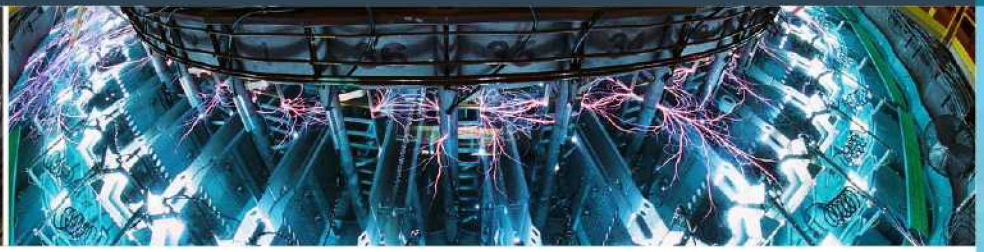
SAND2019-6490PE

LDRD Impacts



PRESENTED BY

Susan Seestrom

Advanced Science & Technology Division

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

High density physics advances for safe, rapid, and reliable nuclear weapons components

Research

Ability to design complex components for real world environments

High reliability, high voltage components are ubiquitous in the stockpile and in defense and energy storage applications.

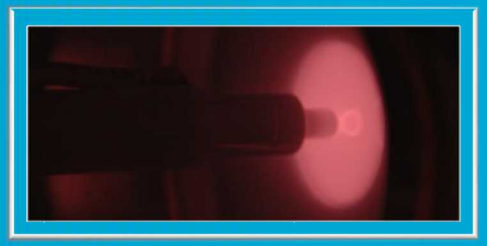
There is need to generate increasingly higher voltages from smaller and more robust devices in less time.

These devices must also have assured performance.

Development

Leverage world-leading, high-density physics, experimental and computational expertise, and team with the Navy and Air Force

Develop new capabilities in electrical breakdown measurement, first principles models, diagnostics, and prediction.



Builds on LDRD projects:

- "Discharge initiation from real surfaces" (FY17-19)
- "Predictive Plasma Science Grand Challenge" (FY18-20)

Mission Impact

New physics-based tools will enable electrical component analysis and design

Proof-of-concept for application to stockpile and weapon, assurance, systems assessment, and product realization.

Cost of unknown margins:

- Production delay > $100 M
- Electrical drive train failures-DDG
- Incomplete technical basis for codes and standards
- > 2,000 arc flash injuries/yr. in US

DDG 1000 Destroyer

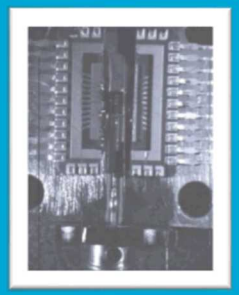
Arc flash

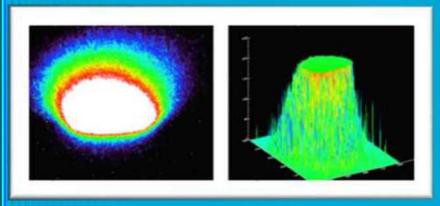
Rad-Hard Trusted Application Specific Integrated Circuits (ASICs)

Research

Multiple LDRD projects

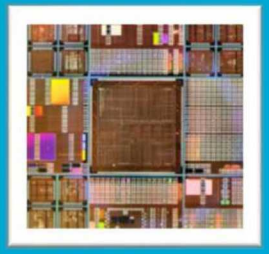
- Designed/modularized integrated solid-state electronics
- Validated short-term radiation resistance
- Ensured weapons life-cycle survivability
- Memory test chip mounted on a specialized high frequency fixture
- False-color and surface plots of ion beam intensity for a 20-MeV carbon ion TRM irradiation.





Development

Metal disposition systems are used for radiation-hardened microelectronics processing.



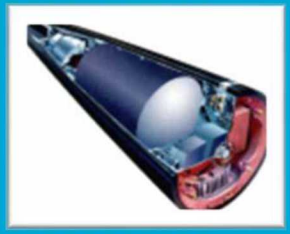
Radiation-hardened ASICs for use in nuclear stockpile and nonproliferation missions.

Mission Impact

Rad-hard ASICs are critical to the performance of nuclear weapons and for systems that operate in space, high altitude, defense systems.

Sandia is scheduled to provide more than 25,000 rad-hard ASICS for the nation's weapons modernization programs FY16-FY25.

