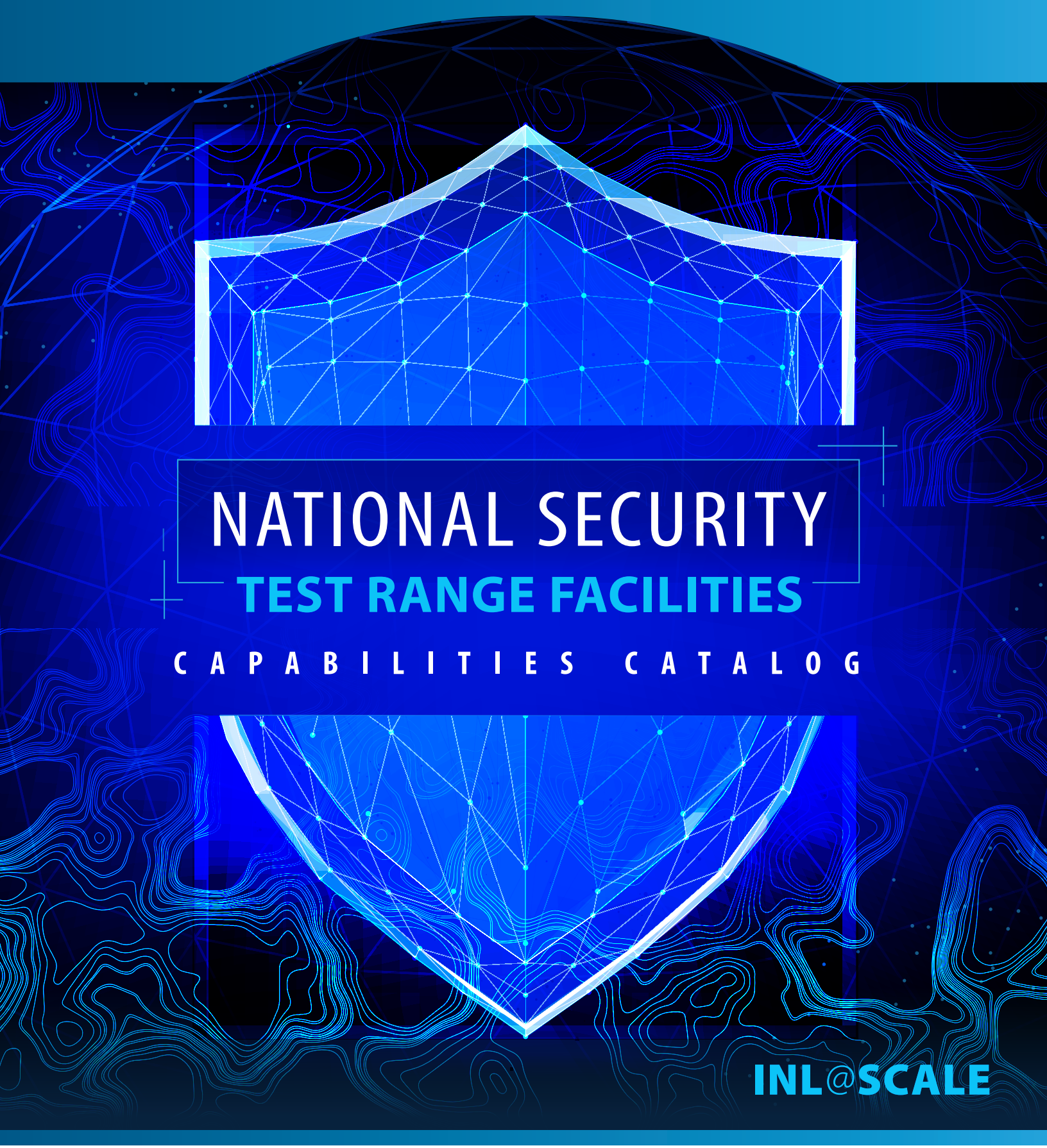


NATIONAL SECURITY

TEST RANGE FACILITIES

CAPABILITIES CATALOG

INL@SCALE

Idaho National Laboratory

OVERVIEW

MISSION

The national security missions of the Idaho National Laboratory (INL) focus on protecting the nation's critical infrastructure and preventing the proliferation of weapons of mass destruction. Within both areas, INL leverages its scientific expertise, engineering discipline, and unique infrastructure to develop military, homeland security, energy, and industry solutions.

VISION

INL's multiple, full-scale test beds are ideal for performing at-scale experiments and conducting realistic training to improve the resiliency of systems, including the electric-power grid, communications networks, and nuclear security. These facilities also allow us to conduct world-renowned training in radiological response, industrial cybersecurity, and explosives breaching.

