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This paper provides and overview of the simulation, stimulation, and modeling capabilities that were developed to meet the requirements of the Infrared Sensor Stimulator (IRSS) program. Much of this capability has been installed at the ACETEF since September 2000, putting the IRSS at IOC status.

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Infrared Sensor Stimulator (IRSS) Installation in the ACETEF, NAWC-AD, Patuxent River, MD

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ABSTRACT

Military platforms are increasingly dependent on the use of installed RF and Electro-optical sensor systems, and their data correlation/fusion to contend with the increasing complexities of multi-mission warfare. Prior to expensive flight and field testing, rigorous test and evaluation (T&E) of the installed/integrated sensors' performance and interaction is needed. Consequently, the optimum use of scarce testing resources requires simultaneous T&E of multiple installed avionics and sensor subsystems in ground test environments.

The combination of increasingly sophisticated test requirements and declining investments in test assets requires the coordinated and innovative development of modeling, simulation and emerging technologies to maximize use of scarce testing investment resources. This paper addresses the capabilities and development of the recently operational JISTF Infrared Sensor Stimulator (IRSS) system at the Naval Air Warfare Center Aircraft Division (NAWC-AD) at Patuxent River, Maryland, under the sponsorship of the Office of the Secretary of Defense (OSD) Central Test and Evaluation Program (CTEIP). IRSS is a modular system used to generate high fidelity Infrared (IR) scenes for stimulation of installed IR Electro-Optic (EO) sensors on military aircraft undergoing integrated developmental and operational testing. The IRSS is capable of stimulating multiple types of sensors such as Forward looking Infrared (FLIR), Missile Warning Systems (MWS), Infrared Search and Track (IRST) and Missile Seekers.

This paper provides an overview of the simulation, stimulation, and modeling capabilities that were developed to meet the requirements of the IRSS program. Much of this capability has been installed at the ACETEF since September 2000, putting the IRSS at IOC status.

Keywords: Hardware-in-the-Loop, Simulation, Infrared, Scene Generator, Sensor Stimulation, FLIR, Missile Warning, Imaging IR Seeker

1. INTRODUCTION

The Office of the Secretary of Defense (OSD), Central Test and Evaluation Investment Program (CTEIP) is tasked to provide a coordinated process for making joint investments in defense test & evaluation (T&E) to offset the challenges presented by declining investments in test assets and increasing test requirements. Under CTEIP sponsorship, the Navy and Air Force are have jointly developed the Joint Installed System Test Facility (JISTF) Infrared Sensor Stimulator (IRSS) system. IRSS is a modular system used to generate high fidelity Infrared (IR) scenes for stimulation of installed IR Electro-Optic (EO) sensors on military aircraft undergoing integrated developmental and operational testing. The IRSS is capable of stimulating multiple types of sensors such as Forward looking Infrared (FLIR), Missile Warning Systems (MWS), Infrared Search and Track (IRST) and Missile Seekers.

The IRSS is an integrated hardware/software system based on Amherst Systems' Real-time IR/EO Scene Simulator (RISS). The RISS was specifically designed to support the design, development, integration, and testing of IR/EO sensor systems. The baseline IRSS system includes the hardware and software components to provide a complete IR/EO simulation and test environment. Functionally, the IRSS system includes software to support off-line modeling, database development, scenario generation, and simulation control. Real-time functions include scene generation and sensor stimulation. The IRSS system supports both open-loop and closed-loop simulation. Open-loop simulation allows the user to execute predefined, time-sequenced scenarios ensuring total control over scenario events. Closed-loop simulation is supported through an external interface where the unit under test (UUT) and target position data can be generated by external simulations and provided to the IRSS system for reactive engagements.

In an integrated configuration, the IRSS can be coupled with RF simulators and facility level composite mission simulators for correlated, synchronized multi-spectral testing. The IRSS supports the stimulation of single or multiple aperture sensor systems. The system is modular in design to support incremental expansion of both function and performance to meet current and future test requirements.

The IRSS system architecture is illustrated in Figure 1. The IRSS program, including an overview of its major subsystems, was briefed at AeroSense 1999 and AeroSense 2000. This paper provides an overview of the technologies developed and exploited on the IRSS program, a report of the testing accomplished since IRSS achieved IOC status in September 2000, and plans for the future.