B61 Bomb initiated in 2012



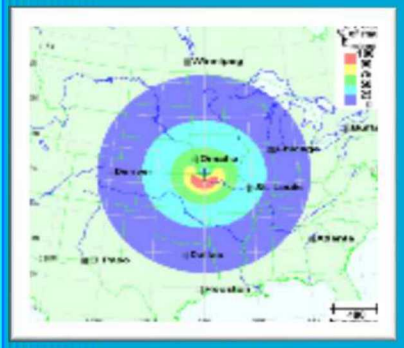
W76 Warhead: Currently in production

Defending the grid against electromagnetic pulses

Research

Understand vulnerabilities to the electric grid and develop feasible mitigation strategies

EMP from explosions and geomagnetic disturbances pose the greatest potential consequences to the grid.



Little attention has been paid to making the grid resilient against these two threats.

Development

Pioneer designing a layered defense for grid EMP resiliency

Vulnerability assessment of grid to EMP events using unique EMP experimental facilities and multi-scale models.

Determine practicality of materials and devices for hardening the grid.

Develop and demonstrate viable approaches to scaling power system models.

Mission Impact

New physics-based tools will allow for electrical component analysis and design

Decision- and policy-makers will use results to:

- Prioritize enhancements and upgrades to the electric grid
- Develop impactful policies
- Remove obstacles to developing hardened approaches

Cost of not having grid EMP resiliency:

- Blackouts and severe grid damage nationwide
- $1 T to restore grid after event
- Up to 4 to 10 years recovery time

Linking quantum computers together using a focused ion beam

Research

Develop the ability to implant emitter atoms at specific locations in a diamond

Researchers searched for emitter atoms among about 1000 randomly occurring defect locations to find even one that emitted strongly enough to be useful.

This made linking quantum computers together by networking atoms on a single chip infeasible.

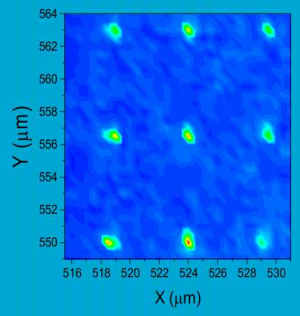
Development

Build on unique nano-Implanter technology and effectively leverage single ion implantation and detection capabilities

Develop diamond processing and cleaning capabilities

Build an implanter able to:

1) Blast single ions onto precise locations on a diamond substrate
2) Count the number of ions that are implanted



Mission Impact

Quantum information processing is transforming computing, sensing, and communications

$130K investment yielded:

- Two new capabilities for Sandia's Ion Beam Lab and Center for Integrated Nanotechnology
- Three publications
- Eleven presentations
- Two collaborating institutions
- $4M grant for quantum research with LANL from DOE

Enhancing the utility of hypersonic flight systems through autonomy

Research

Prosecute fleeting targets in areas with modern anti-access area denial (A2AD) defenses

Currently proposed U.S. hypersonic systems have some limitations:

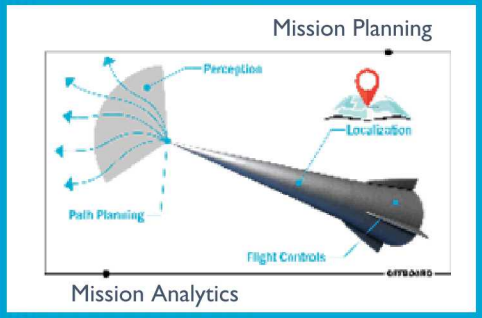
- Complex flight plans take *months* to generate; so, they offer limited utility against time sensitive threats.
- Platforms rely solely on GPS for their terminal accuracy.
- Platforms fly to coordinates following fixed, pre-computed trajectories – mostly useful against stationary targets and anticipated defenses.

Development

Provide autonomous mission planning, and enable adaptive, highly maneuverable vehicles to navigate, guide, and control themselves

Developing novel autonomous systems under 18 LDRD projects across three thrusts:

- Sensor-Aided Autonomous Navigation, Guidance, and Control
- Autonomy for Fire Control and Adaptive Endgame
- AI-Enabled Mission Analysis

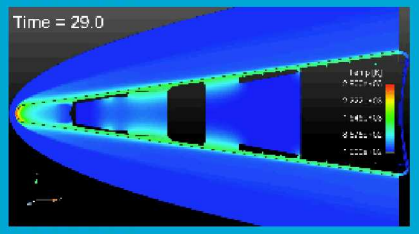


Mission Impact

New computational methods speed up aerothermal modeling and trajectory generation

Machine learning methods will reduce cost of simulating complex aerothermal models.

