Electromagnetics

Analysis and Testing

Sandia National Laboratories

Sandia National Laboratories was created in 1949 to support the nuclear weapons program developed by the Manhattan Project. Our original emphasis on ordnance engineering — turning the nuclear physics packages created by Los Alamos and Lawrence Livermore National Laboratories into deployable weapons — expanded into new areas as the national security needs of postwar America evolved. In addition to ensuring the safety and reliability of the nuclear weapons stockpile, Sandia applies the expertise it developed to support the nuclear weapons stockpile to a variety of national security needs including energy and critical infrastructures surety, defense systems, homeland security, nonproliferation, and industrial competitiveness.

Flap, Inside Front Cover

Electromagnetic Solutions
from Sandia National Laboratories

Technology that harnesses electromagnetic (EM) energy impacts us every day in areas of communications and radar; air, sea, and space navigation; and in an increasing array of complex electronic and radiofrequency systems. As these systems become more complex, understanding and predicting their operation and vulnerability to EM energy requires state-of-the-art capabilities in analysis, computer modeling, and experimental facilities.

With world-class technical staff and state-of-the-art facilities, Sandia National Laboratories offers a broad range of capabilities including:

Computational Analysis & Modeling

Lightning Effects Testing

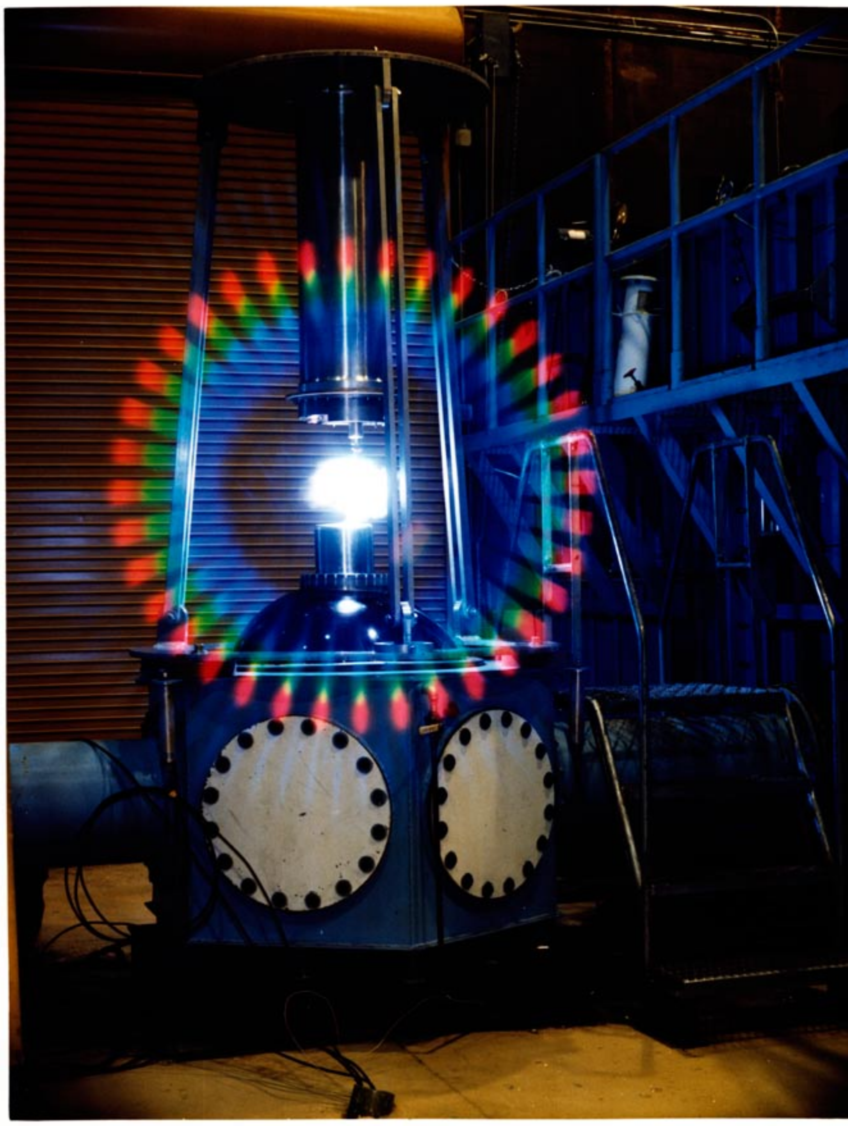
RF Testing

Electromagnetic Pulse Testing

Electrostatic Discharge Testing

Facility—Response Characterization

Pulsed Power & Customized Testing



Computational Analysis & Modeling

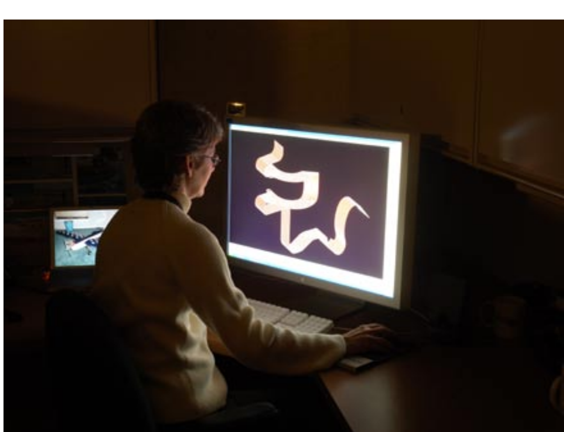
"Our tools enable virtual simulations of unprecedented size and physical fidelity."

Our computational EM and coupled EM-plasma tools can support three-dimensional modeling for virtual prototyping and testing. The combination of our high-fidelity modeling with our physical test facilities is a powerful toolset for solving complex problems. The world's most powerful computers support our analyses and are able to perform virtual simulations of unprecedented size and physical fidelity.