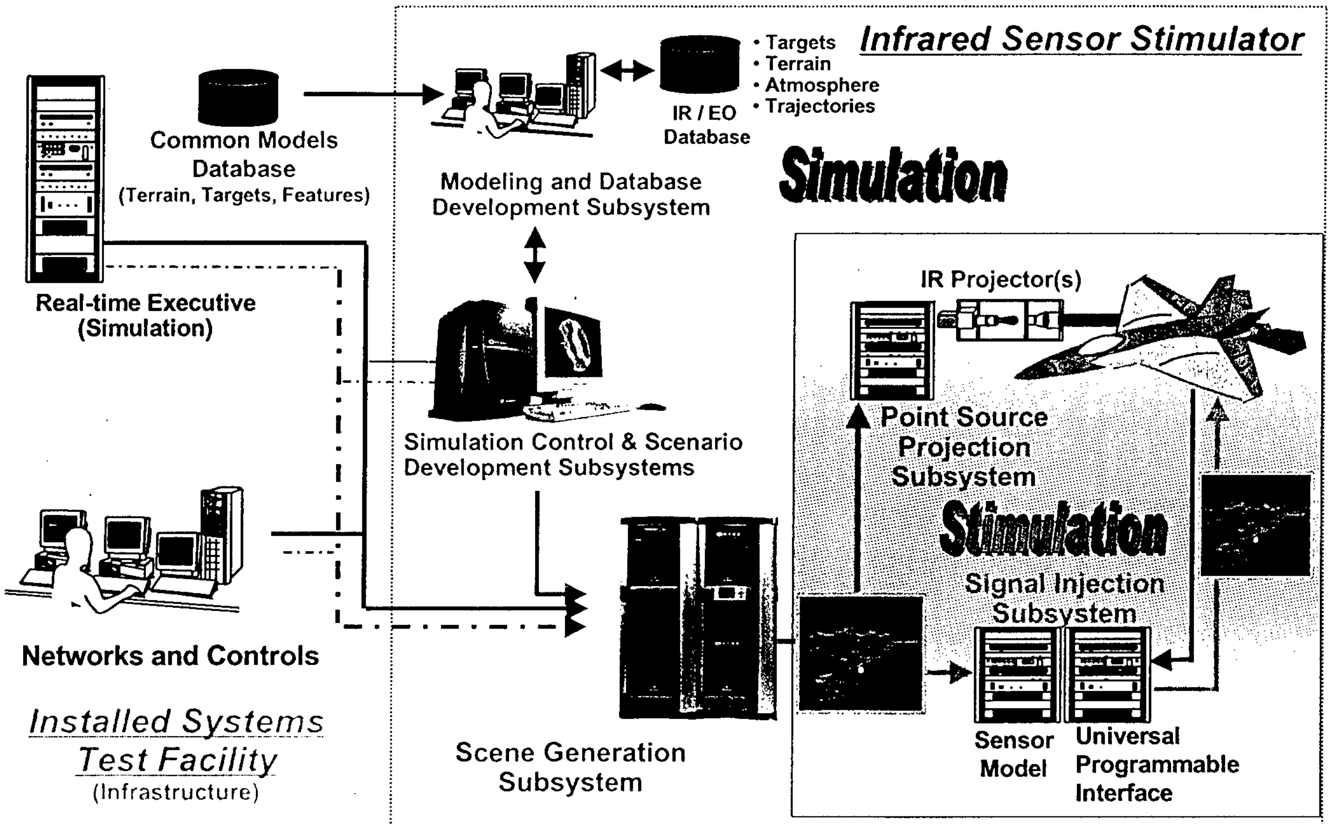

Figure 1-1. IRSS System Architecture

2. IRSS TECHNOLOGY OVERVIEW

Significant advancements in IR/EO modeling and databases, scene generation, sensor modeling, and sensor stimulation have been made under the auspices of the IRSS program. Most of this work has been presented previously at AeroSense. Some of the major accomplishments are briefly described in the following sections.

2.1 Modeling and Database Development

The modeling and database development subsystem of IRSS provides various functional capabilities critical to the overall test objectives of IRSS. These capabilities include: import/creation and attribution of 3-D target and object models; import and attribution of terrain databases; statistical generation of synthetic clutter; and integrated use of 3rd party phenomenology and signature models to build test databases. The modeling and database development subsystem was based on capability provided by Amherst Systems' Real-time IR/EO Scene Simulator (RISS), specifically the Model Builder and Model Toolkit applications.

2.1.1 Open Database Format

An important goal of IRSS was to be compatible with initiatives in the simulation community to establish common terrain database and common target database standards. As described in the introduction, the IRSS is part of a facility upgrade program to support test and evaluation of installed, multispectral sensors and avionics systems. In order to achieve this objective, target and terrain databases must be shared be multispectral stimulators. Several DOD and industry-sponsored working groups are addressing the format and content requirements for shared databases, but no standard was available in a timeframe that supported the IRSS development schedule. Consequently, use of an open database standard in the IRSS modeling and database development subsystem was a key design driver.

