



2018 Directed Energy Educational Outreach

The United States Leads the World in Directed Energy Technology

High Energy Lasers

Optical Technology

Support Systems

High Power Microwaves

Non-Lethal

DIRECTED ENERGY IS HERE TODAY!



Directed Energy to the District of Columbia DE2DC 2018 Educational Exhibits

**Pentagon Exhibit of DE Hardware
March 19th - 1230-1600 - Pentagon Courtyard
March 20th - 0900-1500 - Pentagon Courtyard**

**Congressional Exhibit and Reception of DE Technology
March 22nd - 1300-1900 - Rayburn Building Foyer**

What is the purpose of the Directed Energy Educational Outreach Campaign -

The National Directed Energy Outreach Campaign aims to :

- (1) promote transition of directed energy technologies into operational use through educational outreach to decision makers and warfighters, and
- (2) provide technical expertise to warfighters and decision makers as they incorporate directed energy systems.



Directed Energy Educational Outreach Campaign Initiated in 2009

What is Directed Energy—Directed Energy (DE) technologies encompass a wide range of non-kinetic capabilities that generate beams or fields of electromagnetic energy.

Directed energy weapons (DEWs) propagate this energy to engage a target remotely at the speed of light, including High Energy Lasers (HEL) or High Powered Microwaves (HPM), producing precise, scalable effects against multiple targets at a very low cost per shot.

DEWs offer non-lethal warning, escalation of force, ISR and counter-ISR, counter-electronics, counter-munitions, and counter-IED capabilities at a fraction of the cost per engagement compared to traditional, kinetic options. As a complement to existing weapons, DEWs offer the U.S. Military a cost-effective capability enhancement to address evolving threats.

One of the key benefits of DE technologies are scalable effects, i.e., target impacts that range from temporary disruption to permanent damage. With HELs, effects can range from “dazzling,” or blocking visibility only when illuminated, to ablation and damage, usually causing the target to catch fire. With HPM, effects can range from interruption (e.g., shutting off an engine that can later be restarted) to permanent damage to electronics within the target.



The Directed Energy Professional Society (DEPS) fosters the research, development and transition of directed energy (DE) technologies, including high energy laser (HEL) and high-power microwave (HPM) technologies, for national defense and civil applications through professional communication and education. We are recognized as the premier organization for exchanging information and advocating research, development and application of Directed Energy. Founded in 1999, DEPS is incorporated as a nonprofit corporation in New Mexico, organized and operated exclusively for charitable, scientific, and educational purposes.

Each academic year, DEPS offers individual graduate scholarships of \$10,000. The number of annual scholarship awards depends on available funding, which is provided by grants from the Joint Directed Energy Transition Office and the Office of Naval Research.

The traditional academic disciplines involved in DE research include physics, electrical engineering, chemistry, chemical engineering, materials sciences, optical sciences, optical engineering, and aerospace engineering.

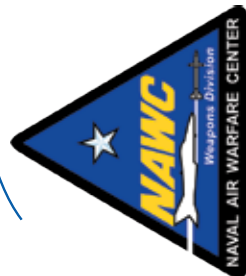
DEPS hosts several conferences and workshops annually and bi-annually to further information exchange and collaboration amongst the DE community. Unique to DEPS is our ability to host meetings at varying classification levels, from sessions that are open to the public to those that cover classified research material. DEPS provides each attendee a copy of the respective proceedings from the meeting, based on their individual clearance level. In addition to the annual symposia, DEPS also sponsors a series of short courses that support continuing DE education and further professional development. Continuing Education Unit (CEU) credits are offered upon completion of such DEPS courses. A listing of DE short course offerings and upcoming events can be found at our website, www.deps.org.



DIRECTED ENERGY OUTREACH CAMPAIGN



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Sandia National Laboratories

Table of Contents

Government Organizations	1
Joint Directed Energy Transition Office	2
DoD Non-Lethal Weapons Program	4
Air Force Research Laboratory	6
Defense Systems Information Analysis Center	9
U.S. Army Space and Missile Command	10
Naval Surface Warfare Center—Dahlgren Division	19
Naval Air Warfare Center Weapons Division	20
Labs and Academia	23
Sandia National Laboratories	24
University of Missouri Center for Physical Electronics & Power Electronics	27
Industry Partners	29
II-VI Optical Systems	31
Applied Research Associates	32
Applied Technology Associates	34
BAE Systems	37
Boeing	38
Booz Allen Hamilton	40
Coherent	43
General Atomics	44
Heraeus	47
L3 Brashear	48
Lasertel	50
Leidos	52
Lockheed Martin	54
NanoElectromagnetics LLC	59
Northrop Grumman	60
Nutonics	62
Optimax	63
Radiance Technologies	64
Raytheon	66
Contact Information	70

Government Organizations





Joint Directed Energy Transition Office (DE JTO)

Establishing the Foundation

for Directed Energy Weapon (DEW) Systems

The DE JTO has four primary functions for the transition of technologies that will underlie DE weapons platform development. These include: (1) Acceleration of the development and fielding of DEW capabilities; (2) Advice for exercises and demonstrations; (3) Material/Non-material solution support for development and validation of requirements; and (4) Coordination of the joint DEW portfolio. DE JTO success is critically dependent on other organizations throughout the military departments and defense agencies, consistent funding, and acquisition methods to streamline and accelerate fielding of DEW capabilities to improve the readiness and responsiveness of the Department of Defense.

FY17 BAA Call – Industry

- 89 White Papers; 38 Orals

FY17 S&A and FFRDC Call

- 45 White Papers; 31 Orals

FY17 MRI Call – Academia

- 65 White Papers; 27 Orals



Advocates DE development & transition

Addresses joint technology requirements

Stimulates inter-service research

Orchestrates portfolio of R&D projects across government/industry/academia

Establishes community standards & tools

Educates next generation of DE technical, policy, & program leaders

The DE JTO utilizes a multi-pronged approach to advance DE technologies through basic and exploratory research working with Universities, DoD Service & Agencies (S&A), and Industry. In addition to advancing the state of the art in DEW for military applications, the DE JTO established an Educational Outreach program to address the issue of limited numbers of US students trained in the various HEL disciplines.



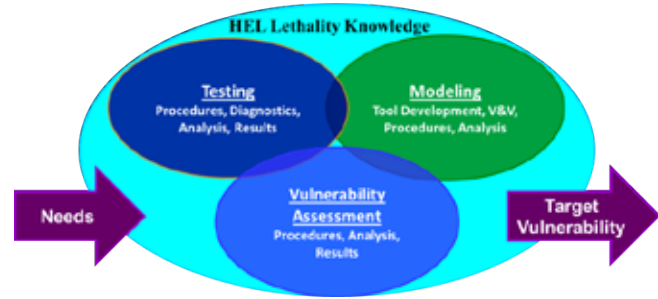
University students and instructors conduct HEL Atmospheric Propagation experiments



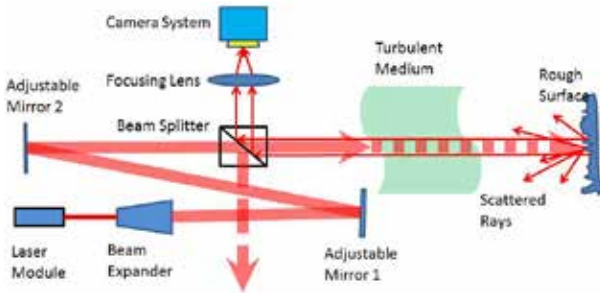
Service Academy cadets and midshipmen are benefactors from the DE JTO Educational Outreach program

Joint Directed Energy Transition Office (DE JTO)
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 Albuquerque, NM 87106 Phone: [505] 248-8200
 Email: HEL-JTO@jto.hpc.mil

Subject matter experts, as members of Technical Area Working Groups (TAWGs), represent DoD organizations and advocate for their DEW interests.



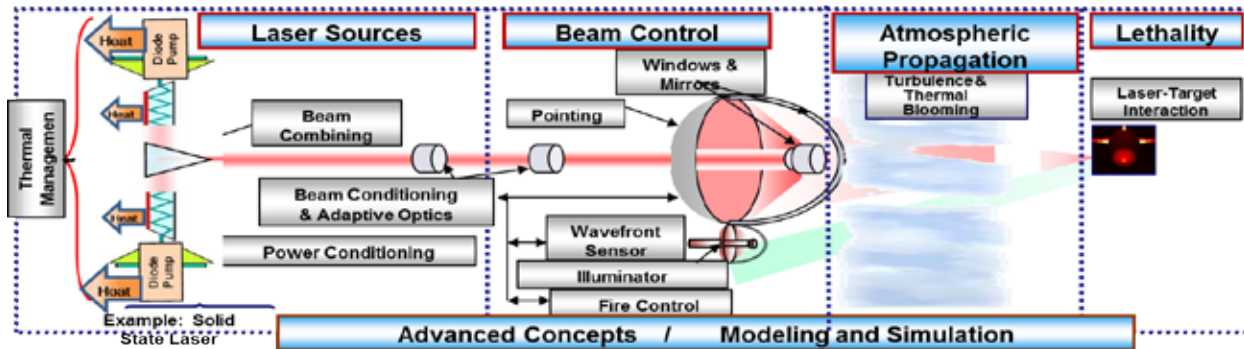
Lethality TAWG: To develop and provide DEW lethality knowledge and expertise in support of DoD projects and activities.



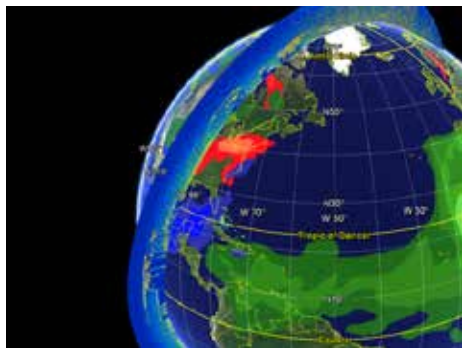
Beam Control (BC) TAWG: Communicate Service BC needs to DE JTO and support investment strategy



Laser Sources (LS) TAWG: Pursues technologies needed for mature, rugged, reliable, efficient, affordable high power solid state lasers.



Advanced Concepts (AC) TAWG: Focus on high risk, high payoff basic science and research across the entire system and out to the target for all Services



Atmospheric Propagation (AP) TAWG: Understand impact to any power laser anywhere in the world, at any time.



Modeling & Simulation (M&S) TAWG: Accurately capture DEW weapon system capabilities in various scenarios



DoD Non-Lethal Weapons Program Directed Energy Capabilities



“There is no military force in the world that has proven more sensitive to civilian casualties. We go out of our way to always do everything humanely possible to reduce the loss of life or injury among innocent people. The same cannot be said for our adversaries.”

– Secretary of Defense James Mattis, March 2017

The Nation’s Joint Forces’ missions span the full range of military operations across the globe, from peacekeeping, disaster response, and humanitarian assistance to major combat campaigns. The current toolkit of non-lethal weapons, supported by the Dept. of Defense Non-Lethal Weapons (DoD NLW) Program and Armed Services, provides commanders with additional decision time and space before resorting to lethal force, helping to mitigate the negative consequences of unintended injuries and fatalities.



Active denial technology uses mmW emitters to deny, suppress, and move individuals posing a threat in ambiguous situations.

Non-Lethal Directed Energy Applications. Non-lethal weapons, developed to have reversible effects on personnel and materiel, complement lethal force and maximize mission effectiveness while minimizing risk to U.S. forces, coalition partners, civilians, and critical infrastructure. Directed energy (DE) technology can deliver effective non-lethal effects over long distances almost instantaneously, addressing threats at safer standoff distances. The DoD NLW Program, a leader in DE technology development, increased its investment in DE enabling technology to target individuals, equipment, and facilities with safe, effective, and less expensive non-lethal capabilities.



Radio Frequency/High-Power Microwave energy can stop vehicles, vessels, and other systems by disrupting electrical components.

NLW DE Portfolio. The DoD NLW Program’s DE portfolio showcased at DE2DC events demonstrate that these capabilities exist today. As NLW DE systems undergo assessments in FY18/19, they demonstrate the ability to 1) stop vehicles, vessels, and other systems with Radio Frequency/High-Power Microwave (RF/HPM) energy, 2) deny/suppress/ move individuals using millimeter wave (mmW) electro-magnetic energy commonly referred to as Active Denial Technology, and 3) hail and warn individuals at safer standoff ranges through low-power lasers and long-range audio devices.



The DoD will remain at the forefront of non-lethal DE capabilities to ensure the Joint Force maintains its competitive advantage over potential adversaries.

Visit: <http://jnlwp.defense.gov> for more information on these and other DoD NLW Program efforts

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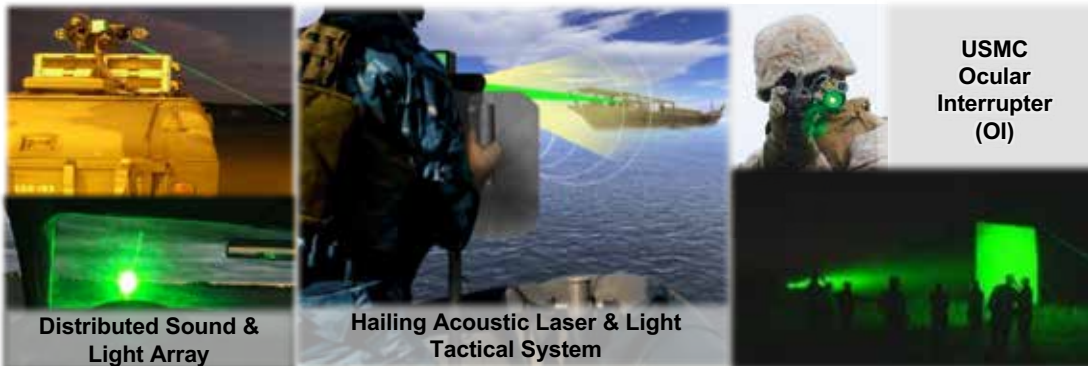
Non-Lethal Directed Energy Weapon (NL DEW) Technology Thrust Areas:



Active Denial Technology: Non-lethal mmW energy creates an intolerable heating sensation by penetrating a targeted individual's skin to a depth of only 1/64th of an inch - the equivalent of three sheets of paper - compelling them to instinctively move.



RF/HPM NLWs: Emit directed wide- and narrow-band high-power microwave energy to stop advancing vehicles and vessels by temporarily disrupting the platform's control electronics without necessarily harming persons on or near materiel targets.



Long-Range Sound and Light Technology: Low-power lasers and long-range audio devices hail, warn, move, disrupt, and suppress individuals with very low risk of significant injury.

