# Current Status of IR Scene Projection at the U.S. Army Aviation and Missile Command

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## ABSTRACT

This paper describes the recent addition, characterization, and integration of emerging technologies for dynamic infrared scene projection at the US Army Aviation and Missile Command's (AMCOM) Advanced Simulation Center (ASC). Infrared scene projection performs a vital role in the daily testing of tactical and theatre missile systems within these Hardware-in-the-Loop (HWIL) laboratories. Topics covered within this paper include the addition and characterization of new Honeywell and Santa Barbara Infrared emitter arrays, the integration and operation of the Honeywell and SBIR emitter array systems into a HWIL test, the development of high speed reduced-size IRSP drive electronics, the development of a NUC/characterization station, added software support, and the status of DMD-based infrared scene projector. Example imagery and test results from several of the projector systems are included within this paper.

**Keywords:** Infrared, Scene Projection, FPA testing, Hardware-in-the-loop.

## 1.0 INTRODUCTION

The Advanced Simulation Center is located within the AMCOM Research, Development and Engineering Center (RDEC). The ASC provides high-fidelity, value-added hardware-in-the-loop simulation support to Program Executive Officers (PEO) and Project Managers (PM) who are responsible for developing and fielding tactical precision guided missiles and submunitions for the U.S. Army. The ASC is also engaged in cooperative HWIL simulation tasks which support other DoD Agencies, NATO members and other U.S. Allies. This test support focuses primarily on testing missiles/munitions employing infrared, millimeter wave, and microwave sensors and seekers.

The ASC has six simulation facilities for testing systems which utilize IR sensors or seekers. The ASC IR HWIL facilities are capable of generating dynamic in-band IR images in real-time using advanced IR projector and scene generation computer equipment. This paper provides an overview of the recent advancements made to the IR projector capabilities resident within the ASC.

## 2.0 DEVELOPMENTS IN DYNAMIC PROJECTOR TECHNOLOGIES AT AMCOM

### 2.1 APPLICATION OF INFRARED SCENE PROJECTOR TECHNOLOGIES TO HWIL TESTING

#### 2.1.1 Integration of IRSPs into a Closed-Loop Flight Motion Simulator Test Environment

The state-of-the-art in closed-loop simulation of infrared imaging seekers/sensors involves the integration of the projection devices and unit under test (UUT) within a five-axis flight motion simulator environment. AMCOM personnel recently completed the successful integration of three unique dynamic infrared scene projection technologies within a five-axis flight motion simulator environment. Full closed-loop interfacing between test subsystems was attained using the IRSPs, UUT, and facility control systems. The IRSP technologies integrated during this test entry included: 1) IRSP based on

Honeywell's MSSP emitter array, 2) SBIR MIRAGE IRSP, and 3) a dynamic multi-band triangle target projector. Figure 1 below shows two of these projector systems, along with the UUT, integrated onto the FMS.

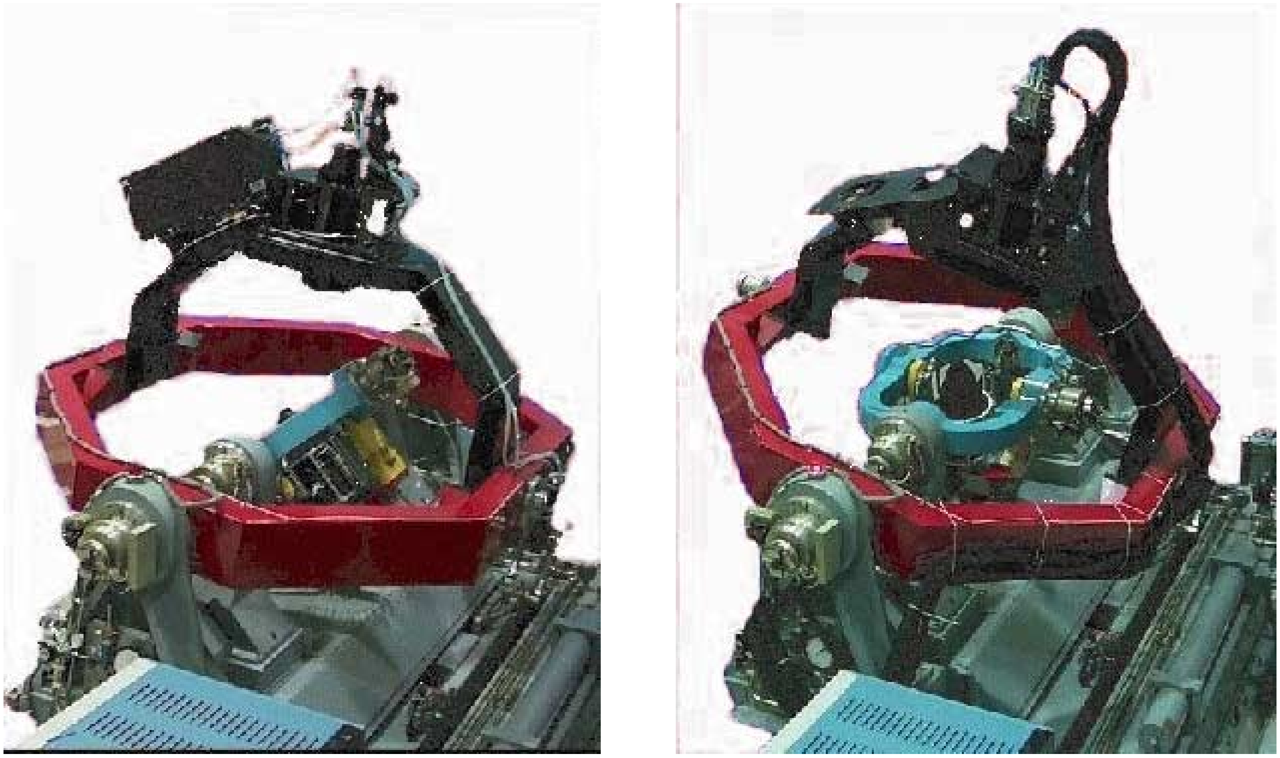

Figure 1: Integration of Honeywell Emitter IRSP (left) and MIRAGE IRSP (right) into TMD HWIL test entry.