The Model Builder application was enhanced on the IRSS program by integrating MultiGen/Paradigm's CreatorPro 3-D modeling tools. CreatorPro was selected because MultiGen's OpenFlight file format was and is an open, published standard widely embraced by the visual simulation community. Furthermore, the availability (in 1999) of an application programming interface (API) provided a means to extend the OpenFlight format to include attribution needed for multispectral simulation databases such as IR/EO and radar. These factors made Amherst and the IRSS IPT confident that any common database standard to emerge from various working groups sponsored by DoD and industry will be compatible with OpenFlight.

Amherst Systems enhanced the Model Builder application by developing IR/EO material and texture palettes that are seamlessly integrated into the CreatorPro tools via the API. OpenFlight objects can thus be attributed at the vertex or facet level with temperature, infrared texture codes, and infrared material codes that define emissivity, reflectivity, and transparency. Objects defined with extended OpenFlight format can be viewed, edited, and stored using the standard features of CreatorPro. OpenFlight extensions are ignored by applications that don't use them, so, for example, a visual object that was extended with infrared characteristics can still be rendered in a visual simulation environment. This mechanism holds great promise for multispectral target and terrain databases.

2.1.1 Terrain Simulation

The IRSS program also sponsored work that leverages advancements in large area terrain databases primarily developed for visual simulations. These databases use satellite imagery to represent geospecific regions at various levels of resolution without the cost to generate and render three dimensional models of all the cultural features of the landscape.

The terrain databases utilized in IRSS consist of three components: (1.) a faceted, three-dimensional surface description derived from digital elevation data; (2.) a material map or material mix map; (3.) an elevation map. The material (mix) maps are derived from analysis of multispectral satellite imagery. Classification techniques are employed to determine the material or material mix of the terrain from the images on a texel-by-texel basis. A material code number is assigned to each texel, and all the codes for a specific patch of terrain are assembled into a material map, or, in the case of a material mixture being assigned to a texel, a material mix map. The material codes are cross-referenced to a table that gives all the pertinent properties of each material. The use of material mixtures has an advantage over using a single material per texel in that it enhances the level of detail in the terrain image and smoothes the transitions between regions of differing material types.

The 3-D wireframe and the elevation texture provide two types of topographic descriptions of the terrain. The elevation texture provides a topographic description at a texel-level resolution. This is necessary due to the sensitivity of the texel's radiance to its normal vector and its elevation. While the texel's source radiance is modeled as being independent of its orientation (i.e., Lambertian), its normal vector and elevation can have a significant impact on the source radiance by effecting the texel temperature. The normal vector also determines how much sunshine, skyshine, and earthshine the texel reflects. The texel-level topographic data can be readily derived from digital elevation data using standard interpolation and gradient estimation techniques when texel level elevation data is not available.

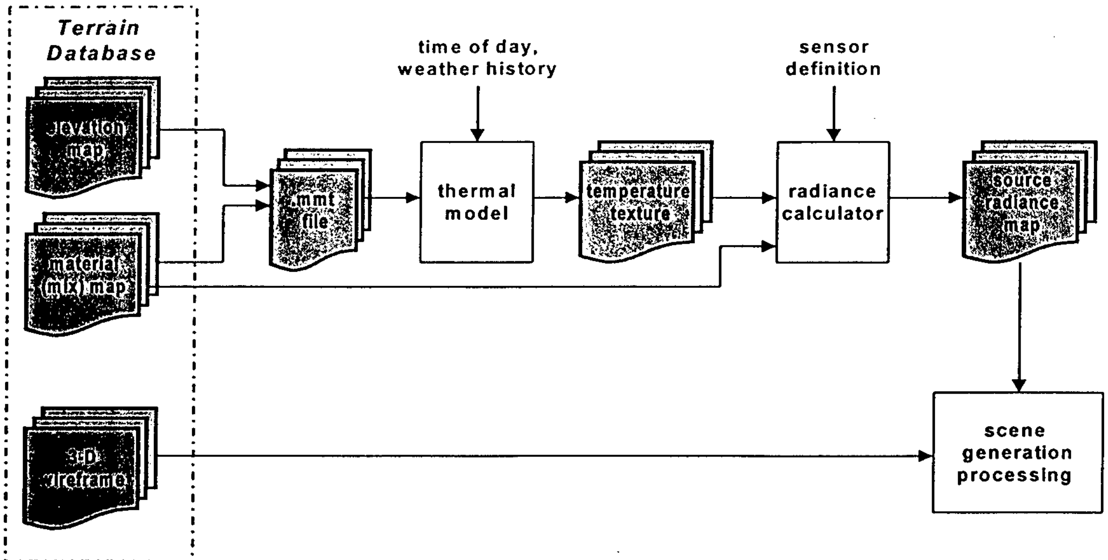

Figure 2-1. Terrain database processing in IRSS.