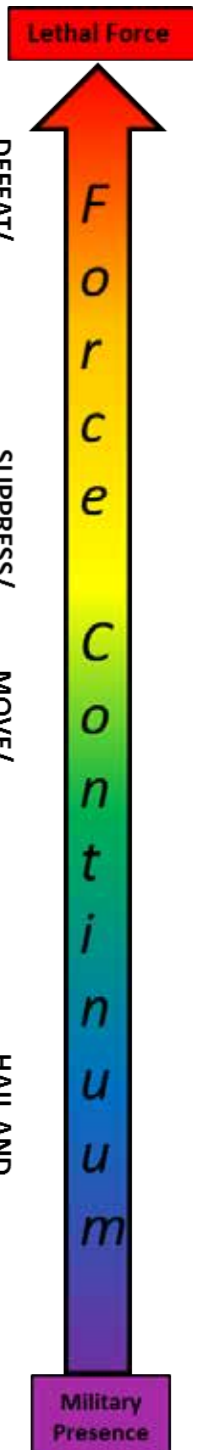
NL DEW SWaP/C² Reduction: NL DEW system, subsystem, & component size, weight, and power consumption with thermal cooling and cost reduction efforts (SWaP/C²)

NLW DE Bioeffects Program: The DoD NLW Program has a robust and active NLW DE Bioeffects program in collaboration and partnership with DoD laboratories, industry, and academia. The goals of the NLW DE bioeffects program include advancing the science and knowledge of DE bioeffects and building predictive Modeling and Simulation (M&S) capabilities to support system design and acquisition. The focus and end state of the M&S capability is to characterize the desired non-lethal effects and risk of injury of DE systems in line with policy outlined in DoD Instruction 3200.19.



Visit: <http://jnlwp.defense.gov> for more information on these and other DoD NLW Program efforts

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DIRECTED ENERGY DIRECTORATE

The Air Force Research Laboratory's mission to equip the United States Air Force with cutting-edge technology is vital to our nation's security. The Secretary of the Air Force and the Chief of Staff of the Air Force identified directed energy as a game-changing technology in the 2017 Air Force Strategy, "America's Air Force: A Call to the Future." The AFRL Directed Energy Directorate is proud to play a critical role in our nation's defense as experts in developing directed energy weapons that offer transformational capabilities to the warfighter.

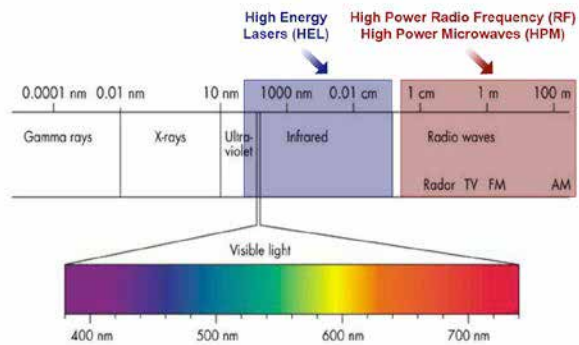
THE AFRL DIRECTED ENERGY DIRECTORATE IS LEADING THE WAY IN:

- Offensive and defensive laser concepts
- Non-lethal counter electronics
- High power microwaves
- Space situational awareness
- Weapons modeling, simulation and analysis

WHY DIRECTED ENERGY

DE is a beam of concentrated electromagnetic energy.

- Speed-of-Light Delivery
- Precision Engagement
- Controlled/Scalable Effects
- Logistical Advantages
- Low Cost per Shot



DE OFFERS:

- Precision Imaging/Tracking/Engaging
- Low Collateral Damage
- Scalable & Non-lethal Effects
- Deep Magazine



SELF-PROTECT HIGH ENERGY LASER DEMONSTRATOR (SHIELD)

SHIELD is an effort to integrate an agile, compact, high-power laser system, with its associated power, cooling, and battle-management systems onto a tactical aircraft to demonstrate self-protection in contested environments. AFRL's SHIELD program will demonstrate the maturity of integrated laser systems in a complex flight environment, improve situational awareness, and enhance survivability. The Air Force, with this technology, can boast advanced self-

defense capability against highly sophisticated missile threats.



LARGE ARRAY AT THE HIGH ENERGY RESEARCH AND TEST FACILITY (HERTF)

A 31-element diagnostic array at AFRL's HERTF facility, designed to characterize radiated antenna patterns, helps researchers measure and understand the intense fields and radiation patterns of high power electromagnetic sources. Large Array is used to test and characterize a number of directed energy weapon systems.



ADVANCED CONCEPT EXPERIMENT (ACE)

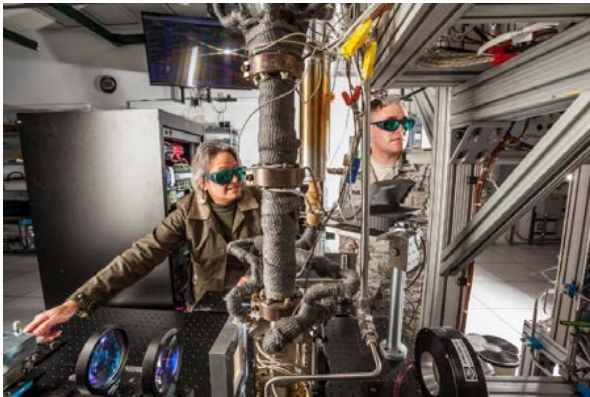
The 2017 AFRL ACE successfully advanced Directed Energy capabilities against a variety of potential threats. Air Force, Army, and Canadian forces were linked at multiple sites throughout CONUS to conduct DE related missions on a virtual battlespace. Scenarios assessed lasers and high power microwave systems defending targets against attacks and applied the Microwave Electromagnetic Air

Defense concept to enhance survivability of downed Airmen and a self-defense laser on the Future Personnel Recovery vehicle. Direct and immediate interaction between scientists and warfighters allowed the Concept of Employment of these critical technology enablers to be optimized in real time, increasing future system lethality and enhancing the projected effectiveness of joint forces equipped with DE weapons.



COUNTER-ELECTRONICS HIGH POWER MICROWAVE ADVANCED MISSILE PROJECT (CHAMP)

CHAMP is a proven high power radio frequency precision weapon system that allows the Air Force to defeat electronic systems without using kinetic weapons. CHAMP is an unmanned, adaptable, multi-launch platform system capable of flying into a contested area and avoiding danger to life and damage to infrastructure. The technology has been developed over two decades at AFRL and tested through a Joint Capability Technology Demonstrator program.



DIODE PUMPED ALKALI LASER (DPAL) LAB

The Diode Pumped Alkali Laser lab is where the Next Generation Laser program researchers are working on science and engineering experiments related to the research and development of DPALs and other gas lasers. The Potassium (K) DPAL (pictured) is the first kilowatt-class potassium laser in the world. AFRL has been researching DPAL technology since 2007, contributing significantly in the development of DPAL and other gas laser systems. DPAL is a candidate for future high power laser weapon applications, including the counter-ICBM and ground-based air defense missions.



AFRL AIR FORCE MAUI OPTICAL AND SUPERCOMPUTING (AMOS) SITE

The state-of-the-art Maui Space Surveillance System combines research and development with an operational mission—the only one of its kind in the world. The MSSS houses the DoD's largest ground-based electro-optical telescope, the Advanced Electro-

Optical System 3.6-meter telescope. The laser from the AEOS creates an artificial guide star 60 miles above the surface of the earth that when used with adaptive optics on the telescope reduces the blurring effects of atmospheric turbulence, providing a clearer view of objects in space.



STARFIRE OPTICAL RANGE (SOR)

AFRL's Starfire Optical Range primary mission is to develop optical sensing, imaging, and atmospheric compensation technologies to support Air Force aerospace missions and space situational awareness.



Using adaptive optics, objects outside Earth's atmosphere become much clearer as shown in this photo of Saturn.

SOR is a vital resource in achieving the Air Force's mission to operate freely in an increasingly important space domain through leading industry changing technology of laser beacon adaptive optics for military and civilian applications. This world-class optical research facility and center for Air Force strategic optical exploration is located 6,240 feet above sea level at Kirtland Air Force Base, New Mexico.



THE DEFENSE SYSTEMS INFORMATION ANALYSIS CENTER SUPPORTS THE DIRECTED ENERGY COMMUNITY

**FREE
TECHNICAL
INQUIRY
SERVICE**



U.S. Navy



U.S. Air Force



U.S. Marine Corps

In an era of growing global technicalization and improvised tactics, the necessity for a third offset strategy to combat this new paradigm is becoming increasingly evident. To ensure the United States maintains an advantage over our potential adversaries, the Department of Defense (DoD), is concentrating research and development efforts on innovation, such as Directed Energy technology, which holds great promise for maintaining technological superiority in a budget-conscious environment.

Accordingly, the charter of the Defense Systems Information Analysis Center (DSIAC) is to provide an information resource for the DoD, U.S. Government agencies, academia, industry, and other Directed Energy

stakeholders to increase the value of government-owned research and development information through re-purposing, reuse, and enhancement.

DSIAC's free technical inquiry service (limited to 4-hours) is available to provide the Directed Energy community with:

- Document retrieval.
- Literature searches.
- Answers to technical questions.
- Technology assessments.
- Modeling & simulation tools.

Other services include;

- Collecting, organizing, and disseminating Directed Energy-related scientific and technical information.

- Fostering and supporting the Directed Energy community with subject matter experts.
- Providing training, conferences, state-of-the-art reports and publishing *DSIAC Journal* articles.

For analysis tasks that exceed the free 4-hr limit, a Core Analysis Task delivery order vehicle is available for DSIAC to perform specialized work under our pre-competed IDIQ contract. For more information on DSIAC or the DoD IACs, visit <http://iac.dtic.mil>.



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INFORMATION PAPER ON HIGH ENERGY LASER MOBILE TEST TRUCK

November 2017

1. The High Energy Laser Mobile Test Truck (HELMTT), see Figure 1, is a data collection asset providing knowledge points for future high energy laser demonstrators and weapon systems. Key HELMTT features are:

- Army's first mobile solid-state high energy laser platform
- Rugged, agile, and stable beam control system
- Modular building block approach
- Speed-of-light engagement of threats with pinpoint precision
- Demonstrated lethal effects on small caliber mortars, unmanned aerial systems (UAS), and ground targets



Figure 1. USASMDC/ARSTRAT's High Energy Laser Mobile Test Truck

2. The HELMTT, formerly the High Energy Laser Mobile Demonstrator, is a technology integration and demonstration effort with a solid state laser system, agile beam control system, and supporting subsystems integrated into a large tactical vehicle. The goal is to integrate and demonstrate maturing technologies to the point where lethal engagements in a relevant environment can be demonstrated. The Heavy Expanded Mobility Tactical Truck-based HEL MD became HELMTT when the Army decided in early fiscal year 2016 to integrate a more compact laser system on a family of medium tactical vehicles. This new effort is the HEL Tactical Vehicle Demonstrator and is designated an Army Capability Enabler (ACE). HELMTT provides knowledge points that support, and is funded under, the ACE effort.

3. The HELMTT efforts support development of future deployed high energy laser systems capable of executing missions such as: force protection, counter-unmanned aerial systems, and offensive operations, which are critical functional elements at every level of the brigade. The benefit to Warfighters is progress in multiple areas toward a weapon system that will provide:

Distribution Statement A. SMDC PAO #7214

cost-effective engagements, reduced manning, significantly reduced logistics burden, and a multi-mission capable platform. The average engagement across the threat set uses approximately \$30 worth of diesel fuel; this cost was validated by the Army Materiel Systems Analysis Activity. This low-cost engagement enables the Army to counter mortars, cheap rockets, and small unmanned aerial systems threats at a cost ratio that is advantageous to the U.S.

4. The HELMTT currently consists of a laser projected through a precision pointing, high-velocity target tracking beam control subsystem. To support the laser and beam control system, the HELMTT has power and thermal management subsystems that power and cool all the subsystems. A Battle Management, Communications, Command and Control subsystem receives target cues from radars and points the laser beam to engage the targets.

Upgrades are underway in the HELMTT system. The previous modified commercial-off-the-shelf 10 kW welding fiber laser is being replaced with a 50 kW-class fiber laser. The new laser was developed by the Robust Electric Laser Initiative (RELI) and uses a spectrally-combined beam. The beam control system is being modified to interface with the RELI laser. The size, weight, and power requirements of the system are being reduced with the RELI laser. The new fiber laser modules are being cooled with refrigerant instead of water, a first for fiber lasers. The HELMTT power system is also being upgraded to enable the system to operate on batteries, which provide clean power to the laser. While the vehicle is being modified to accept this new configuration, the laser, thermal management and electrical subsystems have been assembled in a laboratory and successfully operated in a mission-like scenario at full power.

5. Before becoming the HELMTT, this system conducted numerous lethal target engagements and data collections. In fiscal year 2014, the system destroyed small caliber mortar projectiles in flight and downed unmanned aerial system (UAS) targets. In fiscal years 2014 and 2015, the system collected more than 4 TB of data on laser beam propagation in environments ranging from coast to high-desert including pristine as well as degraded weather conditions. In fiscal year 2016, the HELMTT participated in the Maneuver Center of Excellence sponsored Maneuver

Table 1. HELMTT Subsystem Summary

Laser	50 kW-class fiber laser using spectral beam combining architecture
Beam Control System	50 cm aperture retracting telescope, target illuminator, low jitter precision pointing and tracking system
Acquisition and Track Sensors	IR-based wide field-of-view for target acquisition and IR-based narrow field-of-view fine target tracking sensor
Warfighter-Machine Interface	Ruggedized laptop with "X-box"-type controller
BMC3	Modular design with manual/semi-automatic/automatic target acquisition, aim-point selection, and aim-point management
Electrical Power	On-board generator charging Lithium-ion batteries. The batteries power the laser during operation
Thermal Management	Refrigerant/chilled-water system for laser and standard heating, venting and air conditioning for all other subsystems
Platform - HELMTT	500 hp Caterpillar C-15 engine, Allison 4500 SP/5-speed automatic transmission, 8x8 axle, 16 ton payload capacity
Minimum crew	Two person: vehicle operator and laser operator Data collection efforts require additional personnel

Fires Integration Experiment 2016 (MFI-16). During the course of the event, HELMTT shot down Group 1 UAS rotary-wing and fixed-wing targets and destroyed ground targets. In fiscal year 2017, the HELMTT participated in the Joint Improvised-threat Defeat Organization's (JIDO) Hard-Kill Challenge and was ranked first in demonstrated capability.