Each IRSP presented it's own unique challenges to the integration task. These included the placement of power, cooling, and support electronics. Common to each system was a 3x MWIR zoom collimator. This optical assembly provided the necessary flexibility to interface two significantly different sized emitter arrays to a single common UUT. The testing completed to date included the integration of the projector technologies onto the FMS and checkout of all subsystem interfaces. Limited radiometric data was collected in preparation for future testing. Figure 2 below shows a simple 'RV-like' output image collected by the UUT during testing with each of the three IRSP technologies.

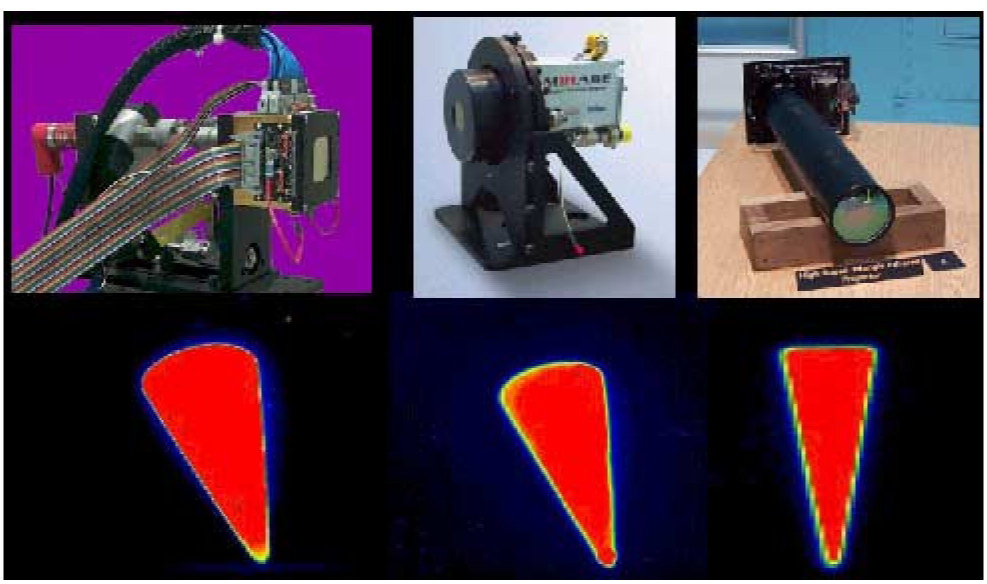

Figure 2: Dynamic IRSP Technologies and Example 'RV' Imagery

## 2.1 HONEYWELL TECHNOLOGY CENTER (HTC) EMITTER ARRAY BASED PROJECTORS

The dynamic infrared scene projectors built around the emitter array based technology developed by the Honeywell Technology Center continue to play a significant and vital role in the HWIL test support provided by AMCOM. AMCOM personnel have continued the characterization, integration, and operation of dynamic infrared scene projectors based upon this technology. The previous year's efforts have continued the establishment of a leading edge test capability. The following sections discuss many of these advancements, along with results from ongoing operation and characterization efforts.

### 2.1.1 MSSP Emitter Arrays

Through a tri-service program entitled the 'Central Test and Evaluation Investment Program' (CTEIP), the latest Honeywell array was developed under the program name "Multi-Spectral Scene Projector" (MSSP). In mid-2000, AMCOM received several of these MSSP arrays from the Air Force CTEIP participant, the Kinetic Kill Vehicle Hardware-in-the-loop facility (KHILS) at Eglin AFB. This latest type of array by Honeywell incorporates a new 'thin emitter' design allowing for greater speeds while not sacrificing significant dynamic range. Additionally, these arrays incorporate the first snapshot circuitry by Honeywell on a 512x512 array. AMCOM personnel have invested significant time in the characterization and operation of these new arrays. More recently, a second phase of MSSP arrays have been fabricated. These arrays, deemed Type 2 arrays, differ from the first phase, deemed Type 1 arrays, only in the emitter structure. This second phase uses smaller emitters of a slightly different structure in an attempt to improve the settling time while minimizing the loss of dynamic range. AMCOM expects to receive several of these arrays in the near future (see Near-term Additions section).

#### *2.1.1.1 Characterization of the MSSP Arrays*

The MSSP arrays, like all emitter-based arrays, require a finite time to heat and cool to the desired temperature. This response time, commonly referred to as rise and fall time, must be properly understood when applying these technologies within a HWIL test environment. Typically the rise time is the longer of the two response times and becomes one of the primary specification values for an emitter array. AMCOM has measured the risetime value for one of the MSSP arrays currently at the MRDEC facility. To record the emitter response, a 64x64 block of emitters were driven at a moderate level (2.5V). The emitter response from this block was recorded using a high-speed single element detector. Measurements were recorded under identical test scenarios with the array in either raster or snapshot mode. Nominal rise times for either mode were consistently between 5 and 5.5 msec. Figure 3 shows two of the collected rise times for the MSSP array, one for each update mode.