The terrain description is based only on its physical properties, so it can be used to simulate the terrain regardless of the waveband(s) of the sensor being modeled, and correlating images with different wavebands is easily accomplished. As illustrated in Figure 2-1, the terrain description is used in conjunction with a thermal model to include realistic seasonal and diurnal effects. The resulting temperature texture, the material (mix) map, and the definition of the sensor's spectral response are utilized to compute a source radiance map which is overlayed on the 3-D terrain skin. Atmospheric effects are applied during the scene generation process.

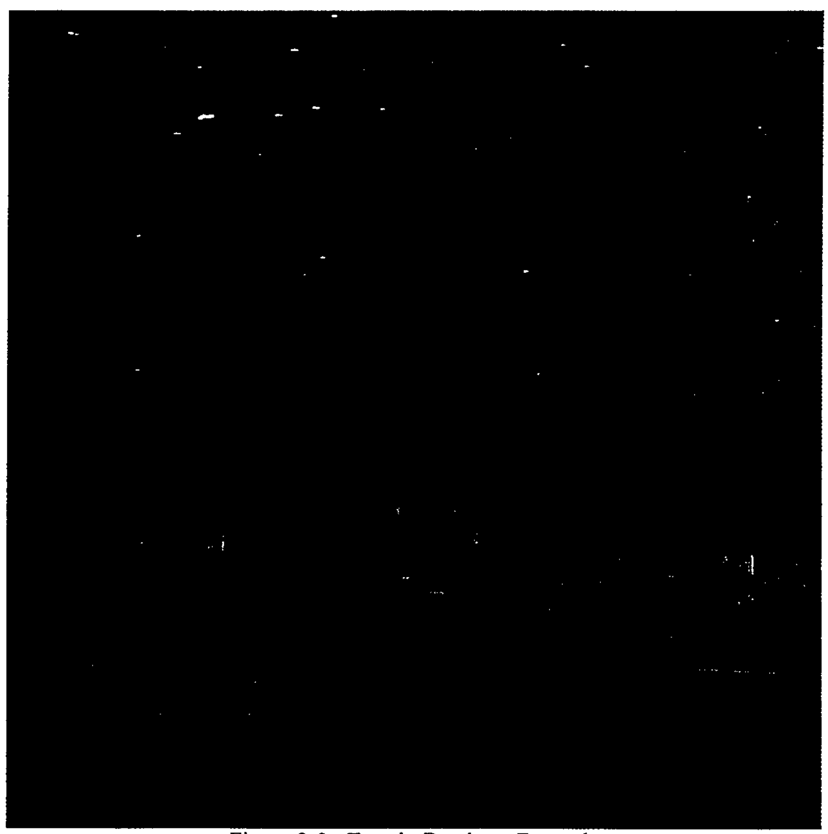

Figure 2-2. Terrain Database Example

The objective of the IRSS program initially was to be able to render terrain databases developed by Photon Research Associates (PRA) for Edwards AFB. In order to accomplish this, Amherst developed the .mmt file format to reduce storage size and improve processing speed. The thermal model employed was PRA's TERTEM model, and MOSART was used to generate the weather history information. Since this work was reported last year at AeroSense, several improvements and generalizations have been implemented. Interfaces to the thermal model and the weather history have been abstracted, to allow other thermal models and weather sources (e. g., MODTRAN) to be used. The radiance map can be pre-computed and stored, or generated at run-time, opening the door to the use of other data. Radiance maps generated by non-real-time, higher fidelity models such as DIRSIG, GENESIS, or GCI Toolkit can now be used in IRSS, as well as other data sources such as IRMA. Figure 2-2 illustrates a scene generated by IRSS from a small portion of the JSF database.

2.2 Scene Generation

In satisfying the requirements for installed systems testing, the IRSS program has sponsored a number of advances in infrared scene generation. These include scenario development tools and displays, an API to support real-time use of non-real-time signature models, synchronized, multichannel simulation, and integration with the Joint Interim Mission Model (JIMM).

2.2.1 Scenario Development Tools

The IRSS program has put a great deal of emphasis on providing a complete test environment for future users. Consequently, tools for database development, building and editing scenarios, and configuring and controlling test assets have been an important part of the IRSS development effort. In contrast to special purpose test environments, the IRSS is equipped with standard graphical user interfaces for selecting test scenarios, initializing simulation hardware assets, executing tests, and collecting results. The intent is to minimize test development time and costs, and make the IRSS a cost effective test resource. Figure 2-2 illustrates some of the scenario development and visualization displays.