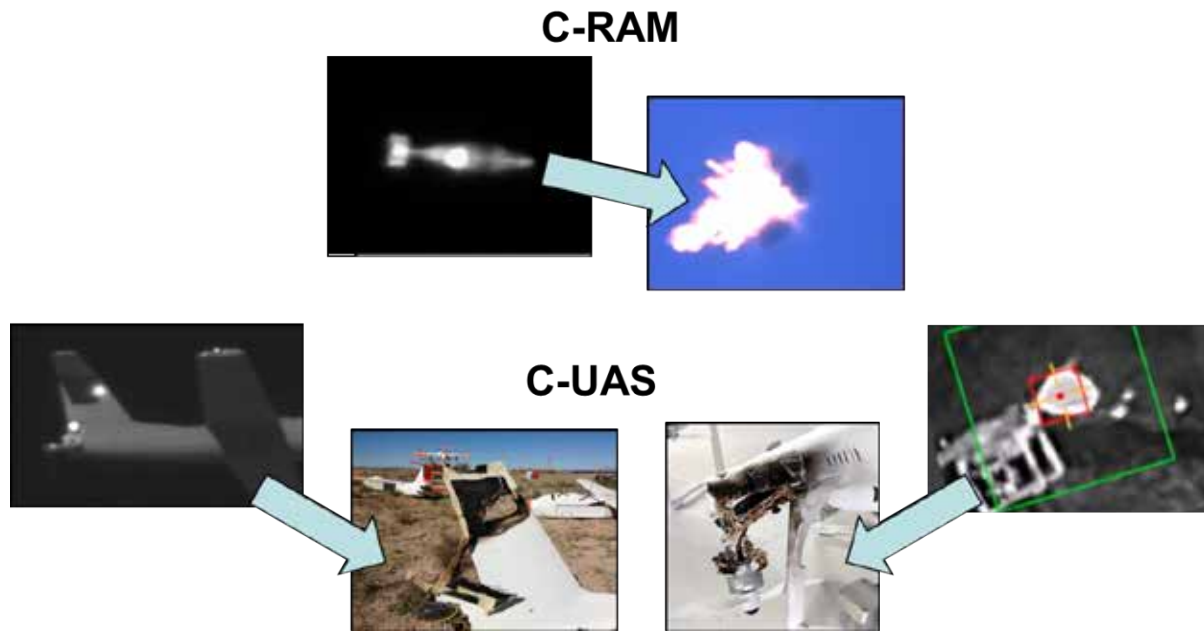


Figure 2. Demonstrated C-mortar and C-UAS Performance



Figure 3. Demonstrated Tactical Mobility

INFORMATION PAPER ON HIGH ENERGY LASER TACTICAL VEHICLE DEMONSTRATOR

November 2017

1. The High Energy Laser Tactical Vehicle Demonstrator (HEL TVD), see Figure 1, will be a pre-prototype system to address Indirect Fire Protection Capability Increment 2 – Interceptor Block 2 (IFPC 2-I Blk 2) objective requirements. Key HEL TVD features will include:

- System to address IFPC 2-I Blk 2 target set
- Compact 100 kW-class fiber laser
- Rugged, agile and stable beam control system
- Modular building block approach
- Speed-of-light engagement of threats with pinpoint precision



Figure 1. Artist Rendering of High Energy Laser Tactical Vehicle Demonstrator Concept

2. The HEL TVD's objective is to build and demonstrate a rugged, mobile, pre-prototype solid state laser weapon system that meets the size, weight, and performance needs of the Army. The effort includes maturing technologies to execute missions to counter-rockets, artillery, and mortars (RAM) at tactical ranges; the system will also be able to defeat Group 1-to-3 unmanned aerial systems. To obtain that capability, multiple subsystems are under development for integration into the pre-prototype weapon system. These subsystems include: laser subsystem (LSS); beam control subsystem (BCS); electrical power subsystem (EPS); thermal management subsystem (TMS); and Battle Management, Command, Control, Communications and Intelligence (BMC4I) subsystem. These subsystems will be integrated into a modified Family of Medium Tactical Vehicles (FMTV).

3. Warfighters face challenges in all aspects of their mission. Soldiers must have weapons that offer precision, controllability, predictability and repeatability to meet the threats of today and

the future. A laser weapon system offers these attributes enabling enhanced tactical battlefield operation with a cost-per-engagement substantially lower than the current C-RAM system. The HEL TVD will demonstrate target acquisition, tracking, aim-point selection/maintenance and defeat for selected threats.

The first mission is to protect U.S. and allied forces at fixed and semi-fixed bases. HELs will complement conventional offensive and defensive weapons at a significantly lower cost-per-engagement than current systems. The HEL system requires only fuel to complete its mission; there is no ordnance logistics burden as with conventional weapons. The average cost-per-kill is approximately \$30, which shifts the engagement cost equation in favor of U.S. forces. With the entire system on a single tactical vehicle, the site's defense strategy can be quickly adjusted in response to a changing threat environment.

4. The HEL TVD will consist of a 100 kW-class laser projected through a precision pointing, high-velocity target tracking BCS. The BCS will have an aperture of at least 30 cm. To support the laser and BCS, the HEL TVD will have power and thermal management systems that power and cool all the subsystems and provide sufficient magazine to defeat multiple targets before recharging. A BMC4I subsystem will receive target assignments with appropriate target cues from radars then point the laser beam to engage the targets.

5. The HEL TVD will conduct a demonstration against a variety of targets in fiscal year 2022. Lethal engagements of a variety of targets is planned for this Technology Readiness Level 6 demonstration. In addition, there will be instrumentation there to characterize the 100 kW-class laser beam propagation; the propagation data will be used to help anchor laser models.

The Warfighters' payoff is progress in multiple areas toward a weapon system which will provide: cost effective engagements, reduced manning, significantly reduced logistics burden and a multiple mission capable platform.

Table 1. HEL TVD Subsystem Summary

Current System	
Laser	100 kW-class fiber laser
Beam Control System	No smaller than 30 cm aperture telescope, target illuminator, adaptive optics, low jitter precision pointing and tracking system
Acquisition and Track Sensors	IR-based wide field-of-view (FOV) for target acquisition and IR-based narrow FOV fine target tracker
Warfighter-Machine Interface	Ruggedized computer with operator-friendly controller
BMC3	Modular design with manual/semi-automatic/automatic target acquisition, aim-point selection, and aim-point management connected to the Army battle management system.
Electrical Power	On-board generator(s) and energy storage
Thermal Management	Laser and container cooling subsystem that maintains all subsystems at operating temperatures
Platform - FMTV	330 hp, 7.2 liter Caterpillar C-7 engine, Allison 3070SP, 7-speed automatic transmission, 6x6 axle, 20,000 lb payload capacity
Crew	Two person: vehicle operator and laser operator

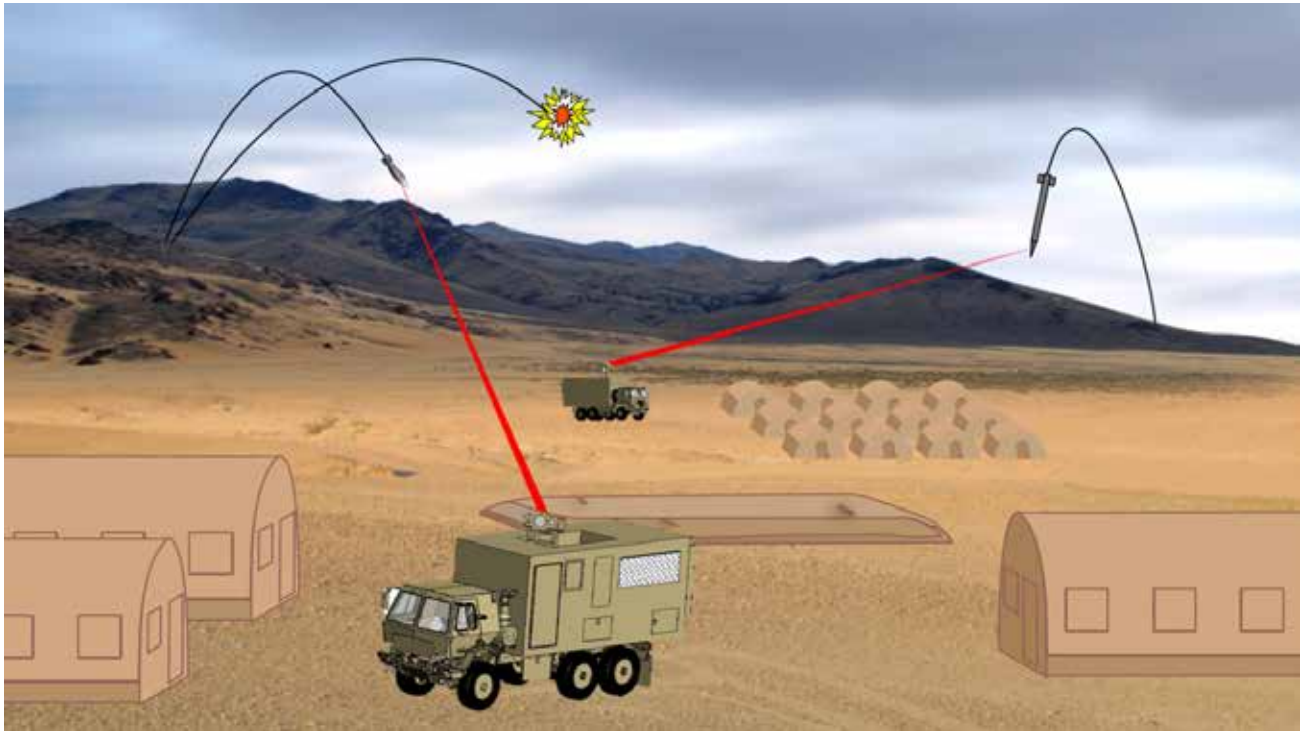


Figure 2. HEL TVD Will Protect Personnel, Equipment, and Facilities

INFORMATION PAPER ON MOBILE EXPERIMENTAL HIGH ENERGY LASER

November 2017

1. The Mobile Experimental High Energy Laser (MEHEL), see Figure 1, is a high energy laser (HEL) system that enables Warfighters to gain hands-on experience operating a HEL system to support development of tactics, techniques, procedures (TTPS), Concept of Operations (CONOPS) as well as inform requirements for future combat platform-based HEL weapons. Key MEHEL features include:

- Compact 5 kW solid state laser
- Rugged and stable beam control system with an aperture of ≈ 10 cm
- Counter-unmanned aerial system (C-UAS) Mobile Integrated Capability (CMIC) components
- Experimental Battle Management Network interface
- Modular building block approach
- Combat platform to maneuver with armored forces



Figure 1. Mobile Experimental High Energy Laser

2. Warfighters face challenges in all aspects of their mission. Soldiers must have weapons that offer precision, controllability, predictability and repeatability to meet the threats of today and the future. A laser weapon system offers these attributes enabling enhanced tactical battlefield operation with a cost-per-engagement substantially lower than the kinetic systems. HEL weapons will be a new technology in the Warfighters arsenal, but they do not yet know how to employ that technology. By providing the MEHEL as a hands-on experiment, the Fires Center of Excellent will be better able to develop mature TTPS and CONOPS. The Warfighter does not have to have the end product, at least a 50 kW system, to develop valid TTPS and CONOPS for maneuvering forces. Some of the key aspects of the TTPS and CONOPS will be managing battle

Distribution Statement A. SMDC PAO #7215

space to include avoiding illuminating satellites and aircraft, selecting weapon to engage threats, and weapon spacing to protect a maneuvering force. HELs will complement conventional offensive and defensive weapons at a significantly lower cost-per-engagement than current systems. The HEL system requires only fuel to complete its mission, there is no ordnance logistics burden as with conventional weapons. The average cost-per-kill is approximately \$30, which shifts the engagement cost equation in favor of U.S. forces.

3. USASMDC/ARSTRAT obtained a Stryker chassis for this experimental effort with industry. The first version of the MEHEL had a 2 kW laser with a 10 cm aperture beam director. That configuration, the first solid state HEL on a combat platform, demonstrated HEL capability in fiscal year 2016. The laser was upgraded to a 5 kW system in December 2016. At the same time, the Ku-band radar and C-UAS CMIC components were integrated. The CMIC components were developed by the Army's Aviation and Missile Research Development and Engineering Center. The Ku-band Acquisition and Track Sensor (KATS) enables the MEHEL to autonomously detect and track targets. There is the potential to upgrade the laser to 10 kW in late 2017/early 2018 to provide longer effective range or half the time required to defeat a target at the same range. In addition to the hardware upgrades, the system software is being upgraded to enable shoot-on-the-move capability in 2017.

4. The 2 kW configuration of the MEHEL participated in the Fires Center of Excellence sponsored Maneuver Fires Integration Experiment 2016 (MFI-16).

There it downed a number of small rotary-wing UAS. After the laser was upgraded to 5 kW, this experimental system participated in the Joint Improvised-Threat Defeat Organization's C-UAS Hard-Kill Challenge in March-April 2017. There the contractor operators defeated a number of small rotary- and fixed-wing UAS. Following the JIDO event, Soldiers were trained to operate the MEHEL. Training took place at Fort Sill, Oklahoma just prior to MFI-17. During MFI-17, Soldiers shot down a UAS with a solid state laser for the first time. At the conclusion of MFI-17, a number of small rotary- and fixed-wing UAS were defeated by the Soldier

Table 1. MMHEL Subsystem Summary

Current System	
Laser	5 kW ruggedized commercial fiber laser with potential to increase to 10 kW in late 2017/early 2018
Beam Control System	≈10 cm aperture telescope, low jitter precision pointing and tracking system
Acquisition and Track Sensors	Infrared (IR)-based wide field-of-view (FOV) for target acquisition and IR-based narrow FOV fine target tracker and Ku-band radar
Operator Interface	Mounted Family of Computer Systems (MFoCS)
Battle Management Command, Control, Communications, Computers, and Intelligence	Maneuver Aviation Fires Integrated Application Battle Operating Software Suite (MAFIA BOSS)
Electrical Power	Stryker generator charging 28 VDC batteries
Thermal Management	Advanced Vapor Compression with poly-Glycol/water mixture
CUAS Mobile Integrated Capability (CMIC) components	Additional counter-air and fire support capability
Platform – Stryker	350 hp Caterpillar C7 engine, Allison 3200SP automatic transmission, 8x8 axle

operators. The MEHEL will participate in MFIX-18 and potentially Joint Warfighter Assessment 18.1.

The Warfighters' payoff is progress in multiple areas toward a weapon system which will provide: cost effective engagements, reduced manning, significantly reduced logistics burden and a multiple mission combat platform.

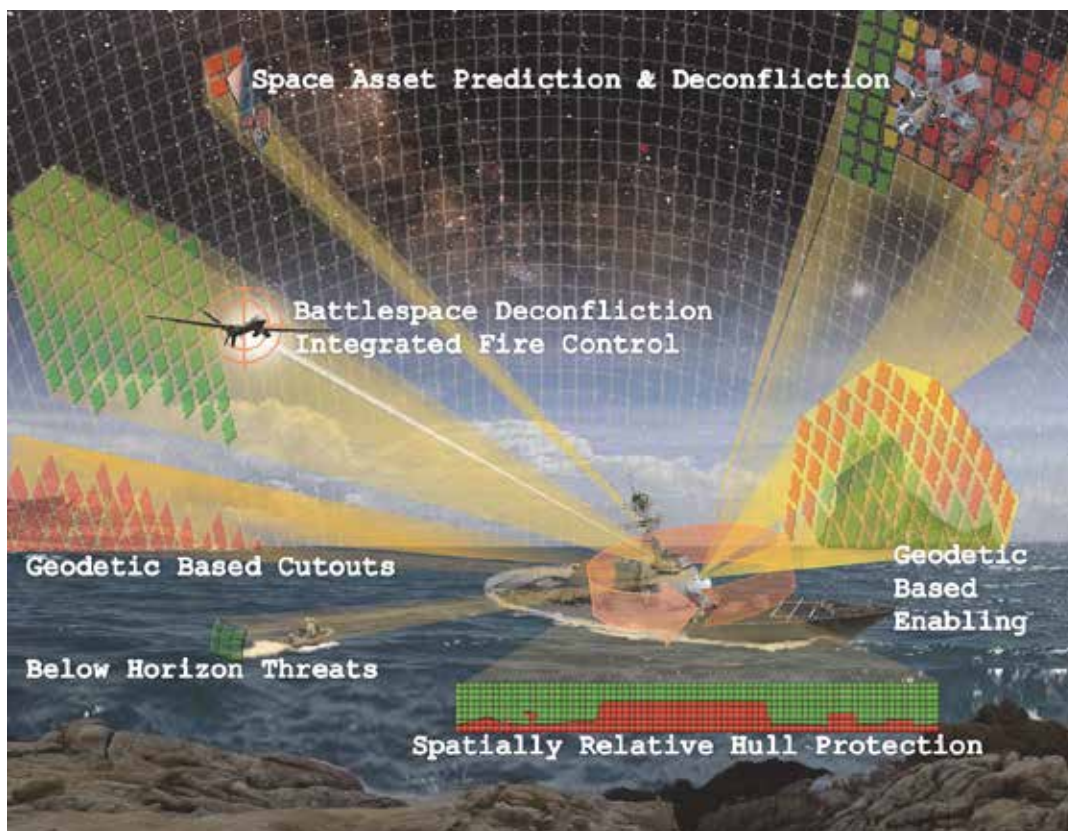


Figure 2. MEHEL with Capability to Maneuver with Armored Forces



Joint Laser Deconfliction Safety System (JLDSS)

The Joint Laser Deconfliction Safety System (JLDSS) will provide automated High Energy Laser (HEL) Fire Control (FC) support for Satellite Deconfliction and Battlespace Deconfliction with Command and Control (C2) systems enabling flexible integration of operational HELs in joint environments. National and Department of Defense (DoD) policy recognize that lasers are vital to United States military applications. As laser capacities and applications increase, decision support capabilities, such as JLDSS, are needed to ensure laser illuminations do not impact upon the safe and effective operation of satellites, aircraft, and ground elements in the battlespace. Current DoD laser Satellite Deconfliction (SD) policy places restrictions on laser operators. JLDSS will enable warfighters to determine if specific elements and activities in the battlespace may be inadvertently illuminated; and make informed timely decisions on the safety of laser activities in accordance with policy and Rules of Engagement (ROE). The solution is a multi-service standardized capability that will serve a variety of laser platforms.