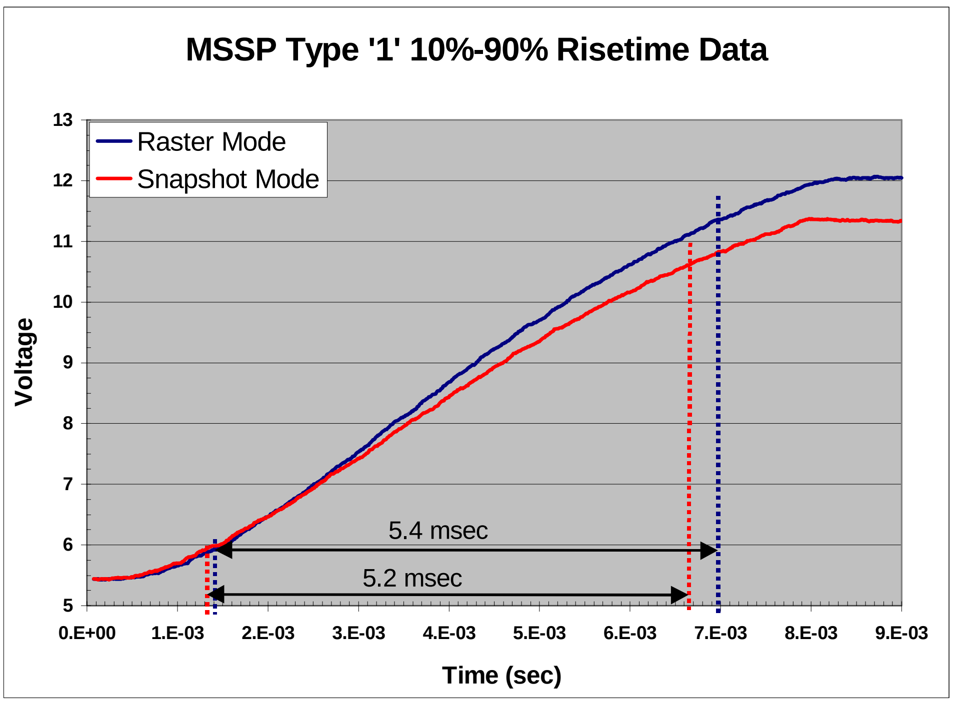


Figure 3: MSSP Raster and Snapshot Risetime Values

The MSSP array incorporates Honeywell's first snapshot frame updating capability on a large format array. Previous Honeywell arrays have incorporated a raster updating scheme whereby the emitters were provided new update information vertically across the array. This update typically took ~8 msec to complete. With nominal settling (rise/fall) times in the 5 msec range, the raster updating period was significant compared to the emitter response. Sampling of the emitter by short integration time systems could reveal variations in output across the array. The snapshot updating scheme was designed to remove this effect. AMCOM performed a series of tests to determine whether the emitters were being updated simultaneously. A series of increasing amplitude uniform blocks was projected to the UUT. Each subsequent frame presented to the UUT would contain a large block whose amplitude was moderately greater than that within the previous frame. After ~10 frames the series was repeated. Data was collected using this input series of frames while the emitter array was operated in each of the two available updating schemes, raster and snapshot. Figure 4 shows a column of data collected from each frame. Each column of data was sequentially plotted across the x-axis. The vertical axis plots the amplitude of each applicable detector within the column of data. As expected, the data projected using the raster updating scheme clearly shows a variation in the emitter array output between the top of each column and the bottom. The data projected using the snapshot updating scheme shows a uniform output across the column of data within each frame. The non-uniformity present in the snapshot data at higher outputs was due to camera non-uniformity and does not reflect a significant difference in output by the emitter array.

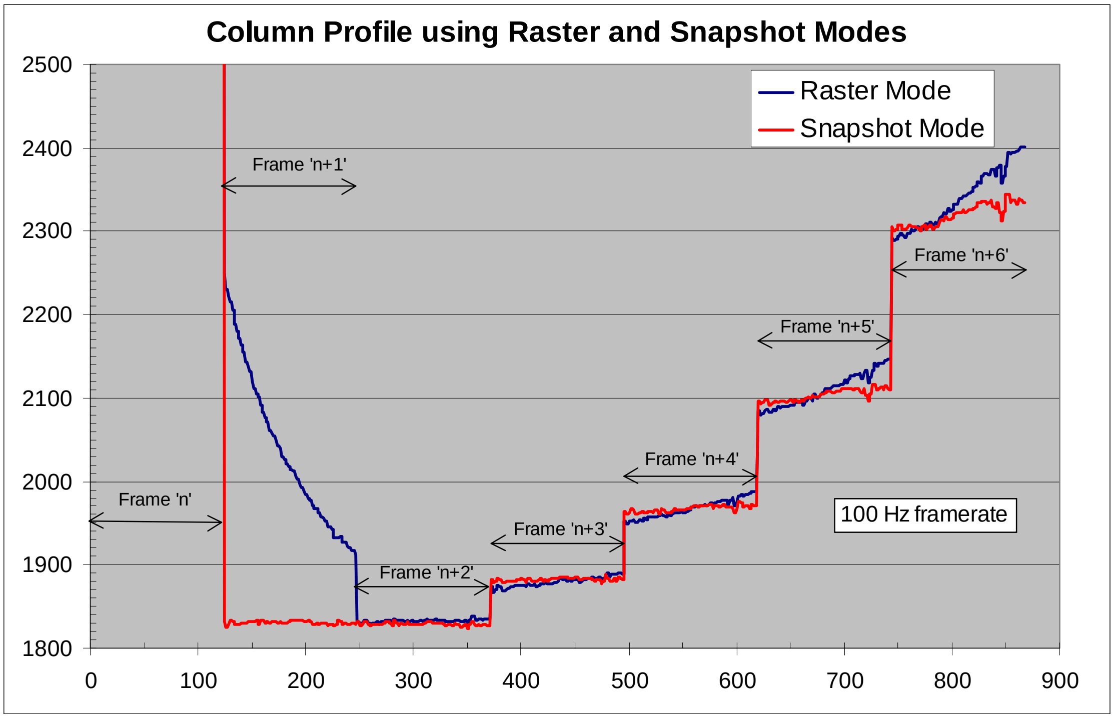


Figure 4: Comparison of MSSP Raster and Snaphot Update Mechanisms

### 2.1.2 IRSP Drive Electronics

*2.1.2.1 AMCOM's High-Speed, Miniaturized Drive Electronics*

Perhaps the most significant hardware advancement within the ASC over the previous year has been the development of an advanced set of interface electronics for the operation of the Honeywell emitter array based systems. The AMCOM MRDEC's testing of advanced state-of-the-art seekers requires a continuous increase in capability from the IRSP test equipment. Specifically, near-term test needs required a significant increase in frame rate from the IRSP than was currently available. To meet this need, AMCOM undertook the development of a high-speed, reduced-package size set of IRSP drive electronics. Both digital and analog portions of the drive electronics were designed along the requirement for higher speeds and lower size/weight. AMCOM has recently successfully completed the initial checkout and operation of these electronics. This development provides the ASC with greater performance, in-house support, and reduced cost. Figure 5 shows a picture of the analog portion of the new IRSP drive electronics next to a Honeywell emitter array.