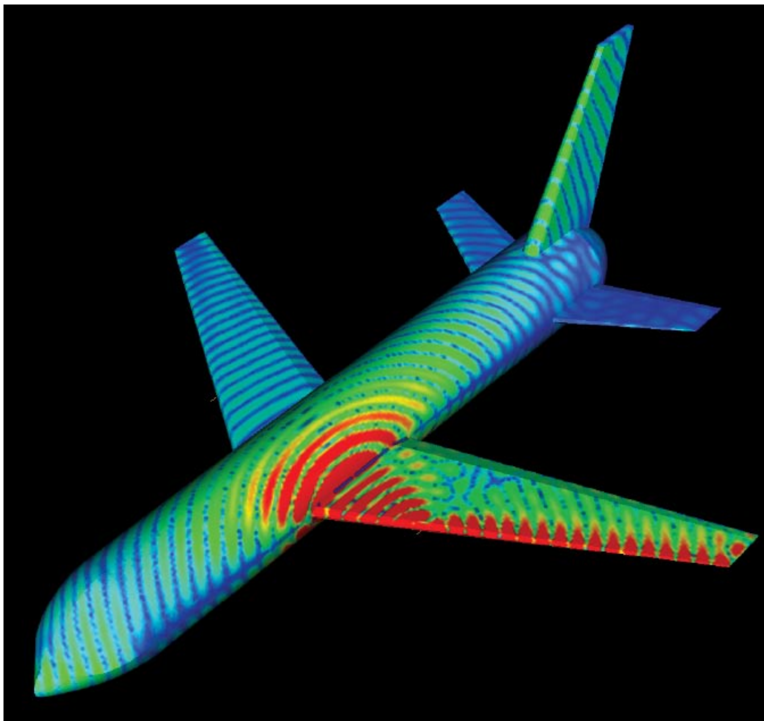
Our computational tools have been used to model:

- EM/electrical behavior of systems that contain metallic cavities with apertures, cabling and antennas
- EM/electrical response of systems due to intense X-ray environments (SGEMP – System Generated EMP)
- Lightning and high-voltage initiated electrical breakdown
- Leakage currents in high-voltage components
- EM performance of periodic-structure devices, such as photonic bandgap crystals, frequency-selective materials, and diffraction gratings for high-power lasers
- EM behavior of cavities and enclosures at very high frequencies
- Performance of integrated high-frequency electronics and RF-MEMS components
- Antenna performance and compatibility
- Terawatt-level powerflow in complex magnetically insulated transmission lines
- Electrical breakdown in water and gas for fast, high-power switching
- High-power, charged particle beam devices

In collaboration with universities and other agencies, Sandia creates and tests advanced numerical techniques in EM and plasma physics and performs research that enhances the body of knowledge in the theoretical foundations in EM and electrical science. Codes for advanced applications are validated via quantitative comparison between experiments in our EM facilities and computational models. Current validation efforts are focusing on quantifying margins of uncertainty via numerical simulation.

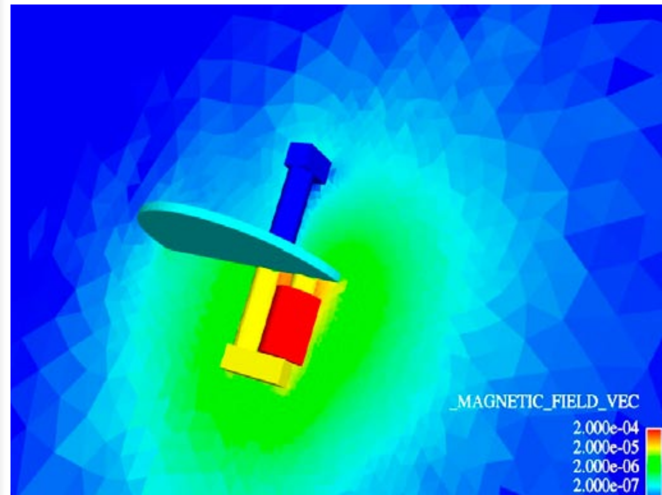


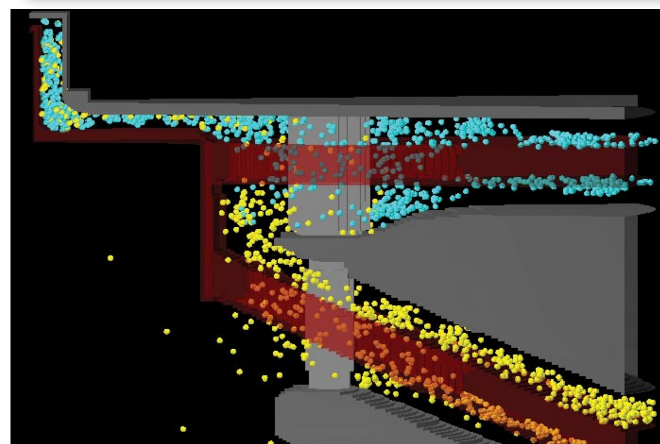
Staff member prepares a flat-flex cable model for electromagnetic analysis.



Magnitude of electric currents induced on an airframe due to a wing-mounted transmitter.

Magnitude of the magnetic field in a plane at one instance in time in a magnetic component with very small geometric features.





Electron flow in a Terawatt level transmission line.

Our code suite will function on computers from desktop systems to the world's largest parallel computers. The suite includes EM computational modules for:

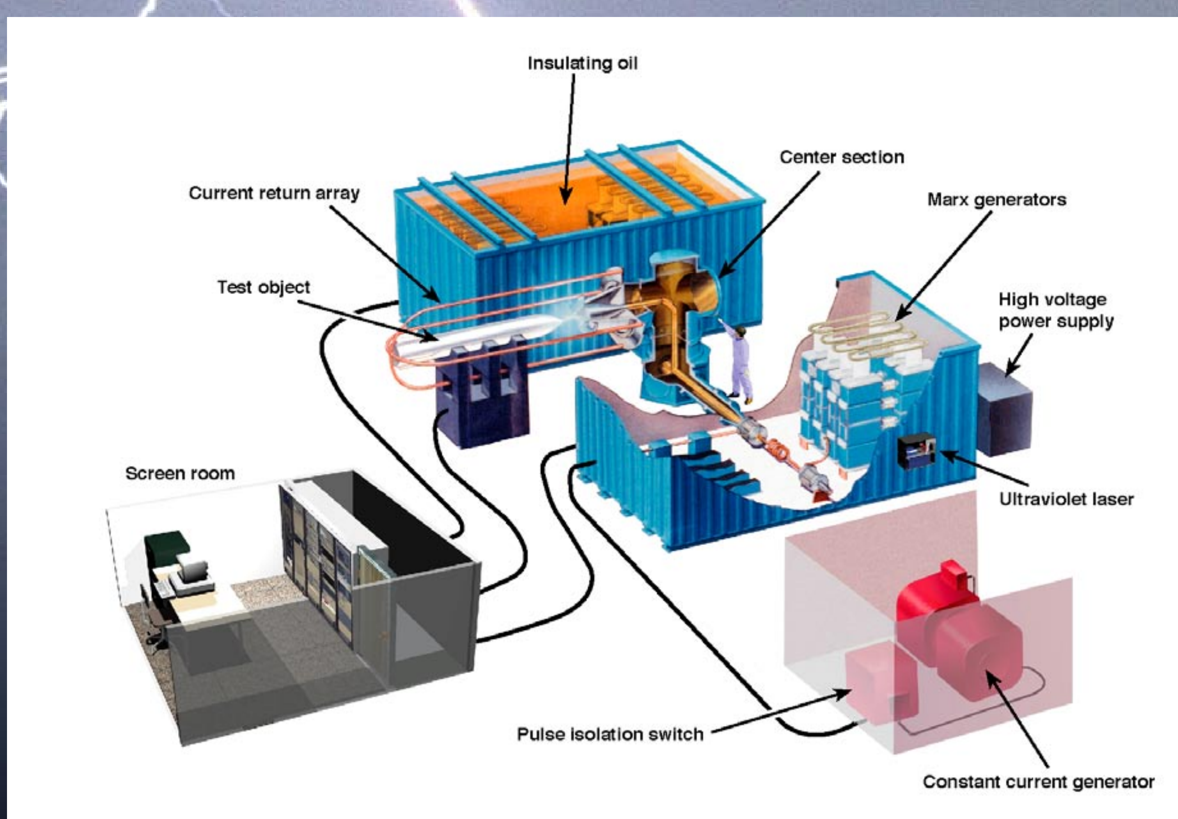
- Time-domain solution of the full set of Maxwell's equations of EM ("full-wave") via flexible hybrid finite-element/finite-difference methods
- Charged particle-in-cell capability self-consistently coupled with our full-wave, time-domain capability for high power plasma simulation (e.g., magnetically insulated powerflow)
- High-accuracy, finite-element-based electro-statics solution and, soon, magneto-statics solution
- Coupled electron-photon radiation transport for high-fidelity simulation of system EM/electrical response due to intense X-ray environments (SGEMP) in conjunction with EM modules
- Eddy-current magnetics solution based on a variant of our time-domain, full-wave methods which allows use of magnetic materials
- Frequency-domain, full-wave EM solution using boundary-element/method-of-moments techniques. This module was one of the first to demonstrate performance exceeding 1 TeraFLOPS (Trillion Floating Point Operations Per Second) on large parallel computers.
- Boundary-element-based electro-statics and magneto-statics solution. Because this method requires only surface meshes, these modules have been coupled to modules that model mechanical motion and structural and thermal physics in order to simulate micro-mechanical devices during operation.

Lightning Effects Testing

Every year lightning threatens lives and causes significant damage to personal and public property. Sandia has the capability to assess small components to extremely large systems, including facility infrastructure response to lightning.

The Sandia Lightning Simulator can test objects with realistic direct-strike lightning pulses up to a maximum peak current of 200 kA for a single stroke, 100 kA for a subsequent stroke, and several hundred Amperes of continuing current for hundreds of milliseconds. Its output waveform is comparable to natural lightning in pulse rise and fall times, peak current, and continuing current amplitude and duration.

Tests may be configured for direct-attachment lightning (where the simulator is connected to or arcs to the test object), burn-through (which incorporates continuing current), and exposure to nearby magnetic fields.



Sandia Lightning Simulator: We can make sensitive measurements by housing diagnostics in a shielded instrumentation box and transmitting signals back to a screen room via fiber optics.

For situations where testing is desired, but a severe lightning pulse is excessive, other options are available to provide a typical lightning waveform (1.2 us rise time x 50 us pulse width). Components or small systems can be evaluated using lower currents into any type of load.

High-voltage breakdown characterization of optical fibers penetrating a metal chamber.

When high-voltage standoff is of interest, the high-voltage breakdown characteristics of a variety of items can be assessed. Two options are available: 1) DC voltage testing up to 200 kV, or 2) high-voltage pulse testing with a typical lighting waveform. Voltage and current are measured, including leakage current on the order of 10s of μA, or breakdown current on the order of several kA.

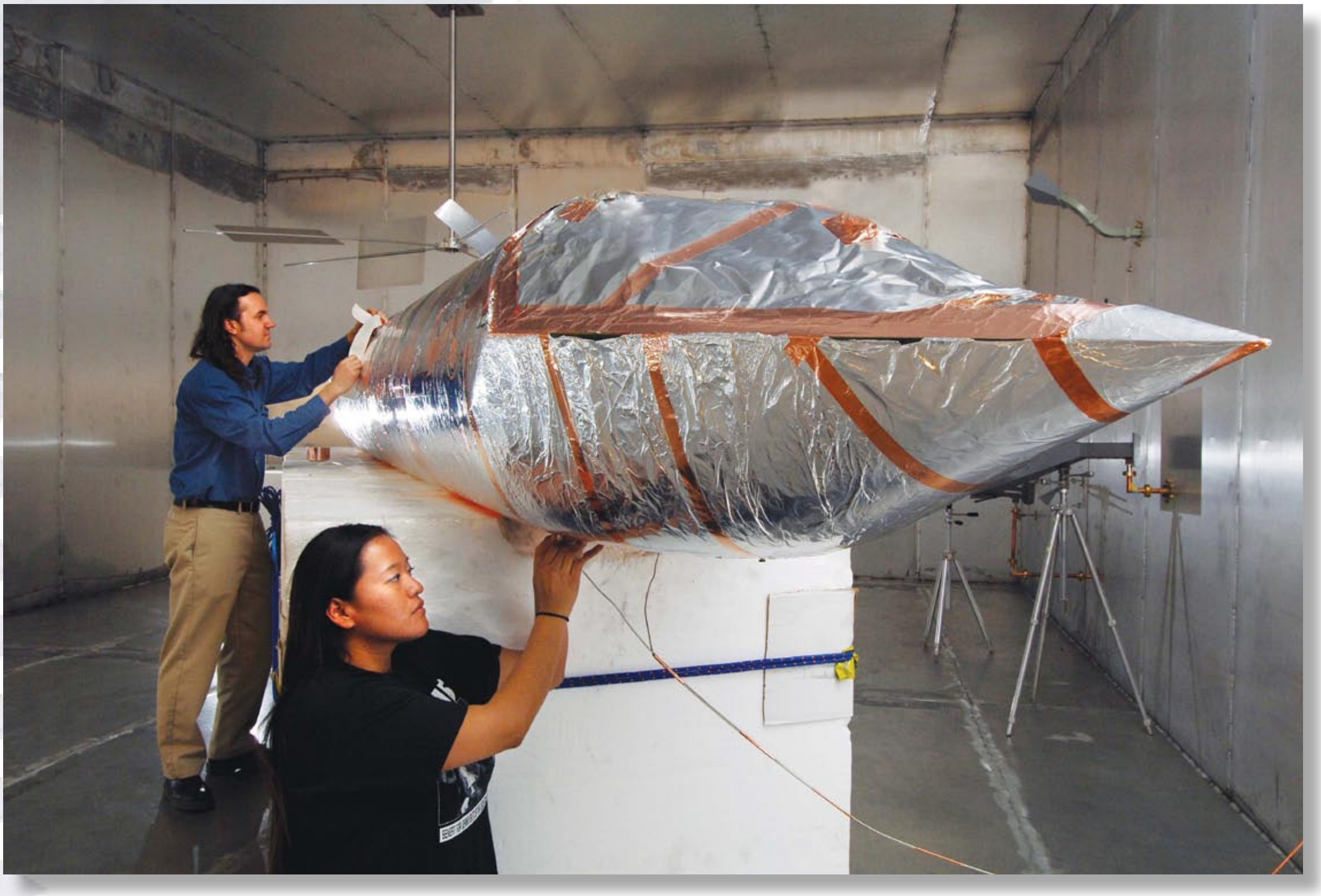
Magnetic fields associated with a nearby lightning strike can couple into structures, systems, or components causing electronic malfunction or damage. Sandia can assess the response of test objects subjected to magnetic fields with lightning pulse characteristics.

