Application of Multiple IR Projector Technologies for AMCOM HWIL Simulations

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ABSTRACT

This paper describes the application of multiple IR projector technologies to Hardware-in-the-Loop (HWIL) simulations at the US Army Aviation and Missile Command's (AMCOM) Missile Research, Development, and Engineering Center (MRDEC). Several projectors utilizing a variety of emerging technologies are currently being successfully applied within the HWIL facilities of AMCOM's MRDEC. Projector technologies utilized at AMCOM include laser diode array projectors (LDAP), Honeywell's bright resistive infrared thermal emitter (BRITE) arrays, an IR zoom projector with thermoscenes, and steerable point source projectors. Future plans include a new resistor array projector called the Multispectral Infrared Animation Generation Equipment (MIRAGE), which is being manufactured by Santa Barbara Infrared. These projector technologies have been used to support multiple HWIL test entries of various seeker configurations. Seeker configurations tested include: two InSb 256x256 FPAs, an InSb 512x512 FPA, a PtSi 640x480 FPA, a PtSi 256x256 FPA, a HgCdTe 256x256 FPA, a scanning linear array, and an uncooled 320x240 microbolometer FPA. The application, capabilities, and performance of each technology are reviewed in the paper. Example imagery collected from each operational system is also presented.

Keywords: Infrared, Scene Projection, Diode lasers, Simulation, FPA testing, Hardware-in-the-loop.

1.0 INTRODUCTION

The AMCOM Advanced Simulation Center (ASC) provides high-fidelity, value-added HWIL 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. [1]

The ASC facility is located on Redstone Arsenal, adjacent to Huntsville, Alabama. The ASC consists of 14 HWIL simulation facilities developed over a period of 25 years. These facilities contain special purpose computers, signal generation equipment, projectors, and radiation chambers, supported by signature measurement-based mathematical models. They provide targets signatures, countermeasures, and background scenarios in the microwave, millimeter wave, infrared and visible regions of the electromagnetic spectrum. Some of the programs currently supported include THAAD, Patriot, Army TACMS-BAT, Javelin, EFOG-M, TOW, Stinger, Longbow, and SADARM.

The ASC has six simulation facilities for testing systems which utilize IR sensors or seekers. A photograph of one of the facilities is shown in Figure1. 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 IR projector technologies utilized within the ASC and the performance capabilities of each system.

Figure 1. Photograph of an ASC IR HWIL facility.

2.0 IR PROJECTOR TECHNOLOGIES IN USE AT AMCOM

Several projectors utilizing a variety of emerging technologies are currently being successfully applied within the HWIL facilities of AMCOM's MRDEC. These projectors have been used to support multiple HWIL test entries of various seeker configurations. Seeker configurations tested include: two InSb 256x256 FPAs, an InSb 512x512 FPA, a PtSi 640x480 FPA, a PtSi 256x256 FPA, a HgCdTe 256x256 FPA, a scanning linear array, and an uncooled 320x240 microbolometer FPA. Two of these seekers have dual-FOV optical systems which may be switched during the simulation. The application, capabilities and performance of each technology are reviewed below. Included is example imagery collected from each operational system.

2.1 Laser Diode Array Projector (LDAP)

The LDAP is a two-dimensional dynamic infrared scene projector capable of generating high resolution imagery at very high frame rates. Development of the first LDAP was begun in 1993, and it became operational at MRDEC in early 1995. The LDAP system is based upon the technology of Pb-salt (PbEuSeTe) diode lasers and a high-speed multifaceted polygon scanner. Detailed design and performance information is contained in the references.[2,3,4,5] Currently, three LDAP systems are operational within the AMCOM MRDEC. These systems have been used to test several missile seekers of various formats and wavebands. Table 1 is a summary of the LDAP performance values. Example imagery collected from these LDAP systems is shown in Figures 2 and 3.

Parameter	Performance
Wavelengths	3.7, 4.6, 4.7, and 9.0 µm arrays available
Formats	544x544 or 672x544
Projector Frame Rate	2000 Hz
Effective Frame Rate	200 Hz (Scene Generator limited)
Amp. Resolution	12 bit
Spatial Uniformity	96%

Table 1 – Summary of LDAP Performance Parameters.

