armstrong Laboratory's air crew training personnel described in general terms the actions the pilot takes to break a radar lock. When the pilot determines that he is being tracked he tries to fly behind terrain features (if available) to interrupt LOS between himself and the radar. Failing that he will try to maneuver the aircraft essentially perpendicular to the radar beam creating maximum LOS rate changes. Specifically, he will sharply turn the aircraft to put it between approximately a 2 and 4 o'clock (60 to 120 degrees) or 8 and 10 o'clock (240 to 300 degrees) aspect to the radar. He will try to change directions in both the horizontal and the vertical planes and drop chaff at the same time to breaklock.

Based on this information, we modeled breaklock as a probablistic function, with the assumption that the probability of breaking lock is a function of aspect angle to the radar, a radar effectiveness parameter, presence of chaff and a tuning parameter. The equation we developed is as follows:

$$Pr(breaklock) = (1 - (Ro * (1 + \cos(2*angle))/2 * k)) * c$$

where:

Ro	is a radar effectiveness parameter
angle	is the aspect angle between the aircraft heading and the radar
k	is the degradation (to maintaining lock) factor
c	is the overall tuning parameter

The term, 1 + cos(2*angle))/2, is the probability of the radar maintaining lock without the radar effectiveness (Ro) or chaff degradation parameters applied. If the aircraft is heading directly toward the radar (0 degrees) or directly away (180 degrees) then the probability of maintaining lock is one. Between 60 and 120 degrees, and 240 and 300 degrees (2 to 4 o'clock and 8 to 10 o'clock) the probability is very small, reaching zero as the aircraft turns perpendicular to the radar.

In implementing the algorithm, a time factor was also included that requires the pilot to maintain the aspect angle for a user designated time period (i.e., 1 second) before breaklock can be achieved. Including time is necessary because the World Modeler receives aircraft position updates 50 times a second and just looking at the position for a single instance gives unrealistic results. All of the parameters for the breaklock equation are data items that can be easily changed prior to each simulation run. Thus, the user can easily change the parameters to achieve the desired level of difficulty required for the pilot to breaklock against a given radar.

The aircraft evasive maneuver logic was written in a modular fashion; as other breaklock algorithms are developed they can easily be incorporated into the model. A command line argument was added to the World Modeler so the user can choose which breaklock algorithm to use for a simulation run.

4.1.4 Missile Flyout

The third major function added is the capability to fly missiles to the vicinity of the target when a fire message is received from Janus. When a Janus entity fires a missile, a fire message is sent to the World Modeler. World Modeler creates a missile entity and sends entity state PDUs for the missile. The actual position updates for the missile are determined by missile flyout routines written to model command guided, semi-active homing or infra-red guided missiles. Two algorithms were created: a predicted intercept model for command guided missiles and a simple tail chase model to model semi-active homing or infra-red guided missiles.

The breaklock logic is linked to the missile fly out for semi-active homing missiles. If lock is broken prior to missile launch then no missile is launched. If the missile is in flight and lock is broken, the missile will continue in the last given direction, receiving no further position corrections and will, with high probability, miss the aircraft.

4.2 Janus Fast Movers MULTIRAD System

A hardware diagram is shown in Figure 6. Components of the Armstrong Laboratory's Multi-Ship Research and Development (MULTIRAD) System are shown in the upper portion of the diagram.

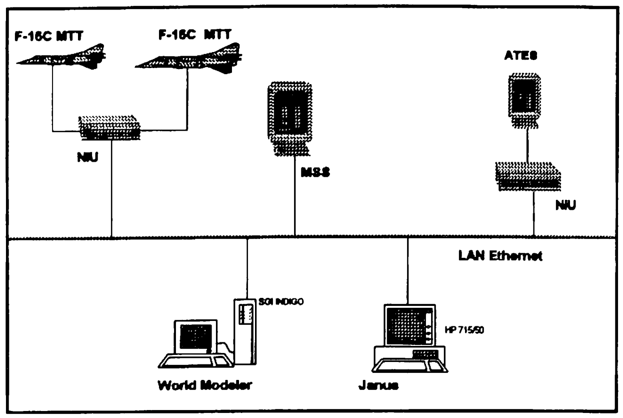

Figure 6: Hardware Diagram

The configuration of MULTIRAD used for the demonstration consisted of two F-16C Multi-Task Trainers (MTT), the Automated Threat Engagement System (ATES), and the Multi-ship Support Station (MSS). The MSS is the master management, control and display station. All simulation entities are displayed on its maps. Cockpit information is also displayed, including a video screen of the pilot and cockpit instrument displays (i.e., radar warning receiver and heads up display). The F-16Cs operate with a Network Interface Unit (NIU) on a shared memory network communicating at 50 Hz. The NIU performs the required data translations, dead reckoning, and filtering to connect the F-16Cs to the DIS 2.0.3 Ethernet LAN. The ATES also uses the NIUs with Ethernet interfaces on both the host and DIS 2.0.3 LAN side of the NIU. The ATES provides a realistic threat Surface to Air Missile (SAM) and Air to Air Fighters for the F-16C pilots training on the simulator. For the demonstration, one ATES SA-6 site was integrated with the Janus SA-8 and ZSU's.

Pictured on the lower portion of Figure 6 is the World Modeler interface model and Janus. ModSAF is also connected directly to the Ethernet.

5 SUMMARY AND CONCLUSIONS

The objective of seamlessly connecting Janus to ground combat vehicle and fixed-wing simulators and attaining realistic interaction was achieved. Major challenges to producing a realistic interaction between Janus and DIS applications were met. Items like battlefield scale, terrain correlation and event step versus continuous real time were addressed to produce satisfactory results. However, more research to improve on our solutions remains.

Limitations in the Janus aircraft and air defense model were overcome by modeling key parts of those functions within the World Modeler. The World Modeler has become much more than a translator for Janus. Functionality not present in Janus, such as aircraft evasive maneuvering, radar emissions and missile flyout were incorporated in the World Modeler. The result is a significantly increased capability for Janus to interact in the DIS environment.

Finally, the most significant aspect of the JLINK Project is that Janus with the World Modeler has become an intelligent Computer Generated Forces (CGF) model for aircraft as well as ground combat vehicle simulators.

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