Drive national research and development (R&D) efforts

Develop partnerships with government, academia, and industry

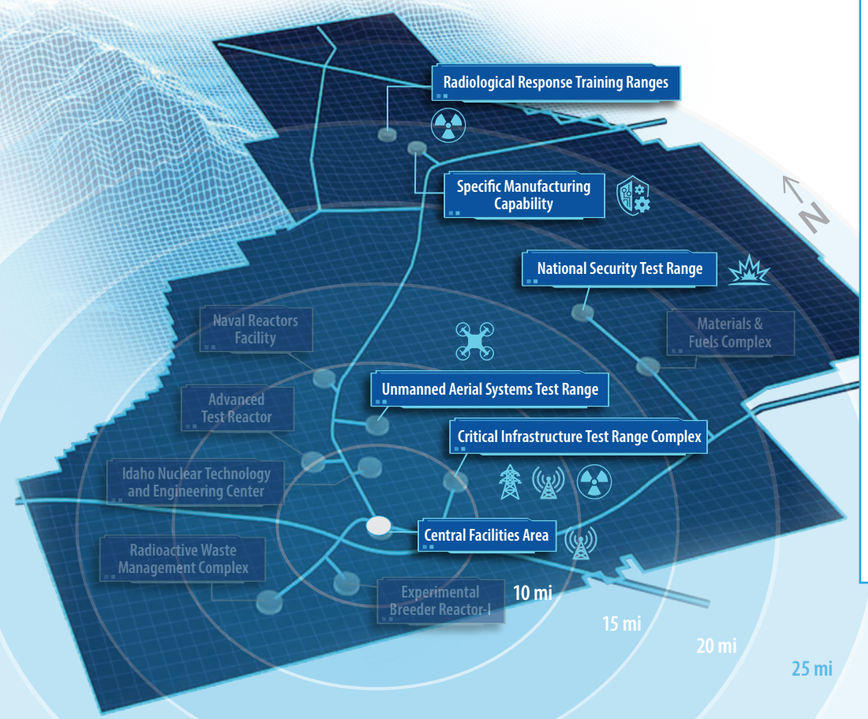
Accelerate national workforce development

For more info, contact: NHStesting@inl.gov

INL NATIONAL SECURITY TESTING FACILITIES:

1. Operational Technology Cybersecurity
2. Electric Power Grid
3. Wireless Communications
4. Unmanned Aerial Systems
5. Nuclear Safety and Radiological Response
6. Breaching and Explosives
7. Materials Science and Manufacturing

NATIONAL SECURITY TESTING



- Over 100,000 ft² of cybersecurity labs, and collaborative and secure meeting spaces
- Over 78 mi of 138 kV lines, multiple substations, and power grids
- Cellular, microwave, satellite, and fiber-optic backhaul wireless communications
- Over 8,100 mi² of Federal Aviation Administration-authorized airspace with a 1,000-ft unmanned aerial systems (UAS) runway
- Several firing ranges and a blast ceiling of 20,000 lb
- Access to large nuclear material and post-irradiation examination hot cells.

1 OPERATIONAL TECHNOLOGY CYBERSECURITY

INL offers a variety of configurable and scalable facilities and laboratory space dedicated to multisector infrastructure operational technology cybersecurity research, development, and training.

Cybercore Integration Center

This state-of-the-art, 80,000-ft^2 facility is equipped with secure office spaces and laboratories to develop cutting-edge operational technology (OT) cybersecurity solutions through analysis, research, and development. The center facilitates collaboration with partners nationwide, including federal entities, other national laboratories, industry, and universities. Featured lab spaces include:

- **University Lab.** Dedicated to workforce development and university engagements focused on OT research.
- **Real-Time Digital Simulator.** Offers high-fidelity modeling focused on power grid protection and at-scale testing.
- **OpDefender Research and Development:** Highlights Laboratory-Directed Research and Development activities by demonstrating harvest opportunities within Cybercore's mission space.
- **Cyber Testing for Resilient Industrial Control Systems (CyTRICS):** Partners with critical infrastructure (CI) stakeholders to identify high-priority OT components, perform expert testing, share information regarding the digital supply chain, and improve component design and manufacturing.

Controls Laboratory

The Controls Laboratory is an environment for government and private industry partners to experience the possible effects of kinetic cyber-physical attacks. This facility allows users to perform security research on industrial control systems (ICS) and supervisory control and data acquisition (SCADA) systems found across multiple infrastructure processes such as oil and natural gas pipelines, electric transmission and distribution, industrial processing, and building management. These versatile and virtually accessible model platforms:

- **Host simulated risk scenarios against real CI processes**
- **Enable the study of complete cyber-warfare against our nation's CI targets and impacts on vital everyday operations**
- **Simulate numerous corporate network configurations and provide control system hardware and kinetic outputs of various CI sectors**
- **Allow concurrent simulations for analysts across the nation to interact with the environment while being both on and offsite through extended range connections.**

FAST FACTS

- An 80,000-ft^2 facility with 20 research laboratories
- Collaborative secure compartmented information facilities
- Separate control system platforms for oil and natural gas, chemical, electrical distribution, transportation, water treatment, and heating, ventilation, and air conditioning
- Off-campus ICS and a Red Team versus Blue Team training center
- A SCADA systems laboratory with remote industry and academic access for security research.

MORE INFO

Cybersecurity Analysis and Training Center

INL has developed unique OT cybersecurity programs to deliver a broad range of training, specifically designed to help industry professionals and all levels of government with cybersecurity defense. The trainings offered are the product of nearly two decades of engaging with industrial workforces, OT equipment manufacturers, and subject-matter experts from multiple CI sectors worldwide. Our approach leverages investments in expertise, research programs, technical infrastructure, and accelerating the sharing of discoveries and emerging threats. Our training facilities provide a unique opportunity for students to participate in fully immersive, hands-on exercises using integrated OT systems and processes.