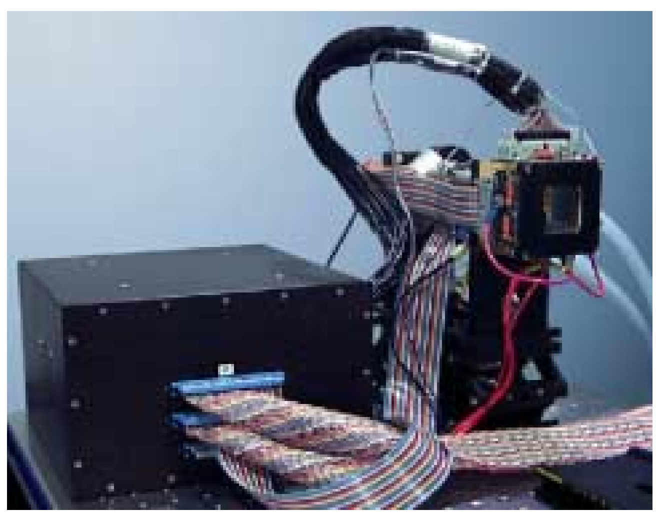

Figure 5: AMCOM IRSP Analog Electronics

The analog electronics, shown in Figure 5 above, consists of four 6x6 inch digital-to-analog conversion boards and a single 6x6 inch digital data address controller board. Each of the four DAC boards handles 8 channels of information. All boards are identically designed and are completely interchangeable. The analog electronics can currently be interfaced to the digital electronics using either 10ft or 20ft cables. Interfacing to the emitter array is performed via either 32 two foot or ten foot low-noise cables.

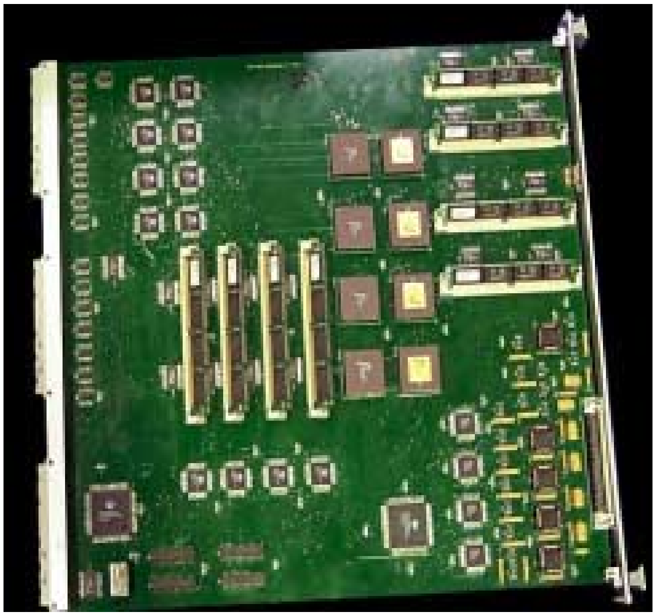

Figure 6: AMCOM IRSP Digital Board

The digital electronics, shown in Figure 6, are completely contained in a single 400mm 9U VME board. This board contains all necessary tables for application of the 32 unique DAC tables and 16 RNUC tables as well as pre- and post-table scene memory capable of holding up to a 1024x1024 single image. The board supports interfacing, using either an 8 or 40 foot cable, to the real-time scene generation systems via the Silicon Graphics' Digital Video Port (DVP) format. The 14-bit digital electronics currently supports frame rates up to 240 Hz for both raster and snapshot capable Honeywell 512x512 emitter arrays. The arithmetic functions for the RNUC application are performed from off-the-shelf devices while two Cypress CPLD's, compiled with VHDL, control all other functions on the VME board.

Table 1: AMCOM IRSP Drive Electronics Specifications

| | |
|---|---|
| **FORMAT** | 512x512 (10242 w/o RNUC) |
| **DATA RATE** | (240Hz @ 512x512) |
| **RNUC** | YES – 16 Breakpoints |
| **RESOLUTION** | 14 Bits |
| **ANALOG SIZE** | 8x8x6 |
| **INPUTS** | PC and SGI DD02 |
| **SNAPSHOT** | YES |

Two example images, shown in Figure 7 below, were collected in the MWIR using a Honeywell MSSP array and the AMCOM IRSP drive electronics.

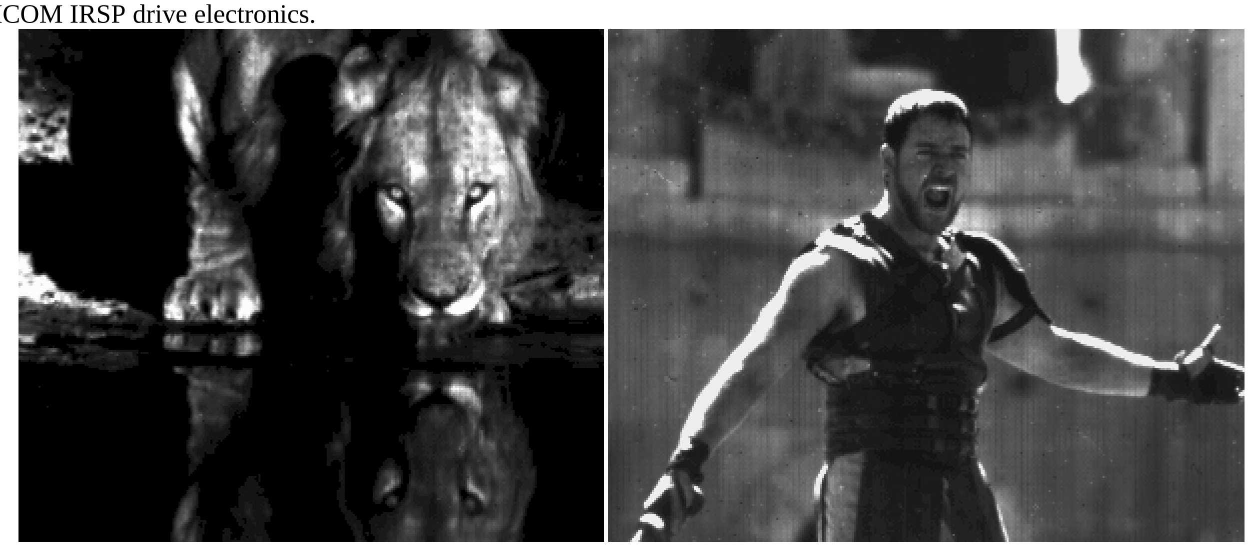

Figure 7: Example MWIR Imagery Generated with AMCOM's IRSP Drive Electronics

*2.1.2.2 IRSP Electronics Upgrades and Acquisitions*
AMCOM has updated their IRSP capabilities through additional acquisitions and upgrades of the commercially available IRSP drive electronics. AMCOM took delivery in mid-2000 of the latest generation of IRSP drive electronics from Computer Science and Applications, Incorporated. This system introduces the new 'Scene Input Board' and provides additional capabilities above those of previously available electronics including supporting Honeywell's snapshot capable arrays. AMCOM has developed a custom in-house system control software (SCS) package for the operation of these new electronics. These electronics have been successfully integrated into the IRSP systems within the MRDEC HWIL facilities.