The LDAP has proven to be an effective and cost-efficient technology for the generation of dynamic infrared imagery. As with other projector technologies, the LDAP does possess it's own unique advantages and disadvantages. The major advantage of the LDAP is its frame rate. The LDAP offers the highest frame rate of any projector technology currently available. With a frame rate of 2 kHz, the LDAP can meet the stressing requirements of the highest frame rate HWIL simulations. The LDAP also has no dead pixels, and currently has the largest format (672x544) available. In addition, the LDAP has the most workable path to the larger image formats (1024x1024). However, spatial uniformity and the application to non-scanning systems remain the most prominent limitations of this technology. Near-term development efforts with respect to the LDAP will concentrate on the refinement of the image quality and exploitation of the frame rate capability.

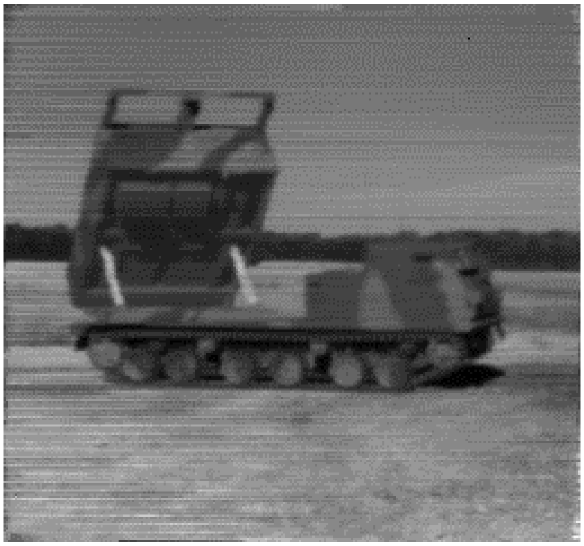

Figure 2 – LDAP Sample Imagery

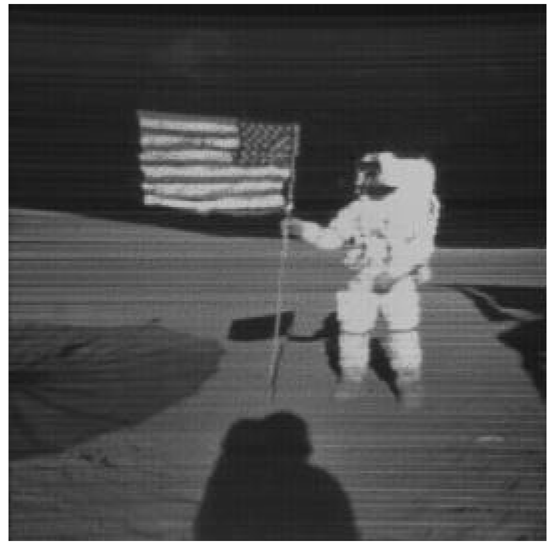

Figure 3 – LDAP Sample Imagery

2.2 Honeywell BRITE Array (Emitter for the WISP Program)

The BRITE resistor array is a mosaic array of thermal emitters manufactured by Honeywell Technology Center. The BRITE array is a third generation emitter array developed under the Wideband IR Scene Projector (WISP) program. The WISP contract was awarded in 1993 under the auspices of the Kinetic Kill Vehicle HWIL Simulator Center at Eglin Air Force Base. This technology consists of single pixel microbridges of thin film silicon nitride membranes supported on legs. These pixel structures are replicated in two dimensions to form an array of emitters capable of selective spectral emission across the full MWIR and LWIR wavebands.[6] The latest generation arrays, officially designated Phase III arrays, offer a large format and excellent image quality. The BRITE array is driven using electronics manufactured by CSA and control software written by OSC. AMCOM's MRDEC currently operates two BRITE systems within their HWIL facilities. Table 2 below summarizes the performance characteristics of the BRITE array.