Cybersecurity-focused escape rooms challenge participants with a variety of industrial control system (ICS) puzzles. These escape rooms are designed to test teams of ICS experts against OT and information technology problems, evaluating their teamwork, communication, and technical skills against a ticking clock. INL has developed more than eight different scenarios to be used for training at INL or at a remote location.

2 ELECTRIC POWER GRID

To ensure our energy delivery system is secure, resilient, and reliable, INL operates a utility-scale electric grid test bed. It is a collection of specialized capabilities that creates a centralized location where government agencies, utility companies and equipment manufacturers work together to find solutions to many of the nation's most pressing security issues.

The Critical Infrastructure Test Range Complex (CITRC) is home to INL's power grid test bed, featuring the commercial-grade Special Power Excursion Reactor Tests (SPERT) substation, Raghorn transmission line, Obsidian transmission substation, and several grid-edge test pads and laydown areas. With redundant lines, breakers, and relays, CITRC is ideal for component and controller testing without disruption to critical loads. INL's expert line crew, engineers, researchers, and spare-component stock make CITRC a flexible and powerful tool for many types of at-scale testing needs.

This complex is an operational, commercially fed system that provides power on INL's sprawling 890-mi^2 desert site. The test bed includes:

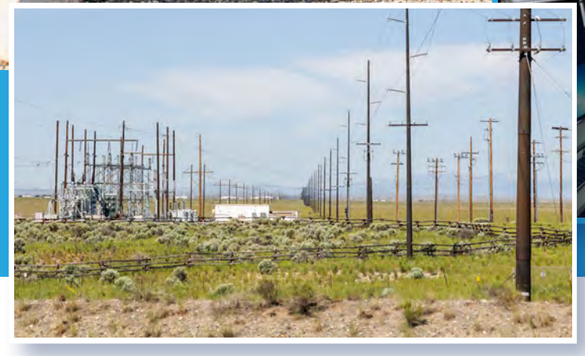
- **Eleven substations, a control center, 78 mi of 138 kV transmission lines and multiple distribution circuits at 15 kV, 25 kV, or 35 kV**
- **Dedicated 16.5 mi of 138 kV transmission line used solely to conducting full-scale test experiments for equipment like diesel generators, transformers, gas-filled circuit breakers, switchgears, load banks, instrumentation, and battery trailers**
- **Sections of the grid can be isolated and reconfigured for integrated testing and demonstration of state-of-the-art power systems, components, and smart-grid technologies**
- **Two-thirds of the United States (U.S.) distribution-class voltages alongside fiber connectivity, instrumentation, and smart-grid interface test points**
- **Loop-fed substations are linked with modern SCADA systems and a dedicated fiber-optic communications network**
- **Loop-fed substations are linked with modern SCADA systems and a dedicated fiber-optic communications network**

Power Quality

INL's robust power-systems engineering, modeling, and analysis capabilities at the power test bed collectively represent a rare resource across the U.S. Department of Energy (DOE) laboratory complex. These systems support:

- **Power-quality and phenomenology studies associated with new equipment and system operations**
- **High-fidelity measurement systems that capture transients, harmonics, voltage, and current**
- **Development and full-scale testing of new technologies and devices for interoperability, operational performance, reliability, and resiliency contribution.**

Geomagnetic-disturbance research and testing is also underway with several DOE offices that will employ INL's power testing to validate select protective-relay security methodologies and demonstrate, at scale, the effects that certain classes of cyberattack exploits could have on critical grid operations.



FAST FACTS

- Power grid security expertise, laboratory space, and a full-scale test bed complete with modern commercial infrastructure
- Located on the laboratory's 890-mi^2 desert site inside CITRC
- Supports government, military, and industry customers with full-scale research, testing, and training services
- Offers collaborative approaches to power grid security and control systems cybersecurity.

MORE INFO

3 WIRELESS COMMUNICATIONS

INL's Wireless Test Bed offers large-scale, end-to-end testing of cellular, fixed, and mobile radios, wireless local area networks and telecommunications backhaul (microwave, free-space optical, fiber-optic, and satellite) systems to industry and government.