- 1000X dimensionality reduction
- Incurs <1% errors
- May enable AI-inspired glide body



Re-entry Analysis Program to Optimize Roll (RAPTOR)

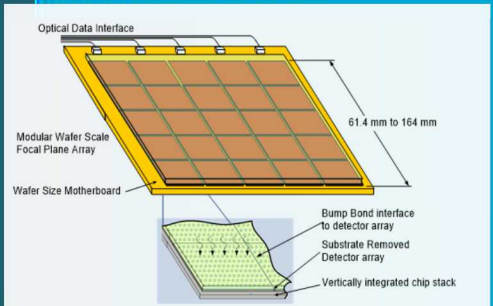
- Order-of-magnitude speedup in trajectory generation
- 3D heating and thermal response

Hyper-Temporal Sensor Focal Plane Array for Treaty Monitoring

Research

Enable critical tactical and strategic optical remote sensing applications

Improved resolution and sensitivity in FPA architectures are crucial in treaty monitoring.



Scalable FPA architecture supports very high pixel count and sample rates.

Development

Prototype of HTS-FPA developed in a Pathfinder System

Technology developed out of this project includes:

- Modular and extensible large-area FPAs
- 3-D silicon integration
- Ultra-low power analog-to-digital conversion per pixel

Mission Impact

HTS-FPA concept was adapted by the next-generation U.S. Nuclear Detonation Detection system

Are a key component in satellite-based, airborne, and ground-based systems.

Next Generation Treaty Monitoring Technologies

Solid State Lighting

Cut U.S. lighting-electricity consumption in half by solving impediments to hyper-efficient, affordable LEDs for home/commercial lighting

Research Need

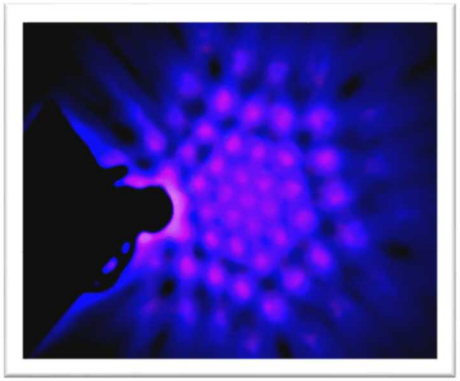
To remove barriers to implementation of efficient and affordable LEDs in the U.S. :

- Semiconductor light-emission needs to be optimized
- High-power electronics for SSL and other national security applications must be developed
- Ultraviolet LEDs for bio-sensing and communications need to be cultivated

Science Technology & Engineering Development

Two projects over seven years focused on:

- Creating ultraviolet-light emitters with funding from three DARPA programs
- Capturing Solid State Lighting Energy Frontier Research Center



Photonic Crystal LED

Impact

- Elevated awareness of SSL technology to the national level and helped implement a government-funded R&D program.
- Technical innovations were adopted by industry in the manufacturing of solid-state-lighting products.
- National security military applications include bio-agent detection and high power radar.

Handheld *Bacillus anthracis* Diagnostics (BaD_x)

Research

Sense realistic concentrations of pathogenic bacteria in challenging environments

Detecting anthrax bacteria is challenging because samples must be tested in a laboratory that requires a consistent power supply, something often unavailable in the developing world.

An inexpensive, self-sterilizing, power- and equipment-free device is needed to detect anthrax.

Development

Build a reliable prototype with increased functionality and sensitivity

- Develop a microfluidics platform with patent-pending magnetic valves that move the sample through the testing process.
- Create on-device decontamination.
- Follow-on LDRD minimized false negatives.