Distribution A - 377ABW-2017-0018



Naval Air Systems Command (NAVAIR)
Naval Air Warfare Center Weapons Division (NAWCWD)
China Lake and Point Mugu, California
Directed Energy Strategic Initiative



Charter. The Naval Air Warfare Center Weapons Division (NAWCWD), China Lake and Point Mugu California, has been designated as active participants in the Directed Energy (DE) Initiative Advanced Technology Enterprise Team, with a specific focus of how DE will impact Naval Aviation. The Division, part of the Naval Air Systems Command (NAVAIR), serves as the technology advocate for high power microwave (HPM) and high energy laser (HEL) weapons with the Office of Naval Research.

NAWCWD – The Place to Test Directed Energy!

With land ranges larger than the state of Rhode Island, the world’s largest sea range, 36 major facilities including six uniquely suited for directed energy projects, NAWCWD is the place for directed energy testing.

Directed Energy Projects. Significant HPM and HEL testing has included fiber and pulse lasers, laser architecture support beam control, microwave radiation emitters, and diode pumps.

- **Atmospheric Characterization.** In 2008, NAWCWD began developing the Differential Image Motion Monitor (DIMM) that measures path turbulence. In 2012, a Wide Angle Telescopic Transmissiometer (WATT) was developed that measures path transmission loss using a common optical reference. Ongoing developments with Dahlgren include a new Non-coherent Extended Source Beacon (NESB).
- **New antennas.** Developing new and easier methods to fabricate wideband high-voltage antennas
- **New connectors / modules.** Developed and manufactured a new, custom high-power radio frequency (HPRF) connector that was one-fifth the cost of a commercial unit. Designed and built solid state HPRF modules which outperform magnetrons 100 times larger and heavier.
- **Airborne Direct energy kill sequence.** During one test, a laser system shot down six drone aircraft over the Land Ranges. In another test, a laser weapon system successfully tracked, engaged, and destroyed a drone in flight during a test at San Nicolas Island. In 2009 the Airborne Laser (ABL) conducted numerous milestone tests off of San Nicolas Island, simulating a directed energy kill sequence against an instrumented boosting missile target using three onboard low-power lasers.
- **S&T for Tactical Aviation.** Work includes HEL atmospheric propagation of laser beams, laser source developments in fiber lasers and beam control & aimpoint maintenance.



High Power Authority. NAWCWD has authority to operate up to the highest levels allowed on DoD ranges: 1 MW for HEL and 200 PW for HPRF (frequency dependent). Very few DoD facilities allow HEL weapons to be fired over the horizon including China Lake, Point Mugu, and White Sands. Ranges can maintain an exclusion zone of 19+ miles for aircraft testing over land.

Environmental Requirements in Place. Full documentation now supports HEL and HPRF testing. A certified DON laser safety specialist coordinate with the Laser Clearing House. HPM systems include narrow band, wide band, and ultra wide band.

Unique Facilities Specifically Suited for Directed Energy T&E. Detailed factsheets on the following 6 facilities, as well as all 36 major facilities at NAWCWD can be found on the public site at: navair.navy.mil/navcwwd/

Weapons Survivability Laboratory (WSL). WSL is the largest live fire test and evaluation (LFT&E) facility in the world and serves as the national aviation weapons survivability and lethality location for the US Air Force and US Navy. It is the only facility with three High-Velocity Airflow Systems (HIVASs) generating flight representative airflow to aircraft. Multiple airflow capabilities exist for both kinetic and directed energy T&E. Additional T&E capability includes a hostile fire indicator (HFI) test facility.



Junction Ranch. Due to its remote location, surrounded by mountains, this maximum security facility provides a perfect venue for highly sensitive directed energy T&E. There is a minimum level of spurious electromagnetic interference ensuring the highest data quality possible. Routine testing includes radar cross section and microwave measurement. Features a Look Down facility at over 8,200 MSL with 10 and 17 degree slant angles to test sites.

Thermal Dynamics Test Facility (T-Range). Conducts R&D testing of air-breathing engines, liquid rocket engines, and solid rocket transition to liquid propulsion systems and subcomponents. T-Range has performed many directed energy tests using high-energy lasers to understand and quantify missile component vulnerability.



Missile Engagement Simulation Arena (MESA). This huge facility, secure and highly instrumented, is a perfect indoor venue for DE testing. Measuring 84,190 square feet, 90 feet high by 405 feet long x 150 feet wide it is used to measure the electromagnetic interaction of a sensory system (fuze or guidance) with its intended target. It provides cost-effective, timely, and accurate dynamic missile engagement test data. Missile fuzes are tested against various targets, including full-scale aircraft.

Supersonic Naval Ordnance Research Track (SNORT). Four mile long, dual-rail, precision-alignment track that tests rockets, guided missiles, model and full-scale aircraft, and components under free flight conditions at velocities from subsonic through supersonic. Second longest and fastest sled track in the world. Capable of reaching speeds up to 6,000 feet per second. Frequently used for DE atmospheric characterization/validation testing.



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San Nicolas Island (SNI). SNI, 60 miles south of Point Mugu, is regularly used for laser and DE testing. NAWCWD also participates with Port Hueneme who has the Self Defense Test Ship (SDTS) that hosts laser systems and DE testing. The ship provides an at-sea, remotely controlled, T&E platform for conducting advanced combat systems and weapons evaluation. SNI supports a wide variety of T&E and training operations including surface-to-air, surface-to-surface, air-to-air, air-to-surface, missile defense, fleet training, and large-scale complex warfare exercises.

Proven experience with HEL and HPRF T&E – Land & Sea Environments

- **HEL T&E:** Airborne Laser lab / high energy laser damage effects • Above-horizon laser engagement capability • Black Dart Demonstration • Laser Weapon System (LaWS) demonstrations
- **HPRF T&E:** RF weapon survivability testing • GPS jamming testing since the early 1990s • Commercial infrastructure and OSD testing • Active denial and pulsed RF emitter systems • Tested 10TW ultra HPM system in 2011 • Spectral topographical range mapping to characterize containment of RF energy • Tested 1.1kW 30MHz system • Demonstrated HPM non-linear transmission line (NLT) system



High-Energy Lasers (HEL). HEL weapons are intended to damage or destroy enemy systems. These weapons may be integrated onto land, aircraft, and ship platforms and will be used to enhance area defense, aircraft self-protection, strategic and tactical missile defense, and precision strike. HEL weapons remain focused over a great distance, thus providing significantly more energy on a target. Types of HEL systems anticipated for testing at NAWCWD include solid state, fiber, and carbon dioxide (CO₂). Power levels are expected up to and including megawatt class, and wavelengths will range from nanometers to micrometers.

High-Power Microwave (HPM). These counter-electronics systems, which operate across a broad range of the microwave frequencies, are typically characterized as having a short, intense energy pulse that can yield relatively high voltage surges in targeted electronics.



Testing Non-lethal HPM Systems. NAWCWD is testing systems that operate at relatively high frequencies causing discomfort, but the effects are non-lethal. HPM weapons may be integrated onto land, aircraft, and ship platforms and will be used to enhance both counter-electronic and non-lethal anti-personnel capabilities. Types of HPM systems anticipated for testing at NAWCWD include, but are not limited to, narrowband, wideband, and ultra wideband.

Operational Characteristics of Directed Energy Systems. Testing of DE systems will support the ongoing development of non-kinetic weapons in response to theater requirements. HEL and HPM testing would include air-to-air, air-to-ground, surface-to-air, surface-to-surface, and electromagnetic scenarios as well as static tests. HEL and HPM safety protocols are in place.

NAWCWD Specific Projects and Initiatives 2015-2016

Weapons

- Compact 2.5 Billion Watt Man-Portable HPRF Vehicle Stopper
- HPRF Vessel Stopping Bomb Demonstrator
- UAS Hosted HPRF Electronic Attack Demonstrator

Weapon Systems Simulators

- Weapon-Class Laser Weapon Simulator
- Passive Wavefront Sensing for HEL application

Antenna Development

- Half-parabolic Impulse Radiating Antenna (HIRA)
- Wideband Monopole Antenna with Reflector Dish for Impulse HPRF
- Helical Antenna Design for HPRF System
- Compact, Conformal, Collapsible Antennas

Analysis, Modeling and Simulation

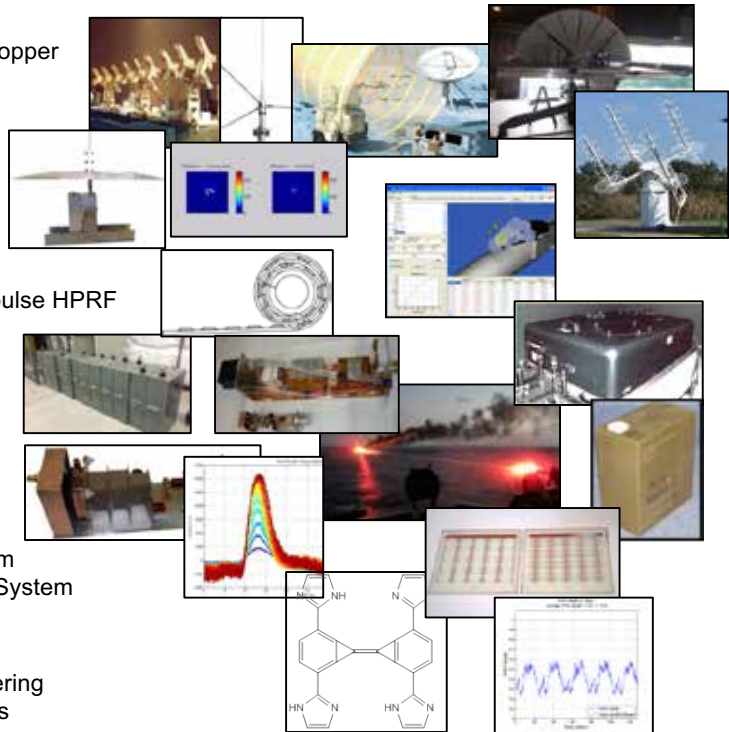
- High Energy Laser Mission Utility Assessment Modeling

Systems, Components

- 100+ MW High Power Radio Frequency (HPRF) Module
- Compact HPRF Power Combiner
- Temperature Stabilization for Man-Portable HPRF System
- Battery Powered Power Supply for Man-Portable HPRF System
- Higher Frequency Power Semiconductors

Counter Directed Energy

- Polymers: Multi-functional Reflective Coatings for Countering High Power Microwave (HPM)-Directed Energy Weapons
- Disposable Electric Field Intensity Indicator



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Labs and Academia



Sandia is a multidisciplinary national laboratory and federally funded research and development center (FFRDC) for the National Nuclear Security Administration. Sandia also supports the warfighter by accelerating the development of innovative systems, sensors, and technologies for the national security community. We provide technical solutions for global security; engineering and integrating advanced science and technology to help defend and protect the United States. We partner with the DoD, other federal agencies, and highly qualified industry and university partners to accomplish our missions.

Sandia National Laboratories is a world leader in pulsed power science and technology. Sandia has decades of experience in directed energy research for National Security with expertise in Compact Pulsed Power System Design, High Power Electromagnetics, Modeling and Simulation, Semiconductor RF/Optoelectronic and Microelectronic Circuit Design, Effects Testing, Laser Applications, Materials Development and Characterization, Microsystems & Engineering Sciences Applications, and Sensor & Systems Exploitation.



Directed Energy Laser Applications

Sandia's Directed Energy Laser Applications Department specializes in research, development and applications in nonlinear optical and laser phenomena, high-voltage technology, and electrical breakdown phenomena.

- Fundamental theory
- Laboratory experiments
- Modeling and simulation
- Field experiments

▼ Contact:

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HPEM Technologies

- Development of Compact Sources, Drivers, and Components
- Modeling from Components through Engagements
- Weaponization of Technology Pathfinders



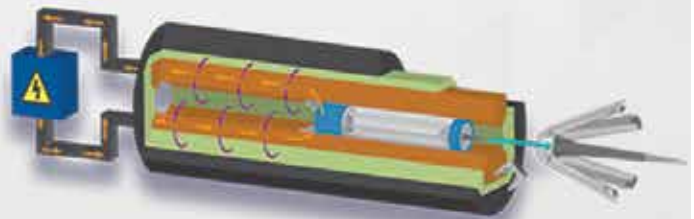
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Electromagnetic Launch Technology

- Developing railgun and coilgun technology
- Projectile and payload/warhead development
- Performance and inbore effects modeling and measurement
- Materials assessments and development



Contact:

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Manager, Electromagnetic Launch Systems
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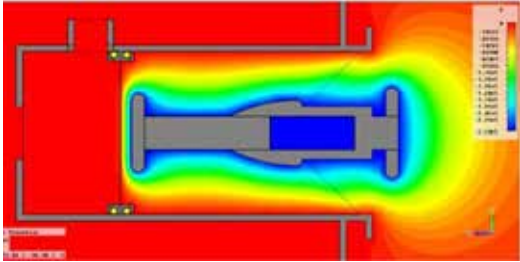




**Center for Physical
and Power Electronics**
University of Missouri

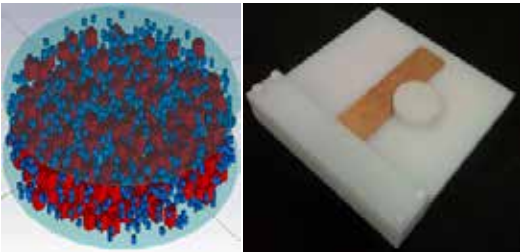
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Directed Energy



The Center for Physical and Power Electronics strategically solves complex problems in the areas of directed energy, high-voltage materials, plasmas, laser applications, high power antennas, applied electromagnetics and translational medicine. Our focus is rapid development of solutions for our customers and demonstration of prototypes.

High-voltage materials



Our team consists of former industrial, Department of Defense, Department of Energy and aerospace engineers, as well as academic teams of engineers, physicists, chemists, material scientists, doctors and veterinarians.