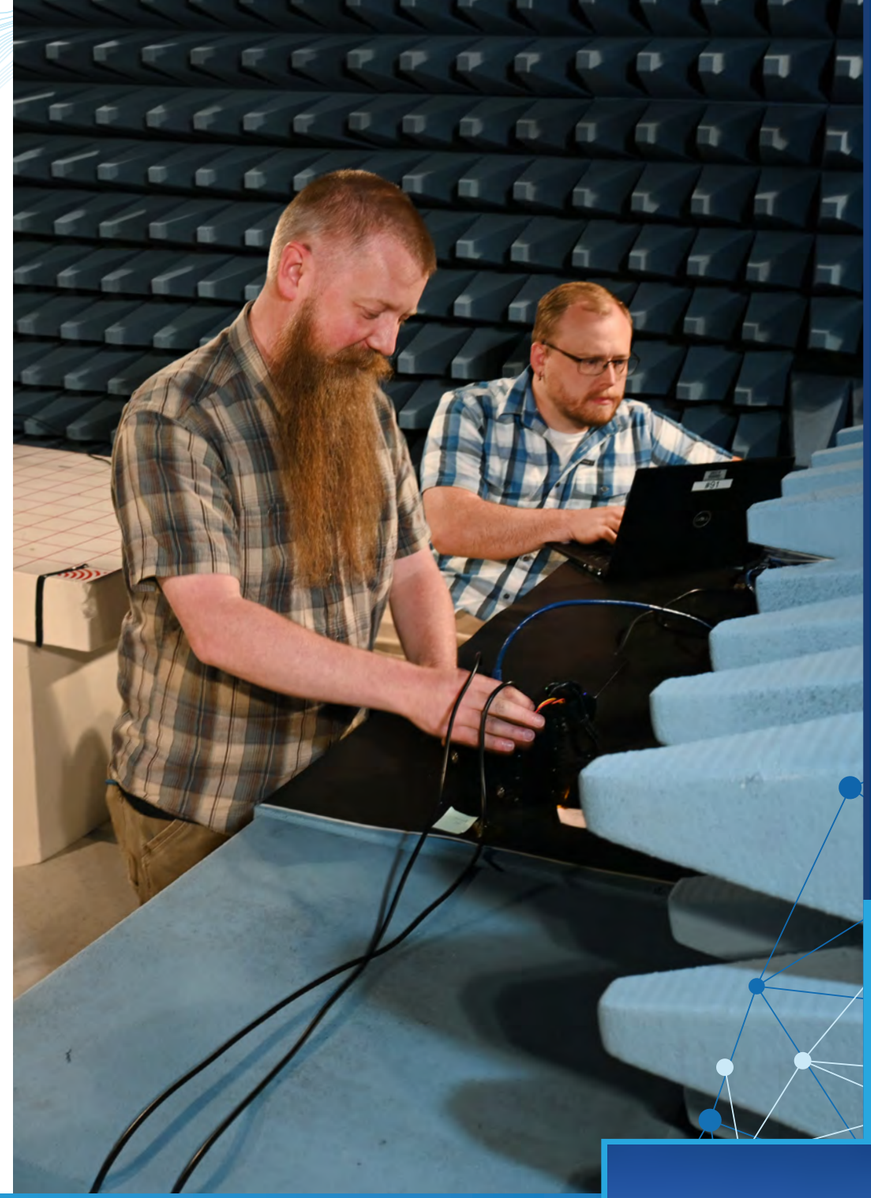
This large-scale, open-air, controlled range includes full-scale communications networks, a low-radio frequency noise floor, and spectrum-use authorization to support rich communications experimentation. INL has industry-experienced technical professionals who design, build, and operate real-world networks for realistic testing and evaluation. This includes dynamic customization of network parameters to ensure operationally relevant testing.

Situated in a natural caldera, INL's wireless test bed is buffered from outside radio-frequency sources. This allows engineers to test devices and hardware ranging from high-frequency (HF), ultrahigh-frequency (UHF), cellular, satellite, and microwave platforms, as well as everything in between.

5G and Beyond Wireless Test Bed

As one of the nation's premier wireless test beds for academia, industry, and government organizations, INL offers the ability to test and demonstrate full-scale wireless systems and equipment with a range of congested and contested environments, such as:

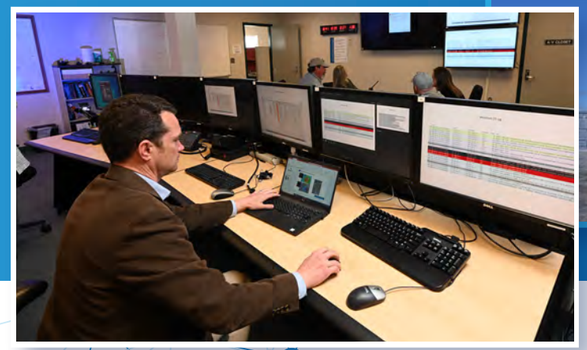
- **Tier 1, carrier-grade cellular networks, including 5G standalone and non-standalone, 4G Long-Term Evolution, 3G Universal Mobile Telecommunications System, and 2G Global System for Mobile Communications networks. Technicians also monitor and record cellular interfaces during test events.**
- **Lab-scale 5G networks for security assessments, research, and experimental configurations.**
- **Limited urban- or military-communication congestion for more-sensitive radio-frequency reception. Typical noise threshold is less than -120 decibel mW over 10 kHz resolution bandwidth.**
- **National Telecommunications and Information Administration experimental radio-station status that offers a range of available spectra and testing on most frequencies.**
- **The ability to provide users with rapid experimentation approval within weeks and to offer maximum power and frequency test options and remote spectrum monitoring.**



Spectrum Innovation Laboratory

INL's communications research facilities and test equipment encompass:

- More than 3,500 ft^2 of laboratory space, complete with anechoic chambers and Faraday cages
- Signal generators and vector-signal analyzers
- Network analyzers and oscilloscopes
- Various software-defined radio waveform-development tools
- Radio-frequency record and playback systems



FAST FACTS

- Next-generation wireless infrastructure including 5G and beyond
- National Telecommunications and Information Administration authorization for an experimental radio station
- 3,500 ft^2 of laboratory space with anechoic chambers and Faraday cages
- Expertise in cellular, WiMax, HF, UHF, radar, antenna, and satellite fields
- Ability to host large exercises and demonstrations with up to 500 participants.

