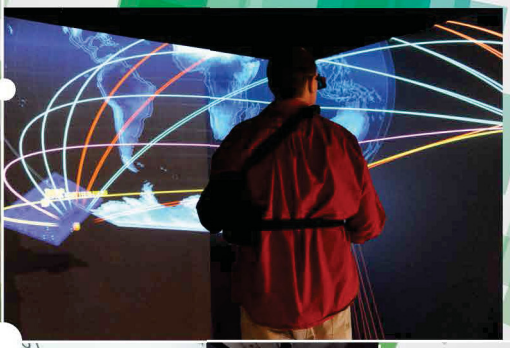
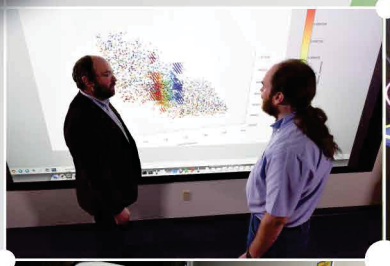
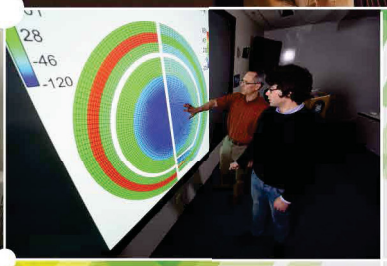
TECHNOLOGY TRANSFER

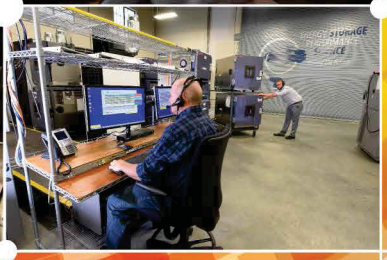
December

Annual Report
Fiscal Year 2016









Idaho National Laboratory

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 other 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 cooperatively with researchers and technical staff from the university and industrial sectors to further develop emerging technologies. In this global economy, INL is contributing to the development of the next generation of engineers and scientists by licensing software to educational institutions throughout the world.

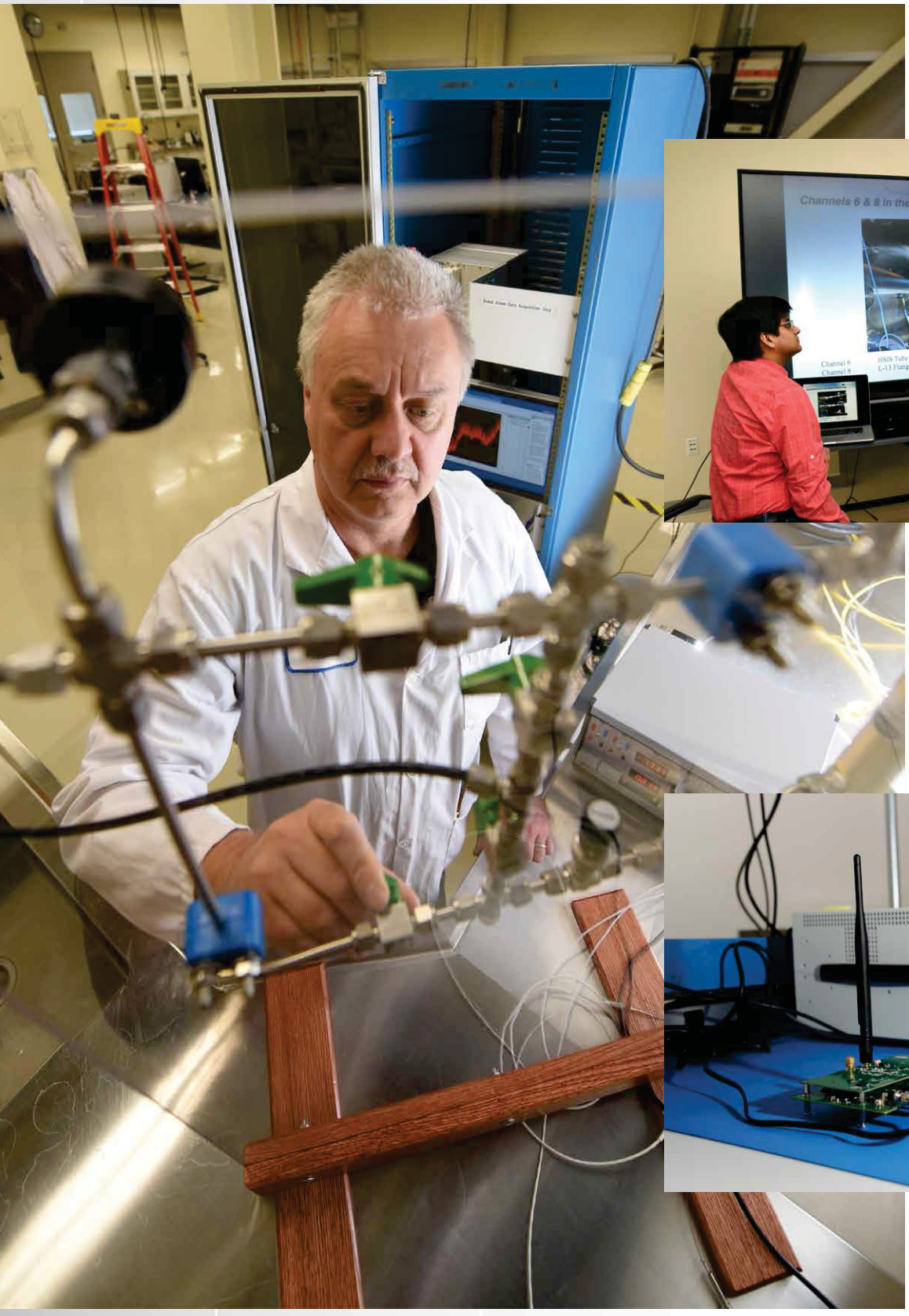
This report is a catalog of select INL technology transfer activities, including commercialization transactions and research agreements, executed during this past year. The size and diversity of INL technical resources, coupled with the large number of relationships with other organizations, virtually ensures that a report of this nature will fail to capture all interactions. Recognizing this limitation, this report focuses on transactions that are 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 the INL's Technology Deployment and Contracts Management offices. Accomplishments cataloged in the report reflect the achievements and creativity of the researchers, technicians, support staff and operators of the INL workforce.

