TECHNOLOGY TRANSFER

ANNUAL REPORT

Idaho National Laboratory

Contents

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Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy.

From the Technology Deployment Director

As director of Technology Deployment at Idaho National Laboratory, I am proud to serve an organization with such dedication to our mission, outcome and strong spirit of innovation.

Deploying INL technologies and capabilities for industry use is our number one goal. It's imperative that we transfer our technologies to improve lives, keep our nation safe and help our economy flourish. Every time industry leverages the lab to overcome a challenge or a technology moves from the benchtop to the marketplace, INL is making an impact. This cannot be done without our esteemed innovators, experts and champions who worked tirelessly to contribute to the many achievements and accomplishments in 2022.

Our innovators and technology transfer staff members delivered impressive numbers of innovation disclosures and license agreements in 2022. Through fiscal year 2022, there are 483 active licenses. We also continued to capture more Strategic Partnership Projects, User Facility, and Cooperative Research and Development Agreements to address industry challenges.

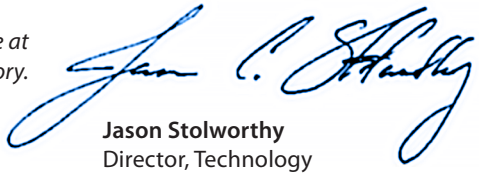
We also were honored to have three INL technologies named as 2022 R&D 100 winners.

Technology Deployment fully takes on the Next-Level INL initiative as it pushes to find new approaches and opportunities to commercialize and license INL technologies. This past year, we underwent an extensive, first-of-its-kind-study called ETHOS to lay the groundwork on how the laboratory can improve its innovation culture and advance cutting-edge technologies. This study validated that innovation and collaboration are at the heart of achieving even greater accomplishments, and if we can improve our support and ability to innovate, we can achieve the Next Level INL vision.

We appreciate the strong support from private and government sponsors, the Department of Energy, commercial partners and lab leadership over this past year.

We encourage you to read more about the impactful deployments captured in this report.

It truly is an exciting time to be at Idaho National Laboratory.



Jason Stolworthy
Director, Technology Deployment

IN 2022, THE LAB LAUNCHED THE NEXT LEVEL INL INITIATIVE TO GUIDE OUR DECISIONS AND HOW WE WORK, WHILE KEEPING INL FOREMOST IN OUR MINDS.

TRANSFORM OUR CULTURE

TRANSFORM THE WAY WE WORK

TRANSFORM OUR INFRASTRUCTURE

TRANSFORM INL TO NET-ZERO

Corey McDaniel
Director of Industry Engagement and Chief Commercialization Officer

Jason Stolworthy
Director of Technology Deployment

Sheena Kanyid
Manager, Agreements Management

Abstract

Idaho National Laboratory (INL) is a U.S. Department of Energy (DOE) multiprogram national laboratory that conducts research and development in all DOE mission areas. Like all national laboratories, INL has a statutory technology transfer mission to make its capabilities and technologies available to federal agencies, state and local governments, universities, and industry.

To fulfill this mission, INL encourages its scientific, engineering and technical staff to disclose new inventions and creations to ensure the resulting intellectual property is captured, protected and made available to others who might benefit from it. As part of the mission, intellectual property is licensed to industrial partners for commercialization, job creation and delivering the benefits of federally funded technology to consumers. In some cases, unique capabilities are made available to other federal agencies, international organizations, domestic and foreign commercial entities, or small businesses to solve specific technical challenges.

INL employees work with researchers and technical staff members from the university and industrial sectors to develop emerging technologies. In this global economy, INL helps develop the next generation of engineers and scientists by licensing software to educational institutions throughout the world.

This report is a catalog of select INL technology transfer activities, including commercialization transactions and research agreements, executed during the past year. The size and diversity of INL technical resources, coupled with relationships with other organizations, virtually ensures the report will fail to capture all interactions. Recognizing this limitation, this report focuses on transactions specifically authorized by technology transfer legislation (and corresponding contractual provisions) or involve the transfer of legal rights to technology to other parties. This report was compiled from primary records that were readily available to INL's Technology Deployment and Agreement Management offices. Accomplishments cataloged in the report reflect the achievements and creativity of INL's researchers, technicians, support staff and operators.

Prepared for the U.S. Department of Energy Under DOE Idaho Operations Office

Contract DE-AC07-05ID14517

Intellectual Property

INL's Intellectual Property portfolio includes invention disclosure records, patent applications, issued patents and copyright assertions, providing a basis for collaboration with commercial enterprises, academia, and other parties, both domestic and international. INL's science, engineering and technical Intellectual Property portfolios provide the laboratory and opportunity to deploy its creative, meaningful research.

Technology Deployment works closely with INL management and researchers to identify and pursue opportunities for technology commercialization and business development.

In fiscal year 2022, INL inventers submitted 96 invention disclosure records and 54 software disclosures to Battelle Energy Alliance LLC (BEA).

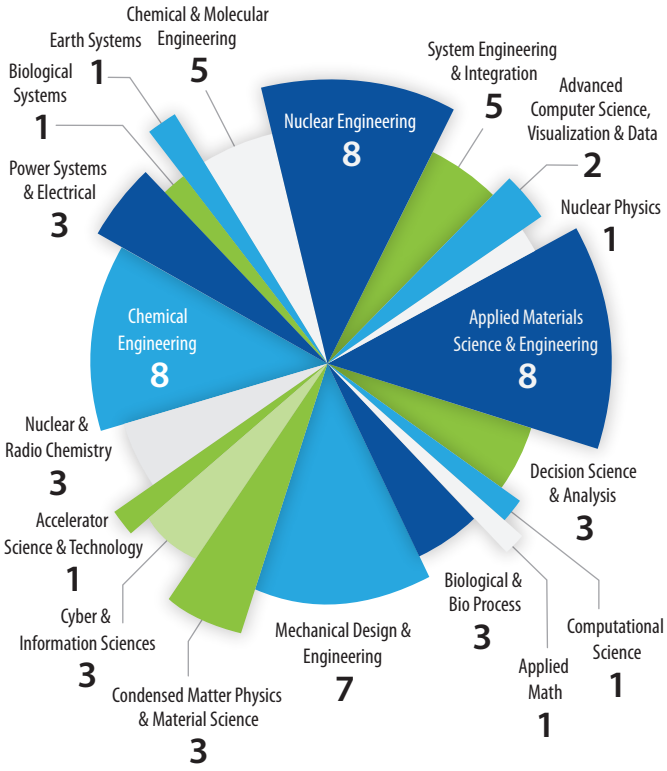
In FY-22, 25 U.S. patents were issued to either INL or DOE based on the inventions of INL scientists and researchers.

Since the commencement of BEA's contract to manage INL in 2004, laboratory researchers have submitted over 1,500 disclosures resulting in close to 700 issued U.S. patents. Over 1,100 new licenses have been executed over this period.

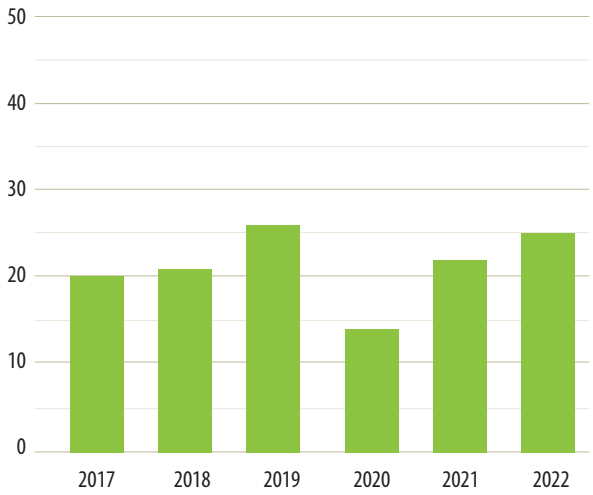
BEA has Intellectual Property ownership rights under its contract with DOE and can retain title to inventions and seek patent protection, subject to some exceptions. The decision of whether to seek patent protection is based on market and technical assessments of the technology and its subsequent programmatic value.

Market assessments inform a recommendation presented to a committee composed of department or project managers, an assistant laboratory director or designee, market analysts, commercialization managers, and a patent attorney. The Technology Deployment director makes a final decision to elect or decline the technology for patent protection. Generally, potential inventions judged to be commercially valuable, crucial to a primary mission or valuable in terms of motivating further research funding are elected.

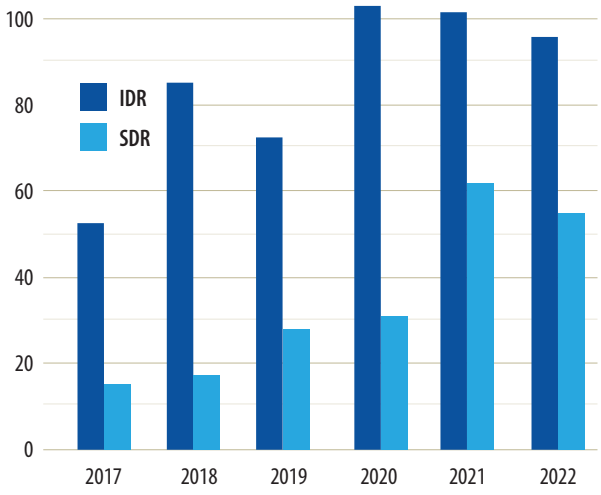
CORE COMPETENCIES ASSOCIATED WITH FY 2022 PATENTS



U.S. PATENTS ISSUED FY 2017–2022



DISCLOSURE RECORDS RECEIVED FY 2017–2022



Challenge Accepted: ETHOS Study on Innovation Culture

The Next-Level INL initiative, launched in early 2022, challenged employees to focus on transforming culture, transforming the way they work, transforming our infrastructure, and transforming Idaho National Laboratory to net-zero; all to improve how we achieve the lab's overall mission. INL's Technology Deployment team took on this challenge – particularly in focusing on transforming our culture and how we work – to improve the lab's innovation.

The United States invests more than $30 billion every year into its national laboratories, which are owned and operated by the U.S. Department of Energy. Their mission, according to DOE's mission statement, is to "ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."

Innovation plays a key role turning ideas into practical solutions to advance the lab's mission, said Jason Stolworthy and James Keating of INL's Technology Deployment office.

Stolworthy and Keating produced a report for DOE's Office of Technology Transitions entitled "Entrepreneurial Thinking: Historical and Observational Study (ETHOS)." The report describes itself as "an evaluation of cultural impact on technology transfer performance in semi-homogeneous research and development organizations."

With help from two private firms, InnovationOne of Scottsdale, Arizona, and IdeaScale of San Francisco, the two have analyzed 2,136 survey responses across six DOE national laboratories, quantifying innovation culture and assessing the impact of "innovation drivers" against key performance metrics.

In conducting their study, Stolworthy and Keating discovered innovation culture at the six DOE labs surveyed differed greatly. "There are common opportunities with respect to innovation culture in the labs, that if addressed, could provide DOE and the public a significantly greater return on investment into the labs," they wrote. In fact, a key finding was that a one-point difference in a lab's innovation culture score on a 100-point scale corresponded with a 20-30% increase in performance of key research and development outcomes.

Based on their findings, lab leadership should consider the following recommendations:

- **PROMOTE:** Get the message out that a culture of innovation profoundly improves lab performance. "Highly innovative organizations learn to achieve their goals while funding and supporting innovation activity, which in turn improves outcomes and financial performance. It is not one or the other."

- **INVEST:** Compared to private industry, the labs have the greatest opportunity for improvement here. "Invest in employee skills and creativity, technology and financial support, and employee and team empowerment."
- **INNOVATE:** Leaders at every lab need to improve engagement with employees. This will accelerate experimentation and improve collaboration, with rewards for collaboration, risk-taking and empowerment.

At higher-scoring and lower-scoring labs, leadership is advised to establish and incorporate innovation strategies into strategic planning. "Leaders need to communicate their vision and strategies frequently and ask employees and external partners to jump in and recommend solutions," they wrote.

If DOE prioritizes and incentivizes it, innovation will happen. It will involve envisioning the culture, defining the goals and communicating them consistently.