AMCOM has also updated the IRSP drive electronics, acquired through the CTEIP program, to support snapshot updating. The KHILS facility, one of the CTEIP partners, provided the personnel for upgrading the existing electronics. This upgrade brings the total number of snapshot capable IRSP electronics currently within the AMCOM MRDEC HWIL facilities to three.

**2.1.3 System Control Software (SCS) Improvements**

*2.1.3.1 SCS Versions*
AMCOM continues to pursue the development of in-house software for the characterization, calibration, and operation of all IRSP systems used within the facility. This approach insures the HWIL test facility has all necessary capabilities and controls for the application of the IRSP technology to HWIL testing. While multiple SCS packages are required, each shares a similarly designed graphical user interface (GUI). This greatly minimizes the amount of time necessary for each operator to familiarize themselves with the various IRSP systems. Each system will include a complete on-line help program discussing all phases of operation of the IRSP software and hardware. Over the previous year, AMCOM has begun development of several new SCS packages including those for control of: 1) Latest CSA IRSP drive electronics (incorporating the Scene Input Board), 2) AMCOM IRSP drive electronics package, and 3) Non-Uniformity Correction (NUC) and Characterization Station.

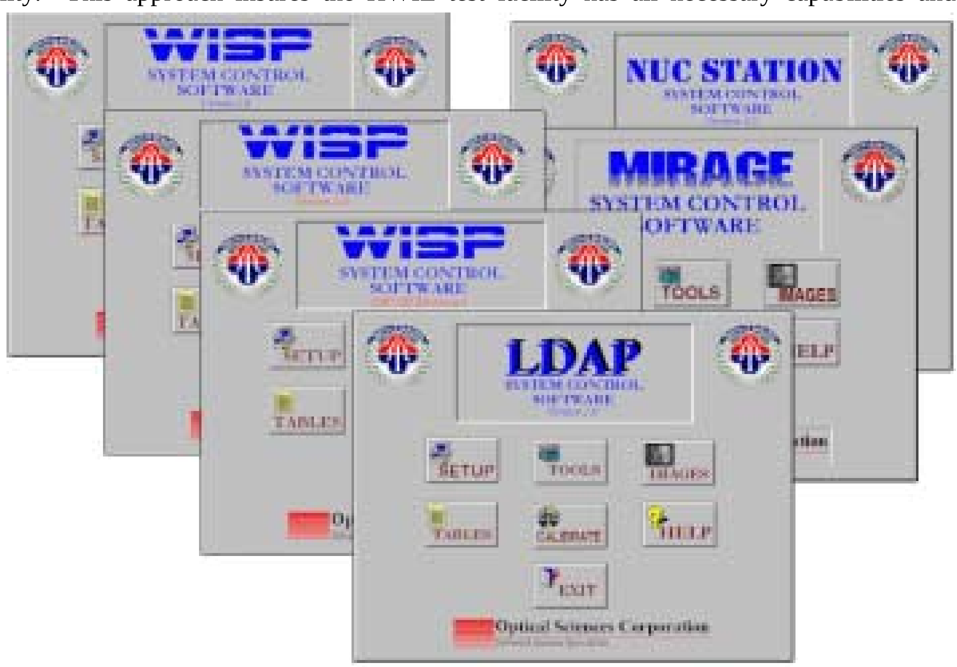


Figure 8: AMCOM IRSP SCS Versions

*2.3.1.2 Additional SCS Capabilities*
Currently, the SCS packages for control of the Honeywell emitter array based (designated WISP) IRSP systems contain a vast array of tools for the characterization, calibration, operation, and maintenance of these systems. The most recent tool to be added to the SCS packages provides the capability to 'map' the response of the projector. A simple GUI has been developed to perform this mapping in closed-loop fashion based upon user designated inputs. A visual false color display of the collected information allows the user to quickly evaluate the array using various types of information. Figure 9 below illustrates the 'mapping panel' available within the SCS. The display shows the false color mapping of the emitter array.