When lightning strikes a structure, it can create very large voltages within the structure, jeopardizing critical operations, sensitive equipment, or high-value assets. Analysis and field testing can determine the transmission of lightning current through structures by using very low-level signal measurements that will not disrupt ongoing operations or endanger essential equipment.

Characterization of impact of a lightning strike to railroad communication system.

RF Testing

Sandia provides several options for RF testing over a broad frequency range using Mode-Stirred Chambers, Transverse Electromagnetic (TEM) cells, and an Anechoic Chamber. The chambers and cells can be used separately or in combination to allow a more comprehensive evaluation.



Staff prepare an Advanced Cruise Missile for testing in the large Mode-Stirred Chamber.

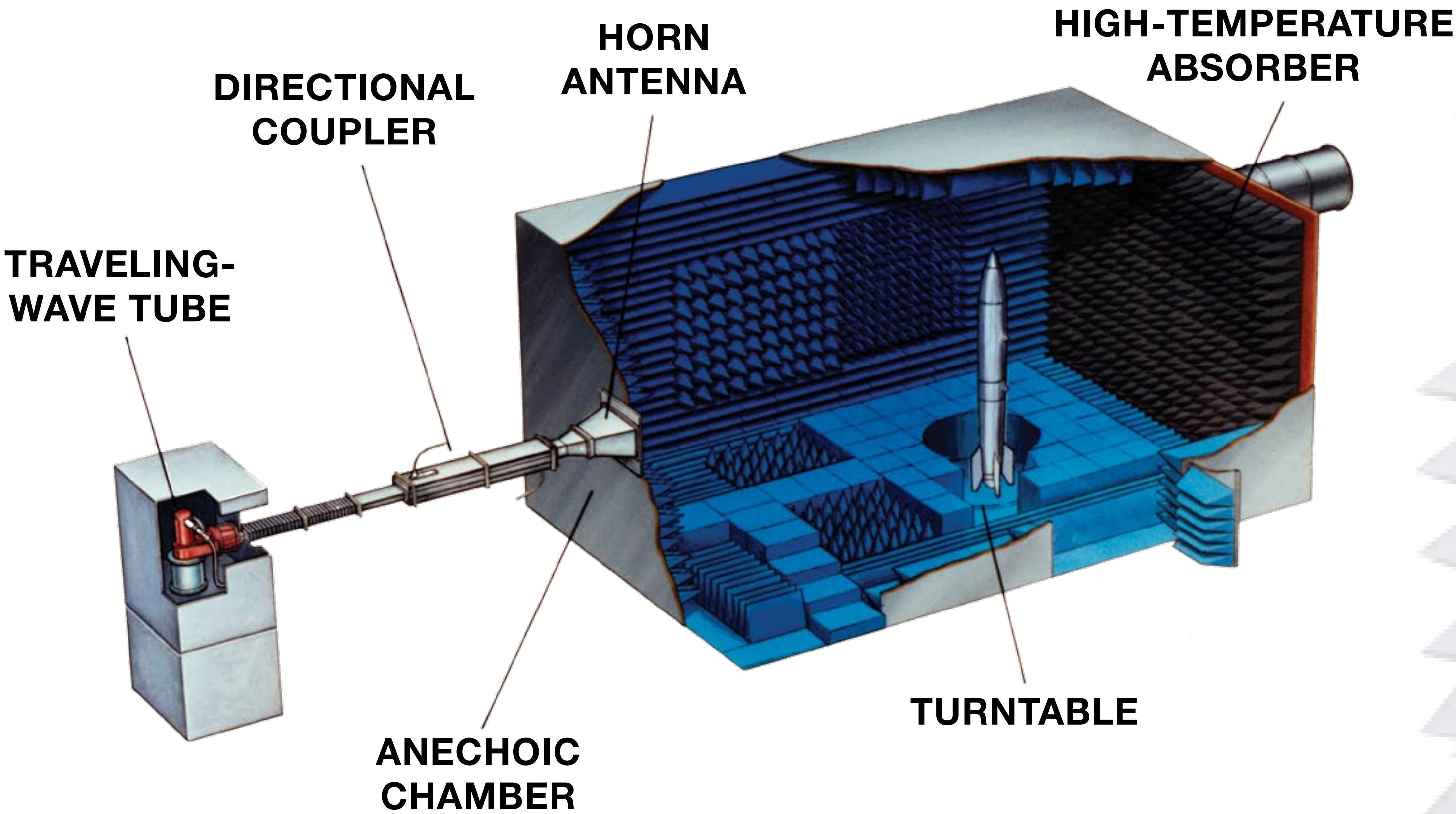
Large and small Mode-Stirred Chambers are typically used to characterize electronics susceptibility and electromagnetic leakage into test objects. Our large Mode-Stirred Chamber is 4 x 7 x 11 m, large enough to accommodate an automobile. State-of-the-art amplifiers supply up to 1 kW of power from 220 MHz to 18 GHz and 40 W of power from 18 GHz to 40 GHz. A significant advantage of Mode-Stirred Chambers is that items can be exposed to RF energy at all angles of incidence and polarization in a single test run.