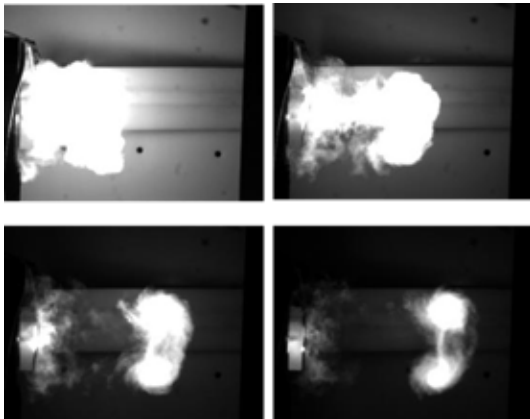
**High Powered Antennas and
Applied Electromagnetics**



We are an integrated team that can deliver solutions to complex problems.

In academia, we are recognized as one of the top two leaders in the research and development of directed energy applications, new high-voltage materials, compact high power antennas, and plasmas.

Plasmas



With more than 17,500 square feet of high-bay test area, radiation rooms and anechoic chambers, we can rapidly test solutions. Our approach to problem solving utilizes 3D electromagnetic computations, and the development of prototypes to be tested in our laboratories or the field.

**Laser and Nuclear Pumped
Applications**



CPPE's Anechoic Chamber Wall

Industry Partners





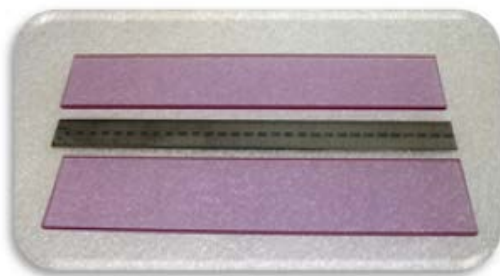
II-VI OPTICAL SYSTEMS

Materials That Matter

II-VI Optical Systems (II-VI OS) produces Materials, Optical Assemblies and Laser Sub-assemblies to support Laser, EO and IR requirements. II-VI OS designs, manufactures, coats, integrates and tests precision laser sub-assemblies, optical systems and components. Our products support all of the DoD Prime Contractors and are deployed with these customers' products on military platforms for all branches of the DoD.



II-VI Optical Systems has grown over the years from a producer of specialty optical materials including Sapphire and Diamond Windows to a full service provider of engineered solutions including optical sub-assemblies such as SiC Beam Expander Telescopes. We have a Laser Materials Foundry producing YAG and YLF and we have a Ceramic YAG facility producing Ceramic YAG components. We established a DoD laser diode manufacturing capability in California to address our customers' emerging needs domestically. We are tailoring laser diodes for the unique needs of military solid state lasers that are matched to high performance gain media and coatings used inside HEL laser systems.

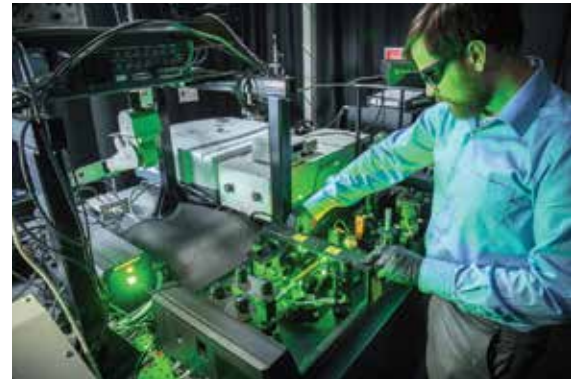
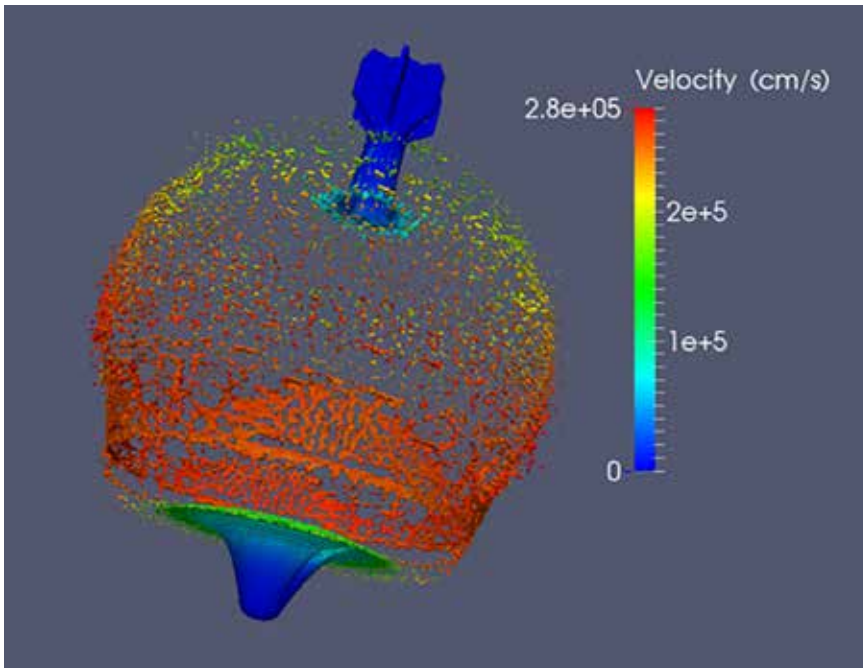


Regardless of the type of laser or optical system, II-VI Optical Systems stands ready to support customer requirements through all TRL levels and into production. Hard-ware: Laser Diode Stacks, SiC Beam Expanders, Sapphire and Diamond Windows, YAG, YLF, Ceramic YAG HEL Coatings.

II-VI Optical Systems

Murrieta, California - Tustin, California - Port Richey, Florida - Philadelphia, Pennsylvania
www.opticalsystems.com - Dennis Lehan (978) 509-5001 or dennis.lehan@ii-vi.com

DIRECTED ENERGY WEAPONS (DEW)



ARA offers advanced directed energy weapons solutions to support our warfighters including:

- Small, high power laser weapons creating counter-material, counter-drone and explosive ordnance disposal (EOD) solutions
- System engineering support to advanced laser weapon architectures and system concepts
- Advanced laser technologies and counter high energy laser (HEL) approaches to protect our warfighters
- High power, frequency selective surface (FSS) radome technology for high power microwave (HPM) weapons
- HPM propagation including atmospheric, structure penetration and coupling effects
- Integrated Weapon Environment for Analysis (IWEA) including DEW tools for mission and lethality analysis



Applied Research Associates (ARA)
Joseph Paranto • 505-883-3636 • jparanto@ara.com

NON-LETHAL WEAPONS (NLW)



ARA provides research and development support for non-lethal weapons systems including:

- **Electrical Stimulus-Based Disabling Technology**
- **Active Denial Technology**
- **Blunt Impact Technologies**
- **Laser Technology**
- **High Power RF / Microwaves**
- **Sound and Light – Testing our prototype Non-Pyrotechnic Diversionary Devices (NPDD)**
- **Other Counter-Personnel Technologies**
- **Other Counter-Materiel**
- **Human Effects - Investigating health effects from muscular incapacitation (HEMI)**

June 26, 2017: ARA awarded contract N00174-17-D-0032 to compete for task orders under a U.S. Navy contract to provide research and development support for non-lethal weapons systems across a range of capability functional and technology areas.

Applied Research Associates (ARA)

Barry Coceano • 703-412-9425 • bcoceano@ara.com



Providing key enabling solutions for directed energy systems.

Laser Communications Systems

High Energy Laser Systems

Applied Technology Associates (ATA), in business since 1975, is a precision measurement, sensing and controls company providing services and products to government and commercial customers. ATA has demonstrated a remarkable ability to transition technology to operational use and commercial products by leveraging internal and government funded research and development. Our products and services span ground, air, and space applications. ATA has 40 years of experience developing innovative technologies and solutions for advanced optical, electro-optical, sensors, lasers, and space flight systems. ATA is at the forefront of line of sight stabilization (LOSS) architectures and component solutions. ATA is a market leader in integrated beam control, pointing control / tracking, image processing systems, and free space optical communications technologies and demonstrations.

LASER WEAPON SYSTEM / FIRE CONTROL



ATA develops highly reliable, modular, low-SWaP, and low-cost processing electronics and software that process and control the entire suite of high-energy laser weapon system (HELWS) components and subsystems, including beam director and beam control, laser device, power and thermal management, fire control and target tracking. In addition to small SWaP, we achieve key improvements in modularity, diagnostics, and distributed safety.

TRACKING AND AIMPOINT MAINTENANCE



ATA develops field-proven target tracking systems that achieve real-time acquisition and fine tracking and aimpoint maintenance with lower tracking jitter, reduced aimpoint drift, and longer operating range than current systems. Our architecture offers reductions in size, weight, and power, and cost (SWaP-C) and the hardware and software are modular, enabling reuse across different laser weapon programs and services.

BEAM CONTROL SOLUTIONS



Beam stabilization technology forms the backbone of a beam control system, and ATA is at the forefront of stabilization architectures and component technologies. ATA supports the full range of beam stabilization architectures and is an innovator, designing and manufacturing the enabling inertial sensors, optical inertial reference units, and fast steering mirrors for directed energy systems.

www.atacorp.com

ATA *Applied Technology Associates*

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Leading the development
of **advanced technologies**
for our military

Electric Energy weapons will be a game changer in future combat engagements. BAE Systems is at the forefront of this revolutionary technology with initiatives including our Electromagnetic Railgun, the Mk 38 Tactical Laser System, and a solid state High Powered Microwave System, bringing Electric Weapons directly to our warfighters. Our remarkable successes with Pulse Power Generation Systems for the EMRG program are enabling high-power-demanding electric weapons and represent significant capability advances for the U.S. military.

We're extending range, increasing effects on target, and reducing costs.
That's what we call a win-win-win.

www.baesystems.com

BAE SYSTEMS

INSPIRED WORK



High Energy Laser Weapons Precision Engagement for the Warfighter



Stryker Mobile Expeditionary High Energy Laser



*HELMTT
High Energy Laser Mobile Test Truck*

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*Compact Laser Weapon System
portable configuration*

Legacy of Expertise

For more than 20 years, Boeing and its legacy companies have extensively developed directed energy technologies, creating solutions ranging from Compact and Tactical Laser Weapon Systems, to Strategic Laser Systems for missile defense. Directed Energy systems deny and defeat threats with precision. With a low cost-per-shot and an infinite magazine, Directed Energy systems are effective over land, air, and sea.

Boeing has expertise in a wide range of directed energy-related technologies, including:

- Beam control and scalable beam directors
- Lethal and non-lethal weapons
- Acquisition, tracking and pointing
- Space surveillance
- Relay systems
- Advanced sensing
- Real-time processing
- Electro-optical processing

Compact Laser Weapon System

The Compact Laser Weapon System (CLWS) is a modular, high energy laser (HEL) weapon system that can be operated as a stand-alone system, integrated on combat vehicles, or mounted onto a Containerized Weapon System. The CLWS can accommodate from 2 to 10 kW lasers and is ideal for the counter-UAS mission, in addition to C-ISR, special event and force protection. The Stryker MEHEL is a real-life example pairing a DE weapon with a tactical vehicle. Successful integration and demonstration on that vehicle in 2016 and 2017 performing the C-UAS and C-ISR missions proved that lasers are an effective, low-cost solution to countering the growing UAS threat.



Tactical Laser Weapon Modules

Boeing has proven HEL weapon systems integration experience on programs such as the Airborne Tactical Laser (ATL) and the U.S. Army's High Energy Laser Mobile Test Truck (HELMTT) – which has tracked and destroyed mortar rounds and unmanned aerial vehicles. Our Tactical Laser Weapons Modules can be integrated with 10 to 150 kW lasers for ground, maritime and airborne missions.



Strategic Systems

Boeing has done pioneering work in Strategic Laser Systems, demonstrating the viability of directed energy against missile threats on the Airborne Laser Test Bed. Boeing is committed to partnering with the Missile Defense Agency to advance the state-of-the-art in directed energy to keep allied forces secure against such threats.

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YOUR **ESSENTIAL** PARTNER

Booz Allen Hamilton offers a broad range of engineering capabilities, combining our deep understanding of our clients' missions and operating environments with an innovative mix of engineering skills, tools, facilities, and best-in-class technologies. Our directed energy (DE) team draws from Booz Allen's 3,000 well-rounded engineers and scientists, who are not only accomplished in their fields but also strong in other disciplines, including policy, business, and leadership. Booz Allen delivers high-quality services and solutions tailored to client objectives. Across technical areas and applications, our innovative approaches offer comprehensive capabilities throughout the development and deployment process to advance DE systems from concept to reality.

To find out more about how our people can help you drive your purpose and passion, visit [BoozAllen.com](https://www.BoozAllen.com).

Use of DoD image does not constitute or imply endorsement.

COMMITTED TO ADVANCING DIRECTED ENERGY SOLUTIONS

Booz Allen has established itself as an authoritative source for analysis, expertise, and solutions to accelerate the development, validation, fielding, and sustainment of operational directed energy (DE) systems. We are united with our clients in a relentless pursuit to address our nation's toughest problems with innovative and holistic solutions.

Booz Allen has been performing technical work in DE for 20 years, providing our science, engineering, and analytic expertise across the DE research and development lifecycle for both high-energy laser (HEL) and high-power microwave (HPM) technologies.

DE FUNCTIONAL AND DOMAIN EXPERTISE

HPM Prototyping and Demonstration

Design, development, test, and evaluation of sources, supporting subsystems, and prototype weapons

HEL Development and Deployment

Performing subsystem selection; integration; deployment; and operational test, evaluation, and support

DE System and Target Modeling and Simulation

Modeling DE systems and engagements from the component to mission level

Source Characterization and Effects Testing

Identifying, characterizing, and evaluating DE sources and targets to guide technology maturation and system design

DE Systems Engineering, Integration, and Mission Analysis

Managing and incorporating requirements, interfaces, interoperability, operational utility, and documentation

Stakeholder Engagement and Thought Leadership

Fostering collaboration across stakeholders in government, industry, and academia to advance DE



About Booz Allen

Booz Allen Hamilton has been at the forefront of strategy, technology, and engineering for more than 100 years. Booz Allen partners with private and public sector clients to solve their most difficult challenges. To learn more, visit BoozAllen.com. (NYSE: BAH)

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LEADING & INNOVATING TO ENABLE DIRECTED ENERGY

Whether scaling systems to a higher power or developing lightweight beam delivery systems, Coherent has robust photonic solutions for theater ready, real-world directed energy weapon applications.

From **Laser Diodes** to **Fiber Amplifiers**, **Custom Optics** to **Specialty Gain Mediums** and **Q-Switching Crystals**—Coherent delivers superior components for your directed energy systems—coherent.com/directed-energy



ADVANCING INNOVATIONS IN ELECTRIC WEAPON SYSTEMS

General Atomics Electromagnetic Systems (GA-EMS) technologies are designed to arm the future force with the capabilities necessary to counter existing and emerging threats.

HIGH ENERGY LASER WEAPON SYSTEMS

GA-EMS' advanced solid state High Energy Laser (HEL) Weapon Systems provide proven laser technologies to enable the detection, denial and defeat of an expanding range of unmanned vehicles, Intelligence, Surveillance & Reconnaissance (ISR) systems, rockets, artillery, mortars, and missile threats. GA-EMS HEL weapon systems offer significant power-on-target for shortened engagements and rapid retargeting, while lowering the cost per engagement with a deep magazine for offensive and defensive applications. The system's modular, scalable design also offers significant reductions in size, weight and power consumption for land, air and sea-based platforms.

