HPM Test Safety and Permitting

- **Scanning Target Board (STB).** Scientific Applications and Research Associates, Inc. (SARA) in Cypress, CA developed the STB, a W-band HPM target board that uses an array of compact, multi-layered wideband patch antennas to directly measure and map the power spectrum emitted from a W-band HPM source. ***COMPLETED—transitioned to High Energy Research and Technology Facility***
- **Magneto-Optical Field Sensors (MOFS).** Opteos in Ann Arbor, MI developed prototype fiber-coupled, 3-axis magneto-optical sensors for magnetic field detection using the Faraday effect during HPM irradiation at millimeter resolution to meet ANSI Std C95.1 Radiation hazard requirements. ***COMPLETED***
- **HPM Soil and Electrical Properties (HSEP).** SAIC in Albuquerque, NM is evaluating different in situ techniques to rapidly determine the electromagnetic properties of soil at HPM test sites for propagation modeling and hazard prediction.

HPM Energy at Source

- **Cine Radiography Imagery Measurement (CRIM**). L3 Communications in San Leandro, CA developed the CRIM prototype instrumentation device that permits the rapid, successive x-ray imaging of short duration explosive-driven HPM sources for performance evaluation. Achieved frame rates of 2.5-50 microseconds. ***COMPLETED—transitioned to Army Aviation and Missile Research, Development and Engineering Center (AMRDEC).***
- **Terahertz Imaging Profiler Array (TIPA).** AEgis Technologies in Huntsville, AL is developing a prototype 0.2-1.4 THz-band detector array and optical beam steering subsystem to quantify beam profiles of new THz sources.

HPM Area Effects

- **Directed Energy Data Acquisition Transformation (DEDAT).** The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, VA produced the Compact Remote Digitizer for HPM and pulsed power test and measurement, they then produced several more and are using at their site. ***COMPLETED—Directed Energy Technology Office, Dahlgren***
- **Field Strength Sensor Network (FSSN).** ITT Information Systems of Albuquerque, NM is developing a prototype wireless mesh network of sensor nodes for capturing and reporting the amplitude of radiated HPM fields in a geographically dispersed test configuration. The multi-node array prototype will demonstrate the ability to place up to a hundred unattended sensor nodes across an area as large as a square kilometer to gather and report the HPM field strength of narrowband systems operating at frequencies up to 4 GHz.

DET S&T Program Status

DET S&T is an on-going TRMC test technology area to mature critical T&E technology required for the full spectrum DE testing and to create viable transitions for test range field applications. The DET S&T Test Technology Area identifies high priority DE test technology shortfalls, solicits for potential solutions in a Broad Agency Announcement (BAA), and awards selected innovative high-risk, high-payoff solutions based on available funding biannually.

DET S&T Broad Agency Announcement Opportunities

The BAA is released biannually in the March-April timeframe with selected projects awarded between October-December. Additional information regarding BAA solicitation for interested bidders may be viewed at both FedBizOpps (FBO) and Army Single Face to Industry (ASFI) links below:

FBO Link:
https://www.fbo.gov/index?s=opportunity&mode=form&id=62fe2c3805dadab5dbe544f96f2ff9f8&tab=core&_cview=1

ASFI Link:
https://acquisition.army.mil/asfi/solicitation_view.cfm?psolicitationnbr=W900KK10R0010

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Directed Energy Test Science and Technology

The Directed Energy Test Science and Technology (DET S&T) Test Technology Area was initiated at the direction of the Office of the Secretary of Defense (OSD) Test Resource Management Center (TRMC) due to the current inability to conduct required full spectrum test and evaluation (T&E) on emerging directed energy (DE) weapon and threat systems prior to fielding. To support high fidelity T&E of future revolutionary DE weapons, timely S&T investments to fill high priority test shortfalls are required now to develop critical, nascent technologies for utilization by Department of Defense (DoD) test ranges, facilities, and laboratories. This test technology area aims to mature and then transition enabling technologies to reduce the engineering development risk of test capabilities required by test ranges. Successful DET S&T projects produce verified prototypes by advancing high-risk, high-payoff technologies for transition into a full T&E capability required for effective DE weapon system evaluation.

DET S&T Test Technology Area Objectives

The objective of the DET S&T Test Technology Area is to ensure the required innovative test technology infrastructure (methodologies, instrumentation, data/information, and modeling and simulation tools) is matured for use by DoD test ranges for DE systems T&E. On a biannual basis, the DET S&T Test Technology Area coordinates with the DE T&E community, including Major Range and Test Facility Base (MRTFB) sites, service laboratories, test ranges/facilities, the Directed Energy Test and Evaluation Capability (DETEC) team, and DE program offices to identify DE test shortfall areas requiring S&T investigation. These high-risk, high-payoff topic areas are developed for inclusion in the annual DET S&T Broad Agency Announcement (BAA) solicitation that Government, industry, and academia partners may respond to. The BAA submissions are reviewed by an all Government, multi-Service T&E/S&T Working Group that provides recommendations to the DET S&T Executing Agent (EA) for contract award prioritization.