Sandia has a small and a large TEM cell. The large TEM cell, called the Electromagnetic Environments Simulator (or EMES), is also used for Electromagnetic Pulse testing. Both TEM cells are designed to deliver uniform plane wave electromagnetic fields. EMES has additional RF absorbers at the load end to further minimize high-frequency reflections.

The Anechoic Chamber simulates a free-field environment with minimal reflections above 500 MHz and is suitable for either pulsed or continuous wave testing. It is typically used to characterize antennas and antenna-like structures and to take very sensitive measurements. The Anechoic Chamber has a 2 m turntable which can rotate test objects a full 360° in precise increments.

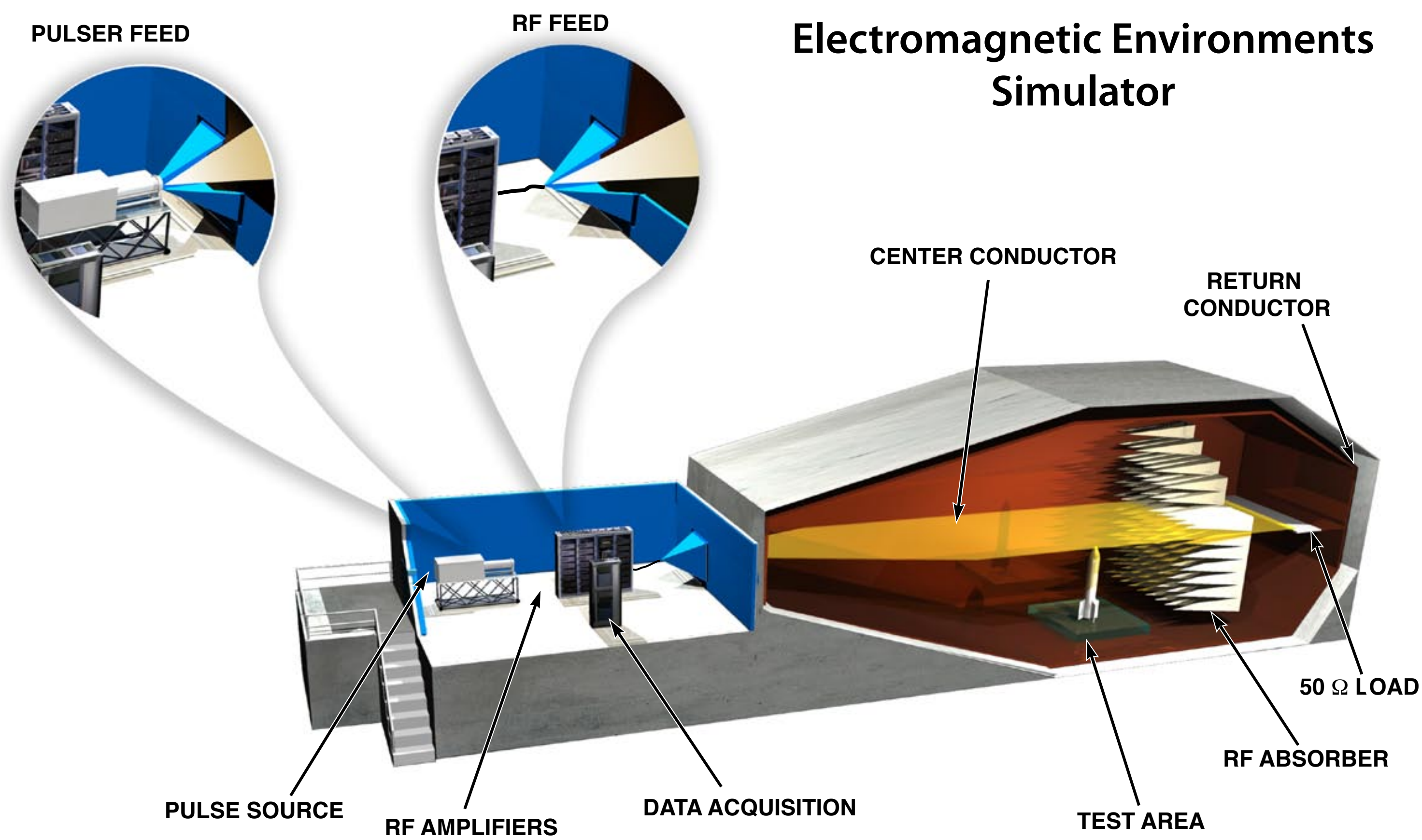
Cables and connectors play an important role in the electromagnetic shielding of interconnected systems. Sandia can quantify their performance over a broad frequency range. A unique Cable Tester evaluates the effectiveness of cable shields by measuring the current induced on internal wires as a function of current on the shield. In addition, voltage induced on internal cable wires can be evaluated as a function of an incident electric field.

Anechoic Chamber



Electromagnetic Pulse Testing

The Electromagnetic Environments Simulator can be used for high-altitude EMP testing as well as for RF plane-wave testing. With its test area dimensions of 4 meters by 11 meters by 5 meters, EMES can accommodate large-scale items. In addition to its large size, its unique features include the fast rise time (1 ns) of the pulse and the broad range of electric field amplitudes (30 kV/m–250 kV/m) that can be delivered. RF absorbers effectively facilitate the transmission of a uniform, repeatable pulse throughout the test cell volume for every shot.