From taking part in ETHOS, each participating lab received a specific action plan to improve its culture of innovation. Using a methodology developed at INL to measure incentive alignment, this was the first time the alignment of incentives was considered both internally and with external stakeholders.

ETHOS

Entrepreneurial Thinking: Historical and Observational Study

A PACT Project Funded by
DOE Office of Technology Transitions

Innovation cultures and organization performance are shown to be positively correlated with claims that innovative companies have up to **10x** higher returns on innovation investments. The ETHOS project hypothesized that culture similarly impacts performance in Department of Energy labs. **2,136** survey responses were analyzed to quantify the culture of **six DOE National Laboratories** by measuring innovation culture and assessing the impact of "innovation drivers" against key performance metrics. Quantified cultures were correlated against normalized metrics.

Conclusions:

1. The innovation cultures at DOE labs differ greatly and can be significantly improved based on tech-based company benchmarks.
2. Lab performance, in nearly all areas measured, correlate strongly with the health of a lab's innovation culture.
3. There are common addressable innovation culture challenges in the labs, that if addressed, could provide DOE and the public a significantly greater return on investment.

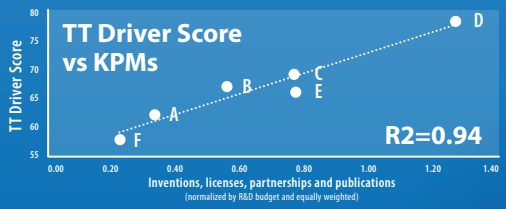
Innovation Culture Score Results

2,136 surveys analyzed

- **72** US F1000 Average Company Benchmark
- **71** Lab High
- **66** Lab Average
- **60** Lab Low

CORRELATIONS SHOW…

Improving culture score by: **+1** point → **can increase inventions, licenses, partnerships and publications by:** **30** percent



Analysis of: 1,226 comments

High scoring labs show leadership frequently promotes:

--- Support for innovation ---
--- Collaboration and learning ---
--- Working with industry ---

Top factors that impact key metrics based on correlation data…

Inventions

- Leadership encouragement
- IP recognition skills
- Effective TT processes

Publications

- Encourage pushing boundaries and taking risks in research
- Encourage employees to be innovative

Commercial Outcomes

- Innovation skills
- Value propositions
- Knowing market needs
- Understanding how innovation contributes to mission

Partnerships

- Lab encouragement
- Knowing market needs

In the full report…

50 Interviews from lab thought leaders analyzed

Comparisons by:
- Tenure
- Manager/researcher
- Innovativeness
- Gender

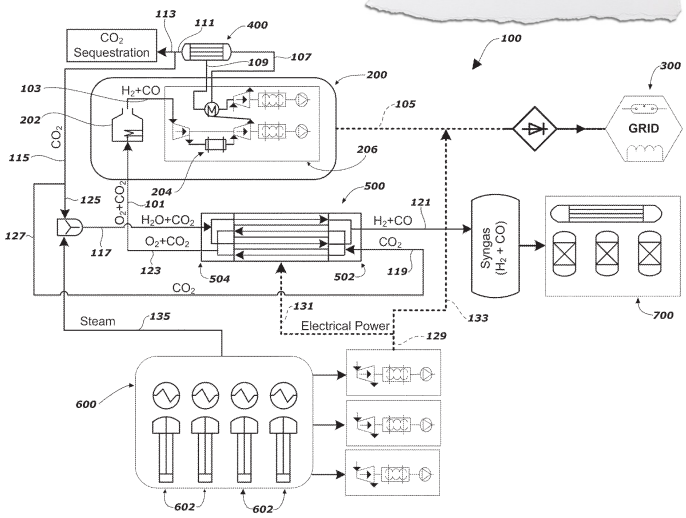
Insights on:
- Improving culture outcomes
- Talent acquisition
- Alignment and empowerment
- Value creation … and more!

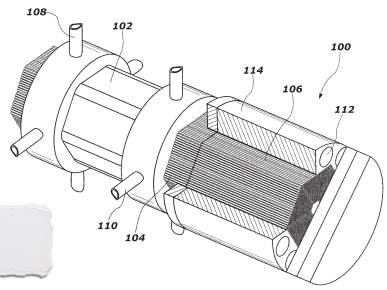
INL Idaho National Laboratory

- Advanced computer science, visualization and data
- Applied materials science and engineering
- Biological and bioprocess engineering
- Chemical and molecular science (emerging)
- Chemical engineering
- Computational Science
- Condensed matter physics and materials science (emerging)
- Cyber and information sciences
- Decision science and analysis
- Environmental subsurface science
- Large-scale user facilities/ R&D facilities/advanced instrumentation
- Mechanical design and engineering
- Nuclear and radiochemistry
- Nuclear engineering
- Power systems and electrical engineering and integration
- Systems engineering and integration

[1] Accelerator Science and Technology
[2] Applied Mathematics
[3] Biological Systems Science
[4] Earth System Science
[5] Nuclear Physics

Patent 11,142,832





Patent 11,174,536

FIG. 1

Patent Overviews

Methods and Systems for Syngas Production and for Efficient, Flexible Energy Generation

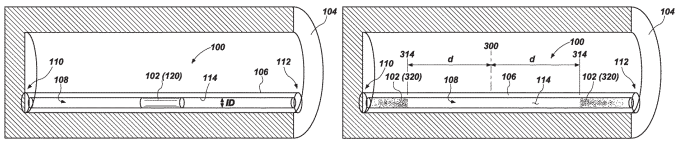
Methods for producing syngas (e.g., H_2 and CO) include introducing a stream comprising H_2O and CO_2 to a high-temperature coelectrolysis (HTCE) unit. A CO_2 sweep gas is also introduced to the HTCE unit. Both H_2O and CO_2 are reduced in the HTCE unit to form the syngas and O_2,which is swept away from the HTCE unit by the CO_2 sweep gas. The O_2 and CO_2 are then introduced to a combustion device (e.g., a gasifier), which may be configured to generate electrical power as a result of combusting a carbonaceous fuel in the presence of the O_2 and CO_2. The HTCE unit is powered at least in part by an electricity-generating subsystem (e.g., at least one nuclear power plant). Related systems are also disclosed.

Patent No. 11,142,832 granted Oct. 12, 2021, to James E. O'Brien, Carl. M. Stoots, Michael George McKellar and Richard D. Boardman.

Temperature Locale Sensors and Related Methods

Temperature locale sensors include an enclosure defining a sealed volume with a phase-change material therein at a known pressure. The phase-change material is formulated to exhibit a gas-to-solid phase change, without condensing to a liquid phase, at the known pressure and a targeted temperature, i.e., the material's "deposition temperature." The phase-change material – while at least partially in gaseous form, either initially or after sublimation – is exposed to an environment with temperatures varying by location, including a maximum temperature above the phase-change material's deposition temperature and other temperatures at or below the deposition temperature. The gaseous phase-change material, in a location at the deposition temperature, solidifies from its gaseous phase to form solid grain deposits on a surface within the enclosure of the sensor. The solid deposits precisely identify the location of the specific, targeted deposition temperature.

Patent No. 11,150,143 granted Oct. 19, 2021, to Richard S. Skifton and Lance A. Hone.



Patent 11,150,143

Methods of Forming Metals Using Ionic Liquids

A method of forming an elemental metal (e.g., a rare-earth element) includes forming a multicomponent solution comprising an ionic liquid, a secondary component, and a metal-containing compound. The multicomponent solution is contacted with at least a first electrode and a second electrode. A current is passed between the first electrode to the second electrode through the multicomponent solution. The metal-containing compound is reduced to deposit the elemental metal therefrom on the first electrode.

Patent No. 11,149,356 granted Oct. 19, 2021, to Donna L. Baek, Robert Vincent Fox and Tedd E. Lister.

Methods and Systems for Aluminum Electroplating

Systems and methods for coating a metallic component are provided. In one embodiment, a metallic coating may be disposed in a plating bath comprising aluminum bromide ($AlBr_3$). The metallic coating may be coupled with, or configured as, a working electrode. A counter electrode formed of aluminum may be disposed within the plating bath. An electric current may be applied between the two electrodes resulting in the electrodeposition of aluminum on the metallic component. In one particular embodiment, the plating bath may include lithium bromide (LiBr), potassium bromide (KBr) and cesium bromide (CsBr), with $AlBr_3$ being present in an amount of approximately 80 percent or greater by weight. Various types of metals may be coated with aluminum using embodiments of the present disclosure. Additionally, the methods and systems described herein are amenable to coating of complex geometries.

Patent No. 11,136,686 granted Oct. 5, 2021, to Prabhat Kumar Tripathy, Guy Lawrence Fredrickson, James Stephen Herring, Eric J. Dufek and Laura A. Wurth.

Tt: Gap Measurement System

This gap measurement device has a circuit having a variable inductor and a capacitor. The variable inductor has an indicator. The device has a gap that includes a gap measurement and a gap length. The gap measurement is related to the inductance. The gap is configured to receive at least a portion of the variable inductor while the variable inductor moves along the gap length. The movement of the variable inductor along the gap length causes the inductance to change in response to the gap measurement.

Patent No. 11,156,447 granted Oct. 26, 2021, to Joel A. Johnson and Ronald J. Heaps.

Systems and Methods for Improved Landscape Management[1]

Disclosed here are systems, methods, apparatus, and/or nontransitory computer-readable storage comprising machine-readable code for the development and application of high-resolution crop yield models. The disclosed yield models may be captured yield data and corresponding remote sensing data covering relatively limited areas. Embodiments of the disclosed yield models may be capable of estimating spatial yield characteristics in areas for which accurate yield data are not available (and/or not practical to acquire), thereby enabling more widespread application of integrated land management techniques.

Patent No. 11,170,219 granted Nov. 9, 2021, to Lloyd M. Griffel, Damon S. Hartley and Matthew R. Kunz.

Transition Metal-based Materials for Use in High Temperature and Corrosive Environments

A material (e.g., an alloy) comprises molybdenum, rhenium, and at least one element selected from the group consisting of tellurium, iodine, selenium, chromium, nickel, copper, titanium, zirconium, tungsten, vanadium, and niobium. Methods of forming the material (e.g., the alloy) comprise mixing molybdenum powder, rhenium powder, and a powder comprising at least one element selected from the group consisting of tellurium, iodine, selenium, chromium, nickel, copper, titanium, zirconium, tungsten, vanadium, and niobium. The mixed powders may be coalesced to form the material (e.g., the alloy).

Patent No. 11,174,536 granted Nov. 16, 2021, to Prabhat Kumar Tripathy.

Methods of Forming Structures and Fissile Fuel Materials by Additive Manufacturing

A method of forming one or more structures by additive manufacturing comprises introducing a first layer of a powder mixture comprising graphite and a fuel on a surface of a substrate. The first layer is at least partially compacted and then exposed to laser radiation to form a first layer of material comprising the fuel dispersed within a graphite matrix material. At least a second layer of the powder mixture is provided over the first layer of material and exposed to laser radiation to form intergranular bonds between the second layer and the first layer. Related structures and methods of forming one or more structures are also disclosed.

Patent No. 11,177,047 granted Nov. 16, 2021, to Sean Robert Morrell and Isabella J. Van Rooyen.