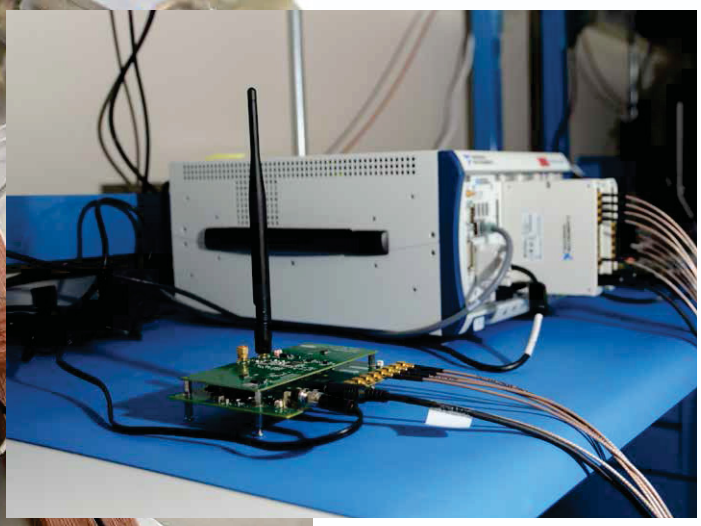
Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office

Contract DE-AC07-05ID14517

Contents




Channels 6 & 8 in the Nozzle Trench Area



From the Laboratory Director

Research and development at Idaho National Laboratory helps ensure America's energy security, today and into the future. However, that happens only when our science and technology move from the laboratory to the market; when an idea is tested, developed and demonstrated and completes the journey from theory to practice.

Working with industry partners to make sure INL's results are put to use is a laboratory-wide responsibility that requires an ongoing team effort, and includes researchers, managers, technology deployment professionals, intellectual property experts, and many others.

This report is reflective of that team effort. It highlights our outcomes and impacts, and details a record of achievement that inspires pride in our people, our innovative research and development, and the exceptional productivity of our laboratory. Technology Deployment and INL's research directorates work together to develop and deploy technologies that support the nation's energy and security missions. And this team effort generates results.

Let me offer an example:

The Department of Energy (DOE) in fiscal year 2016 created the Technology Commercialization Fund. This new outreach program uses federal dollars to match private funding sources in an effort to increase the impact of DOE laboratory technologies through commercial development and deployment. Technology areas of emphasis include many in INL's wheelhouse: nuclear energy, renewable energy, energy efficiency, electric grid technologies, advanced fossil energy, and energy storage.

I'm pleased to say that DOE awarded INL researchers more than $1 million for nine projects. INL expertise and matching funds will help move these promising technologies to the marketplace, where they can begin to make a difference in people's lives.