Figure 2-3. Scenario development and visualization displays

One of the key factors in the development of the scenario development tools has been input from IRSS users during the development process. Amherst Systems implemented a modified spiral development process for the IRSS program. As part of that process, versions of software with increasing functionality were delivered to the Government at regular intervals. Each version was evaluated by the IRSS IPT. This approach provided many opportunities to solicit feedback from users and incorporate their observations and requests into a subsequent version. It is hoped that the test environment will continue to evolve and improve as a direct result of input from a varied user community.

2.2.2 IRSS Application Programming Interface (API)

As described in the introduction, extensibility has been an important consideration in the design and development of the IRSS. IRSS is an installed systems facility upgrade, not a dedicated program test asset. Future users of the IRSS will likely have requirements for databases, models, etc. that are not currently integrated with the system. Consequently, open database formats and model integration issues have been design drivers. An important development is an application programming interface called the Plug-in Interface (PII). The PII supports functional extensions to IRSS by allowing external applications to be associated with a modeled object (terrain, vehicle, etc.) during the scenario development process. The external application then can control the temperature, geometry, etc. of the object or part of the object during scene generation. For example, a high fidelity signature model such as PRISM can be executed at a 1 Hz rate and provide vehicle facet/vertex temperature updates to the IRSS scene generator running at sensor frame rates of 100 Hz or more.

2.2.3 Multichannel Simulation and Stimulation

The IRSS is capable of providing synchronized multichannel simulation for coordinated simulation and stimulation of missile warning systems utilizing multiple sensors for complete coverage, as well as integrated avionics systems that rely on inputs from different sensors to provide coordinated functionality. This is a key requirement for installed sensor testing, where verification of the interoperability of several, possibly multi-spectral sensors is often required to assess the overall performance of a system under test.

Multichannel simulation in the IRSS is achieved by executing the simulation control application on an SGI Octane workstation which is interfaced to one or more scene generation pipelines or channels. Each channel is initialized with the same scenario components (atmosphere, terrain, targets, etc.), and processes the same events, synchronized in time with other channels. However, each channel can be independently configured to perform scene generation tailored to a specific UUT, in terms of frame-by-frame field of view changes, waveband, frame rate, frame size, etc. The IRSS implementation allows multiple systems under test (SUT) and units under test (UUT) to be defined in a single scenario (see figure 3-2).

The IRSS installations at ACETEF and Edwards AFB are currently configured with one scene generation pipeline. The pipeline utilizes SGI Origin/Onyx2 MIPS processors to calculate geometry and radiometrics. Scene rendering is performed by the user selecting either the SGI InfiniteReality, or the Amherst RISS scene rendering subsystem (SRS).

2.2.4 External Control Interface

In order to provide coordinated, multispectral simulation and stimulation of installed sensor systems, IRSS must be synchronized in time and space with the other JISTF stimulators described in section 1. Synchronization and control is accomplished via an external control interface. This interface allows an external simulator or simulation to control execution of an IRSS scenario, as well as the position and other characteristics of specific players (SUT and/or targets).

External control is implemented using internal shared memory to communicate with a separate configuration application. The configuration application isolates the IRSS from the hardware and protocols used for external control. This design can support external control interfaces such as DIS and HLA, as well as custom hardware-in-the-loop interfaces. Configuration applications can be written to use SCRAMNet, Internet, Gigabit LAN, ATM, or reflective memory interfaces for communication with the controlling system.

The first external control implementation developed for IRSS was for the Synthetic Warfare Environment Generator (SWEG), a composite mission model used at the ACETEF. The configuration application for SWEG uses SCRAMNet with IRIG time synchronization. After the SWEG interface was designed and implemented, ACETEF transitioned to the Joint Interim Mission Model (JIMM), which encompasses the functionality of SWEG as well as those of Suppressor, a composite mission model used by the U. S. Air Force. The switch from SWEG to JIMM required almost no modification of the configuration application, which illustrates the extensibility of the shared memory concept.

2.3 Sensor Modeling and Sensor Stimulation

IRSS currently provides two methods of sensor stimulation, direct injection via the Signal Injection Subsystem (SIS), and optical projection via the IR Point Source Projector (IRPSP). The SIS is based on the Universal Programmable Interface (UPI) technology. The UPI provides a user-programmable digital sensor model and a variety of I/O options including fiber-optic output, DDO2 input/output, NTSC/PAL input/output, and SVGA output. Depending on the interface requirements of the UUT processor, it may be necessary to develop a Signal Injection Module (SIM) to electrically interface with the UPI.

Signal injection is utilized to emulate bypassed components (optics, detectors, etc.) of the UUT and directly interface with the UUT processor. This method of sensor stimulation is preferred when frame size, frame rate, or scene resolution requirements exceed the performance capabilities of optical projectors. As part of the IRSS program, a sensor model and Signal Injection Module (SIM) for the F-22 missile launch detector (MLD) was developed. A sensor model and requirements analysis for the AN/AAS-44(V) FLIR was also developed.