Parameter	Performance
Wavelength	Broadband Selective Emitter
Format	512x512
Max. Address Rate	120 Hz.
Max. Effective Frame Rate	60 Hz.
Amp. Resolution	14 bit
Uncorrected Spatial Uniformity	>98%
Corrected Spatial Uniformity	TBD

Table 2 – Summary of BRITE Performance Parameters.

The BRITE system provides a two-dimensional object source exhibiting excellent uniformity, resolution, and registration. Significant improvements were made in the uncorrected spatial uniformity with the release of the Phase III arrays. This is now the major advantage of the BRITE technology. However, the physical properties of the emitter material limits the response time and hence the overall frame rate of the system. The system is limited in application to systems with truly dynamic full-field scene update rates of ~60 Hz or less. In addition, with its rolling scene update, it must be properly synchronized to avoid temporal aliasing. Another drawback to this technology is dead and weak pixels. The best arrays have no dead columns or rows, but all arrays produced to-date have at least some dead pixels and weak pixels which will limit the uniformity of the array.

Although the BRITE arrays have only been available for a short time, the ASC has already successfully applied this technology to the testing of two seekers. These systems make use of a 640x480 PtSi and 512x512 InSb array. Example images collected from a BRITE system are shown in Figures 4 and 5 below. Near-term development work with the BRITE at the MRDEC will continue the processes of characterization, calibration, and application to testing in a HWIL environment. A higher frame rate BRITE array is in development. Honeywell has a goal of 200 Hz address rate with a snapshot update.

Figure 4 – BRITE Sample Imagery

Figure 5 – BRITE Sample Imagery

2.3 Infrared Zoom Projector (IRZP)

AMCOM's IIRSS1 HWIL facility utilizes an IR Zoom projector to generate quasi-dynamic IR scenes. Procurement and design of the IRZP was begun in 1992. The system was delivered and integrated in 1995. The IRZP provides simultaneous dual band (LWIR & MWIR) imagery using pre-created static "thermoscenes" back-illuminated with blackbodies. The thermal scene and temperature profile remain fixed during a HWIL test. However, the dynamics of the missile scenario are simulated via a 30:1 optical zoom system and X-Y translation of the thermoscenes.

Two 6:1 zoom systems and a high-speed transition mirror were required to generate the 30:1 total zoom. Separate optical systems were required for each band, thus there are a total of four zoom systems. The thermoscenes are basically a high-resolution bit map image patterned onto a ZnSe substrate using photolithographic techniques. Four thermoscenes are required for a single dual-band scenario. Each thermoscene is mounted on an X-Y translation stage for generation of angular rates. Figure 6 is a photograph of a portion of the zoom system. Table 3 below summarizes the performance characteristics of the IRZP. Sample imagery collected from the IRZP system is shown in Figures 7 and 8.

The IRZP has been used over the past four years for testing a dual-band IR seeker. The IRZP provides outstanding image quality. However, the IRZP is only quasi-dynamic. The HWIL test imagery is limited to the available library of thermal scenes. The inability, therefore, to easily test various excursions from the nominal test sequence is a significant shortcoming as compared to other dynamic infrared scene projector technologies.