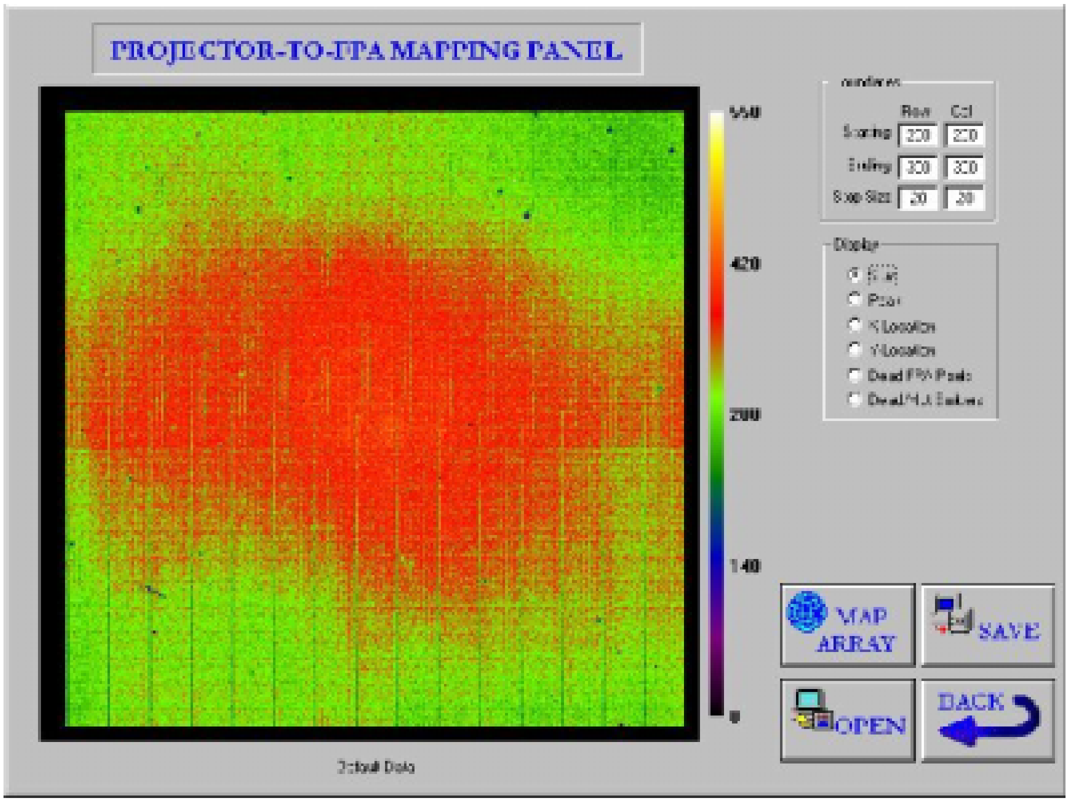

Figure 9: AMCOM IRSP SCS Emitter Array Mapping Panel

### 2.1.4 Unique Lessons Learned

AMCOM personnel currently have several years of experience in the characterization and operation of the Honeywell emitter array based IRSP systems. Through this experience, many seemingly insignificant, yet important, lessons have been learned. Two such items are presented here: 1) DAC re-calibration, and 2) High frame-rate VOF settings.

The Honeywell emitter arrays accept input along 32 analog channels driven by 32 DACS. Each DAC operates over a slightly unique voltage range. Figure 10 to the right illustrates the voltage range differences across one set of 32 DACs. The small variations in output from DAC to DAC are compensated for within the DAC tables loaded by the SCS. It has been observed that the output of each DAC will drift over significant periods of time. AMCOM has performed a re-calibration of the 32 DACs within one of the original IRSP drive electronics systems. Failure to do so could reduce the system amplitude resolution by a bit or more.

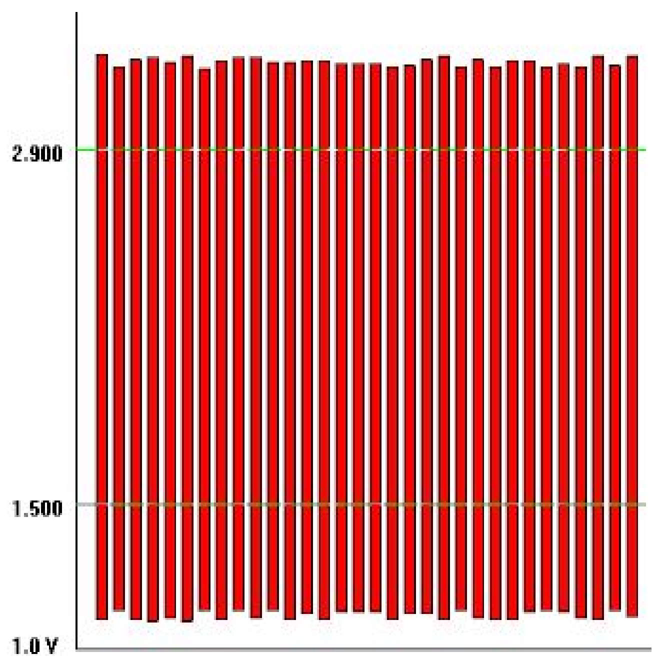

Figure 10: IRSP DAC Voltage Ranges

The Honeywell emitter array based systems accept, as the primary dynamic data source, SGI DD02 format imagery. This data stream can be accepted by the CSA/KHILS systems built to date at frame rates up to 120 Hz. For each data rate, the SGI output must be tuned via information commonly referred to as the VOF. This information sets the timing of the SGI to match that of the IRSP drive electronics. At slower frame rates, the IRSP system provides an acceptance window sufficiently wide to allow for considerable variation in the VOF setup. However, at higher frame rates, the timing constraints tighten significantly. After considerable testing, the acceptable VOF inputs were identified for high frame rates. These configuration parameters are shown in Figure 11 below. In each case, the horizontal front porch, horizontal back porch, and horizontal sync width were set to 20, 68, and 40 lines respectively. Likewise, the vertical sync width was consistently set to 3 lines.

| Desired Frame Rate | VOF # Cols | VOF # Rows | Vertical Front Porch | Vertical Back Porch |
|---|---|---|---|---|
| 60 Hz | 640 | 1150 | 300 | 335 |
| 100 Hz | 640 | 690 | 75 | 100 |
| 110 Hz | 640 | 627 | 52 | 60 |
| 115 Hz | 640 | 565 | 20 | 30 |
| 120 Hz | 640 | 540 | 10 | 15 |

Figure 11: SGI VOF Configuration Values

**2.1.5 Near-term Additions**

*2.1.5.1 MSSP Type II Emitter Array*

Honeywell Corporation, in their ongoing development of new emitter array types, has developed their latest emitter arrays under the designation "Multi-Spectral Scene Projector" (MSSP). These arrays have been produced using two sizes of emitters. The initial set of arrays, termed type 1 here, incorporated a 60% fill factor emitter. The second set, termed type 2 here, reduce the fill factor to ~50% in order to achieve faster settling times. Each of these array types use a thinner "Gen3" emitter and incorporate Honeywell's first large format snapshot updating scheme. Preliminary characterization of the emitter response as well as verification of the snapshot mode of operation was discussed in the section entitled "Characterization of the MSSP Arrays" above. AMCOM will shortly take delivery of a type 2 MSSP array. Although the snapshot mechanism is not improved over the type A MSSP arrays, the lower fill factor should lead to sub-5 msec rise time values.

*2.1.5.2 Brite II Emitter Array*

Honeywell Corporation is currently manufacturing the next level of emitter arrays for IRSP systems. These array, designated Brite II, leverage off the MSSP design and incorporate many of the same design features. The most significant difference between these arrays is a modified snapshot update scheme designed to alleviate shortcomings observed in the original snapshot circuitry included in the MSSP arrays. Additionally, selected arrays will incorporate an 'extended voltage range' capability designed to expand the operational voltage range. This feature allows these arrays to be operated at cryogenic temperatures without reducing the useful input operating voltage range below acceptable limits. AMCOM is currently scheduled to receive an extended voltage range Brite II array in early 2002.