- 75kW-class laser scalable to 150kW and larger
- Good beam quality for Gen 3, 4
- Efficient thermal management
- Extended target engagement ranges
- Complete azimuthal coverage
- Ruggedized with vibration and shock isolation
- Enhanced Intelligence, Surveillance & Reconnaissance (ISR) capabilities

MULTI-MISSION RAILGUN WEAPON SYSTEMS

GA-EMS is advancing the development of electromagnetic railgun weapon systems to support integrated air and missile defense, counter battery fire, and precision indirect fire, providing greater flexibility for future Navy and Army applications. GA-EMS railgun weapon systems integrates high energy density pulsed power, a launcher, and a weapon fire control system to launch projectiles at a high muzzle velocity, leading to shortened engagement times, rapid defeat of threats, and longer range.

- High firing rates enable engagements of simultaneous multiple threats
- Compact form factor enables mobile IAMD warfare
- Electromagnetic launch eliminates explosives and propellants
- High capacity (deep magazine) and low engagement cost
- Scalable pulsed power technology to reduce overall system footprint

HIGH POWER MICROWAVE TECHNOLOGIES

GA-EMS is leading the research, development and demonstration of high energy density capacitor technologies, pulsed power modules, and integrated pulse power containers that enable more powerful, compact system designs. GA-EMS is advancing high power microwave and electromagnetic railgun weapon systems to support next generation tactical land and sea-based platforms.



Learn more at www.ga.com/ems





DIRECTED ENERGY. WHERE IT COUNTS.

General Atomics Electromagnetic Systems is transforming innovative concepts into breakthrough electric weapon systems to support the future warfighting force.

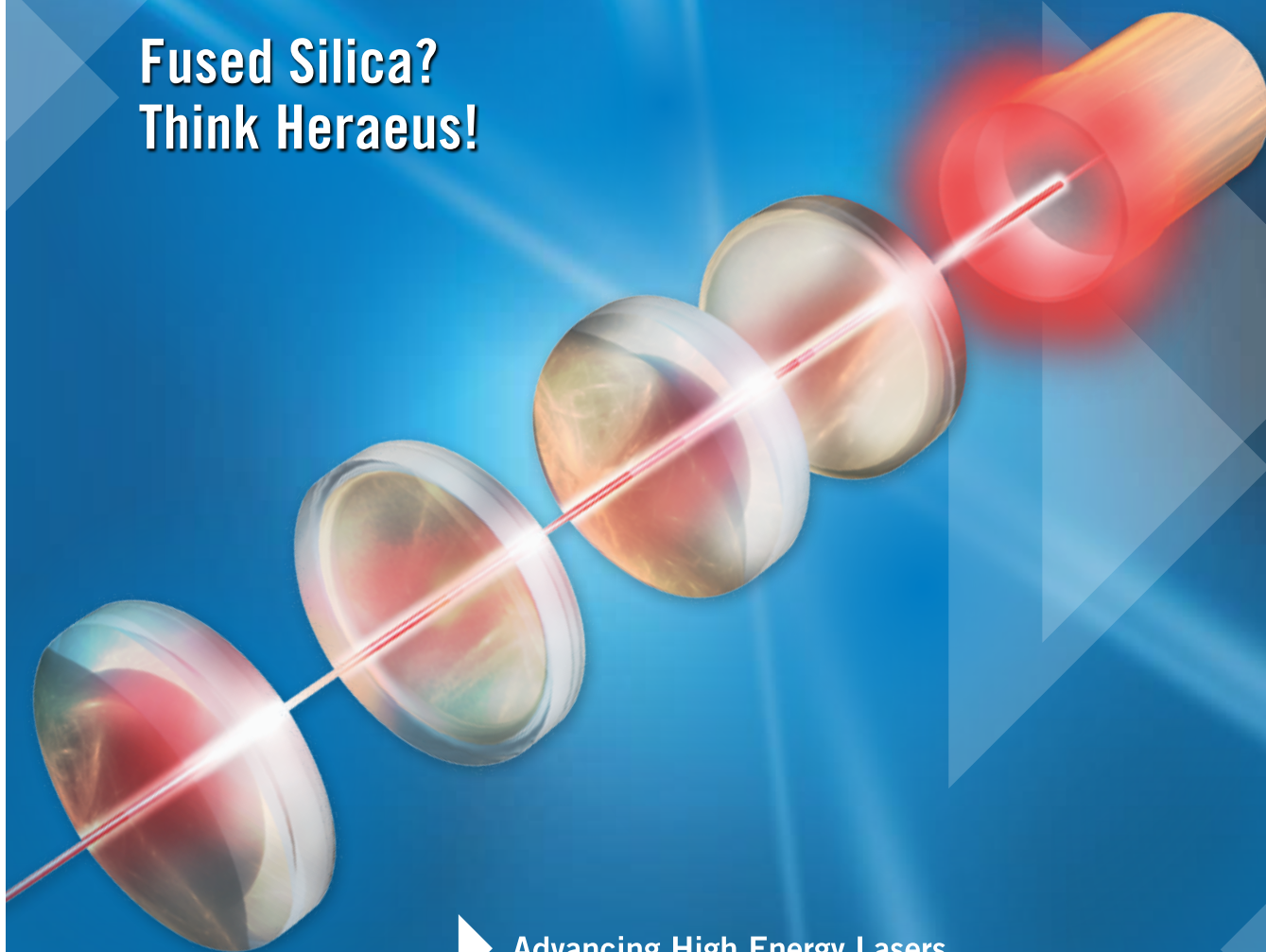
From flexible High Energy Laser (HEL) weapon systems and High Power Microwave (HPM) technologies, to electromagnetic railgun systems, our portfolio of multi-mission directed energy solutions provide the precision, range, speed and power to efficiently and effectively defend against a growing range of complex threats from the land, sea, and in the air.

Learn more at www.ga.com/ems





Fused Silica? Think Heraeus!



Advancing High Energy Lasers

Your reliable partner with commercial off-the-shelf high-volume fused silica production

High power lasers:

- optimized fused silica from UV to near IR
- laser transmission fiber
- active laser fibers

Highest power NIR Laser Optics:

- low absorption
- large size homogeneous fused silica



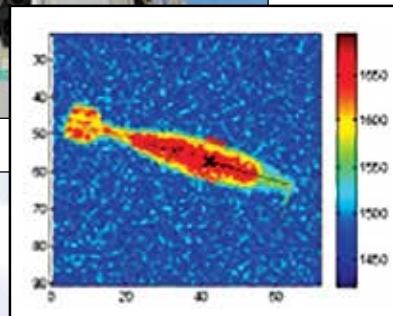
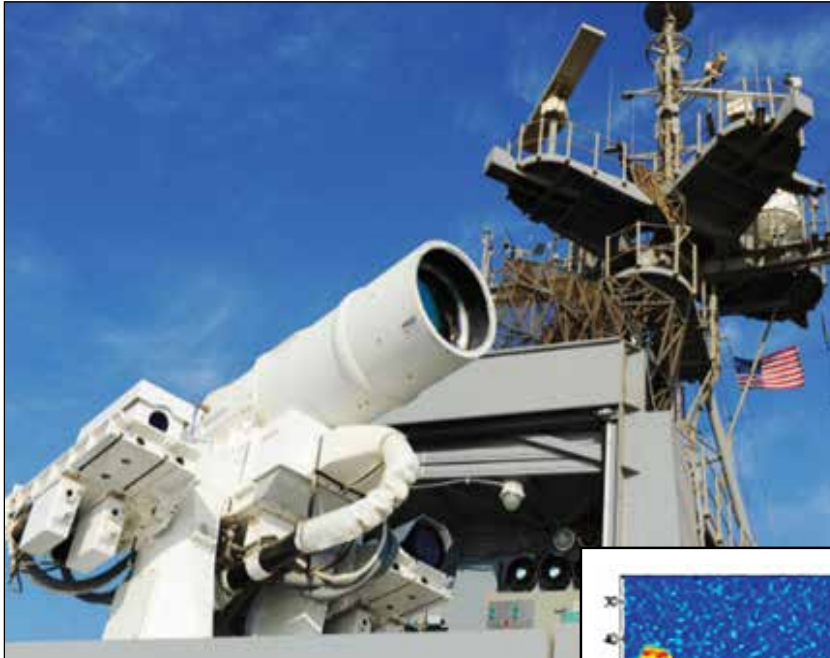
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sales.hqs.optics.us@heraeus.com

Specialty Fiber USA
Heraeus Tenevo LLC.
30518 Buford, Georgia
fiber-optic-sales-us@heraeus.com



Brashear



L3 Brashear is the premier provider of beam director assemblies for High Energy Laser (HEL), laser weapon components and controls for all branches of the U.S. Department of Defense (DoD). In the air, on land and at sea, L3 is proud to support the defense and protection of our warfighters. Our laser weapon systems have supported successful and extended demonstrations, including U.S. Navy deployment of the Sailor-operated LaWS in the Persian Gulf area.

The beam director is the “gun” that shoots the laser “bullet.” It is the ruggedized optical system that stabilizes the laser beam and keeps it on the moving target, significantly reducing down time and increasing lethality. Within the past year, L3 Brashear supports several HEL programs that are advancing the state-of-the-art for precision engagement weapon systems on multiple platforms up-to megawatt class lasers.

Scan /Detect

ID

Laser Beam Directors

Protection for our Warfighters



Protecting our warfighters and critical assets from inbound threats:

- Mortars
- Small boats
- Rockets & missiles
- Unexploded ordnance
- Long range rockets
- Artillery
- UASs
- IEDs



For more info:
L3 Brashear
615 Epsilon Drive
Pittsburgh, PA 15238
412.967.7700
Sales.Brashear@L3T.com

Engage

Defeat

2108 DEFS program

High Energy Laser Systems for Directed Energy & Emerging Applications

Directed Energy Potential

“Light speed” weaponry is a key component of the Department of Defense’s Third Offset Strategy, which seeks to develop long-range methods to counter adversarial threats. Laser-based systems are ideal for countering modern-day threats, as they offer very low consumable costs while also offering greater speed and range compared to conventional ballistic weapons.

Specifically, laser systems:

- Provide virtually instant target engagement
- Have low cost per shot
- Achieve highly focused damage on specific areas of a target for precision targeting

The successful integration of the Laser Weapon System (LaWS) aboard the USS Ponce has proven that directed energy is a viable defensive technology. The depth of applications for laser-based directed energy systems is extensive and includes anti-UAV, small ship deterrent, and missile defense. Each application and platform represents unique challenges and a wide range of performance requirements. The optical output power demanded can range from 10’s of kilowatts for counter-UAV applications to megawatts of power for intercontinental ballistic missile defense kill lasers.

Several laser technologies are being studied for scalability and deployability in the multitude of platforms that might serve as a home for directed energy weapons. Fiber lasers, solid state and hybrid (DPAL) lasers, among others, are being researched and developed by defense and industry partners. All of these lasers have one commonality: they use semiconductor laser diodes as pump sources.



Power scaling is not the only technical challenge in directed energy lasers. Weight and volume restrictions are of paramount importance for airborne applications such as the F-35 Joint Strike Fighter, AC-130 gunship, and lasers mounted on unmanned aerial vehicles. The US Department of Defense and DARPA are actively researching methods to drastically decrease the current weight/power ratio and volume of pump diodes for directed energy lasers.

Diode Pump Sources for Directed Energy Lasers

Due to the thousands of pump diodes required for directed energy laser systems, it is essential to develop and optimize the laser diode pump sources. Pump sources are the single largest contributors to the size, weight and costs of these systems.

The performance challenges on the diode pump sources are significant. In addition to power scaling, designers are under significant pressure to miniaturize and reduce the weight of these diodes as well as greatly increase their brightness and efficiency.

Key laser diode performance parameters include:

- Operation at temperatures ranging from -40°C to +80°C and beyond
- Maintaining brightness of the pump diodes as laser systems scale up in power
- Physical size and weight reduction
- Improving optical conversion efficiency
- Reducing complexity of optical systems
- Minimizing demands on the external power supply

Lasertel has been working tirelessly to meet and exceed these performance metrics.

Laser Diode Bars

With wavelengths available from 760nm to 1700nm, the semiconductor laser diode bar (1cm) is the most basic element of the system. A variety of cavity lengths and fill factors can be chosen to optimize for performance. Typically, electrical-to-optical efficiencies >60% can be achieved. Both high average power and high peak power laser diode bars are available.

Laser Packaging

Lasertel's T6 package is a heat sink building block used to deliver very high power to the laser diode bars while also efficiently maintaining operation temperature. The T6 uses high performance heat sink materials that are expansion matched to minimize thermally induced mechanical stress. Up to 50 individual diode bars can be mounted on each T6. The small form factor and back-mounted mechanical and cooling fluid interfaces allow for multiple devices to be stacked in very close proximity, enabling megawatt-level scalability while maintain brightness. This package has been qualified for harsh MIL environments including airborne qualified systems.

Beam Shaping and Collimation

A high degree of beam collimation is needed to focus and shape the light into the desired form factor needed for pumping or direct diode illumination. To minimize the physical footprint and weight of the device, it is advantageous to perform this collimation at a micro optic level. The T6 package allows for the addition of fast and slow-axis lenses, as well as more advanced optics that correct for smile and pointing errors, all of which can be attached directly to the laser diode package. These optics are attached using a proprietary process that provides extreme physical ruggedness and maintains alignment over large temperature ranges. Additional beam shaping and focusing can be added to provide a well-conditioned, homogenized output beam. Designs have been developed for coupling the light into a delivery fiber, direct coupling into a solid state rod or slab or directly on target.

Scalability

Scaling power is essential for directed energy systems. Lasertel manufactures systems capable of megawatts of power with a common coolant and electrical manifold. These laser diode systems have provided brightness over 11kW/cm² and total powers over 1 Megawatt per unit.



T6

Fluid Cooled Laser Diode Array

- Scalable building block
- Reliable in harsh environments
- Advanced beam conditioning



Megawatt

Collaborative research with LLNL proves T6 scalable density.



Applied Technology, Advanced Solutions

At Leidos, we have a history of performance excellence built on a culture of innovation. Our diverse and talented employees turn information into insight, delivering answers to our customers that help protect and enrich lives around the world. Looking beyond the limitations of today, we deliver innovative solutions and services that matter most for tomorrow.

Key Stats Reston, Virginia

Headquarters
32,000+/-
employees worldwide
\$10B
annual revenue

\$3.9B Defense & Intelligence	\$1.2B Advanced Solutions
\$3.6B Civil	\$1.7B Health

TECHNICAL CORE COMPETENCIES



**SENSORS,
COLLECTION, AND
PHENOMENOLOGY**



CYBER



**SYSTEMS
ENGINEERING AND
INTEGRATION**



**SOFTWARE
DEVELOPMENT**



DATA SCIENCE



**ENTERPRISE IT
MODERNIZATION**



**OPERATIONS
AND LOGISTICS**

THE MARKETS WE SERVE



ADVANCED SOLUTIONS

Conducts research and development across all markets to unlock potential scientific discoveries or improvements in technology, supporting C4ISR and data analytic requirements for our customers.



DEFENSE & INTELLIGENCE

Provides a diverse portfolio of systems, solutions, and services covering air, land, sea, space, and cyberspace for Defense and Intelligence customers worldwide.



CIVIL

Delivers a range of aviation systems and integration, complex logistics and infrastructure support, cybersecurity and analytics, facility and campus management and operations, energy engineering, environmental management, IT infrastructure modernization and transportation security solutions.