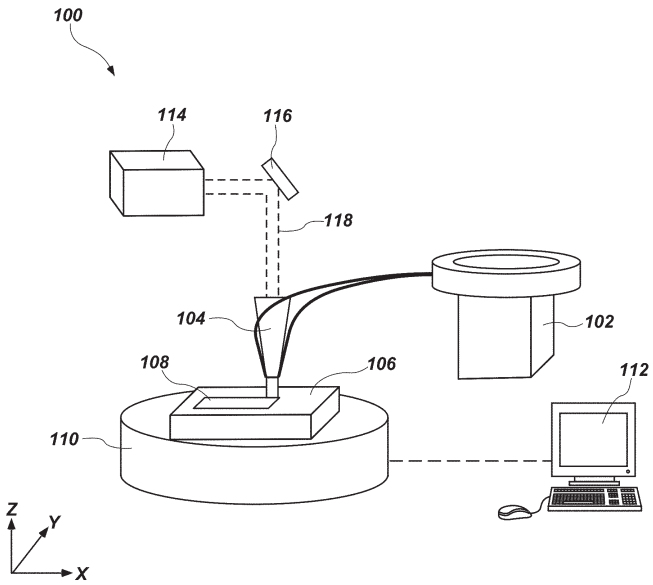
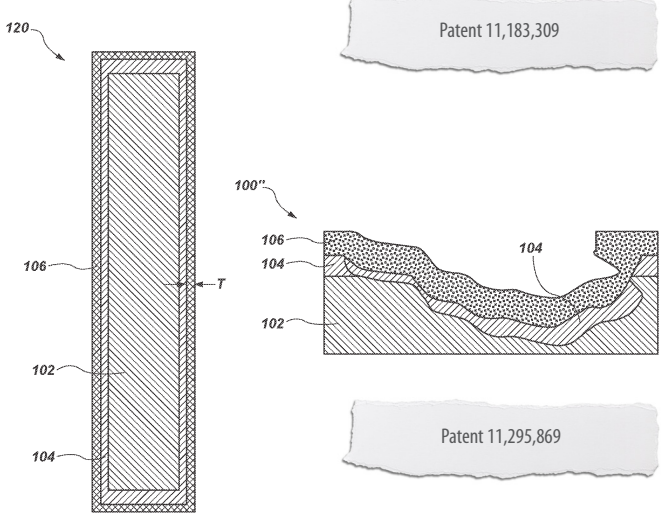
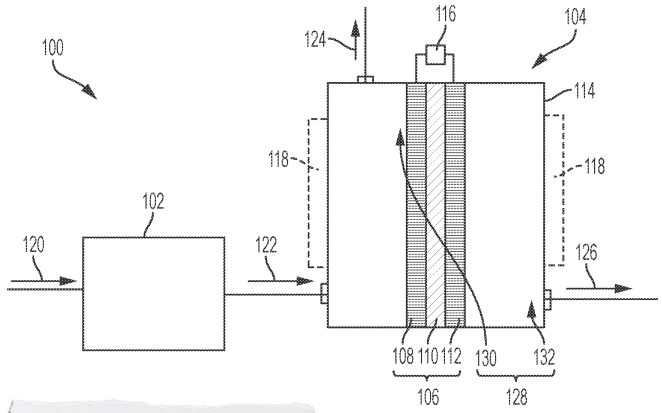


FIG. 1

Patent 11,183,309



Patent 11,295,869



Patent 11,198,941

Methods of Forming Fuel Rods Comprising Porous Fuel Materials (as amended)

A method of forming a fuel rod for a nuclear reactor comprises disposing a powder comprising particles of a fuel material on a substrate, exposing the powder to energy from an energy source to form a first layer of a nuclear fuel, the first layer comprising intergranular bonds between the particles of the fuel material, disposing additional powder comprising particles of the fuel material over the first layer of the nuclear fuel, and exposing the additional powder to energy from the energy source to form a second layer of the nuclear fuel and to form the nuclear fuel to have a void fraction greater than about 0.20, the second layer comprising intergranular bonds between the additional powder and the first layer of the nuclear fuel. Related nuclear fuels comprising a porous structure, fuel rods, nuclear reactors, and methods are disclosed.

Patent No. 11,183,309 granted Nov. 23, 2021, to Robert C. O'Brien.

Nuclear Fuel Elements and Methods of Preserving a Nuclear Fuel

A method of preserving a nuclear fuel includes exposing a surface of a fuel element comprising aluminum to a phosphorus-containing acid and reacting the phosphorus-containing acid with the aluminum to form aluminum phosphate (AlPO.sub.4). A nuclear fuel element includes a nuclear fuel and a shell surrounding the nuclear fuel. The shell comprises aluminum phosphate.

Patent No. 11,295,869 granted April 5, 2022, to Aleksey Victor Rezvoi.

Methods for Hydrogen Gas Production Through Water Electrolysis (as amended)

A method of producing hydrogen gas comprises introducing gaseous water to an electrolysis cell comprising a positive electrode, a negative electrode, and a proton conducting membrane between the positive electrode and the negative electrode. The proton conducting membrane comprises an electrolyte material having an ionic conductivity greater than or equal to about 10−2 S/cm at one or more temperatures within a range of from about 150 C. to about 650 C. The gaseous water is decomposed using the electrolysis cell. A hydrogen gas production system and an electrolysis cell are also described.

Patent No. 11,198,941 granted Dec. 14, 2021, to Ting He, Dong Ding and Wei Wu.

Wireless Signal Monitoring and Analysis, and Related Methods, Systems, and Devices[2]

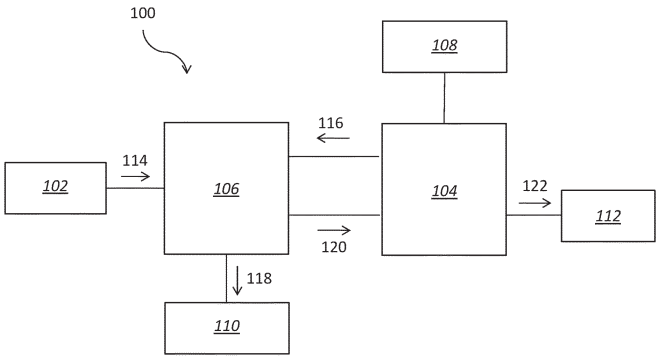
Wireless signal classifiers and systems that incorporate the same may include an energy-based detector configured to analyze an entire set of measurements and generate a first signal classification result; a cyclostationary-based detector configured to analyze less than the entire set of measurements and generate a second signal classification result; and a classification merger configured to merge the first signal classification result and the second signal classification result. Ensemble wireless signal classification and systems and devices the incorporate the same are disclosed. Some ensemble wireless signal classification may include energy-based classification processes and machine learning-based classification processes. In some embodiments, incremental machine learning techniques may be incorporated to add new machine learning-based classifiers to a system or update existing machine learning-based classifiers.

Patent No. 11,251,889 granted Feb. 15, 2022, to Kurt W. Derr, Samuel Ramirez, Sneha K. Kasera, Christopher D. Becker and Aniqua Z. Baset.

Methods and Systems for Treating an Aqueous Solution

A method of treating an aqueous solution comprises forming a treatment stream comprising a condensable material. The treatment stream is introduced to an aqueous solution comprising water and a solute to fractionally precipitate the solute out of the aqueous solution and form a solids stream comprising the solute and an aqueous liquid stream comprising at least one solute-depleted solution of the water and the condensable material. The condensable material of at least a portion of the aqueous liquid stream is separated from the water of at least a portion of the aqueous liquid stream to at least partially reform the treatment stream and form an aqueous liquid product stream depleted in the solute. Aqueous solution treatment systems and additional methods of treating an aqueous solution are also described.

Patent No. 11,261,111 granted March 1, 2022, to Aaron D. Wilson, Christopher J. Orme, Birendra Adhikari, Daniel S. Wendt and Daniel M. Ginosar.



Surrogate Isotope-Containing Materials for Emergency Response Training and Methods of Formation and Dispersal (as amended)[4,5]

Surrogate materials are in the form of solid particles that include surrogate isotopes, namely, short-lived isotopes selected and formed to serve as surrogates for the radioactive materials of a nuclear fallout without including isotopes that are, or that decay to, biologically or environmentally deleterious and persistent isotopes. The surrogate material may be formed using high-purity reactant material and irradiation and separation techniques that enable tailoring of the isotopes and ratios thereof included in the surrogate material, and the surrogate material may be dispersed, e.g., in a training environment, in solid form.

Patent No. 11,276,508 granted March 15, 2022, to Kevin Carney, Martha Finck, Jared Jay Horkley, Matthew T. Kinlaw, Jana Pfeiffer, Erin May, Mathew S. Snow, Nicholas R. Mann and Christopher A. McGrath.

Systems and Methods for Distributed Authentication of Devices

A lightweight, fast and reliable authentication mechanism compatible with the 5G D2D ProSe standard mechanisms is provided. A distributed authentication with a delegation-based scheme avoids repeated access to the 5G core network key management functions. Hence, a legitimate user equipment device (e.g., a drone) is authorized by the cellular network (e.g., 5G cellular network) via offering a proxy signature to authenticate itself to other drones. Test results demonstrate that the protocol is lightweight and reliable.

Patent No. 11,284,255 granted March 22, 2022, to Arupjyoti Bhuyan and Kemal Akkaya.

Engineered Microbes for Rare Earth Element Adsorption[3]

This disclosure provides engineered microbes modified such that the surface of the microbe contains one or more rare earth element binding ligands, as well as methods of use thereof.

Patent No. 11,230,750 granted 1/25/2022 to David William Reed, Yongquin Jiao, Dan McFarland Park and Mimi Cho Yung.

Patent 11,261,111

Linear Differential

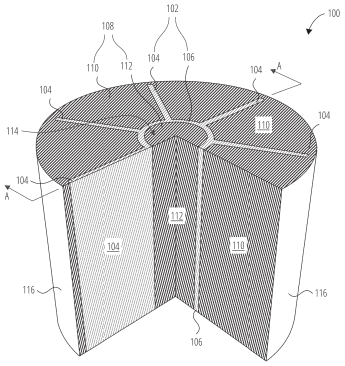
Apparatuses and methods of operating a linear differential (100, 600) are described herein. The linear differential (100, 600) contains a slide portion (102) with parallel right-hand and left-hand threaded rods (112, 114). Threaded onto the right-hand and left-hand threaded rods (112, 114) and attached to the slide portion (102) are right-hand and left-hand gears (116, 118). Meshed between the right-hand and left-hand gears (116, 118) and also attached to the slide portion (102) is a driven gear (200). An end effector (104) is attached to the driven gear (200) and is configured to translate along a translation axis (110) and rotate around a rotation axis (120).

Patent No. 11,320,031 granted May 3, 2022, to Anthony Louis Crawford.

Reactor Fuel Pellets with Thermally-Conductive Inserts, and Related Reactor Fuel Pellet Arrangements

Fuel pellets and fuel pellet arrangements include thermally-conductive inserts within a fuel. The inserts have at least one portion of a thermally-conductive material, such as radially-extending fins. The inserts are configured to dissipate heat during use of the fuel pellets, while minimizing the amount of the total volume of the fuel pellet that is occupied by nonfissile material. The inclusion of heat-dissipating inserts enables the fuel pellets to exhibit improved thermal performance over the lifetime of the fuel, including a relatively low peak temperature and relatively low integrated average temperatures, while the minimal volume of the inserts avoids significantly decreasing the percent of enrichment achievable.

Patent No. 11,404,177 granted Aug. 2, 2022, to Robert D. Mariani and Pavel G. Medvedev.



Patent 11,404,177

Heat Exchangers Fabricated by Additive Manufacturing, Related Components, and Related Methods

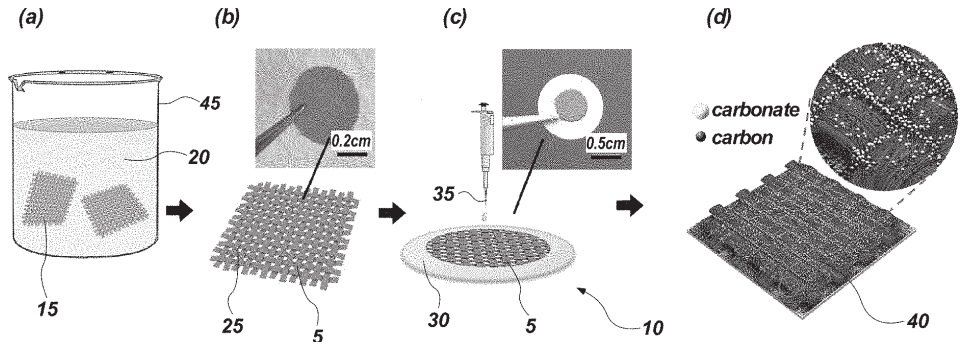
A method of forming at least a component of a heat exchanger comprises introducing a feed material comprising a first portion including a matrix material and a second portion including a sacrificial material on a surface of a substrate, exposing at least the first portion to energy to form bonds between particles of the matrix material and form a first thickness of a structure, introducing additional feed material comprising the first portion over the first thickness of the structure, exposing the additional feed material to energy to form a second thickness of the structure, and removing the sacrificial material from the structure to form at least one channel in the structure. Related heat exchangers and components, and related methods are disclosed.