In this regard, technology development and commercialization provides a significant return on the American taxpayers' investment in the nation's lead nuclear research, development and demonstration laboratory.

Over the past decade, INL has signed 823 new technology license agreements, executed 134 cooperative research and development agreements, and completed 397 agreements with federal agencies and private sector entities worth nearly $1.2 billion.

In 2016, INL established agreements with notable organizations such as the International Fusion Energy Organization, Creare, LLC, Ceramic Tubular Products, LLC, WiTricity, Qualcomm Halo, the Idaho State Department of Agriculture, Southern California Edison, and Wyle Laboratories.

Other highlights from fiscal year 2016 include:

- INL received $1.3 million in royalty revenues from our technology licensing efforts. INL reinvested $1.1 million of royalty income into ongoing research.
- Electrochemical Recycling Electronic Constituents of Value (E-RECOV) won both a TechConnect National Innovation Award and a Federal Laboratory Consortium Far West Regional award for its work to recycle electronic waste.
- INL is the most active participant in DOE's Lab-Corps Program, which continues to succeed at developing relationships with industry, providing insights into commercialization pathways, and creating an entrepreneurial culture at the laboratory.

Additional details can be found in this annual summary. We are proud that INL – along with our partners at DOE – continues to deliver a significant impact from our science and technology while making real progress in helping resolve the nation's big energy and security challenges.

Dr. Mark Peters

Director, Idaho National Laboratory

From the Technology Deployment Director

As the new director of the Technology Deployment team, I am proud to lead an organization with such a profound mission, strong spirit of innovation and dedication to outcome. Thomas Edison once said, "The value of an idea lies in the using of it." As the director, my goal is to build an inspiring legacy of impact by ensuring INL technologies are put to use to grow our economy, improve the quality of our lives and keep us safe from national threats. Deploying an INL technology requires a team effort, which results in shared success among many individuals and organizations.

My goal is to build an inspiring legacy of impact as a result of ensuring that INL technologies are put to use.

The accomplishments cataloged in this report reflect a culmination of notable efforts and demonstrate the value of the hard work and combined talents of numerous INL employees. The outlined projects include contributions made by our scientists with support from members of Technology Deployment and Contracts Management.

Under the leadership of Amy Lientz and Mark Kaczor, INL has restored our licensing and commercialization capabilities, creating a team with a combined total of over 125 years in technology transfer and 135 years in industry experience. New positions in Technology Deployment include a market analyst, an open source software lead, and an additional senior commercialization manager. The team's focus is on increasing value to INL's mission by leading INL's technology transfer program, protecting and deploying INL's intellectual property and fully engaging in DOE's lab impact initiatives. We appreciate the support and encouragement received during 2016 from private and government sponsors, the Department of Energy, licensees, users and partners.

It is an exciting time to be part of INL, and I have never seen DOE more focused on increasing the impact of its research investments through technology transfer efforts. I believe we are setting the stage for new invention opportunities and discoveries that will factor into not only INL's growth, but also America's prosperity, for years to come.

Jason Stolworthy

Director, Technology Deployment

Intellectual Property

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

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

In 2016, INL inventors submitted to Battelle Energy Alliance, LLC (BEA) 53 invention disclosure records (IDR) and 15 software disclosures (SDR) (Figure 1). These include seven IDRs and seven SDRs from Nuclear Science and Technology (NST), 34 IDRs and three SDRs from Energy and Environment Science and Technology (EEST), 12 IDRs and 1 SDR from National and Homeland Security (NHS), and four SDRs contributed by inventors supporting other mission work.

Thirty U.S. patents were issued to either INL or the DOE based on the inventions of INL scientists and researchers (Figure 2). These issued U.S. patents included three from NHS, 24 from EEST, and three from NST.

In addition, 23 new patent applications for INL inventions were filed, with seven from NHS and 16 from EEST.

Since the commencement of BEA's contract to manage INL, laboratory researchers have generated 939 IDRs. These IDRs have led to more than 472 U.S. patent applications and have resulted in excess of 450 issued U.S. patents.

BEA has IP rights under its contract with DOE and can elect to retain title to inventions and seek patent protection, subject to some exceptions. The decision of whether or not to seek patent protection is based on market and technical assessments of the technology and its subsequent programmatic value. Market assessments are performed and a recommendation is presented to a committee composed of department or project managers, assistant laboratory director or designee, market analysts, commercialization managers, and patent attorneys. These recommendations are presented to the committee and then a final decision is made to elect or decline the technology for patent protection by TD's director. Generally, if the invention is judged as commercially valuable, crucial to a primary mission, or valuable in terms of motivating further research funding, it is elected. If BEA decides to decline title, DOE chooses whether to seek patent protection in its own name. If DOE decides not to seek patent protection, the inventor(s) may petition to have the title assigned to them by DOE with the expectation that they will pursue patent protection using their own resources.