DET S&T Test Technology Area Description

The DET S&T Test Technology Area defines DE in terms of high energy laser (HEL) and high power microwave (HPM) domains and identifies DE T&E areas requiring S&T research. The established DET S&T Test Technology Area process enables smart investment decisions based on verified current and future test requirements. The test technology area funds DET S&T projects that address verified DE T&E capability shortfalls by advancing prototype technologies from the laboratory setting into the outdoor operational test range environment. Successful projects may be transitioned directly to other DoD agencies for field T&E use or to other funding sources for follow-on engineering development into a matured T&E capability prior to a field agency transfer.

HEL Effects on Surface and Airborne Targets

- **Bistatic Optical Imaging Sensor (BOIS).** Photon Research Associates in San Diego, CA produced a 2D hyperspectral imager utilizing a fiber-based integral field sensor to provide spectrally-resolved imagery of airborne targets being engaged by HEL weapons. ***COMPLETED—enhances the Advanced Pointer Tracker (APT) at White Sands Missile Range (WSMR).***
- **Quantum Well Infrared Photodetectors/Computed Tomographic Imaging Spectrometer (QWIP/CTIS).** The U.S. Army WSMR, NM with the Jet Propulsion Lab in Pasadena, CA developed the QWIP/CTIS technology to image near infrared/mid-wave infrared laser beams simultaneously incident on the same target while allowing for separation of multiple laser spots at different wavelengths and intensities for detailed evaluation of HEL system performance. ***COMPLETED—Transitioned to WSMR***
- **T&E Adaptive Optics System (TAOS).** The U.S. Army and WSMR, NM and the Air Force Research Laboratory Starfire Optical Range (SOR) in Albuquerque, NM developed TAOS by applying real-time passive adaptive optics and post-processing image reconstruction techniques to compensate for the severe effects of atmospheric distortions on multi-spectral test imagery. This improved spatial resolution and accuracy of remote imagery of airborne targets against HEL weapon systems enhances evaluation of laser-target interaction. ***COMPLETED—enhances the APT at WSMR.***
- **Surface Temperature Estimation Tool (STET).** Northrop Grumman Corporation in San Antonio, TX employed a Constrained Non-Linear Least-Square minimization algorithm and extensions to estimate surface temperature and time-dependent temperature maps based on radiometric images without exact knowledge of the emissivity of the target surface. ***COMPLETED***
- **Heat Flux Sensor Array (HFSA).** University of Missouri, Columbia is developing two Inverse Heat Conduction (IHC) algorithms, utilizing the Conjugate Gradient Method (CGM) and Fourier/Laplace (F/L) method to estimate dynamic front surface temperature and net heat flux maps using 2D back surface temperature array data.
- **Inversion-derived Resistive Temperature Sensors (IRTS).** AEgis Technologies in Albuquerque, NM is developing a prototype conformal resistive temperature sensor array applied to rear HEL target surfaces and integrating the measurement sensor with the IHC algorithms from the HFSA project to determine front surface HEL temperature profiles.
- **Precision Radiometric Surface Temperature Sensor (PRST).** Bodkin Design & Engineering in Newton, MA is developing a 2D hyperspectral imager using 20 wavebands from near- and mid-infrared (NIR-MWIR), producing 3D radiometric data-cubes, and applying algorithms based on temperature-emissivity separation to generate both radiometrically correct surface temperature and emissivity maps.
- **Passive Adaptive Optics (PAO).** Xinetics Inc in Devens, MA is developing a PAO system to attain high-resolution off-board imagery of targets under HEL irradiation to facilitate accurately determination of the target temperature profile and the incident laser irradiance profile. The main objective is to improve the imagery resolution within and near the HEL spot using only the ambient (daytime) illumination of the target to provide the signal for the WaveFront Sensor (WFS).

HEL Energy on Surface and Airborne Targets

- **HEL Target Board (HTB).** Georgia Tech Research Institute (GTRI) in Atlanta, GA developed a large scale prototype scattering diffuser target board based on photo-thermal refractive (PTR) glass that has low absorption, ruggedness, and survivability for HEL beam diagnosis during simultaneous lethality tests. ***COMPLETED—transitioned to Air Force Research Laboratory's Laser Effect Research Branch (AFRL/RDLE).***
- **Temperature and Irradiance Sensor Matrix (TISM).** AEgis Technologies in Albuquerque, NM is developing laser beam sensor array technology. They are developing a prototype target board to measure laser beam characteristics at relevant target distances and a lethality mesh to directly measure laser irradiance and target temperature for relevant targets.
- **Beam Irradiance on Target System (BITS).** SemQuest Inc. in Colorado Springs, CO is developing a survivable optical collector array to HEL irradiance that can be mounted on the outside of a moving aerial or surface target/stationary target board and couple to internal shielded detectors, then measure and transmit HEL irradiance with user-selectable location accuracy with minimal interference on HEL-target lethality, target dynamics, and target optical signature.