Patent No. 11,383,302 granted July 12, 2022, to Isabella J. Van Rooyen and Piyush Sabharwall.

A Three-Dimensional Architectured Anode, A Direct Carbon Fuel Cell Including the Three-Dimensional Architechtured Anode, and Related Methods

A method of fabricating a three-dimensional (3D) architectured anode. The method comprises immersing a fabric textile in a precursor solution, the precursor solution comprising a nickel salt and gadolinium-doped ceria (GDC). The nickel salt and GDC are absorbed to the fabric textile. The fabric textile comprising the absorbed nickel salt and GDC is removed from the precursor solution and calcined to form a 3D architectured anode comprising nickel oxide and GDC. Additional methods and a direct carbon fuel cell including the 3D architectured anode are also disclosed.

Patent No. 11,342,564 granted May 24, 2022, to Dong Ding, Ting He and Wei Wu.



Patent 11,342,564

Energy Management System, Method of Controlling One or More Energy Storage Devices and Control Unit for One or More Power Storage Units

Systems, methods and apparatuses are provided for reducing peak energy demand and to smooth intermittent energy profiles from on-site variable energy sources and loads. Some embodiments use system level and device level analysis and optimization to adaptively adjust the operation of a behind the meter energy storage to smooth out energy generation variabilities and follow a reference load signal, including at short time resolutions.

Patent No. 11,404,875 granted Aug. 2, 2022, to Bishnu Bhattarai and Kurt S. Myers.

Systems and Methods of Forming Densified Biomass

A method includes densifying a biomass feedstock having a moisture content of at least 30% by weight and drying the biomass feedstock to form a densified biomass having a moisture content of less than 10% by weight. Some methods include comminuting a biomass feedstock, pressing the biomass feedstock to form a plurality of pellets, heating the plurality of pellets to remove water therefrom, and cooling the plurality of dried pellets. The plurality of pellets exhibits a moisture content of at least 20% by weight after pressing. The plurality of dried pellets exhibits a moisture content of less than 10% by weight. A system for forming densified biomass may include a preheater, a press and a dryer.

Patent No. 11,414,613 granted Aug. 16, 2022, to Jaya Shankar Tumuluru.

Methods of Recovering Lignin and Other Products from Biomass

The method comprises adding a chemical agent to a stored biomass comprising lignin to form a chemically treated biomass. The chemical agent comprises an acid, a base, an inorganic salt, or a combination of the inorganic salt and one of the acid or the base. The chemically treated biomass is stored under anaerobic conditions. Lignin products, such as high molecular weight lignin, medium molecular weight lignin, or low molecular weight lignin, are recovered from the chemically treated biomass. Additional methods of recovering lignin products and other products from biomass are disclosed.

Patent No. 11,420,992 granted Aug. 23, 2022, to Quang A. Nguyen and Lynn M. Wendt.

Methods and Systems for Carbon Dioxide Hydrogenation

A method of carbon dioxide hydrogenation comprises introducing gaseous water to a positive electrode of an electrolysis cell comprising the positive electrode, a negative electrode, and a proton-conducting membrane between the positive electrode and the negative electrode. The proton-conducting membrane comprises an electrolyte material having an ionic conductivity greater than or equal to about 10-2 S/cm at one or more temperatures within a range of from about 150 C to about 650 C. Carbon dioxide is introduced to the negative electrode of the electrolysis cell. A potential difference is applied between the positive electrode and the negative electrode of the electrolysis cell to generate hydrogen ions from the gaseous water that diffuses through the proton-conducting membrane and hydrogenates the carbon dioxide at the negative electrode. A carbon dioxide hydrogenation system is also described.

Patent No. 11,421,330 granted Aug. 23, 2022, to Ting He, Dong Ding and Chenlin Li.

Selective Transmission and Reception for Stationary Wireless Networks

A system and methods for selective transmission and reception for stationary wireless networks. The system and method include an end user equipment, a primary base station, a core network, and a selective server. The end user equipment transmits a request for transmission to the primary base station receiver. The primary base station authenticates the end user equipment using a cellular network authentication process. The primary base station then searches for a time slot data for the end user equipment from the selective server and determines whether the time slot is open for transmission, steers a beam toward the end user equipment when the time slot is open for transmission. The primary base station then enables transmission from the end user equipment, wherein the enabling is performed by the primary base station. The core network receives the transmission from the end user equipment.

Patent No. 11,444,664 granted Sept. 13, 2022, to Arupjyoti Bhuyan.

Route-Operable Unmanned Navigation of Drones (ROUNDS)

Copyright Assertion Highlights

Copyright is a legal right that grants the creators of original work, such as software, exclusive rights for its use and distribution. INL employees assign such rights to the company as a condition of employment. In accordance with BEA's contract with DOE, all rights are assigned to DOE unless BEA specifically requests authority to assert copyright. BEA requests the permission to assert copyright on software it intends to license via open source and traditional agreements.

During FY-2022, INL received permission to assert copyright on 13 software programs. Since 2005, INL has been authorized by DOE to assert copyright protection on more than 150 pieces of software.

Route-Operable Unmanned Navigation of Drones (ROUNDS)

ROUNDS uses artificial intelligence, advanced image analysis and control techniques to enable any off-the-shelf, camera-equipped drone to accurately find its way, at high speed, in an indoor environment where GPS is not available. The technology overcomes the limitations of modern commercial drone navigation systems and makes drone technology useful in dozens of new venues – plants, security, warehouses, etc. – where GPS is not available. Further, ROUNDS is user-friendly and performs these tasks without the expensive hardware and software currently used by less effective drone navigation systems.

Storm DEPART

Severe weather conditions and storms can be devastating to cities across the globe, particularly in the recovery stage. But what if you could predict damage and materials needed before the storm? Storm DEPART (Damage Estimate Prediction and Recovery Tool) software predicts damage, materials needed and resource allocation modeling capabilities to support pre-incident planning and preparation. It analyzes multiple factors, including information on infrastructure, storm predictions and more, to develop a plan on mitigating storm damage and recovery.

Irrigation Modernization Decision Support Engine

Irrigation systems are some of the oldest existing infrastructures in the United States, and resources are needed to modernize these systems. Traditionally, the scoping of a modernization project takes several years and requires significant financial investment before the potential of the project can be determined. The Irrigation Modernization Decision Support Engine allows users to build out different scenarios. These scenarios allow for a course estimation of a project's potential and the associated costs and benefits of pursuing the scenario. The design of the Decision Support Engine also allows for easy sharing between stakeholders, allowing for increased communication and understanding.

Risk Analysis Virual ENvironment was entered in 2022 R&D 100 Awards.

Open-Source Software Highlights

INL has expanded efforts to release open-source software, which is freely available to the public and open to collaboration directly with researchers and engineers outside of the laboratory. Fostering widespread distribution of this software can accelerate adoption within industry and fuel innovation in other research organizations. INL's Technology Deployment group is defining and refining an overarching strategy around open source and commercial releases to capitalize on the strengths of each. INL's open-source software can be acquired cost-free at

https://github.com/idaholab
https://github.com/idaholabresearch
https://github.com/idaholabunsupported

FORCE Tool Suite

The Framework for Optimization of ResourCes and Economics (FORCE) is a collection of software tools developed under the Integrated Energy Systems (IES) program to enable analysis of technical and economic viability of myriad IES configurations.

RAVEN (Risk Analysis Virtual ENvironment) is a flexible and multipurpose uncertainty quantification, regression analysis, probabilistic risk assessment, data analysis and model optimization framework. RAVEN is used as an engine for the other software tools, providing quality-assured workflows for robust optimization, synthetic history sampling, multicode calculations, and machine learning surrogate models.

FARM (Feasible System Actuator) is a RAVEN plugin using a linear state-space representation of process models to predict the system state and output in the future time steps, and to adjust actuation variables to avoid violation of implicit thermomechanical constraints for the individual subsystems and components.

HERON (Holistic Energy Resource Optimization Network) is a modeling toolset and RAVEN plugin to accelerate stochastic technoeconomic assessment of the economic viability of grid-energy system configurations. HERON provides tools to generate workflows for grid-energy system portfolio optimization based on stochastically generated time-series and dispatch optimization. The stochastic histories are generated using models developed in RAVEN and are based on historical behaviors in specific markets and geographical regions.

HYBRID is a repository containing a collection of transient process models written in the Modelica language. This repository contains detailed models of various nuclear reactors, energy storage processes and ancillary processes (e.g., water desalination, hydrogen production) that can be used by researchers to understand the dynamic behavior, integration and control of integrated energy systems across various time scales.

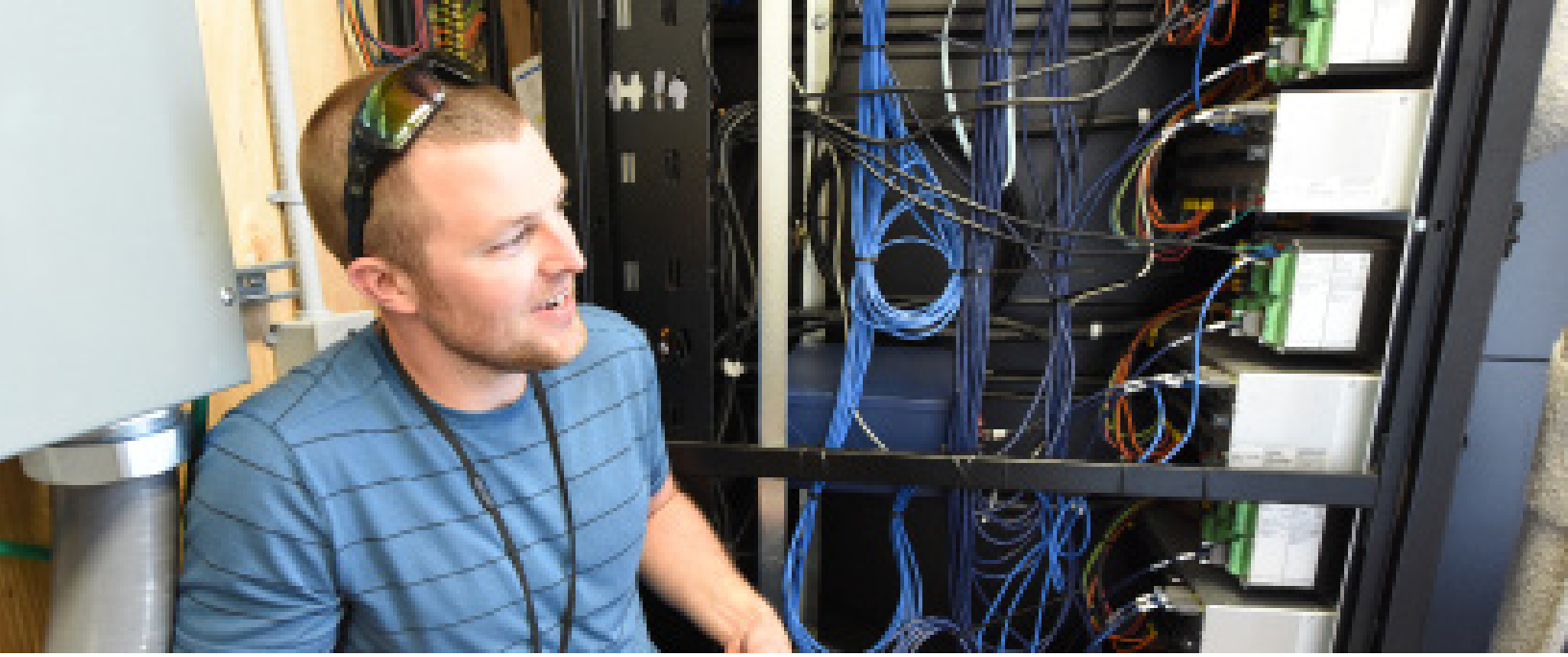
TEAL (Tool for Economic AnaLysis) is a RAVEN plugin that enables a workflow to compute the net present value, internal rate of return and profitability index for a candidate integrated energy system using RAVEN. TEAL is primarily used as a resource for HERON but can also be used to analyze integrated energy system configurations with limited time resolution.