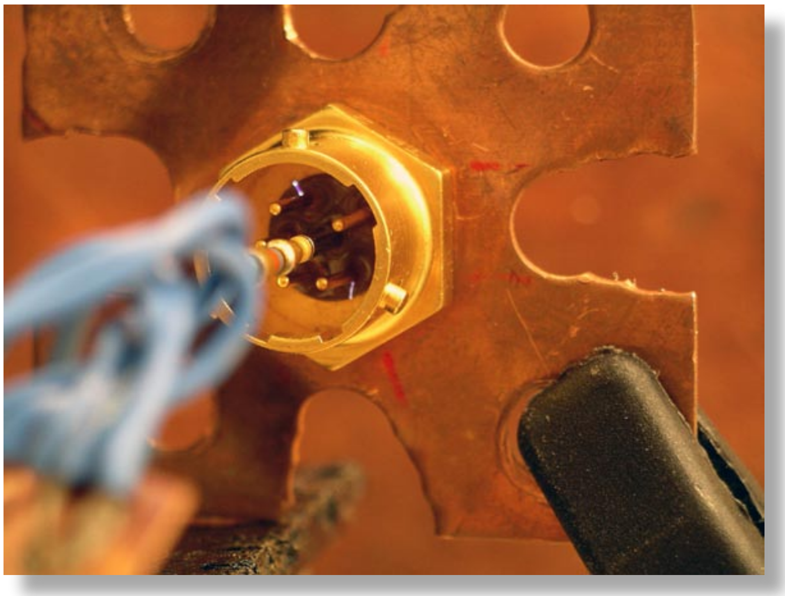


Staff prepares Air Launched Cruise Missile for testing at EMES.

EMES accommodates large items.

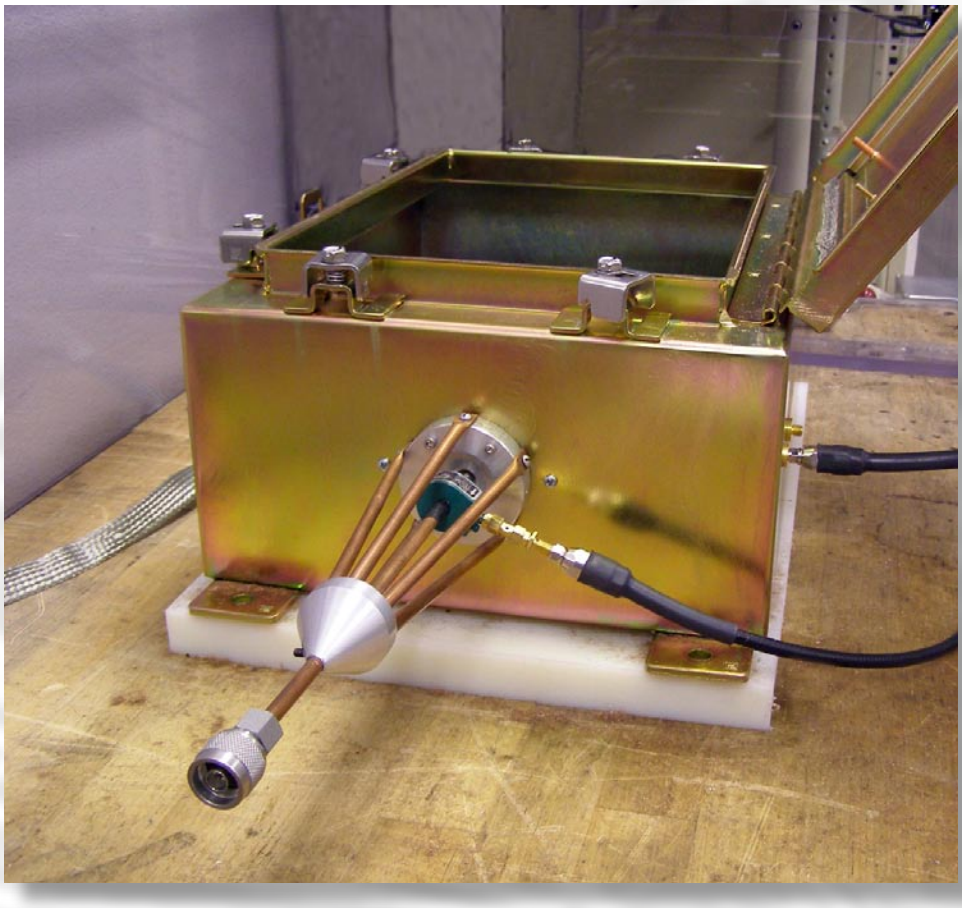
Electrostatic Discharge Testing

The Electrostatic Discharge (ESD) Effects Laboratory investigates the fundamental physics of ESD charge generation and transfer, simulates ESD fast-transient stresses, and measures test-item responses. Capabilities exist to simulate ESD generated by the human body and non-human sources. Key features of the ESD transient are its very fast rise rate, short duration, and high voltage.



Electrostatic discharge delivered to an electro-explosive device.

Sensitive diagnostics measure electrostatic charge accumulation with non-contacting methods, minimizing perturbations to the device being evaluated. Our facility includes specially designed test fixtures to preserve the important high-frequency content of the ESD test environment. Sandia ensures accurate recording of the fast ESD transients with wide-bandwidth diagnostics and instrumentation, including the use of fiber optic transmitters and receivers to minimize noise coupling onto sensitive signals.