Cartridge design

Mission Impact

Mitigate the availability of dangerous bio-threats through a safer, easier, faster and cheaper handheld detector

- R&D 100 Award winner
- Patent pending on magnetic flow valve
- CRADA with Aquila

Broad detection capability

- Bio-threat agents (DoD, public)
- Food borne illness (Salmonella)
- Public health pathogens (MRSA and Streptococcus)
- Diagnostic for livestock diseases
- First responders

GRAND CHALLENGE: SMART SENSOR TECHNOLOGIES

Providing high-quality intelligence of world events

Research Need

Higher sensitivity and resolution real-time tunable sensors are needed to:

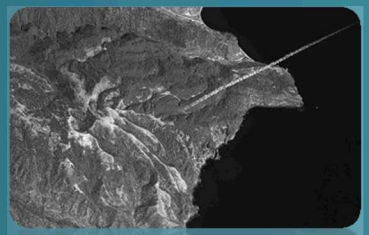
- See smaller / dimmer events
- See different wavelengths in real-time
- Allow for hardware change after launch
- Provide more data to predict a decade of future need before launch

Impact

- Developed, proved and patented a new detector architecture based on nano-antennas.
- Created next-generation detector with lower dark current and higher efficiency at each photon energy level.
- Infrared spectral tunability could be applied on a pixel-by-pixel basis.

Science Technology & Engineering Development

- Design and build new nanoantenna detector architectures using surface waves and ultrathin detector layers .
- Synthesize new materials for tuning the wavelength.
- Integrate new materials with revolutionary architectures to obtain tunable low-noise infrared sensors.



GRAND CHALLENGE: NanoCRISPR

Rapid countermeasures for emerging diseases

Research Need

Advances in engineered interfaces and integrated sensors are needed to:

- Produce medical countermeasures against emerging infectious diseases.
- Help combat the continuous threat from naturally occurring (e.g., Ebola, Zika, MRSA) and engineered organisms (i.e., bioterrorism).
- Significantly decrease the amount of time needed to develop new drug therapies.

Impact

- Demonstrated NanoCRISPR proof-of-concept in model cells.
- Developed CRISPR for host-directed countermeasure against Ebola surrogate.
- First modular nanoparticle delivery system for *in vivo* delivery of CRISPR.

Science Technology & Engineering Development

Make advancements in engineered interfaces and self-navigating, *in vivo* drug delivery by:

- Developing nanoscale material assembly methods based on CRISPR gene-editing.
- Coupling Sandia-developed delivery technology with CRISPR for delivery .

GRAND CHALLENGE: PANTHER

Timely, relevant Big Data insights

Research Need

- Detect connections and patterns using sensor data and analytics.
- Achieve better knowledge and deeper insights from big data in minutes, covering hundreds of km^2.
- Spark a revolution in analytic tradecraft:
  - From maps to graph search
  - From "dots on a map" to computational geometry

Science Technology & Engineering Development

- Convert imagery into a searchable activity graph and find patterns in changes.
- Demonstrate the value of user/performance studies in the development cycle.
- Integrate graph algorithms, human factors, cognitive psychology, image processing, and rigorous uncertainty analysis.
- Compare and search trajectories.

Impact

- Enabled high-consequence decision-making using complex patterns within geospatial data.
- Integrated user studies and human performance research into design of computational analytics and interfaces.
- Partnered with SUNY Stony Brook, Utah State University, NC State, Colorado State University, AFRL, and EyeTracking, Inc.
- Procured R&D and maturation funding from national security community.
- Completed new LDRD investigations across mission areas.

Supply Chain security

Increasing confidence in high consequence components

Research Need

Concerns about things such as counterfeit parts, Trojan Horses make it imperative for components in high-consequence systems to be reliable and trustworthy.

The ability to screen all components within high consequence systems for supply-chain vulnerabilities is needed.

Science Technology & Engineering Development

Several projects over three years focused on:

- Developing a unique, non-destructive technique to prove component legitimacy.
- Developing Power Spectrum Analysis to analyze the response of microelectronic components using standard and unique non-destructive electrical stimuli.

Impact

The Power Spectrum Analysis approach has provided the ability to:

- Readily detect counterfeit devices
- Discover any reliability concerns through normal wear-out mechanisms
- Detect any defect precursors in the device
- Determine manufacturer attribution

PSA is currently being prototyped at the plant in Kansas City.