Boltzmann

A sub-module to MOOSE (Multiphysics Object-Oriented Simulation Environment), which helps physicists and engineers incorporate detailed physical models and run simulations on some of the largest computer systems available, Boltzmann provides a framework for performing generalized Boltzmann transport equations. This allows researchers to study the statistical behavior of thermodynamic systems, simulating mesoscale heat transport in homogeneous and heterogeneous media. At the phonon and electron level, it can be used to calculate microscale dependent heat transport effects at internal interfaces and defect structures within materials. Boltzmann is scheduled to be released in FY-2023.

Scramble

Originally developed for a computer vision project, Scramble is a machine-learning tool focused on improving the accuracy of other machine-learning models. Scramble takes the principle of cross-validation – that resampling data sets is critical to estimating model accuracy during the training and testing process – and utilizes the principle in the module's functions. When a user provides several iterations, the module randomizes each model class k number and then splits the resulting randomized data sets along a user-designated percentage training/testing split (e.g., 80% training and 20% testing). The module can then activate the machine-learning model a user designates. This process will be repeated a number of times, and while it is occurring Scramble records progress and outputs it to the user's IDLE console.



INL engineer Dylan Reen installs a Constrained Communication Cyber Device to a protective relay.

Licensing Activities and Highlights

In fiscal year 2022, Technology Deployment modified or entered 156 new licensing agreements. At the end of the fiscal year, INL had nearly 500 active licenses on technologies with patents, copyright assertions or open-source rights held by its researchers. Licensees include domestic and foreign business, universities, laboratories, governments and other industry partners.

Constrained Cyber Communication (C3D)

The BEA-patented C3D device uses advanced communication capabilities to autonomously review and filter commands being sent to protective relay devices. Relays are the heart and soul of the nation's power grid and are designed to rapidly command breakers to turn off the flow of electricity when a disturbance is detected. For example, when a power line fails because of a severe storm, relays prevent expensive equipment from being damaged. But relays have not been traditionally designed to block the speed and stealth of cyberattacks, which can send erroneous commands to grid equipment in milliseconds. To prevent this kind of attack, INL engineers designed C3D as an intelligent and automatic filtering technology and tested its effectiveness at the Critical Infrastructure Test Range Complex.

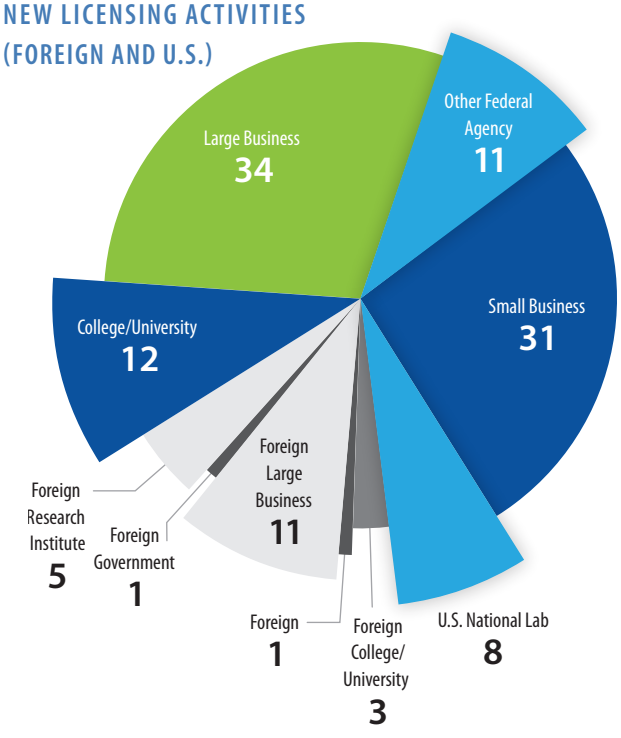
License with Sierra Nevada Corporation

Sierra Nevada Corporation, a privately held U.S. aerospace and national security contractor with more than 5,000 employees, has exclusively licensed the BEA-patented Constrained Cyber Communication technology. Sierra Nevada Corporation will incorporate C3D into its existing Binary Armor line of products, which have historically been sold into Department of Defense and other U.S. Government markets. Sierra Nevada Corporation said the C3D technology will allow the company to better target commercial utilities and associated OEM markets. In addition to cybersecurity, Sierra Nevada Corporation specializes in aircraft modification and integration, space components and systems, and related technology products for the health care industry.

BISON

A 2021 R&D 100 Award winner, BISON is a flexible next-generation nuclear fuel performance analysis code that is unique in its ability to analyze fuels of varying types and geometries in 3D. By making advanced simulation more accessible to nuclear engineers, BISON enhances the safety and effectiveness of existing nuclear plants.

NEW LICENSING ACTIVITIES (FOREIGN AND U.S.)



After the 2011 accident at Japan's Fukushima-Daiichi plants, Congress ordered the U.S. Department of Energy to accelerate national laboratory efforts to develop accident tolerant fuels. BISON has enabled simulations, performed in tandem with real-world fuel experiments, to help engineers identify areas of concern. For the next generation of reactors, research done with BISON helps ensure that only the most promising fuel designs enter the frequently lengthy experiments inside nuclear test reactors. BISON offers value to utilities, reactor and fuel vendors, regulators, university researchers, and advanced reactor designers. Dozens of entities are using BISON, including domestic and international companies, universities and national laboratories.

Licensing agreements for BISON in FY-2022 were concluded with the following companies:

Rolls Royce SMR Ltd. (U.K.) Rolls-Royce has licensed Pronghorn, Sockeye, Griffin, RELAP-7, BISON, and Marmot for reactor physics analyses in support of a U.S.-led nuclear thermal propulsion system. The software will be used for concept design, design optimization and safety-case work.

JFoster & Associates. JFoster & Associates has licensed BISON to analyze advanced nuclear fuel concepts for small modular rectors and microreactors. Additionally, BISON will model how fuel might behave under irradiation conditions, mainly to stress components in different layers of the fuel assembly. The company will use BISON to see how different composite materials interact with each other in new advanced fuels.

U.S. Naval Academy. BISON will be used at the U.S. Naval Academy to create higher fidelity nuclear power reactor concepts for capstone projects and research projects.

University of East Anglia (U.K.) University of East Anglia has licensed BISON to develop a better understanding of fracture mechanisms in TRISO particle fuel. Looking at linking with a peridynamics model, BISON will be used to benchmark models for TRISO fuel particles.

U.S. Nuclear Regulatory Commission. The U.S. Nuclear Regulatory Commission will use the MOOSE-based gas reactor analysis tool suite, evaluating it for use in its evaluation model for advanced non-light water reactors.

Westinghouse Electric Company. Westinghouse will continue to use BISON to develop fuels and cladding capable of better withstanding the harsh conditions inside a reactor and maintaining integrity for longer periods during an accident.

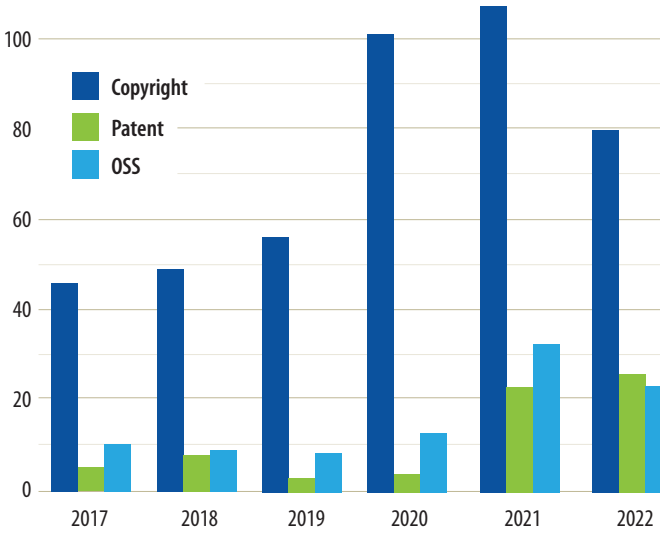
Oak Ridge National Laboratory. Oak Ridge National Laboratory is using BISON to perform sensitivity studies designed to understand conditions that lead to fission gas release under steady-state isothermal irradiation conditions and temperature transient conditions.

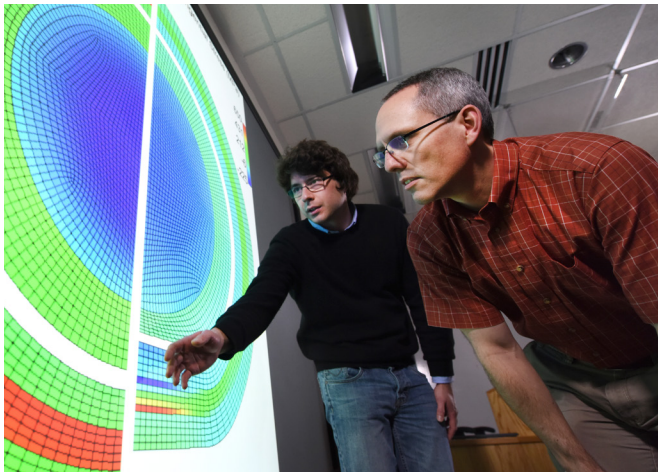
Center for Energy Environmental and Technological Research. Center for Energy Environment and Technological Research has licensed BISON as part of the Spent Fuel Characterization Work Package for waste management and assessing spent nuclear fuel safety during dry storage and transport.

Argonne National Laboratory (University of Chicago) Argonne will use RELAP5-3D to simulate and predict the fuel performance of novel nuclear fuel designs for advanced nuclear reactors. The success of the projects will advance the nuclear power technologies and their applications.

Los Alamos National Laboratory. BISON is used and developed at LANL for enhanced modeling and simulation of metallic and oxide based nuclear fuel, as well as for stress and strain calculations for various solid mechanics models.

Analysis & Measurement Systems Corporation. Analysis and Measurement Systems has licensed Griffin, Sockeye and BISON to develop online monitoring systems that will help microreactor installations identify abnormal operating conditions. Models will be developed to approximate normal, steady state reactor operation and subsequently modified to approximate off-normal behaviors for the online monitoring system to detect.





BISON is a flexible next-generation nuclear fuel performance analysis code.

Royalty Highlights

Royalties

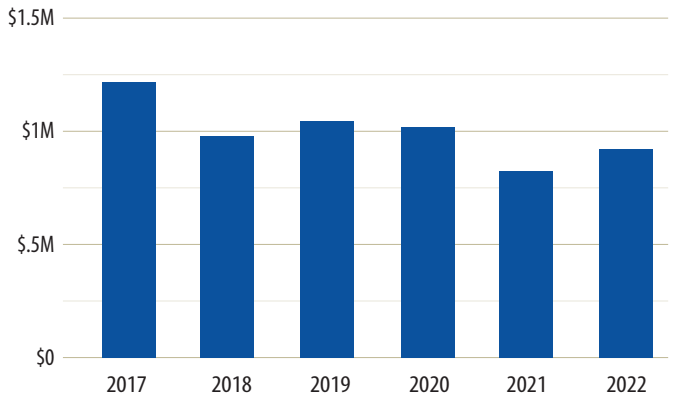
From FY-2005 to FY-2022, INL signed more than 1,300 new licenses to commercialize technologies developed at the laboratory. License agreements generate royalties, and INL has earned more than $24 million in royalties since the inception of BEA's contract in FY-2005. During FY-2022, INL earned close to $800,000 in royalties.

Royalties are one indicator that INL innovations are meeting market needs. INL encourages innovation and to reinvest a significant portion of royalty revenues to promote development of promising early-stage technologies.