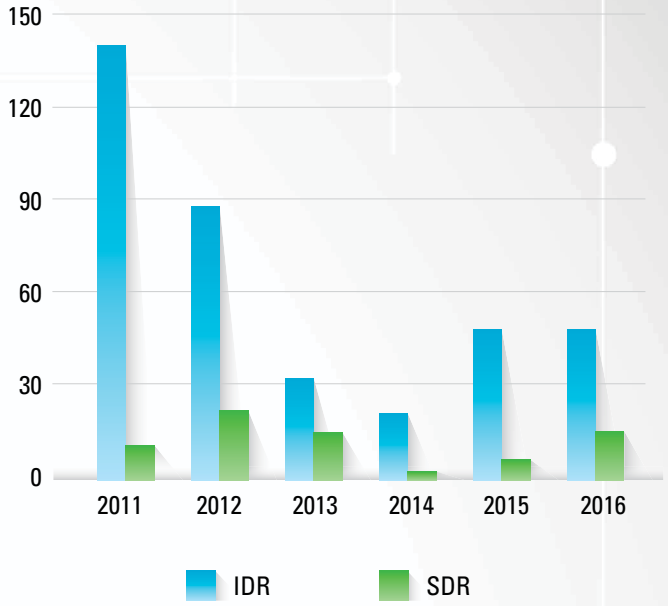


Figure 1. Invention disclosure records completed FY 2011–2016.

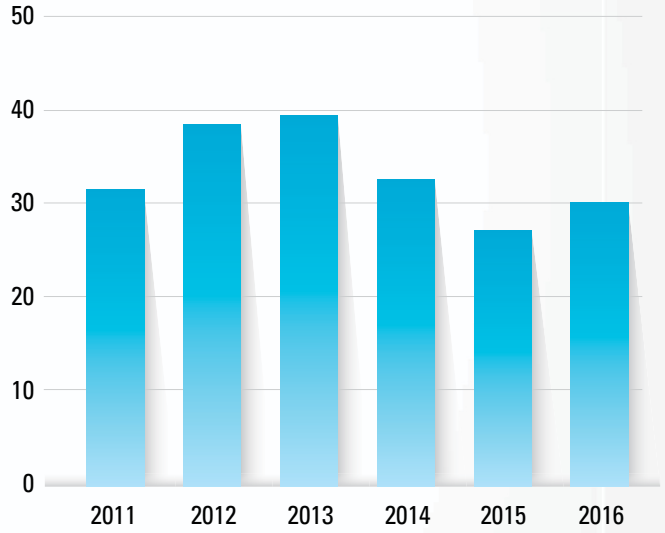
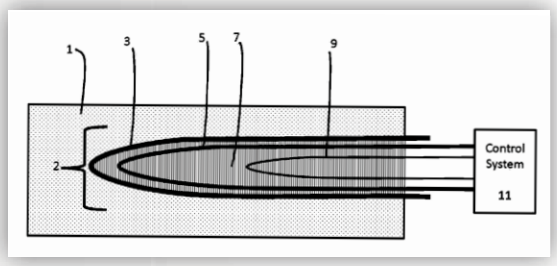


Figure 2. U.S. patents issued FY 2011–2016.



Patents

The following pages provide a brief description of the patents issued to INL during FY16.

Hot Wire Needle Probe for Thermal Conductivity Detection

Current techniques for measuring thermo-physical properties, particularly thermal conductivity, in high-temperature, in-pile applications are slow, expensive and inaccurate. Thermal conductivity is one of the most important properties for predicting nuclear fuel and material performance, and is highly dependent on physical structure, chemical composition, and state of matter – and the fact that these properties change during exposure inside a reactor further complicates the problem. The Hot Wire Needle Probe provides a better method for gathering real-time thermal conductivity measurements of fuels inside a reactor, without the added cost, time and data quality reductions associated with repeated movement of samples into a hot cell environment for measurements.