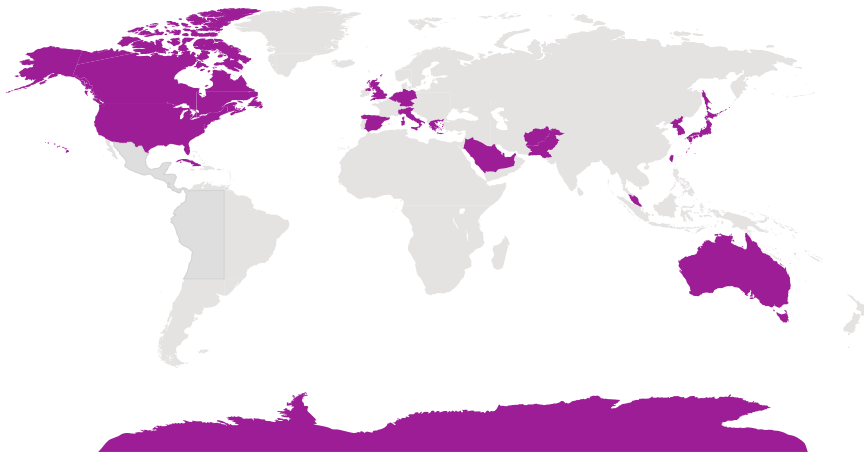


HEALTH

Offers services and solutions to federal and commercial clients, including IT services, population health risk management, case management, health analytics, life sciences, and public health.

EXPANDED GLOBAL FOOTPRINT

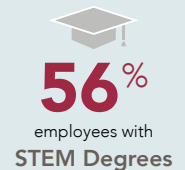
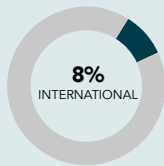
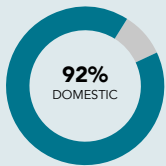
Leidos is well positioned for growth, with subject matter experts currently operating in 410 locations around the world, including more than 2,000 employees in international locations.



KEY LOCATIONS

Baltimore, MD	Afghanistan
Bethesda, MD	Antarctica
Columbia, MD	Australia
Frederick, MD	Canada
Gaithersburg, MD	Germany
Houston, TX	Japan
Orlando, FL	Korea
Reston, VA	Kuwait
Rockville, MD	Italy
San Diego, CA	United Arab Emirates
Washington, DC	United Kingdom

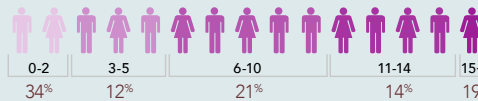
GLOBAL FOOTPRINT



CLEARED PROFESSIONALS



YEARS OF SERVICE



Roger A. Krone
CHIEF EXECUTIVE OFFICER

Roger A. Krone is Chairman and Chief Executive Officer of Leidos.

For Krone, the future of Leidos is one with a laser focus on its customers, shareholders, and employees. Under his strategic vision, the organization remains committed to investing in critical internal and customer research and development efforts. He is the driving force behind the company's culture of innovation, the environment shaped to inspire employees to create innovative technology solutions that respond to clients' challenges today and tomorrow.



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ADVANCED SOLUTIONS
GROUP



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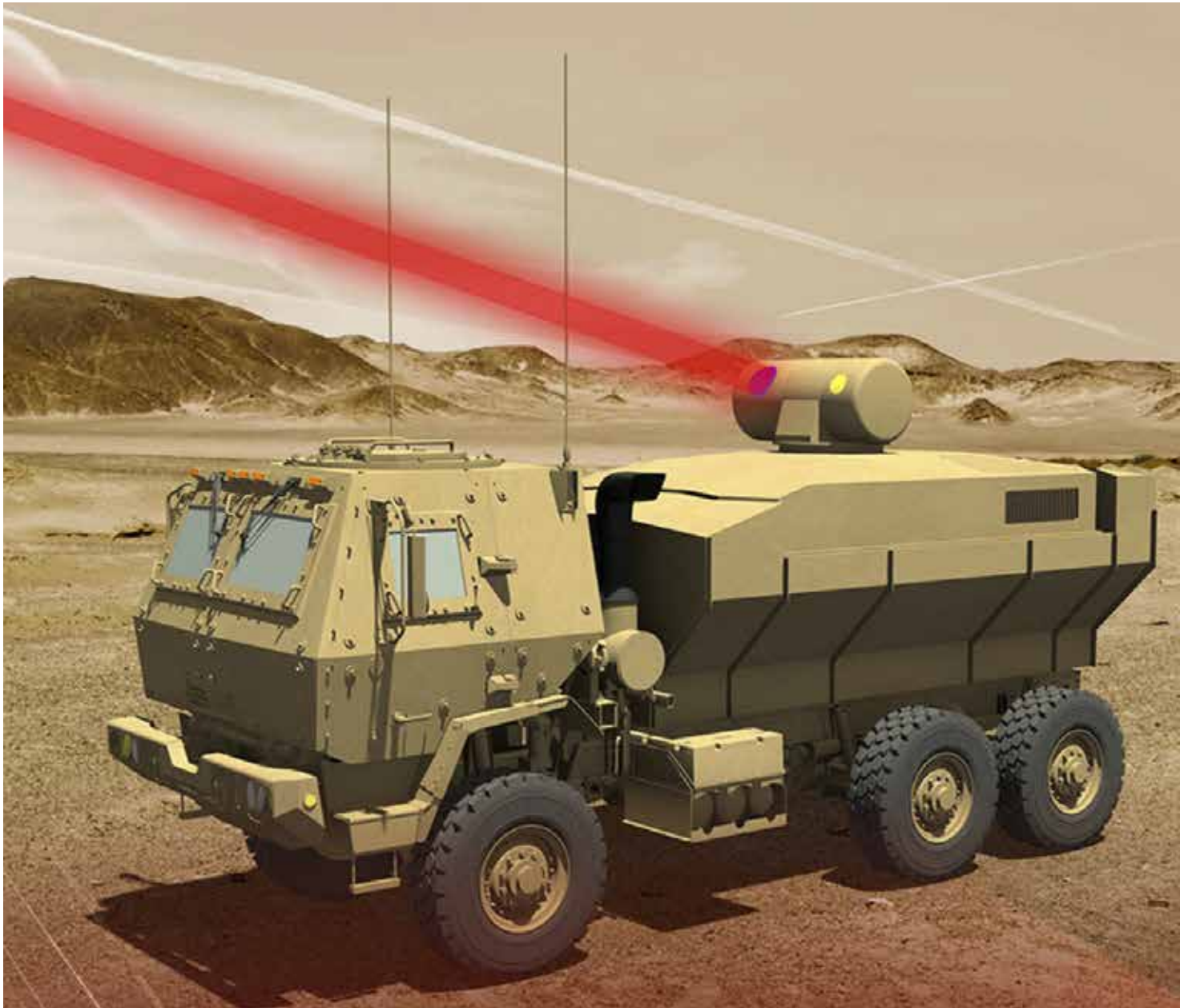
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ANY FEEDBACK FOR US?

We always want to hear from our customers and teammates
Contact Us Today leidos.com/contact



LASER WEAPON SYSTEMS

TURNING UP THE HEAT WITH SPEED-OF-LIGHT RESPONSE

LOCKHEED MARTIN
We never forget who we're working for®



LASER WEAPON SYSTEMS

Lockheed Martin has specialized in laser weapon system development for 40 years, with advancements in areas such as precision pointing and control, line-of-sight stabilization and adaptive optics – essential functions in harnessing and directing the power of a laser beam – and in compact, robust, spectrally beam-combined fiber laser devices that provide unmatched performance.

Lockheed Martin’s directed energy (DE) laser program draws upon our proven expertise across a broad range of capabilities, as well as our spirit of innovation. Our experience includes:

- The beam-control/fire-control system for a megawatt-class laser that destroyed a ballistic missile in flight
- High-power spectrally beam-combined fiber lasers that provide the most efficient conversion of platform prime power into lethal power on target
- Unique SWIR component capabilities that significantly extend the ISR (intelligence, surveillance, and reconnaissance) range of the DE laser system
- Widespread weapons-system and platform integration experience across all DoD services

REVOLUTIONARY TECHNOLOGY

Laser weapons are a revolutionary technology because of the advantages of speed, flexibility, precision and low cost per engagement that are only possible with lasers.

These advantages apply to stand-alone DE laser systems as well as to weapon systems that combine DE and kinetic energy capabilities. In these cases, DE operates as a force multiplier, enabling the warfighter to counter a growing range of emerging threats.

DE weapons are characterized by:

- Very deep magazine
- Extremely low cost per engagement
- Speed of light delivery

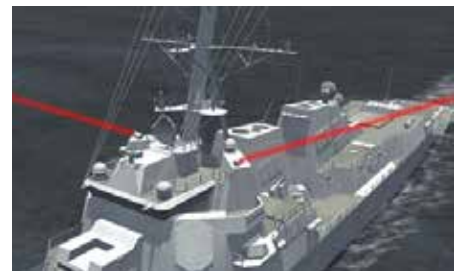
These strengths mean that they are well-suited to countering large numbers of inexpensive, highly maneuverable threats that might otherwise exhaust the magazines of our current defensive kinetic energy (KE) weapons. By using DE and KE weapons together, the warfighter will be able to neutralize emerging swarming threats while reserving our most capable kinetic weapons to defend against our adversaries’ largest and most hardened threats. DE weapon systems support multi-mission scenarios, and can be readily augmented by communications functions, as well as unprecedented intelligence, surveillance and reconnaissance range, and precision.



In addition, Lockheed Martin’s directed energy weapons bring some important and unique advantages to the warfighter:

- A robust and highly-maintainable laser architecture that is designed to minimize life-cycle cost and to maximize up-time

- Output laser power that can be rapidly adjusted between low and maximum power to support disrupt, disable, and destroy capabilities
- Highly parallel laser architecture that supports graceful degradation by eliminating almost all single points of failure



- Highest system efficiency demonstrated in any DE laser system; minimizing size weight and power requirements for DE platforms such as Army and Marine Corps ground vehicles, Navy DDG and LCS ships, and SOCOM AC-130
- Highest lethality laser to minimize engagement time



LOCKHEED MARTIN IS ADVANCING AND DEMONSTRATING A RANGE OF LASER WEAPON SYSTEM TECHNOLOGIES:

ADAM (Area Defense Anti-Munitions)



- Autonomous operations for rocket threats; accepts external sensor cue when required; capable of continuous operation
- Successfully engaged constrained and free-flying rockets, an unmanned aircraft systems (UAS) target in flight, and a small boat
- Affordable commercial-off-the-shelf (COTS) based system with very low cost-per-kill; deep magazine; scalable precision effects
- Capable of close-in defense (1-4 km)

ALADIN (Accelerated Laser Demonstration Initiative)



- 30-kilowatt laser made by combining many fiber lasers into a single, near-perfect-quality beam of light
- Uses approximately 50 percent less electricity than alternative solid-state laser technologies
- Spectral Beam Combining sends beams from multiple fiber laser modules, each with a unique wavelength, into a combiner that forms a single, powerful, high-quality beam

ATHENA (Advanced Test High Energy Asset)



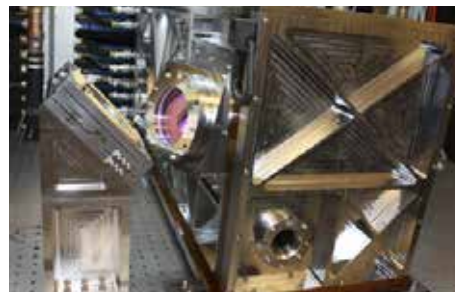
- Represents highest power level documented by a laser weapon system of this type, while retaining excellent beam quality and electrical efficiency
- First field testing of an integrated 30-kilowatt single-mode fiber laser weapon system prototype
- Uses the proven high-energy laser weapon system architecture from our ADAM system, and incorporates the 30-kilowatt ALADIN laser

ABC Turret (Aero-adaptive Aero-optic Beam Control)

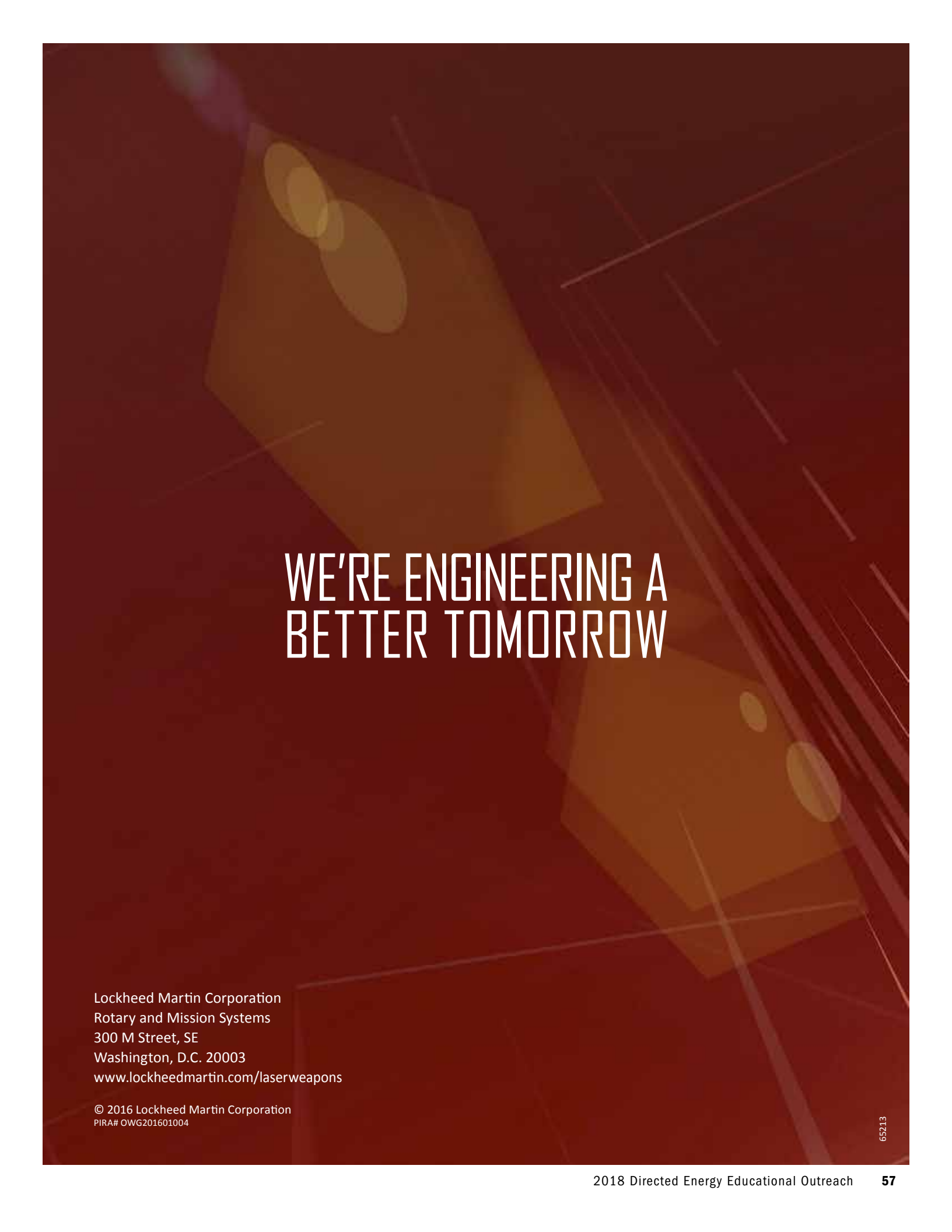


- Prototype turret with the ability to fire in any direction mounted on tactical aircraft
- First turret to demonstrate a 360-degree field of regard for laser weapon systems on an aircraft flying near the speed of sound
- Validated performance with nearly 60 flight tests conducted in 2014 and 2015 using a business jet as a low-cost flying test bed

RELI (Robust Electric Laser Initiative) for Army HELMTT (High Energy Laser Mobile Test Truck) Demonstrator



- Modular 60-kW laser in development for the U.S. Army
- Proven affordable weapon architecture that supports size, weight and power constraints for air, sea and land platforms
- Scalable design combines multiple kilowatt lasers to attain various weapon power levels
- Modularity results in a reliable and low maintenance laser system that minimizes single points of failure



WE'RE ENGINEERING A BETTER TOMORROW

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NanoElectromagnetics LLC

NanoEM - An Emerging Leader in Compact HPRF

From components to systems, NanoEM offers complete solutions

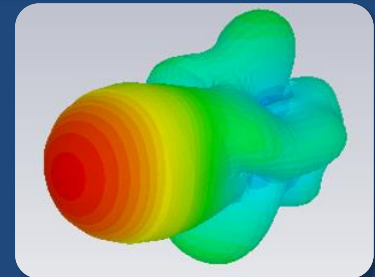
NanoElectromagnetics LLC (NanoEM) specializes in the custom development and production of compact high power antennas, high voltage capacitors, and integrated high power sources. By incorporating proprietary composite materials engineered at the nanoscale, NanoEM's components and systems provide significant advantages in performance, size, and weight in military directed energy systems.