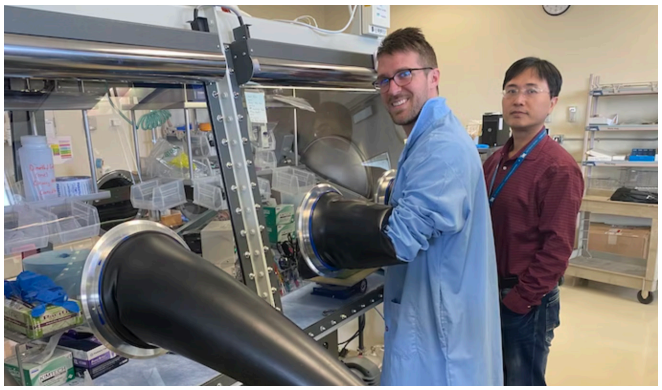
Spending royalty funds is governed by federal regulations and must support technology transfer activities. Roughly 30 percent of INL royalty funds are shared with inventors of licensed technologies. Additional money is spent to reward employees who have supported technology transfer activities through the laboratory, independent of a specific technology having commercial application. The remaining royalties are reinvested via two funds, the Science and Technology Strategic Investments Fund and the Innovation Development Fund.

The Science and Technology Strategic Investments Fund supports R&D capabilities that will lead to new technology development and increase INL's potential to generate new business. A key to the success of these investments is INL's ability to attract industry partners that are so essential in advancing future INL technologies.

ROYALTY RECEIPTS FROM FY 2017-2022



Preprocessing activities at the Biomass Feedstock National User Facility.



Corey Efaw (left) sets up Lithium-Sulfur coin cells in the glove boxes as Dr. Bin Li (right) observes. INL partnered with Cogent through the Technical Assistance Program (TAP) to test new battery capabilities.

Technology-Based Economic Development

Idaho National Laboratory is a vital and fervent partner in Idaho's economic development at all levels around the state. Not only does INL employ more than 5,500 people, but through Battelle Energy Alliance provided several grants in FY 2022 to aid job creation and workforce development. BEA also worked with numerous businesses through the Technical Assistance Program in FY-2022. Here is a breakdown of where the money was spent.

Boise State University's Institute for Pervasive Cybersecurity: $25,000. This project will help rural communities evaluate cybersecurity vulnerabilities and offer city and county officials opportunities to receive cybersecurity training. The project ties into the state's Cyberdome initiative, which creates a statewide collaborative hub for competency-based training, reducing risk and producing a cybersecurity workforce in sync with Idaho's business, technology and government sectors. The BEA grant can help lay the groundwork for a cybersecurity hub in eastern Idaho to support economic development.

Idaho Women's Business Center: $20,000. The Idaho Women's Business Center's mission is to support women in business across Idaho by helping them find resources, mentorships and networking needed to become successful. The women's center has used earlier INL grants to expand its partnerships with local institutions to offer online counseling and training to aspiring women entrepreneurs in rural areas. This grant funding will help the organization continue its efforts to support women, including those in underserved and rural communities, as they start and grow successful enterprises.

City of Rexburg: $15,000. The city of Rexburg was awarded grant funding to support its efforts to create a maker space for eastern Idaho entrepreneurs to prototype their products and inventions. Rexburg is committed to improving the city's economic development by strengthening and building homegrown businesses.

Idaho Veterans Chamber of Commerce: $10,000. The Idaho Veterans Chamber of Commerce's mission is to deliver wrap-around service and a navigation network hub for veterans, military serving and their families. This funding will assist in providing access to services in many areas, including education, housing, entrepreneurship, workforce management, family and wellness.

Technical Assistance Program

Technical Assistance Program (TAP) supports small businesses and state and local governments where INL scientists and engineers provide, without fees, assistance which is not normally available to a community or small businesses. It helps in areas where organizations may find their problems too complex or technical to solve on their own.

INL has partnered with multiple businesses and government entities through this program. Here are a few to highlight from FY 2022.

Spero Renewables

This California-based green technology company partnered with INL through TAP to work with researchers at the Biomass Feedstock National User Facility. Spero is one of many companies working to turn biomass into renewable fuels, products and power. The project helped the company build on its work synthesizing fiber-reinforced polymers using its proprietary technology called SperoSet.

Cogent Energy Systems

As the world moves toward electrifying vehicles, so does progress toward creating and developing more sustainable battery options – mostly in developing batteries that are lighter, smaller and last longer on a single charge.

INL's Bin Li, a senior scientist in the Energy Storage and Electric Transportation department, partnered with an Idaho Falls company, Cogent Energy Systems, through TAP to apply the company's technology – carbon nano-onions – to lithium-sulfur batteries as the sulfur host to improve the battery cycling performance. INL and Cogent designed and conducted tests of the nano-onion's performance in a lithium-sulfur battery.

Agreement Management

The Agreement Management organization is responsible for several functions, including:

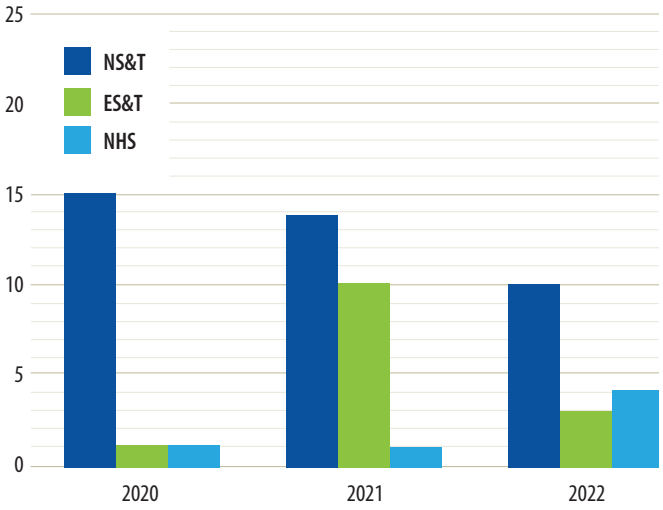
- Preparing, negotiating and executing all funds coming to INL through collaboration agreements with industry, academia and other government agencies to advance INL's mission objectives.
- Leading the process to determine appropriate agreement mechanisms.
- Managing expectations of technical leads, principal investigators, managerial staff members and sponsors related to implementing sound contracting practices.

Agreement Management Summary

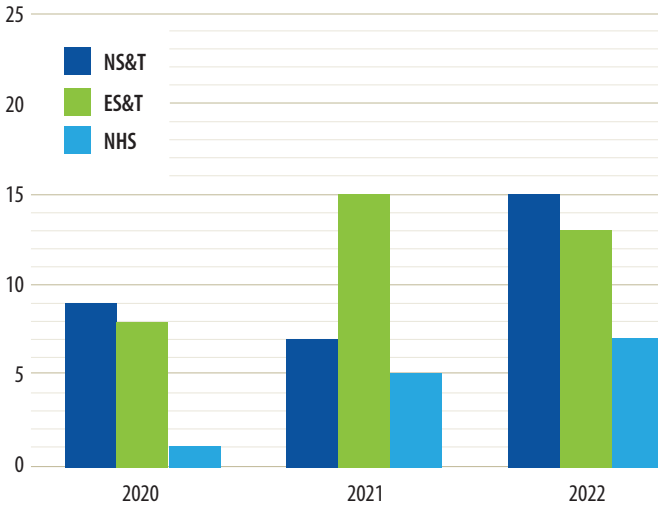
Agreement Type	Agreement Title	Agreement Customer Name
CRADA	BWXT Advanced Technologies, LLC	Development of Advanced Fuel Materials for the BWXT Advanced Nuclear Reactor (BANR)
CRADA	Caltrode, Inc.	New Alloy Anodes for Electrochemical Production of Advanced Materials
CRADA	Clariant Corporation	Catalyst Evaluation for Deactivation and Remediation (CEDAR): Development of Robust Materials and Resilient Processes via Transient Measurement and Data-driven Multiscale Models
CRADA	Idaho Power Company	Hydroelectric Power and Hydrogen Production Integration
CRADA	Korea Atomic Energy Research Institute (KAERI)	Thermophysical Properties of Molten Salts
CRADA	Korea Atomic Energy Research Institute (KAERI)	(KAERI) Advanced Handling and Safety Enhancement Studies
CRADA	Lightbridge Corporation	Lightbridge Irradiation Experiment
CRADA	Multi-party CRADA led by Southern Company Services, Inc.,	Advanced Reactor Demonstration - MCRE Project
CRADA	Sierra Nevada Corporation	Binary Armor Collaboration for Grid Cybersecurity
CRADA	Utilities Service Alliance	Advanced Remote Monitoring
CRADA	X-Energy, LLC	ARDP Demonstration Support
SPP	Advanced Materials Manufacturing	Composite Metal Foam Microreactors
SPP	Alder Fuels	Alder Energy Material Processing
SPP	Ametek, Inc.	Manufacture of PINS Simulant Chemicals
SPP	Applied Nanotech, Inc.	Computed Tomography of SST Tube with Zirconium Liner
SPP	Arete Associates, Inc.	INL Spectral Detection Framework
SPP	Exotanium, Inc.	Mastodon Container Project
SPP	ExxonMobil Technology and Engineering Company	Pyrolysis Reactor System
SPP	General Electric Global Research	Cyber-Physical Resilience for Wind Power Generation: Field Test Demonstration
SPP	Lightbridge Corporation	Lightbridge Fuel Fabrication Work
SPP	Liteye Systems Inc.	cUAS Testing
SPP	Perimeter Security Solutions	Fencing material at the Idaho National Laboratory National Security Test Range (NSTR)
SPP	Radiation Detection Technologies, Inc.	Commercialization of the Micro Pocket Fission Detector (MPFD) (SBIR)
SPP	Seaborg Technologies	Thermophysical Properties Measurements for Seaborg Technologies
SPP	Theia Scientific, LLC	A Scalable Platform for Real-Time Microscopy Image Analysis Using Artificial Intelligence and Machine Learning
SPP	X-Wave Innovations, Inc.	Self-Powered, Wireless Sensor System for Remote and Long-Term Monitoring of Internal Conditions of Spent Nuclear Fuel Dry-Storage Casks
SPP	Zenlabs Energy, Inc.	Cell Characterization and Validation

Select summaries from FY-22 are provided. This list is not inclusive of every agreement.

COOPERATIVE RESEARCH AND DEVELOPMENT (CRADA)



STRATEGIC PARTNERSHIP PROJECTS (SPP)



2022 Agreement Mechanisms

Agreement	Purpose/Use	Funding	Benefits	Requirements
Cooperative Research and Development Agreement (CRADA)	Collaborative research between INL and public and/or private entities for the mutual benefit of the parties	Private and/or federal funds	• Collaborative research efforts with funding by the lab and the partner • Five year data protection • Designed for multi party collaborative research	• Substantial U.S. manufacturing requirements (or benefit to U.S.) for projects embodying CRADA generated intellectual property • 90-day advance payment when privately funded • Government-use license to generated IP • Approval by DOE
Strategic Partnership Projects	Allows INL to perform mission-related reimbursable work	Private or federal (federal sources through nonfederal sponsor)	• **Access:** Highly specialist or unique DOE facilities, services or technical expertise; helps private entities to accomplish technology goals that may otherwise be unattainable • **Inventions:** IP ownership subject to project parameters; transfer INL technologies to marketplace for further development or commercialization • **Confidentiality:** Generated data treated as proprietary when marked; partners proprietary information can be protected • **Strategic:** Maintain core competencies and enhance INL science and technology base	• Sponsor pays full costs recovery • No exclusive third-party license to protect generated IP unless manufactured substantially in the U.S. • Sufficient advance payment • Government use license to generated IP • Approval by DOE
Proprietary User Agreement	User can have merit-based access to designated facilities to conduct its own proprietary research	Private funds	• User may elect title to its Subject Inventions • User may protect generated data as proprietary • Access to unique facilities and equipment so that users may conduct their own proprietary	• User facilities are designated by DOE • Proprietary users pay full cost recovery • Users own their generated data and inventions, subject to no reserved government rights
Non proprietary User Agreement	Users can have merit-based access to designated facilities and perform nonproprietary research	N/A	• Lab and user may elect their own subject inventions • Non proprietary users engage in precompetitive research and share the costs of their research with the government	• User facilities are designated by DOE • Unlimited government rights to generated data • Expected to publish data generated from the research

Marketing

In 2019, Technology Deployment increased its marketing efforts to achieve greater impact from R&D outcomes. INL hired a marketing specialist in 2019 to proactively contact potential commercialization partners, which requires creating materials such as technology summaries, videos, social media posts and license announcements. TD utilizes many website platforms, such as In-Part, Sam.gov and AUTM Innovation Marketplace for outreach.