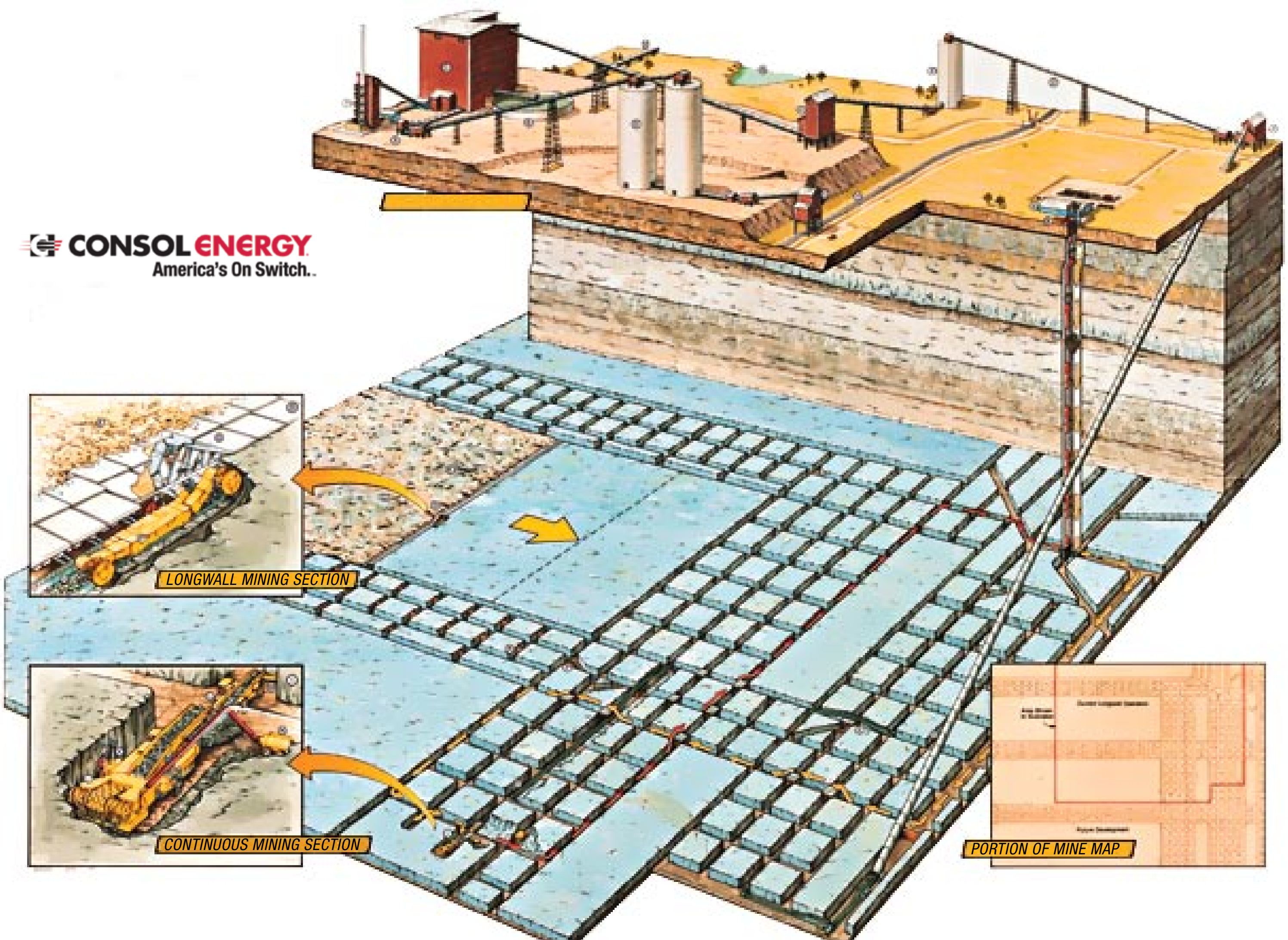


Customized test setup for reducing noise from ESD measurement.

Facility EM Response Characterization

Sandia National Laboratories has a well-established history of evaluating structure susceptibility to Electromagnetic Radiation, lightning, and EMP. We can provide good electromagnetic design practices and practical solutions to troublesome problems. We accomplish this through analysis of a facility and/or by measurements that do not interfere with normal operations or endanger critical operations or equipment.

Some of our customers for facility response characterization have included the congressionally chartered EMP Commission, the Santa Fe Railroad, several sites in the US Department of Energy's (DOE's) nuclear weapons complex, including Pantex and the Nevada Test Site, and the Mine Safety and Health Administration.

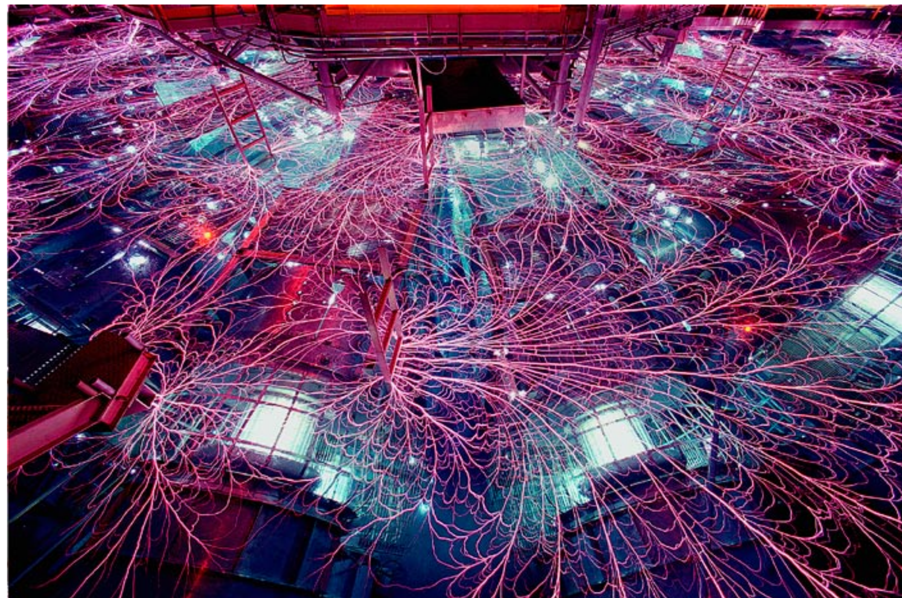


Courtesy of CONSOL Energy

Pulsed Power & Customized Testing

High-Voltage Science & Engineering

As the DOE's lead laboratory in Pulsed Power Sciences, our group is able to address a wide variety of problems by leveraging our electromagnetic expertise with a variety of physics and high voltage science and engineering capabilities. This expertise strengthens our understanding of issues relating to high-voltage phenomenology (e.g., insulator breakdown, surface tracking, transient field effects, and measurement techniques in harsh electromagnetic environments.