*2.1.5.3 Emitter Array Non-Uniformity Correction (NUC) and Characterization Station*

The emitter arrays, much like focal plane arrays, exhibit non-uniform response. This non-uniformity, while perhaps only a few percent, must be compensated for in order to maximize the performance of the system. AMCOM is currently developing a test station for collection of data in the correction of this non-uniformity as well as other emitter array characterization tasks. Currently all hardware items are assembled and the system control software is being tested. Figure 12 shows a picture of the hardware as configured for the collection of data on a Honeywell array.

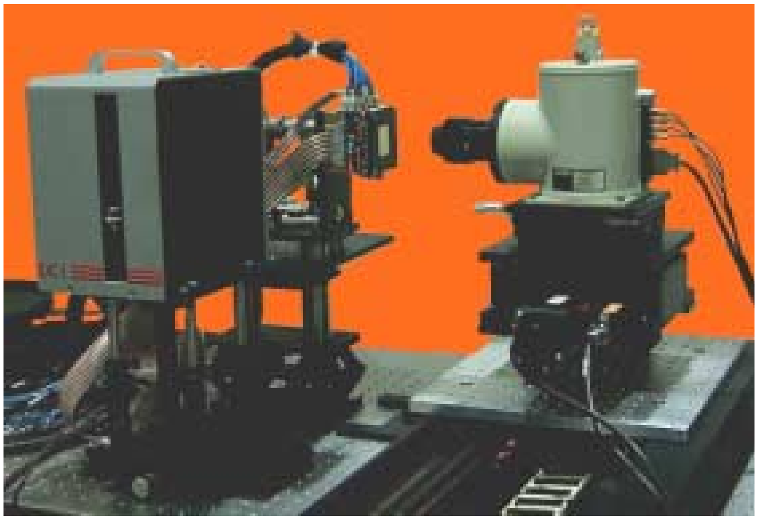

Figure 12 – Emitter array non-uniformity correction and characterization station

**2.2 MULTI-SPECTRAL INFRARED ANIMATION GENERATION EQUIPMENT (MIRAGE)**

AMCOM RDEC has continued to pursue the acquisition of the latest emitter-array based scene projector system. This new emitter technology has been developed through a partnership between Santa Barbara Infrared, Indigo Systems, and the Rockwell Technology Center. Like the current Honeywell emitters, the MIRAGE consists of 512x512 thermal emitters located within a small vacuum chamber on a thermal heatsink. The full IRSP consists of this emitter 'engine' and the thermal control and command electronics sub-systems.

*2.2.1 System Characterization*

Performance characterization of the MIRAGE IRSP is ongoing within the AMCOM MRDEC HWIL facilities. Response time, operability, and dynamic range performance are being investigated in order to characterize this system. Figure 13 below shows operability maps collected at SBIR and AMCOM, respectively. The mapping on the left was provided by SBIR to AMCOM and covers the entire array. Operability measured by SBIR for this configuration was given as 0.37%. AMCOM personnel selected the center 128x128 region for analysis using a high resolution IR camera. The mapping on the right is a composite of multiple images sampled over the 128x128 region. This test configuration allowed for multiple camera detectors to be imaged over a single MIRAGE emitter. Structure within individual emitters is clearly evident within the original images. This data was taken using a moderate input level which resulted in an apparent output temperature by the array of ~60 deg C. Using on this information, AMCOM measured the 'base operability' of the 128x128 region. This 'base operability' was determined by counting those emitters who were clearly 'dead' and dividing by the total number of emitters within the 128x128 region. A total of 85 'dead' emitters were found yielding a 'base operability' of ~0.5%. Radiance output requirements above 'zero' would increase this value. Further testing of the operability at these higher requirements is planned.