MORE INFO

4 UNMANNED AERIAL SYSTEMS

INL excels in sensor and platform testing, validation, and demonstration. With 8,100 mi2 of federally authorized airspace, a secure boundary, and the ability to work with the Wireless, Explosives, and Breaching and Radiological Response test ranges, INL is a prime location for UAS testing. INL works closely with some of the nation's top drone manufacturers and military branches to support the integration and field testing of advanced UAS and counter-UAS platforms.

As UAS capabilities increase, so do their applications in commercial and military operations. Reliable UAS platforms require advanced sensors, thorough testing of equipment, and well-trained personnel.

The INL site provides a secure and isolated environment for federal UAS testing and ensures the proper use of unmanned aerial vehicles for DOE and the National Nuclear Security Administration (NNSA). This environment includes:

- A 1,000-ft runway and a 30 ft × 50-ft enclosed shelter
- More than 40 types of UAS-using mobile control stations that incorporate command and control, sensor communication, monitoring, and data-acquisition capabilities
- Aircraft range in size from less than 1 to nearly 150 lb
- Powered by small reciprocating engines and electric motors
- The ability for most commercial autopilots to use full autonomous operations from takeoff to landing.

FAST FACTS

- 8,100 mi² of federally authorized airspaces with Certificates of Authorization for beyond visual line-of-sight and swarming activities from the Federal Aviation Administration
- Less than 1% radio-frequency noise floor
- 2G–5G cellular communications
- Over 20 years of UAS testing experience
- Over 10 years of counter-UAS experience.

MORE INFO

Advanced Drone Technology

Drones undergo rigorous testing on INL's range, facing severe weather, temperature extremes, and long-distance challenges both day and night. The integrated test bed infrastructure at INL creates real-world conditions to evaluate UAS reliability during critical missions. In parallel, INL supports counter-UAS research and development to assess emerging detection, tracking, and mitigation technologies against evolving drone threats.

5 NUCLEAR SAFETY AND RADIOLOGICAL RESPONSE

The laboratory's desert site can be used for large-scale interagency technology and capability demonstrations. Students and stakeholders also have access to nuclear facilities that include operating reactors, hot cells, and analytical laboratories inside a controlled location that provides a safe and secure environment for training.

Radiological Response Training Ranges

INL has two ranges for radiological search and response training. At approximately 100 acres each, both the north and south ranges provide secure, isolated locations to train personnel, test aerial and ground-based sensors, and develop detection capabilities with radioactive materials under controlled conditions. Students also have access to nuclear facilities including operating reactors, hot cells, and analytical laboratories inside a controlled location that provides a safe and secure environment for training.

This training can be scaled to accommodate any sized group or length of time. Course materials can also be tailored to responder needs to search, interact, and render safe a radiological dispersal device or other potentially dangerous materials.

INL delivers a broad spectrum of field-training exercises, ranging from individual skill development to complex, full-mission profile scenarios. These exercises enable participants to deploy their radiation detection equipment and apply tactics, techniques, and procedures in highly realistic, scenario-based environments.

Participants have access to a robust radiological inventory of over 300 sealed radioactive sources, including both industrial and special nuclear materials. The program incorporates seven isotopes currently used for indoor and outdoor dispersal through mechanical and explosive means. These include sources that emit both beta and alpha radiation, providing rare and valuable opportunities to train with authentic radioactive contamination.

Moran Nuclear Fuels Test Facility

The Moran test bed is a versatile facility used for various programs and interagency missions. Moran facilitates high-impact research and training sessions that strengthen nuclear security. Moran also supports efforts in proliferation detection, counterproliferation, and other national security applications.

The Moran facility is capable of 33-MTHM processing throughput, handling surrogate materials, and dissolving depleted and natural uranium fuel in various forms. Additionally, the facility can introduce radioisotopes in solid, liquid, and gas forms, with fuel-chop and decladding capabilities coming online in 2026.

Moran operates as an NNSA test bed and focuses on developing next-generation solvent-extraction experts. In collaboration with other national laboratories, Moran also supports such NNSA initiatives as Sapphire Phoenix, Athena, and Trident.

Solvent Extraction Equipment Testing Laboratory

This laboratory focuses on the evaluation of solvent-extraction systems, which are crucial for the separation and purification of various chemical compounds, including those used in nuclear fuel reprocessing and environmental remediation. State-of-the-art instrumentation and facilities include:

- Bench-scale and pilot-scale solvent-extraction equipment
- Analytical instruments for chemical analysis
- Simulation tools for process optimization.

These assets enable researchers to study the efficiency, selectivity, and stability of different solvent-extraction processes under various conditions.

FAST FACTS

- Operational testbed since 2013, enhancing U.S. reprocessing capabilities
- Built and tested for the U.S. Department of Defense (DOD) from 2006 to 2012
- Features first- and second-cycle solvent extraction processes
- Supports 18 U.S. government agencies and organizations
- Capable of 33-MTHM processing throughput.