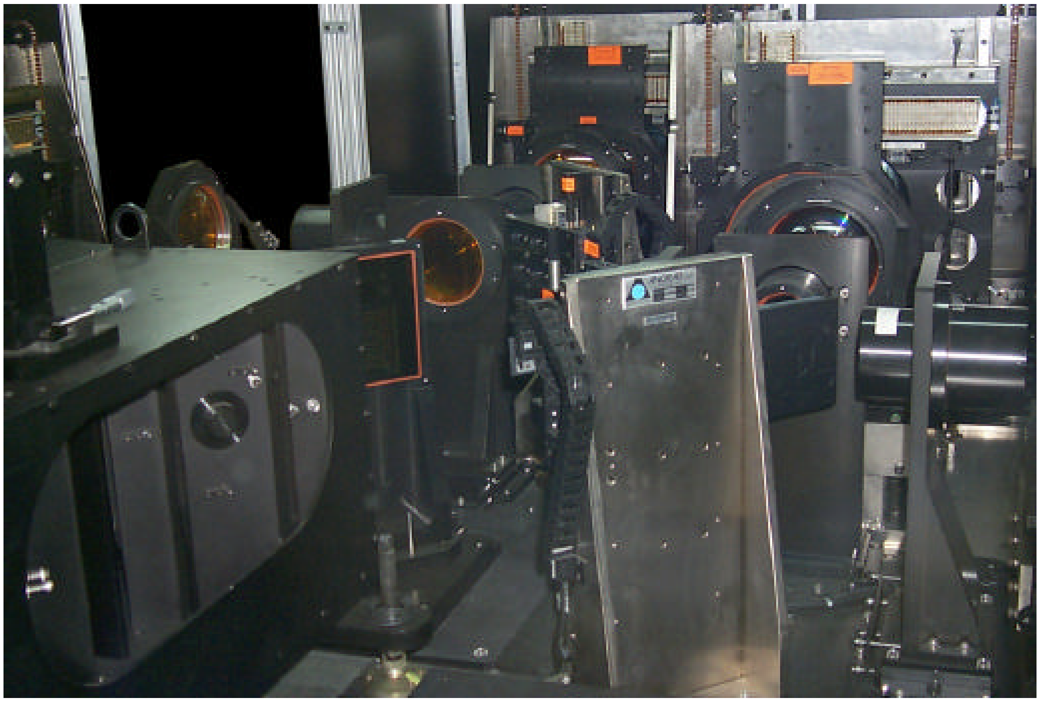

Figure 6 - Portion of the IR Zoom Projector System

Parameter	Performance
Wavelength	3-5μm & 8-12μm
Optics FOV	8° circular
Thermoscene spatial resolution	4500 pixel across diameter. (57μm pixel size)
EFL	150-900 mm.
Max. zoom rate	5400 mm/sec.
Amp. Resolution	8 bits
Uniformity	>99%
X-Y Translation Range	±4°
X-Y Angular Velocity	30 °/sec.

Table 3 – Summary of IRZP Performance Parameters.