Providing real-time information and images through Miniaturized Synthetic Aperture Radar (MiniSAR)

Research

Provide rapid image reconstruction through real-time data processing

Novel imaging and data processing technologies are needed for a number of national security interests:

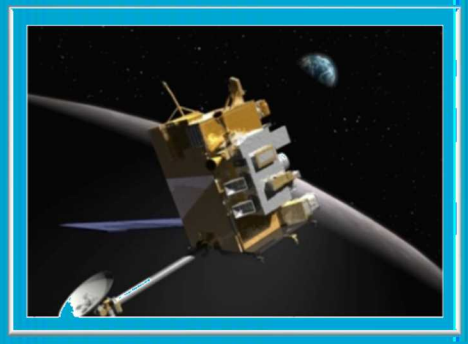
- Intelligence
- Surveillance
- Counter-IED ISR
- Nonproliferation
- Damage assessment
- Search and rescue
- Environmental monitoring

Development

MiniSAR prototype developed and implemented in a pathfinder application

Technology developed out of this project includes:

- New graphical user interfaces for radar operators and ground stations.
- Object tracking at any velocity using Video SAR and ground moving target indicator radar modes.



MiniSAR onboard Lunar Reconnaissance Orbiter

Mission Impact

MiniSAR provides actionable intelligence for the warfighter and decision makers

- High-density interconnect technology improved efficiency while lowering size and weight.
- Accelerated data acquisition allowed for image processing and reconstruction at video frame rates.
- Image-formation algorithms and miniaturized field programmable arrays sped up image reconstruction.
- New data-driven algorithms provided fine resolution inverse SAR images of moving objects and compensate for unknown target motion.

Blast loading, blunt force impact and projectile penetration using wound ballistics modeling

Research

Next-generation wound injury investigation and armor design assessment for warfighters

A new modeling and simulation capability is needed to:

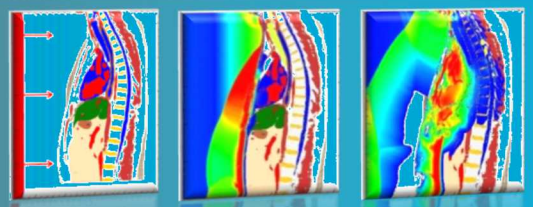
- Advance understanding of wound injury dynamics
- Identify regions of the torso vulnerable to blast and blunt impact trauma
- More effectively prototype personal armor

Development

Leverage simulation and shock physics expertise and team with the Navy

Technology developed out of this project includes:

- A coupled torso and head-neck model
- Advanced EOS model to capture cavitation in soft tissue due to blast, ballistic projectile impact and penetration



Simulation of front blast to torso and resulting impact

Mission Impact

The new modeling and simulation capability will improve warfighter protection systems

- Traumatic Brain Injury simulation funded by Office of Naval Research.
- Created virtual anatomical models of human head, neck, and torso.
- Assessed protective body armor designs and identified armor qualities that optimize protective capability against blast, blunt impact and projectile penetration.

Beneficiaries of capability include:

- DoD, FBI
- Medical community including field triage and hospital surgeries

LDRD investments pay off over time and yield multiple capabilities

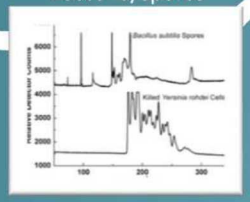
The μChemLab Grand Challenge opened the door to infectious disease diagnostics, environmental monitoring, space applications, toxin diagnostics, and biodosimetry

1996
Original SNL LDRD
Combined Gas-phase Chemical Agent with Liquid-phase Explosives Detector

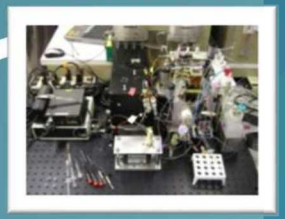
DHS
Sample prep
Viruses
Sensitivity
Methods

Natl. Institute of Dental and Craniofacial Research

DoD
Sample prep
Bacteria/spores

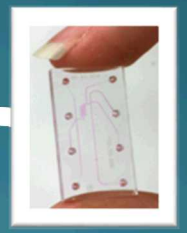


DHS BioBriefcase



Natl. Institute of Allergy and Infectious Diseases
Toxin diagnostics

NIDCR Human Oral Microbiome



DOE
Separated Gas/Liquid
Liquid-phase Biotoxins

Waters CRADA

Tenix CRADA
Unattended
Water Sensor

DoD
Autonomous operation
Bio-aerosols

Sandia LDRD SpinDx