More than 20 licenses executed have originated from the concerted marketing efforts. Other metrics also demonstrate the positive impact of the marketing specialist on licensing INL technologies.

	FY-23 YTD	FY-22 YTD	FY-21	FY-20	FY-19
Outreach Activities		64	83	115	3
Inbound Inquiries		170	82	99	10
Other Activities		5	1	30	0
New Discussions		88	27	54	6
Licenses from Marketing Efforts		10	3	6	1
IN-PART		19	6	27	0
Lab Partnering Service		31	8	34	0
SAM.GOV (FedBIzOps)		56	23	49	0

Energy I-Corps Success Stories

Modeling and Simulation for Target Electrical Resilience and Reliability Improvements (MASTERRI)

A U.S. Department of Energy study estimated that the national cost of power interruptions ranged from $150 to $400 billion per year. Extreme weather events caused many of the power outages, compounding the vulnerability of an aging, antiquated power infrastructure. Never has there been a greater need for a tool that can determine exactly where and how electrical infrastructures are vulnerable, and the likelihood these vulnerabilities will come to bear, so that steps can be taken to prevent the most likely and severe future outages. Modeling and Simulation for Target Electrical Resilience and Reliability Improvements, or MASTERRI, is that tool.

This technology addresses the need to identify and prioritize critical vulnerabilities impacting electrical grid resilience in the United States and around the world quickly and affordably.

Initially, technology commercialization funding facilitated a collaboration with Duke Energy to mold MASTERRI into an effective risk analysis tool for the electrical transmission industry. But in further development with Cyber Capital Partners, the MASTERRI team determined the technology could be applied more broadly. A team, led by INL researcher Courtney Otani, participated in the 14th cohort of Energy I-Corps with industry mentorship from Allison Reardon, partner at Cyber Capital Partners.

In the Energy I-Corps program, the team identified a new market of application and polished their value proposition to initiate a Small Business Innovation Research proposal. The new target market was cybersecurity for government defense systems.

"We gained invaluable insights into how their businesses operate and how emerging technologies are adopted and sold," Otani said. "With this, we were able to refine our value proposition so that it effectively communicated the specific problem our product solved to the decision makers in this market."

MASTERRI received Small Business Innovation Research Phase I funding thanks to connections and proposal refinement made through Energy I-Corps. This project will be able to carry out one of the new cyber applications the team researched and refined in the Energy I-Corps program.

"Along with the research conducted, we will take with us into this new development all the skills and advice we learned about business development from our industry mentor and all of the mentors from the teaching team," Otani said.

Energy I-Corps initiated the creation of an entirely new branch of commercialization for MASTERRI.

Wireless Valve Position Indication Sensor System

American industries need every advantage to maintain a competitive edge without compromising security or safety. A wireless system to check and monitor industrial plant valves can aid that effort to the tune of 95% fewer human error rates, 20% lower maintenance and operation costs, and savings of up to $1 million a day during outages. The wireless Valve Position Indicator (VPI) sensor system reduces cost, lowers risk and improves worker safety by monitoring valve position accurately from a remote location. By automating the process, VPI eliminates the need for workers to physically check and

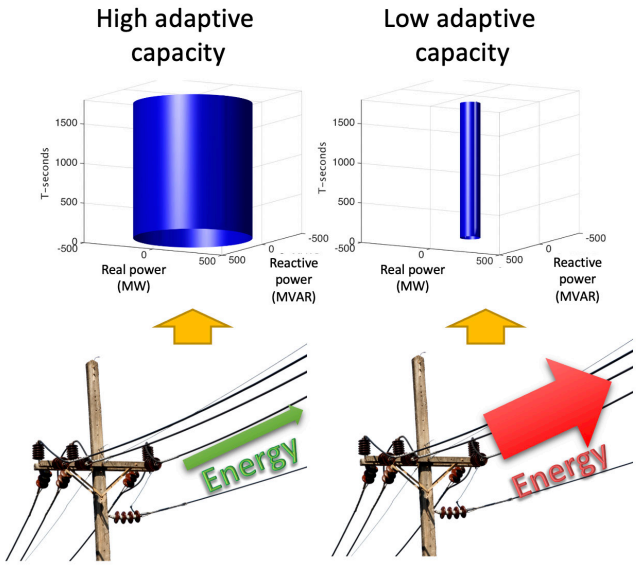
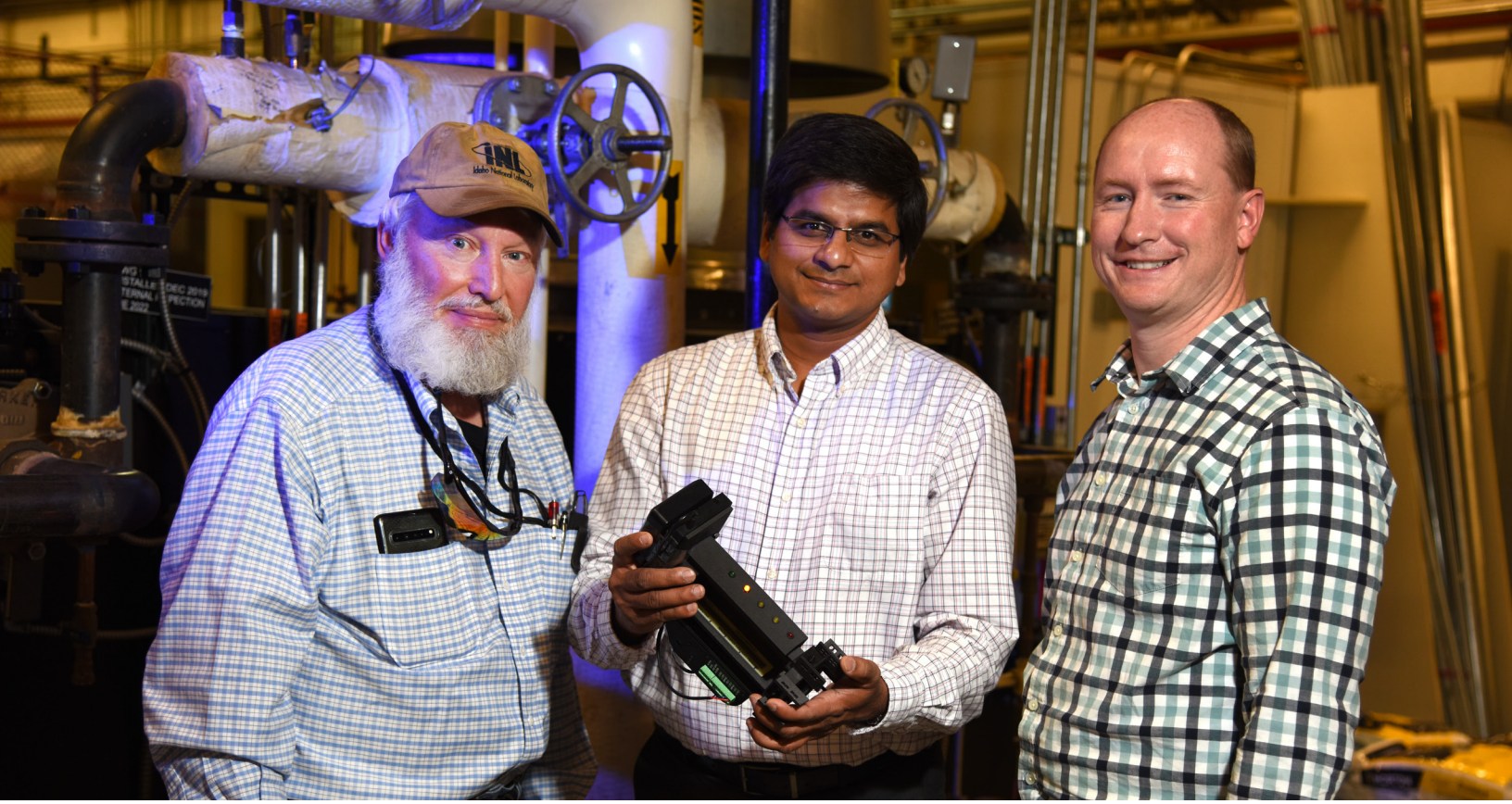


Illustration of adaptive capacity metric where (a) the power line has low energy demands on it and thus high amounts of adaptive capacity and (b) the power line has high energy demand on it and low adaptive capacity

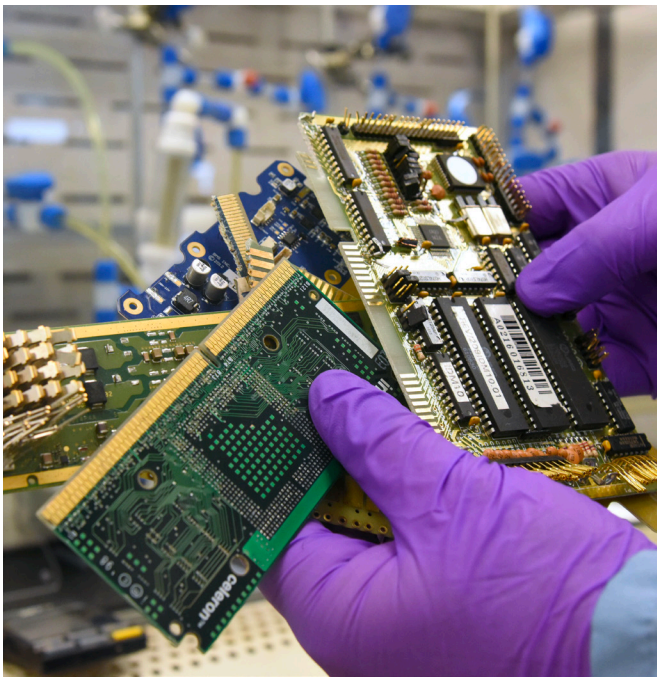


double-check valves, which can put them in high-radiation or high-hazard zones. Best of all, the VPI doesn't require valves to be modified or disassembled for the sensors to be installed, thus averting the costly and time-consuming recertification process. Today, the wireless VPI sensor system is at Technology Readiness Level 9 and is in licensing negotiation with one of the leading U.S. companies providing products and services for various industries across the world.

Vivek Agarwal, principal investigator of the wireless VPI sensor system, was part of the U.S. Department of Energy's sixth Energy I-Corps cohort (October-November 2017). When Agarwal entered the Energy I-Corps cohort along with his team, which included Uuganbayar (Ugi) Otgonbaatar from Constellation (formerly known as Exelon Corporation), the wireless VPI sensor system was at Technology Readiness Level 5. The seven-week Energy I-Corps boot camp transformed the project team's approach. The customer discovery interviews, and the knowledge gained from the faculty members, allowed the team to pivot and consider advanced manufacturing as one of the technologies to further advance the design, development and deployment of the wireless VPI sensor system. One of the important lessons Agarwal learned from Energy I-Corps is that customers live outside the building where innovation is performed. Engaging with your potential customers, understanding the market, and incorporating customer and market needs into your innovation adds value to your innovation and enhances its value proposition. During the Energy I-Corps, the project team also discovered new markets for the wireless VPI sensor system technology, such as oil and gas, chemical plants, and others.

The Energy I-Corps experience has had other measurable impacts. The wireless VPI sensor system received the U.S. DOE Technology Commercialization Funds Topic 2 funding in collaboration with Constellation in 2018. The technology won second place at the Department of Energy's 2017 National Laboratory Accelerator Pitch Competition. It has one issued patent, U.S. Patent No. 10,960,329, and two pending patent applications. The scientific accomplishments of the technology are published in two journals and three conference publications. The wireless VPI sensor system has been a 2019 and 2021 R&D 100 finalist. While working on the Topic 2 funding with Constellation, the team presented the project to Constellation Innovation. William Ansley, Innovation specialist at Constellation, said, "I cannot stress enough how significant the wireless VPI sensor system is to achieving automation in nuclear power plants."