The IRSS IRPSP subsystem is based on Santa Barbara Infrared's MIRAGE projector. Projection optics for the F-22 MLD and AN/AAS-44(V) FLIR were developed to support near-term IRSS test objectives. Current applications of the IRPSP are described in section 3.

3. INSTALLATION OF IRSS AT ACETEF

3.1 Operational Status

The IRSS became fully operational (FOC status) at the Naval Air Warfare Center Aircraft Division (NAWCAD), Air Combat Environment T&E Facility (ACETEF), Patuxent River, MD on 11 April 2001. This status occurred upon the successful completion of Factory Acceptance Testing (FAT) and facility installation and integration at the ACETEFC. The Air Force Flight Test Center (AFFTC), Edwards AFB, CA has an Initial Operational Capability (IOC) and is scheduled to be at FOC 15 May 2001 after acceptance testing on the F-22 Missile Launch Detector (MLD) Signal Injection Module (SIM). The remainder of this paper addresses the ACETEF utilization of IRSS assets.

3.2 Facility Installation

The ACETEF IRSS EO Sensors Testing Laboratory serves as the hub for the creation, control, operation and coordination of dynamic IR scenes ported to Projection/Injection stimulators. The dynamic scenes are ported via Fiber Link to installed sensor stimulators located in the Shielded Hangar, Small Anechoic Chamber, and Large Anechoic Chamber (see Figure 3-1).