Transmission Path for Surface-to-Surface, Surface-to-Air, and Air-to-Air HEL Engagements

- **Range Profiles of Turbulence (RPOT).** GTRI in Atlanta, GA developed a brassboard device that enabled remote measurements to characterize the distributed strength of the atmospheric optical turbulence along an HEL beam slant path as an improvement over prior point measurements. The resulting test measurements can be used to predict the impact of optical turbulence on laser weapon propagation. ***COMPLETED—transitioned to High Energy Laser Systems Test Facility (HELSTF).***
- **Integrated Atmospheric Characterization System (IACS).** GTRI in Atlanta, GA is leading the design, development, and testing of the IACS project that fabricates a prototype light detection and ranging (LIDAR)-based system to characterize the three major causes of atmospheric degradation of laser beams; namely, water vapor, atmospheric turbulence, and aerosol content along HEL slant beam paths.

HEL Test Safety

- **Laser Protected Antenna (LPA).** Science Applications International Corporation (SAIC) in Albuquerque, NM developed novel ways to shield missile termination flight termination system (FTS) antennas from errant HEL beams using material/laser response and thermal performance modeling followed by laser survivability and radio frequency (RF) performance tests. ***COMPLETED—design specifications available.***

HPM Energy on Target

- **Compact Three-Axis Sensor (CTAS).** The Naval Research Lab (NRL) in Washington, DC created a prototype for a low-cost, compact electro-optical, non-intrusive sensor based on crystals that are capable of providing three-axis E-field vector measurements to account for polarization and beam orientation in confined and free-space HPM irradiation test scenarios at sub-centimeter resolution. ***COMPLETED***
- **Microwave Test Diagnostics (MTD)**. L-3 Communications Titan Corporation Applied Technologies/Jaycor in Albuquerque, NM developed a small and rugged stand-alone data recording system that enables measurement of key HPM coupling parameters in both laboratory and live-fire tests of dynamic targets. This capability has been demonstrated while surviving 1200G acceleration. ***COMPLETED—transitioned to WSMR***
- **Integrated Electro-Magneto-optic Sensor (IEMS).** NRL in Washington, D.C. developed a prototype integrated electro-optic / magneto-optic (EO/MO) crystal sensor containing a three-axis EO sensor and a single axis MO sensor using an optical engine capable of measuring HPM electric and magnetic fields within HPM targets. ***COMPLETED—transitioned to Naval Electromagnetic Radiation Facility (NERF), Naval Air Warfare Center – Aircraft Division (NAWCAD), Naval Air Station, Patuxent River, MD.***
- **Advanced Polymer Optical Sensors (APOS).** IPITEK of Carlsbad, CA with BYU and the University of Washington is developing advanced, 3-axis, fiber-optic coupled electro-optical (EO) and magneto-optical (MO) probes based on optimized EO polymers and MO crystals. The sensors are of minimal size and intrusion for measuring electric and magnetic fields within HPM targets.

HPM Effects on Target

- **Skin Heating/Electric Field Strength Measurement Sensor Network (SHEF).** Research Triangle Institute (RTI) International in Research Triangle Park, NC is developing a wearable prototype comprise of co-located fluorescent skin temperature rate and W-band patch antenna arrays with data acquisition systems to provide subject-under-test skin diagnostics in eight locations. SHEF also uses an accelerometer and magnetometer to provide speed and direction of human response.

HPM Shooters or Surrogate Shooters

- **Microwave Rotary Attenuator (MRA).** Ktech Corporation in Albuquerque, NM developed the prototype MRA device that enables continuous and dynamic power variation radiated out of the DETEC HPM Narrowband Threat Systems (NBTS) Capability operating in the 400 MHz frequency band. MRA includes a rotary joint with resistive cards that vary HPM attenuation, a significant improvement over fixed, frequency-dependent foam sheets. ***COMPLETED—transitioned to WSMR.***
- **Resistive Waveguide Attenuator (RWA).** Ktech Corporation in Albuquerque, NM developed a prototype RWA device that enables continuous and dynamic variation of the power radiated out of the DETEC HPM Narrowband Threat System B Capability. Attached to the X-band circular waveguide, RWA uses a sliding carriage that exposes resistive disks to vary HPM attenuation; a significant improvement over fixed, frequency-dependent foam sheets. ***COMPLETED—transitioned to WSMR.***
- **Rotating Step-Twist Polarizer (RSTP).** Ktech Corporation in Albuquerque, NM developed a prototype rotating step-twist polarizer that enables antenna polarization change without the delays associated with breaking vacuum. The technique mimics rigid, step-twist rectangular waveguide but allows the user to dynamically vary the polarization direction without breaking vacuum and the subsequent need for pump down. ***COMPLETED—transitioned to WSMR.***
- **Dual Oscillator for Microwave Generation (DOMG).** ITT Information Systems of Albuquerque, NM developed the balanced dual oscillator pulser technology utilizing a single high voltage spark gap switch with a parabolic antenna to generate wideband HPM radiation. The DOMG effort pushes previous wideband techniques from 500 MHz to over 2 GHz while simultaneously providing a 10x increase over present day electric field level performance. ***COMPLETED—transitioned to Naval Electromagnetic Radiation Facility (NERF), Naval Air Warfare Center - Aircraft Division (NAWCAD), Naval Air Station, Patuxent River, MD.***