Energy I-Corps had a positive impact. It encouraged Agarwal to think and include discussion about potential harvest strategies or potential customers when he develops internal or external research proposals, highlighting both technical and commercial viability of research concepts. He used his knowledge gained during the Energy I-Corps program to successfully collaborate and win a DOE-sponsored industry Funding Opportunity Announcement Award with an industry partner.



Tech Scout Webinars

Federal laboratory licensing and commercialization managers bear the critical job responsibility to develop and cultivate quality relationships between the labs, researchers and industry to assist moving lab technologies from the benchtop to the marketplace. To be successful, commercialization managers must rise to the goals of Next Level INL to find strategic, creative and innovative methods to develop these relationships.

Idaho National Laboratory Licensing and Commercialization Manager Jonathan Cook proposed the series "Tech Scout Webinars" to the Battelle Commercialization Council (BCC), a resource for all the Battelle-operated national labs, to create more opportunities for the labs and businesses to cultivate their relationships.

The webinar series provide a discovery methodology asking industry partners the questions that get to the root of their needs, including technology shortcomings or technology and product wish lists that may come to fruition with laboratory assistance.

Businesses share information about their product and service offerings, explain current and potential industry research and development needs, and engage in discussion with representatives from each of the Battelle labs. To date, more than 36 companies and government agencies – including General Electric, Eastman Kodak Company, Trek and Eastman Chemical Company – participated in the webinars.

Rich Rankin, Lawrence Livermore National Laboratory's director of Innovation and Partnerships Office, said, "The BCC Tech Scout Webinars provide unique views into the inner technology needs of companies. They are presented and discussed in a collegial, informed manner and provide great insight to inform technology transfer efforts across the labs."

These conversations are leading to potential joint projects that will bring new and needed technology to the market. Idaho National Laboratory has been in several conversations with businesses regarding opportunities for collaboration. Other labs reported that the webinars led to license negotiations and Technology Commercialization Fund proposals. This has included a one joint DOE Technology Commercialization Fund proposal.

I-Corps Lite

The success of and participation in I-Corps Lite continues to be strong as more and more researchers attend the six-week program. As of Spring 2022, a total of 51 INL teams have participated in Energy I-Corps or I-Corps Lite. Much of this participation has resulted in partnerships, funding and other programs.

I-Corps Lite helps INL researchers with a concept (intellectual property) to develop a business value proposition for the intellectual property and validate it through numerous customer interviews with industry experts and potential end users.

There are three top reasons why I-Corps Lite plays a unique role in helping technologies become successful in the marketplace.

First, the program focuses research on real-world needs. After completing the program, nearly all researchers change the direction of their research because they better understand the end user's requirements and needs. As a result, the research has a much higher chance of resulting in impact because it is much more likely to be used.

Second, industry feedback can be used to make proposals for funding more competitive – including Laboratory Directed Research and Development, Technology Commercialization Funds, or DOE program opportunities – showing that the need has been validated and giving the proposal an advantage over others.

Third, I-Corps creates meaningful connections within industry. In the process of contacting industry experts, some express an interest in funding the work, partnering on proposals, licensing the technology, or offering additional support.

EC-Leach anode and cathode chambers.

Awards and Recognition

R&D 100 Awards

Since its inception in 1963, the R&D 100 Awards have celebrated research and development technologies from the public and private sectors and are a prestigious distinction for inventors. A panel of more than 40 industry-leading experts ranks the entries based on technical significance, uniqueness and applicability across industry, government and academia. Typically, the U.S. Department of Energy's national laboratories have dozens of finalists every year. Eight INL technologies were selected as finalists, with three being selected as final winners.

2022 R&D 100 Winners

Electrochemical Leach (EC-Leach)

EC-Leach provides a cost-effective, highly efficient, safe, carbon-free and remarkably simple process for solving one of our world's biggest clean energy challenges: Lithium-ion battery recycling. This technology unlocks the green energy potential of li-ion) batteries at the end of their lives by allowing extraction and recovery of critical materials. Although EC-Leach provides an answer to many complicated challenges, it is remarkable for its technological simplicity. It requires no expensive or hazardous materials, has a low operational cost and is compatible with any li-ion battery chemistry. By facilitating battery recycling in a closed loop, EC-Leach enables a carbon-free transportation and manufacturing sector.

Researchers: Tedd Lister (co-principal investigator), Luis Diaz Aldana (co-principal investigator), John Klaehn, Joshua McNally, Meng Shi and Daniel Molina Montes de Oca.

Three Idaho National Laboratory technologies won R&D 100 Awards in 2022.

MIRACLE employs machine learning and natural language processing to automate documentation of condition reports, saving millions of dollars while improving safety.

INL partnered with John Hopkins University Applied Physics Laboratory to assist in the research into the MOSAICS technology which provides a comprehensive solution to detect and prevent cyberattacks.

Machine Intelligence for Review and Analysis of Condition Logs and Entries (MIRACLE)

In the nuclear power industry, every issue, no matter how small, is documented in a condition report. In each plant, hundreds of these are reviewed and characterized every week by dozens of people. MIRACLE employs machine learning and natural language processing to automate this process, saving millions while improving safety. Although MIRACLE is intended for use in nuclear power plants, the methods developed in its creation should be valuable in any industry that requires massive volumes of documentation reviews. MIRACLE offers savings and efficiencies.

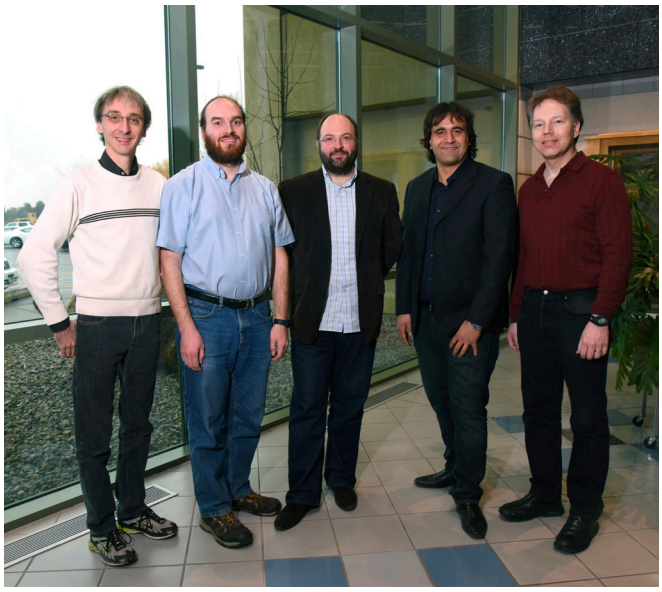
Researchers: Ahmad Al Rashdan (principal investigator), Brian Wilcken, Cameron Krome and Kellen Giraud.

MOSAICS*

MOSAICS is a technology initiated by the Department of Defense to provide the first comprehensive, integrated and automated solution to detect and prevent cyberattacks of industrial control systems. INL focused its efforts to provide scalable evaluation of commercial off-the-shelf security solutions and test harness for initializing, launching and collecting results from cyber-resilience testing in virtual environments.

Researchers: Craig Rieger, Michael McCarty, Bev Novak, and former employee Roya Gordon.

*INL is partnered on this award nomination from Johns Hopkins University Applied Physics Laboratory lists INL, with Sandia National Laboratories and Pacific Northwest National Laboratory.



The RAVEN development team showed remarkable ambition in creating a state-of-the-art technology.

C3D gives utilities time to defend against a cyberattack by limiting protective relays' exposure to outside communications while maintaining operations.

2022 R&D 100 Finalists

Modeling and Simulation for Target Electrical Resilience and Reliability Improvements (MASTERRI)

MASTERRI enables utility leaders to identify and prioritize electrical system repairs and upgrades to prevent cascading failures. The analysis process identifies critical vulnerabilities and the overall potential for system failure. MASTERRI delivers the most accurate information available for electrical industry decision support and is instrumental in preventing failure and building resilience.

Researchers: Bjorn Vaagensmith (principal investigator), Kurt Vedros, Tim McJunkin, Liam Boire, Jesse Reeves, James Case, Jason Wayment, Craig Rieger, Shawn West, Courtney Otani, Pierce Russell and Carol Reid.

Caldera

Electric vehicle ownership is expanding rapidly as the technology becomes more available and affordable. While the increase will reduce carbon emissions and the impacts of climate change, these vehicles and their associated charging infrastructure will have a huge impact on electric grids throughout the world. Caldera provides two essential services to the future of electrical vehicle charging: 1) modeling large-scale electric vehicle charging for a variety of locations and conditions; and 2) modeling charging management strategies to reduce the grid impacts of large-scale electric vehicle charging. Caldera is the missing link between transportation models, grid models and detailed charging data.

Researchers: Don Scoffield (co-principal investigator), Timothy D. Pennington (co-principal investigator), John Smart, Zonggen Yi, Manoj Kumar Cebol Sundarrajan and Paden Rumsey.

Constrained Communication Cyber Device (C3D)

Cybercriminals and nations hostile to U.S. interests have developed increasingly sophisticated ways to attack electricity distribution infrastructure. The patent-pending C3D technology is an added depth of defense against cyberthreats aimed at essential electrical grid hardware called protective relays. C3D sits deep inside a utility's network, monitoring and blocking cyberattacks before they impact relay operations. The C3D technology was licensed to Sierra Nevada Corporation in March 2022.

Researchers: Jake Gentle (co-principal investigator) and Steve Bukowski (co-principal investigator).

Computational Platform Performing Stochastic Analyses (RAVEN)

RAVEN offers a fully integrated working environment, providing everything engineers and scientists need to tackle challenging problems in an efficient and user-friendly fashion. RAVEN is a flexible and multipurpose statistical analysis framework that allows users to conveniently perform a variety of analysis, data mining and model optimization tasks. These operations are performed based on the response of complex physical models through advanced statistical sampling generation to achieve a high degree of realism and accuracy previously unattainable. RAVEN is a unique and powerful tool for risk analysis, offering capabilities not currently available in other software.

Researchers: Diego Mandelli (principal investigator) and Congjian Wang (principal investigator) Team Joshua Cogliati, Paul Talbot, Mohammad Abdo, Robert Kinoshita, Dylan McDowell, Cristian Rabiti, Andrea Alfonsi, Daniel Maljovec, Jun Chen and Sonat Sen

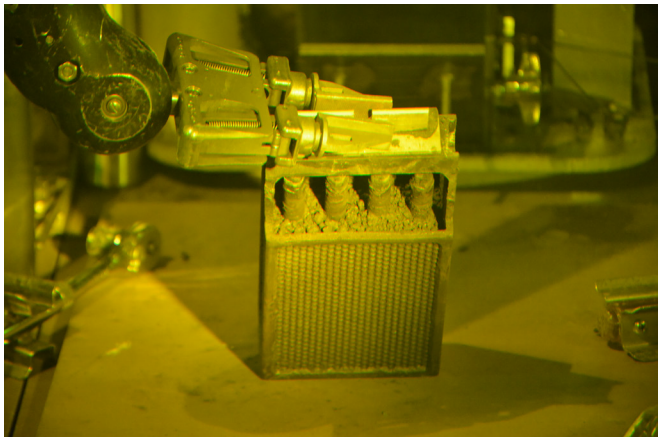
Charging station research at the Laboratory

Robust Anode for Electrochemical in Extreme Environments (Robust Monolithic Anode)

2022 R&D 100 FINALIST

In a world increasingly reliant on technologies with metal-based components, sustainable metal recycling methods are more essential than ever. Recycling these metals provides the dual benefit of reducing waste in landfills and minimizing the need for additional mining. While electrochemical processing is not a new technique, the graphite- and platinum-based anodes most commonly used today lack long-term durability in the extremely hot, corrosive and oxidizing conditions that prevail in the recycling vessel, requiring frequent (and costly) replacement. The iridium anode has demonstrated long-lasting, highly efficient performance to support consumer products recycling as well as spent nuclear fuel reprocessing.

Researchers: Prabhat Tripathy (co-principal investigator), Steven Herrmann (co-principal investigator), Dale Wahlquist, Steven Frank, James King and Ken Marsden.



Cathode basket loaded with uranium oxide prior to electrochemical reduction.

INL has won more than 30 R&D 100 Awards since 2005.

Idaho National Laboratory