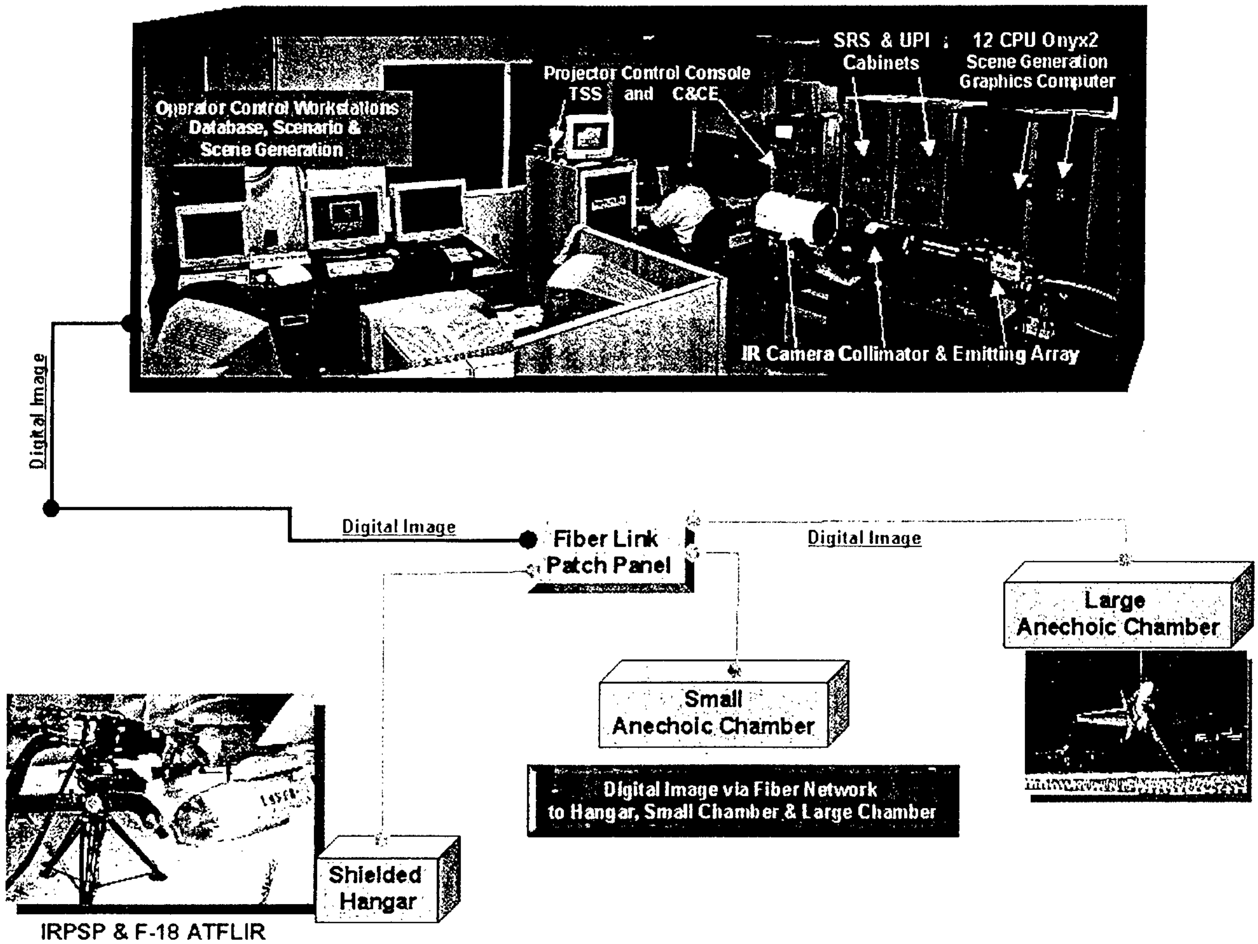

Figure 3-1 IRSS EO Sensor Laboratory and Infrastructure

The IRSS architecture employs Silicon Graphics (SGI) fast symmetric multiprocessing hardware, which has minimized cost and development time. The initial configuration consists of two dedicated SGI Onyy2 graphics computers and a RISS scene rendering subsystem (SRS) to provide three channels of digital video. This configuration supports synchronized testing of multiple EO imaging sensors on a single aircraft or individual sensors on up to three aircraft. The architecture is scalable to a maximum of ten channels of output.

Periodically, the IRSS performance and throughput requirements for dynamic real time rendering and physics-based accuracy may require use of High Performance Computing (HPC) assets for generation of complex scenes or providing additional channels of digital imagery. Accordingly, the ACETEF IRSS EO Sensor Testing Laboratory has been configured to physically co-exist within the architecture of the ACETEF HPC center. Future IRSS capability planning includes the use of HPC resources to scale up to ten channels (See Figure 3-2) of output. Ten channel scale-up will be accomplished by temporarily dedicating up to seven HPC Onyx2/Onyx3 systems for testing of advanced multi-sensor configurations (e.g., distributed aperture concept).

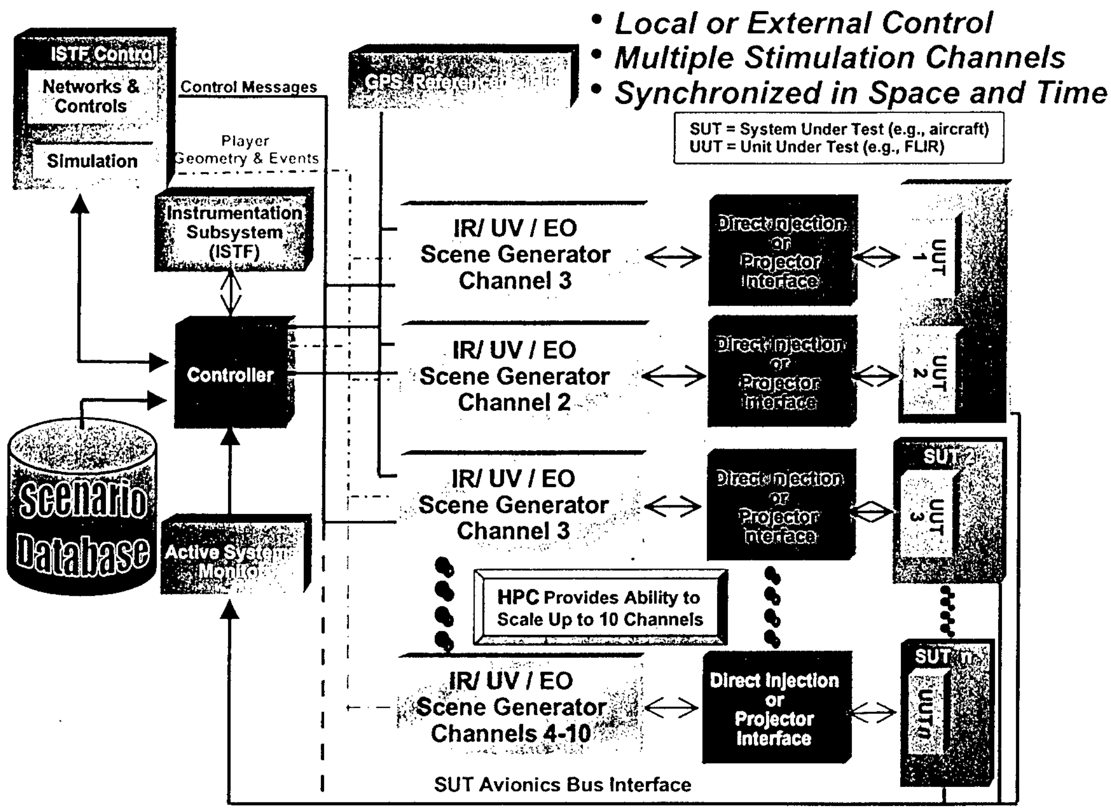

Figure 3-2 Multi-Channel Scene Generation with HPC Resources

3.3 Installed Sensor System Testing

The IRSS system supports both open loop and closed-loop simulation. Open-loop simulation provides the user with the capability to execute predefined, time-sequenced scenarios ensuring total control over scenario events. Closed-loop simulation is supported through an external interface where the sensor unit under test (UUT) and target position data can be generated by external simulations and provided to the IRSS system for reactive engagements. In the integrated configuration, the IRSS can be coupled with RF simulators and facility-level composite mission simulators for correlated, synchronized multi-spectral testing.