HPRF Antennas

- Compact helical antenna arrays
 - Demonstrated order-of-magnitude reduction of volume and weight
- Dielectric-loaded waveguide feeds
- Low-profile dielectric resonators

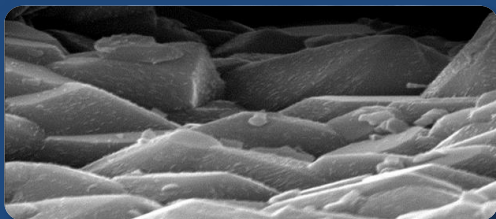
HPRF Sources

- High power RF capacitors
- High energy density capacitors
 - 10x energy density of HV ceramics
 - Custom shapes for tight packing
- High power solid-state switches
- Innovative RF synthesis



NanoEM provides a unique combination of DE development capabilities

NanoEM's dedicated research laboratory for high voltage materials and advanced EM modeling and simulation capabilities provide groundbreaking innovations in compact high power RF systems. NanoEM has the expertise and resources to rapidly design, model, prototype, and test the components and systems that will enable compact mobile DE systems to be fielded by the modern military.



Materials Development

- Patented composite materials
- Tunable properties for each application
- High voltage material characterization

3D Modeling and Simulation

- CST Studio Suite
 - Reduced development cost and risk
 - Fast transition to hardware validation

Start a conversation by contacting us:

Kevin O'Connor

OConnorKA@nanoelectromagnetics.com

573-882-3824



Maritime Laser Weapon Systems

Proven, capable, affordable

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN



Maritime Laser Weapon Systems

Naval Defense at the Speed of Light

Current and advanced threats create increasing operational challenges for the U.S. Navy and conventional defense systems. Traditional and irregular warfare threats – including swarming small boats, UAVs, enemy aircraft and anti-ship cruise missiles – are proliferating and growing more difficult to detect, track, engage, disable or destroy. To counter these threats, the fleet requires affordable countermeasures with operational flexibility and military superiority. Northrop Grumman high-energy laser systems have demonstrated their speed-of-light weapons capabilities and can provide the solutions warfighters need.

Maritime Laser Weapon System

The Maritime Laser Weapon Systems (MLWS) concept leverages solid state laser technology from years of research and proven laboratory demonstrations to create a near-term operational laser weapon with substantial payoff for the warfighter.

Northrop Grumman's solid state laser architecture allows for power levels scaling to the 100 kilowatt class, preserving good beam quality to defend ships from a wide variety of threats.

MLWS is a cost-effective weapon when compared with more traditional munitions, providing the combatant commander the option of using a low-cost- per-engagement laser weapon instead of expensive missiles with limited magazine against low-value targets.

Additionally, high resolution images provided by the stabilized, optical pointing and tracking system yield an extremely effective, multi-mission capability for situational awareness and intelligence, surveillance and reconnaissance missions at long ranges.

Northrop Grumman's recent record-breaking performance of concurrent electric laser power levels, beam quality, and run-time, combined with new compact, modular and rugged designs, solidify the technological readiness of solid-state laser weapons. With low cost per shot, deep magazine, and ultra-precision, Northrop Grumman high-energy lasers will help the U.S. Navy address current and future threats.



Laser weapon ship integration analyses have been performed to determine potential beam director and subsystem locations for DDG 51.



MLWS can be configured to defend against anti-ship missiles providing an ultra-precise, low cost-per-shot solution for U.S. Navy threats.

Northrop Grumman Laser Systems: Defense at the Speed of Light

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

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Nutronics is Leveraging Adaptive Optical (AO) System Technology to Accelerate Employment of Robust High Energy Laser Weapon System Technology

High-power Adaptive Directed Energy System (HADES)



HADES integrates the High Energy Laser (HEL) with the Beam Control System (BCS), reducing size, weight, and power of the HEL Weapon System.

HADES is a 25 kW-class HEL with high duty cycle and long run time with better beam quality for long range applications than alternatives.

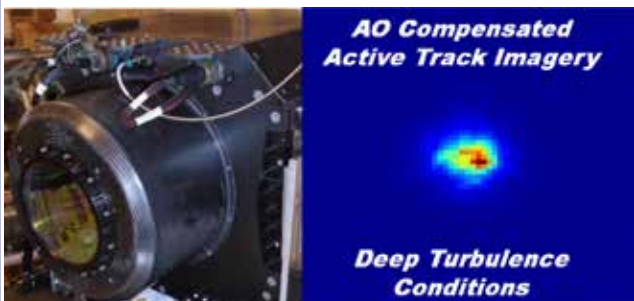
HADES further extends range with field-proven adaptive optics (AO).

HADES Tested at AFRL/RDL Environmental Laser Test Facility



Nutronics successfully conducted vibration and acoustic testing for multiple airborne platforms. HADES is the first HEL to complete rigorous vibration and acoustic testing.

Nutronics AO (NAO): Automated Low-SWaP AO & Tracking Systems



Field Proven Horizontal Path Deep Turbulence AO & Tracking with non-cooperative targets



Nutronics AO enhances turbulence robustness and increases HEL Weapon System range.

Nutronics, Inc. is a Small Business in Longmont CO; Phone: 303-530-2002
Email: jbarchers@naosystems.com

NUTRONICS

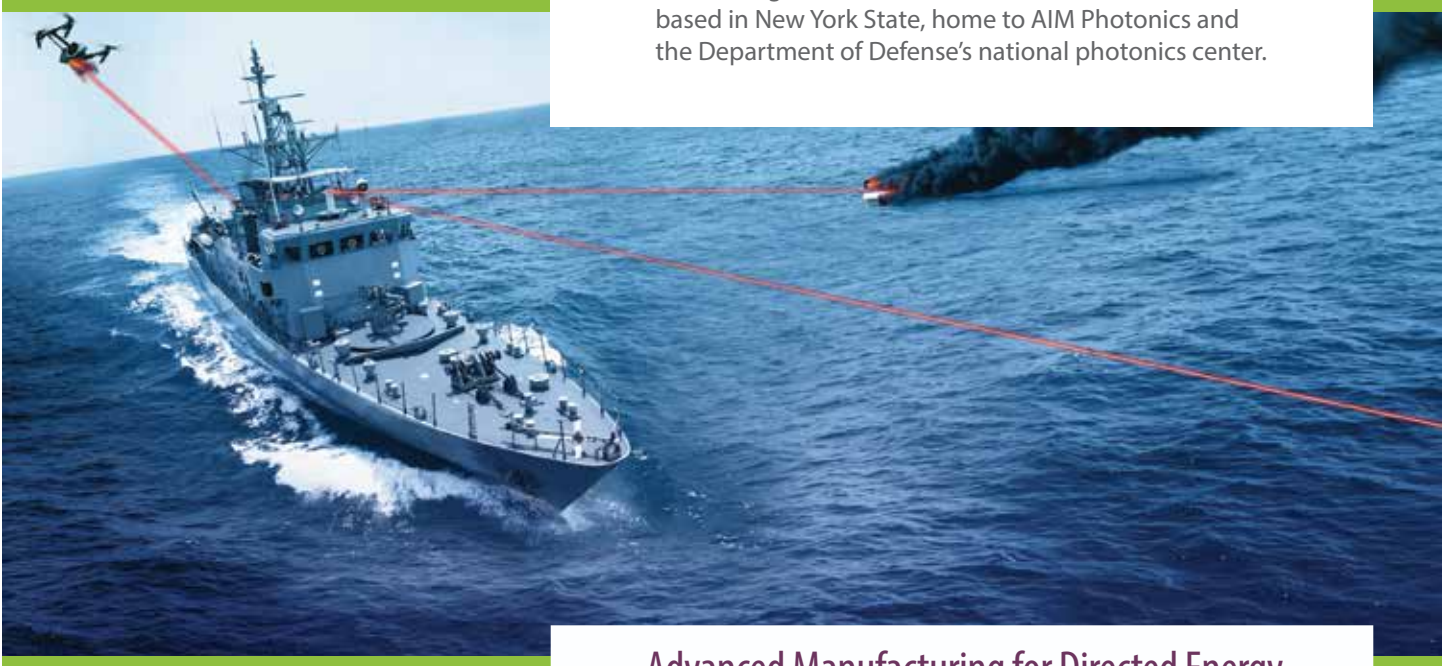
The future is NAO

www.naosystems.com

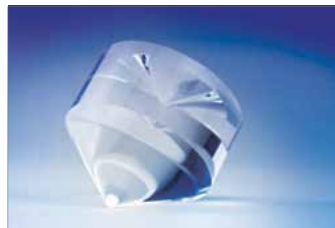


Creating Jobs In Directed Energy

Optimax, a precision optics manufacturer, is committed to enabling United States initiatives in defense. We are based in New York State, home to AIM Photonics and the Department of Defense's national photonics center.



Advanced Manufacturing for Directed Energy



High Power Laser Optics



Research & Development

Initiatives We Support



Directed Energy



C4ISR



National Ignition Facility*



Semiconductor Manufacturing



NASA Mars Rovers

CREATING JOBS IN US

Founded in 1991 • Ontario, NY • 300+ employees • 45 new hires in 2017
20% average annual growth • \$1M+ annual training investment

*Image © Lawrence Livermore National Laboratory/ Wikimedia Commons

RADIANCE TECHNOLOGIES

CONCEPTS TO CAPABILITIES



Radiance Technologies Inc. is a premier, employee-owned small business providing engineering, integration, testing, operational support, and technology and prototype development for military and intelligence communities.

Our business is organized into five groups which focus on Intelligence Analysis, Cyber Research, Technology Development, Operational Support, and Engineering Services where Radiance has built a strong capability in the High-Energy Laser (HEL) domain.

We are the lead integrator for the U.S. Army Space and Missile Defense Command's High Energy Laser Mobile Test Truck (HELMTT). We provide analysis, design, test, verification, and integration for the vehicles 50kW-class laser, beam control, C3, electrical power, and thermal subsystems. Radiance developed the HEL Integration Lab (HIL) for integration risk reduction, procedures development, and baseline performance measurements. Performance verification is conducted by static and dynamic tests in the HIL and at DoD test ranges.

Data and lessons learned from HELMTT are documented and folded into Radiance's extensive suite of models. We can model, simulate, and analyze the end-to-end HEL engagement from beam generation, through the beam train and atmosphere, and finally to the target, including target effects. New simulation software is being developed for Firing Doctrine and Battle Management algorithms to include development of a Software Integration Lab (SIL).

Radiance takes great pride in our successful track record of support to the DoD, armed services, intelligence agencies, and other government organizations and is proud to be a key member of the Army's HEL development efforts.

350 Wynn Drive | Huntsville, AL 35805 | (256) 704-3400 | www.radiancetech.com

EOE/Minorities/Females/Vet/Disabled

RT14/0052

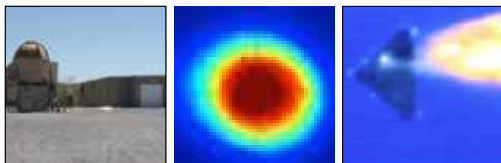
HELMTT

High Energy Laser Mobile Test Truck

- Demonstrate high-energy laser effectiveness against unmanned aerial vehicles, rockets, artillery, mortars, and cruise missiles
- Integrate, test and verify new and emerging component technology to support high-energy laser development.
- Develop tactics, techniques and procedures
- Integrated the spectrally combined 60-kW laser and an adaptive optics system—which improves engagement ranges



SSLT



Solid State Laser Testbed (SSLT) Laser Lethality

- Unique test site suitable for in flight demonstrations and fixed-site lethality data collection
- Instrumental to Army Laser Lethality Program
- Demonstrated effectiveness at negating unmanned aerial vehicles and rockets, artillery and mortar threats
- Up to 50 kW laser source

For more information on HELMTT or the SSLT, contact: **David Lyman**, *Director of HEL Programs*

256-975-6549, david.lyman@radiancetech.com



350 Wynn Drive • Huntsville, AL 35805 • (256) 704-3400


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RT17-0010

HIGH-ENERGY LASERS

BREAK THROUGH AT LIGHTSPEED

An infinite magazine. A definite advantage.
Raytheon is driving enhancements in high-energy lasers to help warfighters sense and strike hostile targets in austere conditions, from diverse platforms, with proven performance.

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RAYTHEON LASER SOLUTIONS

Raytheon is defining the future for high-energy laser weapon systems (HEL), target designators and next-generation Light Detection and Ranging (LIDAR) devices. Our combat-proven sensors and ready-now technology bring trusted, innovative and adaptable solutions that dominate the battlefield.

ACCELERATING TOMORROW

High-energy lasers are no longer the stuff of tomorrow. Right now, Raytheon is field testing mature, fully integrated systems designed to counter the evolving threat.

In May 2017, Raytheon completed the world's first successful HEL weapon engagement from a rotary-wing aircraft. In a series of follow-on ground demonstrations, the company integrated its HEL weapon system onto a Polaris MRZR™ all-terrain vehicle and downed multiple, small UAVs.

Raytheon's rugged and modular weapon system is designed to detect, identify, track, and defend against enemy missiles, mortars, swarming boat attacks and other asymmetric threats.

At the system's core is an advanced variant of Raytheon's widely deployed Multi-Spectral Targeting System™. It provides unmatched Intelligence, Surveillance and Reconnaissance (ISR) capabilities while also delivering precision accuracy as a HEL beam director.

In addition to weapon systems, Raytheon continues to break new ground on rugged, high-power laser devices, including Raytheon's proprietary planar waveguide technology.



BENEFITS:

- High survivability, rugged design with straightforward scalability to higher output power
- Compact and lightweight
- Efficient heat removal and thermal management
- Modular, low-maintenance design
- Automated queuing from the full spectrum of EO/IR sensors
- Proven manufacturing experience

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