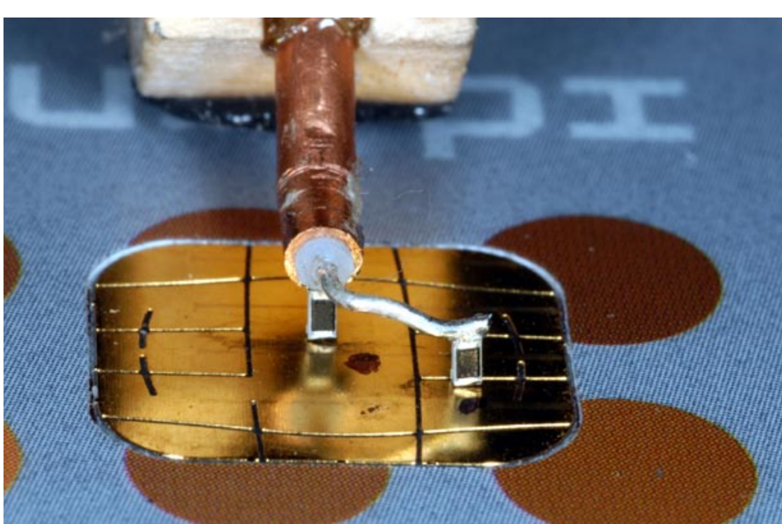


Sandia's Z-Accelerator is an internationally recognized facility for high-energy density physics and dynamic materials research.

Customized Testing and Experiments

Sandia has developed unique test and experiment setups ranging from megaVolt transient pulsers for EMP-related effects to steady-state, high-current sources for equipment safety evaluations. These capabilities span from simulating the most extreme environments to detecting very sensitive responses in a variety of testing situations.

Megavolt transient pulser for EMP-related effects.



Susceptibility testing of a custom microchip.

Partnership Opportunities

Sandia places a high value on its interactions with other federal agencies, universities, and private industry. Several contract vehicles exist to partner with Sandia to purchase services, transfer technology through Cooperative Research and Development Agreements, or to license Sandia-developed technology. Our staff will work with you to develop the appropriate relationship to help solve your most challenging problems in electromagnetics through the use of:

- A wide variety of complementary testing and analysis options
- State-of-the-art modeling, simulation, and computational capabilities
- Unique test facilities
- Product development consultation
  - requirements analysis
  - design guidance
  - prototype evaluation
  - component-to-system level evaluation and qualification
  - surveillance guidance
- Material evaluation
- Basic or applied research

A few of the private companies and government agencies that have entrusted their critical EM testing and analysis to Sandia National Laboratories include:

Atlas Wireline Services

Federal Aviation Administration

Mine Safety and Health Administration

Santa Fe Railroad

Telcordia

US Air Force

US Army

US Defense Threat Reduction Agency

US Department of Defense contractors

US Department of Energy (Pantex, Nevada Test Site, and Nuclear Energy Research Institute)

US EMP Commission (US Congress)

US Navy

Evaluating revolutionary diagnostic to detect aircraft wiring defects.

Sandia National Laboratories is a multiprogram laboratory operated for the United States Department of Energy (DOE) by Sandia Corporation, a Lockheed Martin Company. Sandia is one of the largest engineering research and development facilities in the United States, with major laboratories at Albuquerque, New Mexico, and Livermore, California, and test ranges at Tonapah, Nevada, and Kauai, Hawaii.

For further information on Sandia's Electromagnetic testing, qualification, and analysis capabilities, visit our web site:

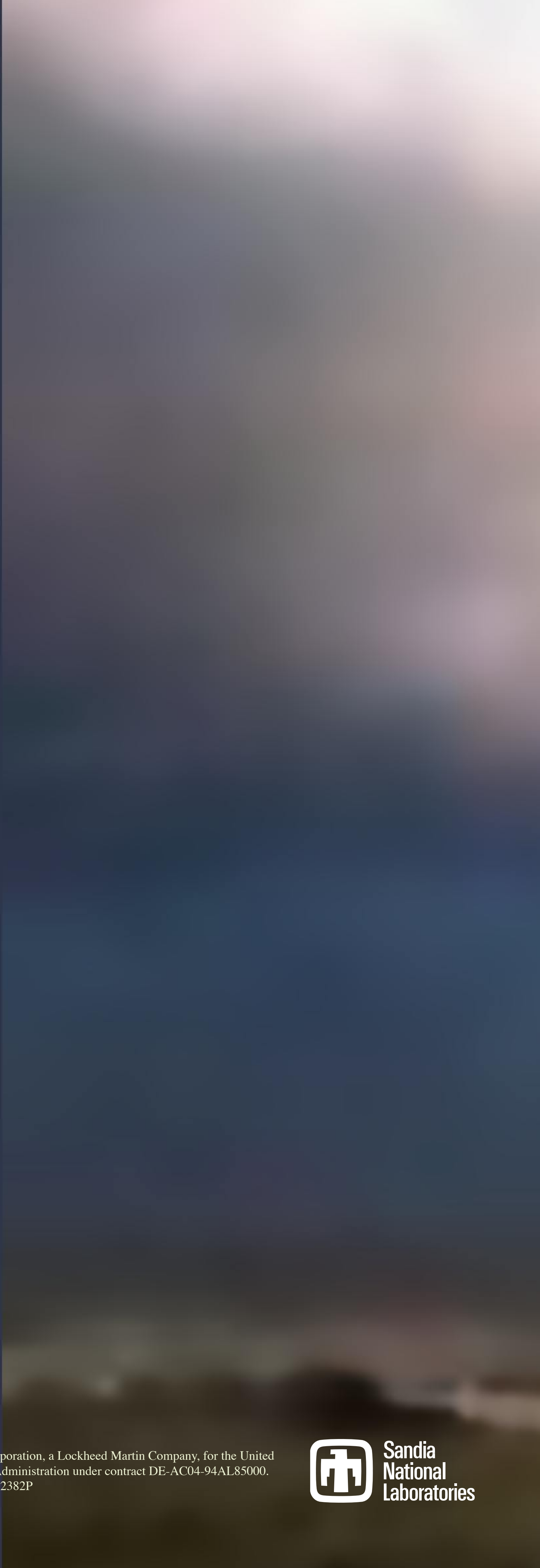
www.sandia.gov/electromagnetics

Contact Information:

Mark Kiefer
Manager, Electromagnetic and Plasma Physics Analysis
Sandia National Laboratories
(505) 845-7271 (work)
(505) 284-6078 (fax)
mlkiefe@sandia.gov

Michele Caldwell
Manager, Electromagnetic Environment Effects
Sandia National Laboratories
(505) 284-3010 (work)
(505) 284-6078 (fax)
mcaldw@sandia.gov

Larry Schneider
Senior Manager, Electromagnetics, Stockpile Support, and Work for Others Programs
Sandia National Laboratories
(505) 845-7135 (work)
(505) 845-7684 (fax)
lxschne@sandia.gov



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