3.3.1 F-18 Multi-Spectral Stimulation (MSS) Testing

Since December 2000, the NAWCAD IRSS system has been utilized in F-18 Multi-Spectral Stimulation (MSS) testing with the AN/AAS-46 Targeting FLIR as part of preliminary F/A-18 E/F Air-to-Air (A/A) Critical Operational Issues (COI's) testing. A/A COI testing is being used for developmental test risk reduction to support the Advanced Mission Computer and Displays (AMC&D)/High Order Language (HOL) system Low Rate Initial Production (LRIP) decision. The F/A-18 project coordination team is using a series of correlated IR/RADAR Multi-Sensor Stimulation scenarios as the basis for performing risk reduction evaluation for the A/A COI's prior to the LRIP decision. Testing is expected to occur in April/May 2001 prior to the LRIP decision in May 2001. Initially, the IR Point Source Projector (IRPSP) will be used for point source and target image projection to test the F-18 AN/AAS-38B FLIR and/or ATFLIR .

3.3.2 E2-C Surveillance Infrared Search and Track (SIRST) Testing

The E2-C Surveillance Infrared Search and Track (SIRST) sensor system has been periodically installed into the IRSS laboratory for ground test preparations. The SIRST is designed to track ballistic missiles during their boost and post-boost phases to provide accurate launch and impact point estimates. During the week of 22 August 2000, the IRSS IRPSP demonstrated successful stimulation of the SIRST sensor assembly. The present SIRST is a one of a kind "Proof of Concept" prototype to demonstrate the feasibility and potential of E-2C long range tracking of Theatre Ballistic Missiles (TBMs) for use in early warning for battle group defense missions. The projector demonstration scenarios consisted of test patterns, static scenes, and dynamic sequences created by the IRSS Scene Generation Subsystem (SGS). The dynamic scenario components included White Sands Missile Range terrain, several surface to air missiles, and a simulated TBM launch to provide the SIRST with a target to detect, acquire, and track. Figure 3-3 shows the prototype SIRST sensor located in front of the IRPSP (left side of image), collimating optics (center of image) and emitting array assembly (right side of image).

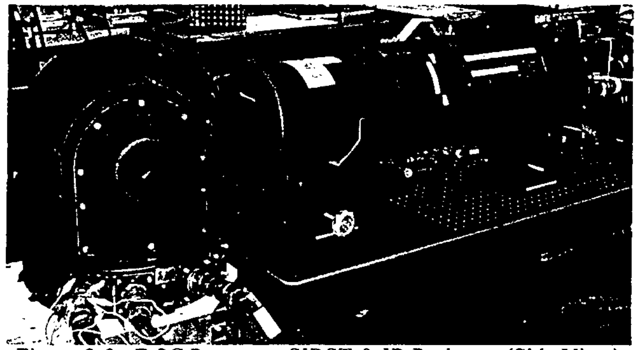

Figure 3-3. E-2C Prototype SIRST & IR Projector (Side View)

4. FUTURE PLANS AND CONCLUSIONS

The Infrared (IR) Sensor Stimulator (IRSS) project is commencing on a Tri-Service Preplanned Product Improvement (P3I) enhancement to provide full field of view (FFOV) IR image projection into installed IR sensors. The IRSS P3I project completes US Navy and US Air Force Joint Installed Systems Test Facility (JISTF) enhancements to support FFOV requirements for recently developed and next generation IR imaging sensors. It will also provide the US Army Test and Evaluation Command (ATEC) with the capability for mobile large format IR scene projection.

Simulation-based acquisition (SBA) is becoming more of an accepted process in the cost-effective development, risk reduction, and life cycle support of major weapons systems. Consequently, IRSS will be increasingly employed in a diversity of challenging T&E functions throughout the process. Typical functions will include the use of IR scene generation to create IR displays for evaluation of crew workload in prototype cockpits, and the UPI to characterize hypothetical sensors for use in the evaluation of the probability of detection and identification for operators and detection/tracking algorithms. Future areas of support will include dual color IR simulation/stimulation of installed Missile Launch Detector (MLD) sensors and next generation FLIR systems.

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