MORE INFO

6 BREACHING AND EXPLOSIVES

The National Security Test Range (NSTR) provides access to capabilities to understand and mitigate emerging challenges being faced on the battlefield. The range is positioned to support a wide variety of full-scale and practical testing opportunities for DOE, DOD, and Homeland Security (DHS), the NNSA, and other federal and industry collaborators. Located about 45 miles west of Idaho Falls, INL's exceptional geography includes 330 acres of isolated desert terrain with eight dedicated test ranges, tactical facilities, and restricted airspace that allow research to be conducted safely and securely.

The research and testing capabilities at the NSTR are flexible and adaptable to meet custom requirements and emerging threats. The laboratory's expertise spans ballistics, explosives, and barrier testing. Breaching strategies, high-performance modeling and simulation capabilities, and mission rehearsal support are part of NSTR's capabilities, which offer:

- A 20,000-lb net explosive weight (NEW) limit
- Military, foreign-improvised, secondary-homemade, binary, and custom explosives
- Domestic small-arms and heavy-weapons ballistics
- Tactical-breaching training
- An 8-km range fan
- A 3000-m firing range
- Explosive-, mechanical-, thermal-, and heavy breaching techniques
- Foreign weapons, grenades, and rockets
- Delay analysis and testing for vulnerability assessments
- Barrier testing, including vehicle-born improvised explosive device testing
- Emerging threat intelligence
- Explosive and energetics chemists
- Scientific test cannons (14.5, 20, and 30 mm)
- Flyer plates, formed penetrators, improvised devices, and shaped charges.

The NSTR enables a strategic approach to technology development and deployment with the following critical advanced capabilities, equipment, and techniques:

- Dynamic scientific measurements, such as pressure, acceleration, force, strain, velocity, and penetration
- Dedicated manufacturing facilities for secure prototyping and production
- Explosives and energetic-materials characterization from a material test chamber, electrostatic discharge testing, and acoustic mixing
- High-speed data acquisition from Hi-techniques meDAQ (16 ch, 2 MS/sec/ch, PC-controlled) and National Instruments-printed circuit board (2 PXI chassis, 96 ch each, 60 MS/sec/ch, extensible) systems
- High-speed photography and advanced flash x-ray systems that offer Phantom cameras, an L3 Titan FXR system, and Shimadzu Hyper Vision HPV-X2 cameras

FAST FACTS

- 330 acres of isolated desert terrain with eight dedicated test ranges
- A 20,000-lb NEW limit
- An 8-km range fan
- A 3000-m firing range and tactical facilities
- 8,100 mi² of Federal Aviation Administration-authorized airspace.

MORE INFO

- High-performance computational capabilities
  - Eulerian and Lagrangian computational mechanics
  - Multiphysics computational analysis and customizable solvers
  - Artificial intelligence and machine learning from full-scale simulation to molecular modeling
  - Immersive visualization for very large data sets
  - Statistical post-processing for optimization and validation

7 MATERIALS SCIENCE AND MANUFACTURING

Survivability engineers and materials scientists at INL design, validate, and manufacture unique armor prototypes that increase protection levels while reducing weight and production costs. Over the last 25 years, many of the lab's survivability designs have been used around the world to safeguard people, vehicles, and facilities.

Manufacturing

INL's manufacturing capability has been the lead manufacturer of armor packages for the Department of Defense for over 40 years. INL experts can provide independent technical evaluations and solutions to manufacturing, engineering, and material science for a variety of programs and customers.

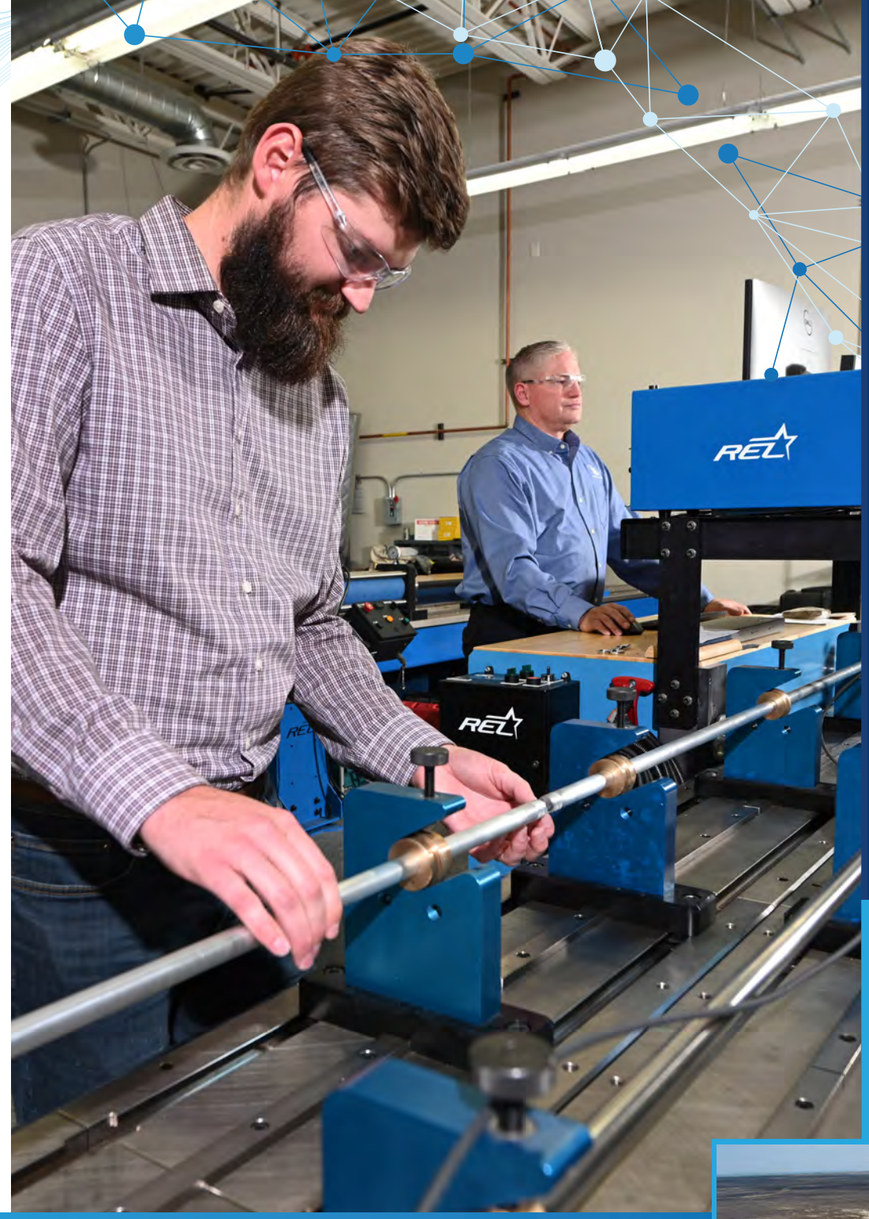
INL material scientists and engineers design and validate multiple forms of survivability solutions, which offer:

- **Lightweight, bullet-trapping armor for law enforcement watercraft**
- **Ballistic-resistant protection**
- **Hardened critical facilities to defend against explosively formed projectiles and shaped-charge threats**
- **Expertise working with ceramic, metallic, and composite materials to create custom survivability applications**
- **Novel material-bonding techniques and encapsulation methods for licensed and patented armor designs.**

Mechanical Testing

INL engineers can execute creep testing, quasistatic compression, and tension experiments using servo-hydraulic load frames; dynamic compression, tension, and torsion testing using a split-Hopkinson pressure bar; and dynamic hardness testing. A multi barrel, single-stage gas launcher can be used to execute standard Taylor cylinder impact testing or moderate velocity impact work. Engineers can also deploy a digital-image correlation system in many of these testing schemes.

Prototypes can then be tested against explosive charges and other dynamic threats at the NSTR's several secure test sites. These tests allow for rapid prototyping with limited-run production and testing of system response.



FAST FACTS

- Lead manufacturer of armor packages for the U.S. Army's Abrams main battle tank since 1984.
- Licensed and patented survivability designs that have safeguarded people, vehicles and facilities for over 25 years.
- A 30-mm smooth-bore powder gun with launch tubes and 2 receivers with barrel calibers ranging from 0.30-in to 30-mm.
- State-of-the-art rapid-prototyping facility with several multi-axis computer numerical control machinery.

MORE INFO

Field Experiments

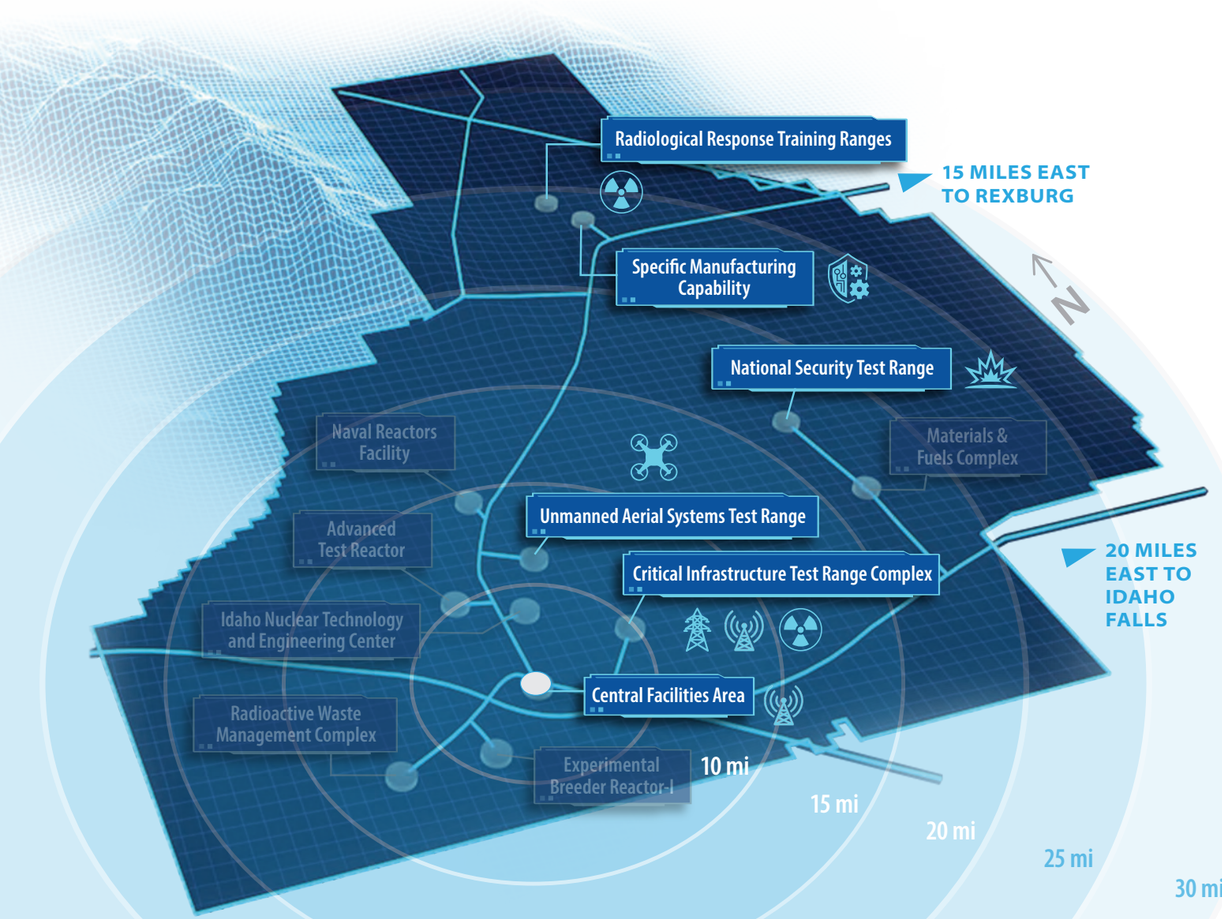
Validation testing of candidate designs can be performed against explosive and ballistic threats ranging from simple blast-loading and live-fired rocket-propelled grenades to static-fired shaped charged jets and explosively formed projectiles, fragment simulating projectiles, and standard armor-piercing projectiles.