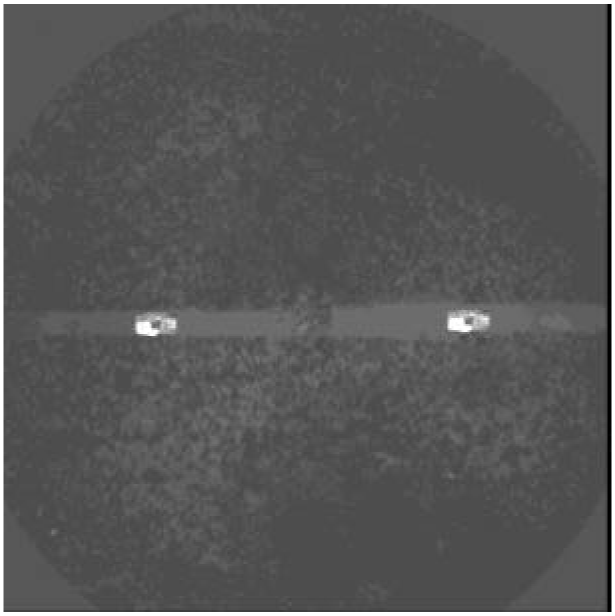

Figure 7 – IRZP Sample Imagery

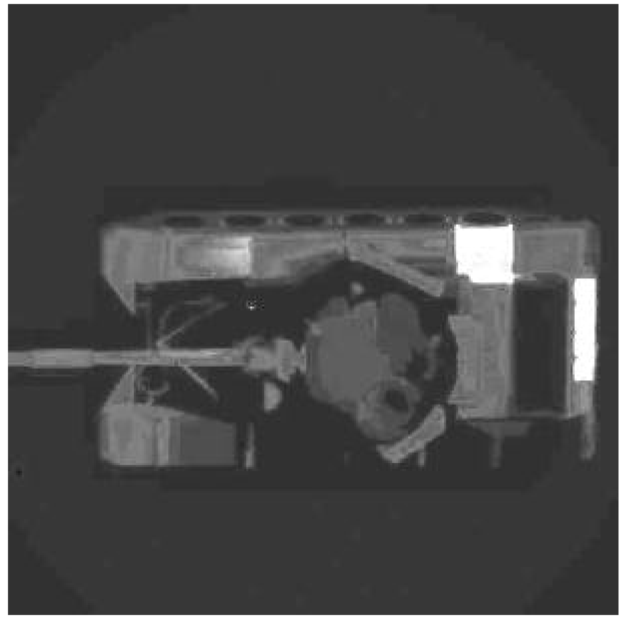

Figure 8 – IRZP Sample Imagery

2.5 1-D (Non-scanning) Laser Diode Array Projector

The first laser diode array projector was designed and built for AMCOM's MM/IR simulation facility in 1992. The projector was designed to specifically address the unique HWIL test requirements of a sensor which utilizes a linear array of detectors and body motion scanning. In actual operation, the UUT's linear array of 16 detector elements scans the battlefield as the unit spins. The scanning mechanism is,therefore, the rotation of the submunition itself. However, in the HWIL facility, the unit is fixed with the detector array staring directly into a 16 element array of laser diodes. Figure 9 is a schematic of the detector array/laser configuration. The HWIL simulation models the scanning motion of the detector IFOVs over a simulated 2-D scene and calculates the energy each detector receives as a function of time. The output of the simulation is then used to drive the IR projector in real-time with a frame rate of 10 KHz. This one-to-one coupling allows scanned battlefield scenes to be simulated by temporally modulating the array of laser diodes. This HWIL concept places stringent requirements on the IR sources temporal response and amplitude control. The laser array was capable of meeting all performance requirments and has been used daily for the past 6 years in the facility. Table 4 summarizes the performance characteristics of the projector. Figure 10 is a photograph of the system showing the projector and the UUT. [7]

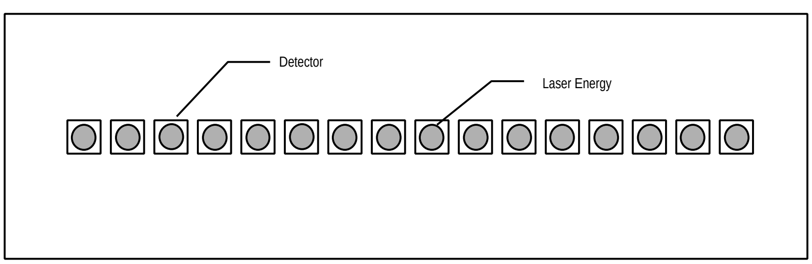

Figure 9 – Laser/Detector Mapping

Parameter	Performance
Wavelength	MWIR
Number of sources	16
Max. App. Temp.	> 1000 K * * Normally filtered to increase temperature resolution.
Amp. Resolution	15 bits
Temporal Response	4 μsec (limited by electronics)

Table 4 – Summary of Laser Array Performance Parameters.