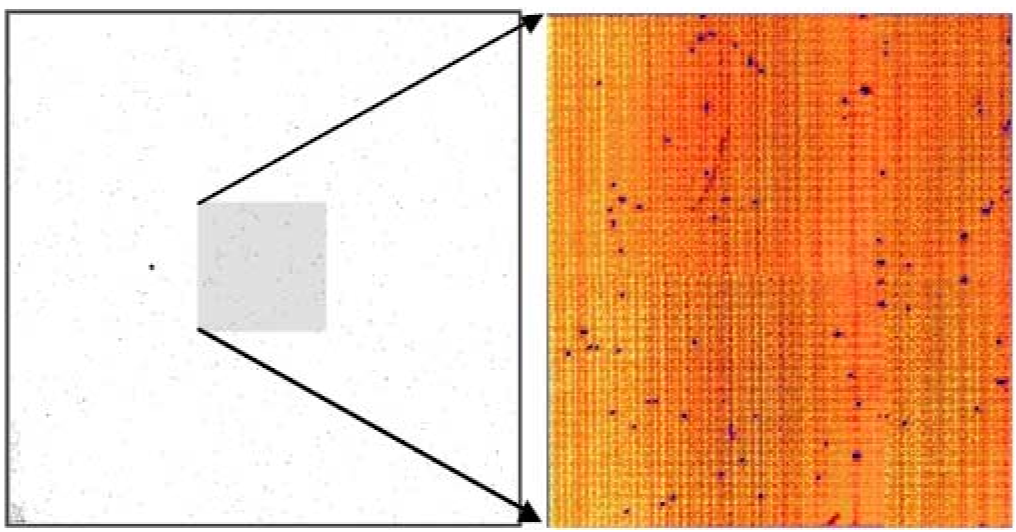

Figure 13 – Mirage Operability Maps

Risetime values for the MIRAGE emitter were measured in the 'non-overdrive' mode last year and reconfirmed this year. Risetime values have consistently shown a 10%-90% measured time of ~17 msec. Within the previous few months, initial testing using the overdrive scheme has been performed. Figure 14 below plots the emitter response at various input frame rates. All response times were taken against a 'zero to mid-scale' uniform input of a size equal to approximately one-fourth the array. Non-overdrive responses, as noted above, would have resulted in all points falling around the 17 msec region. The overdrive mechanism clearly effects the measured response of the system at the shorter frame rates. However, at the longer frame rates, little effect was observed. Discussions with the vendor regarding this data revealed two specific characteristics of the overdrive behavior which help to understand the results. First, the overdrive scheme was 'hard-wired' within the MIRAGE software to generate overdriven amplitude values based on an assumed system update rate of 200 Hz. Operation of the system at the lower frame rates did not provide updates to the emitter at the expected time intervals. Subsequently, the initial amplitude provided greater output at the time of the next update. Significant overshoot therefore occurs. At the higher frame rates this effect is reduced and, at 200 Hz, is non-existent. At the higher frame rates, however, another emitter characteristic limited the performance of the overdrive mechanism. This behavior of the system was related to the snapshot unit cell circuitry. Charge 'sharing' occurred, as designed, between the dual input circuits creating a three-frame latency in the amount of time necessary to attain the desired input amplitude level. For inputs beginning at zero and driven to mid-scale values, as was performed in these tests, the advantages of the overdrive mechanism are offset by this three-frame latency. SBIR has observed 5 msec risetimes for more modest amplitude changes around a starting mid-scale input level. Further testing at AMCOM to investigate the performance of the overdrive mechanism as a function of frame rate, input level, and update scheme (snapshot, raster) are planned for the near future.

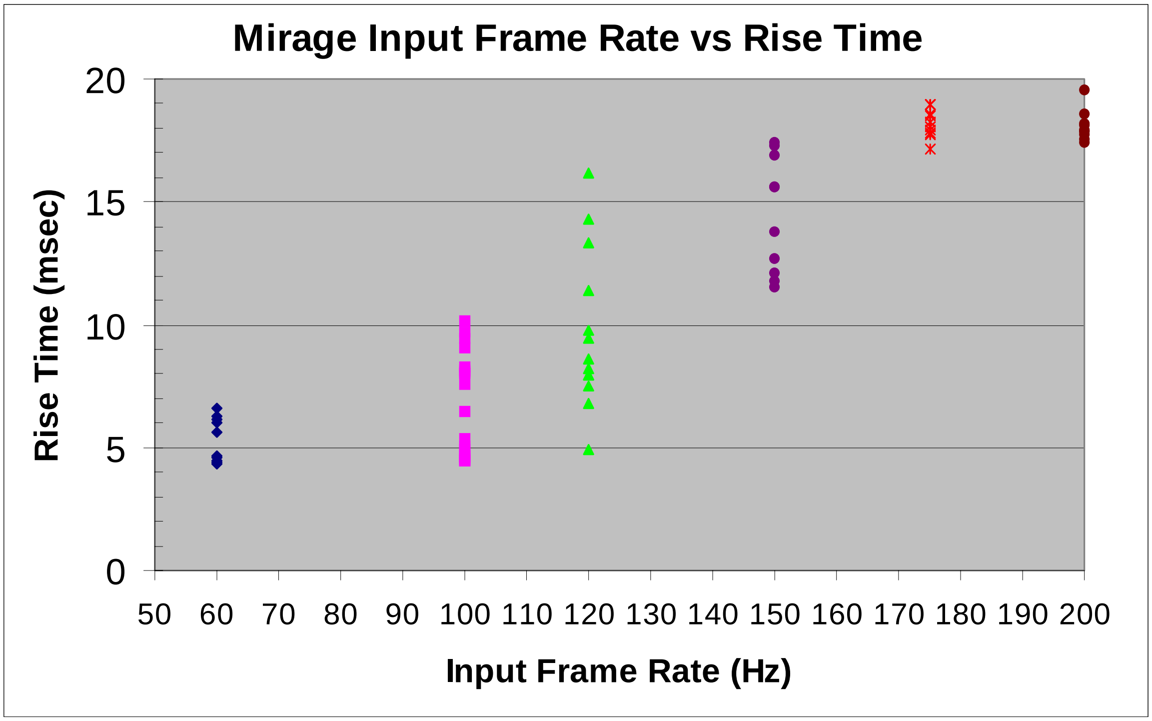


Figure 14: MIRAGE Overdrive Risetime Measurements

### 2.3 DIGITAL MIRROR DEVICE™ BASED IR PROJECTORS

Optical Sciences Corporation (OSC), under a Phase II SBIR sponsored by AMCOM, has developed a new dynamic IR scene projector technology called the Micromirror Array Projector System (MAPS) which is based upon the Texas Instruments Digital Micromirror Device (DMD™). This projector technology is capable of producing very realistic dynamic scenes in the UV, visible, and IR wavebands. The projector technology offers several attractive features including high spatial resolution, high frame rates, no dead pixels, and excellent uniformity. The projector may be used in several configurations which are tailored to specific applications. OSC has successfully demonstrated three prototype configurations of the Micromirror Array Projector System (MAPS) operating in both binary and pulse width modulation (PWM) mode. These configurations include a one-DMD MWIR projector, a two-DMD MWIR projector, and an IR and visible Dynamic Sensor Test Set (DSTS).

*2.3.1 Micromirror Array Projector System (MAPS)*

The MAPS IR projector, shown in Figure 15 below, is capable of generating realistic IR images for advanced testing of IR seekers, sensors, and FLIRS. Applications of the projector include hardware-in-the-loop testing, portable test sets, built-in testing, production line testing and training. The MAPS is capable of operating in two modes: flickerless binary and PWM. In binary mode, the projector is virtually flickerless, with only a brief reset occurring each frame to prevent hinge memory in the micromirrors. The projector is compact and can be produced at a low-cost compared to other IR projector technologies. An example image collected in the MWIR using the MAPS is shown in Figure 16.


Figure 15: MAPS MWIR Projector

Figure 16: MAPS MWIR Output Image

*2.3.2 Dynamic Sensor Test Set (DSTS )*

OSC has developed a second configuration of the DMD-based IR projector called the Dynamic Sensor Test Set (DSTS). This system is designed for automated high speed testing of visible and IR sensors. The DSTS is designed to replace the static target plates and choppers used on industry-standard test collimators. The DSTS is capable of performing standard tests such as MTF, MRTD, and NEΔT at very high speed, as well as advanced dynamic tests such as seeker tracking and correlation. The DSTS is a dynamic scene projector which can be operated in binary or PWM mode. Applications of the projector include any sensor test application which currently uses static test plates, but needs higher speed or dynamic scene capability.

Further details on the DMD-based IR projector may be found within these proceedings in the paper entitled “Dynamic IR scene projector based upon the digital micromirror device”.

## 3.0 ACKNOWLEDGMENTS

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## 4.0 TRADEMARKS

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