These systems provide:

- Ballistic testing supported by a 30-mm smooth-bore powder gun and a single-stage gas gun with 3.5-in. and 5.25-in. ID smooth-bore barrels
- Additional ballistic testing using a Wiseman universal breech with 9-mm, .357, 30 Cal, and 50-Cal barrels, as well as a Sydor breech with 20-mm and 30-mm barrels
- State-of-the-art modeling and simulation tools, including ABAQUS/Explicit, EPIC, CTH, ALEGRA and ALE-3D to model the interaction of dynamic threats with current and proposed protection designs
- The diagnosis of component dynamic response under many environments using pressure gauges and accelerometers, 450-kV flash x-ray imaging, high-speed cameras (up to 10 million frames per second) with laser illumination, dynamic digital image correlation, and photon Doppler velocimetry systems.

INL TESTING FACILITIES MAPS

Within a 30-mile radius sits a range of testing facilities with various capabilities catering to national security and critical infrastructure initiatives.

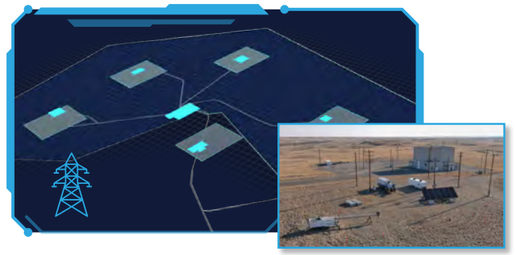


CFA Central Facilities Area

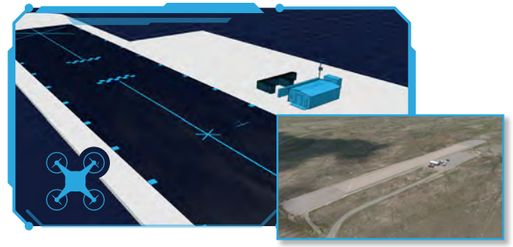
NSTR National Security Test Range

RRTR Radiological Response Training Ranges

CITRC Critical Infrastructure Test Range Complex

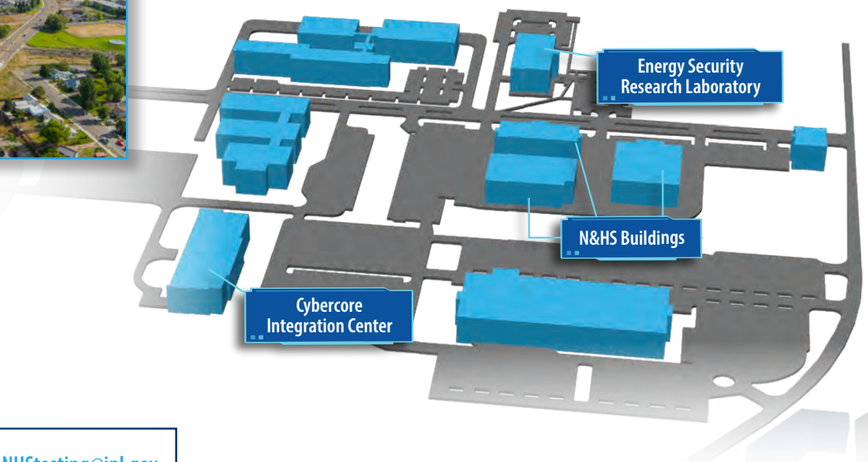


UAS Unmanned Aerial Systems Test Range



REC Research and Education Campus

Located in Idaho Falls, 20 miles east of the desert site.



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Idaho National Laboratory