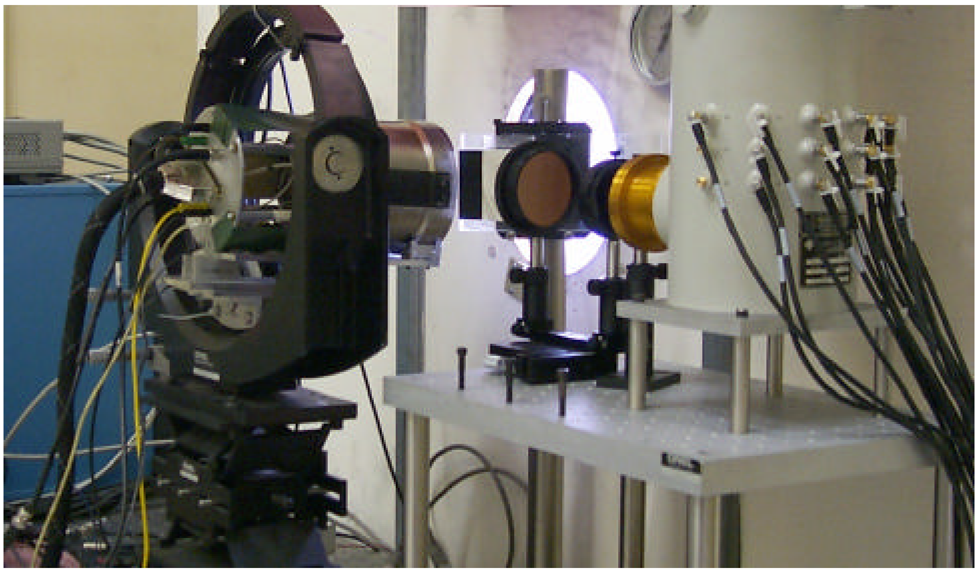

Figure 10 – MM/IR Laser Projector

2.6 Steerable Point Source Projector

In 1998, AMCOM's MRDEC created a supplemental projector system for the simulation of high intensity point source targets such as countermeasures. This projector is based on the same PbEuSeTe laser diodes used within the LDAP projectors. The projector is capable of simulating very high intensity point sources which may be dynamically positioned anywhere within the seeker FOV. The amplitude of the point source can also be varied/controlled at frame rates up to 10 KHz. A single point source is created using one laser diode, and it is steered independently in two axis within the FOV using a galvanometer scanner. This projector was intended to augment the capabilities of the existing two-dimensional projectors (LDAP, WISP, and MIRAGE) by beam-combining the output of the two systems. A 90/10 beamcombiner is typically used to combine the two projectors. Performance levels for the PSP are shown in the table below. The PSP meets all design requirements in providing a high intensity steerable point source target independent of the accompanying 2D IR projector.

Parameter	**Performance**
Wavelength	Selectable
Number of sources	1
Max. App. Temp.	>15,000 K
Max. App. Temp with 90/10 beamcombiner	>2000 K
Amplitude Resolution	16 bits
Temporal Response	100 nsec

Table 5 – Summary of Steerable Point Source Performance Parameters.

3.0 FUTURE DEVELOPMENTS

AMCOM is adding a new resistor array projector to its list of available projector technologies. A "Multispectral Infrared Animation Generation Equipment" (MIRAGE) system is scheduled for delivery to AMCOM in mid-1999. Built by a partnership of Santa Barbara Infrared (SBIR), Indigo Systems Inc., and the Boeing/Rockwell Science Center, the MIRAGE is the latest dynamic infrared scene projector based upon the emitter array technology. Like the BRITE, the core technology is the mosaic array of thermal emitters. However, application of new production methods, emitter materials, addressing schemes, and other unique approaches have created a completely separate technology. The MIRAGE system offers the potential of higher frame rates, greater uniformity and a significantly smaller package. Anticipated operational performance values are shown in the table below. While incorporating several apparent improvements in design and implementation, the MIRAGE, to date, has not demonstrated an operational system capable of generating two-dimension dynamic infrared imagery. A determination of the utility of the system therefore awaits a complete performance characterization. Upon receipt, AMCOM's MRDEC will evaluate the system for uniformity, dynamic range, pixel response, and pixel yield.

Parameter	Performance
Wavelength	Broadband Selective Emitter
Format	512x512
Max. Frame Rate	200 Hz
Amp. Resolution	16 bits
Uniformity	unknown

Table 6 – Summary of MIRAGE Performance Parameters.

4.0 CONCLUSIONS

The US Army Aviation and Missile Command's MRDEC has all of the leading-edge dynamic IR scene projector technologies available within their six IR HWIL facilities. Each of these technologies has been successfully applied in HWIL simulation and testing of Army seekers and sensors. With the availability of these technologies and the intimate knowledge of the performance capabilities and limitations of each, the best projector technology can be applied to each seeker tested.

5.0 ACKNOWLEDGMENTS

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