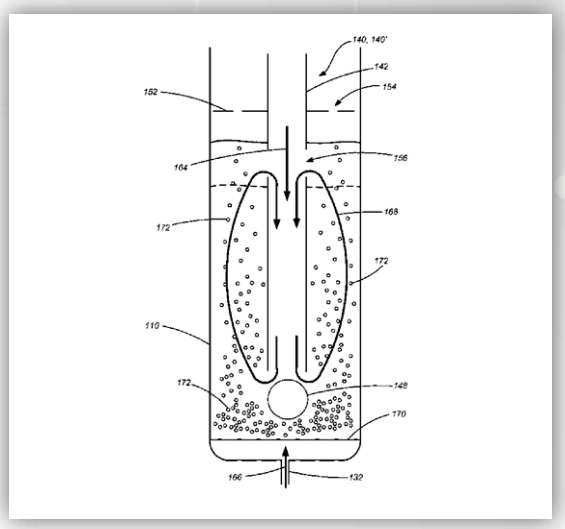
Patent No. 9,182,364 Docket No.: BA-459 - Grant Date: 2015-11-10
Inventors: Keith G Condie, Joy L Rempe, Darrell L Knudson, Joshua Daw, Steven Wilkins, Brandon Fox, Heng Ban

Transcriptional Control in Alicyclobacillus Acidocaldarius and Associated Genes, Proteins, and Methods

One function of bacterial DNA is to code for information that regulates metabolic activities such as cellular growth and carbon processing. The bacteria will adjust metabolic activity in response to its environment as a way to conserve energy. This can be problematic for biofuel process development, because it may lead to suboptimal bacterial growth or interfere with the production of a desired enzyme or compound. This patent describes one of the controlling metabolic mechanisms (transcription) used by this bacteria and methods to genetically engineer the transcription process for favorable enzyme activity at high temperatures.

Patent No. 9,187,753 Docket No.: BA-294D1 - Grant Date: 2015-11-17
Inventors: Brady D Lee, David N Thompson, William A Apel, Vicki S Thompson, David W Reed, Jeffrey A Lacey

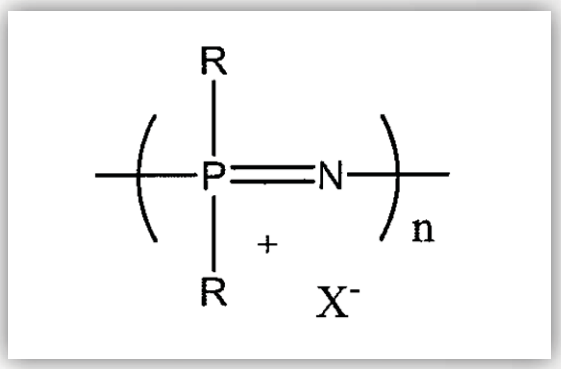
Molten Salt Rolling Bubble Column, Reactors Utilizing Same and Related Methods



Hydrocarbon-based fuels are a major source of energy production, but sustainability and environmental concerns have prompted a search for alternative energy sources. This invention involves chemical reactors which process a wide range of hydrocarbon material (including low-value byproducts of crude oil processing) into useful fuel gases. The system described in this invention uses high temperatures and the formation of gas bubbles to circulate the salt bath in order to increase the exposure and contact area to improve reaction efficiency. The resulting gases can then be separated and marketed as pure gases such as hydrogen, carbon monoxide, and carbon dioxide, or combined to produce synthesis gas to produce fertilizers, chemicals, fuels and other products.

Patent No. 9,187,325 Docket No.: BA-557 - Grant Date: 2015-11-17
Inventors: Terry D Turner, Bradley C Benefiel, Dennis N Bingham, Kerry M Klingler, Bruce M Wilding

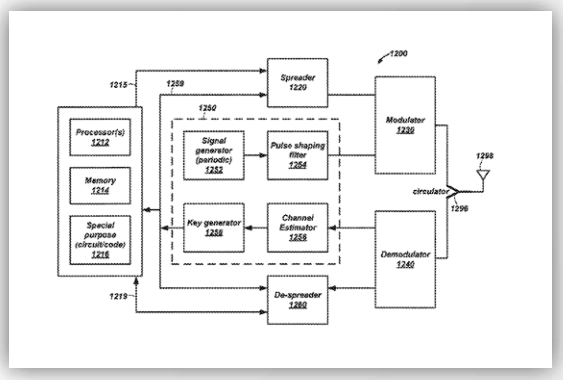
Ionic Liquids, Electrolyte Solutions Including the Ionic Liquids, and Energy Storage Devices Including the Ionic Liquids



Electrolyte solutions used in lithium-ion batteries are typically unstable at high temperatures and high voltages, and over time they can undergo severe degradation, making them unsuitable for good battery performance. This patent describes the synthesis and use of battery electrolyte solvents containing phosphazene compounds (having a phosphorous atom linked to a nitrogen atom) in the form of ionic liquids to achieve improved performance at high temperatures, while reducing flammability and volatility. These compounds are currently under license and being tested by a large battery manufacturer.

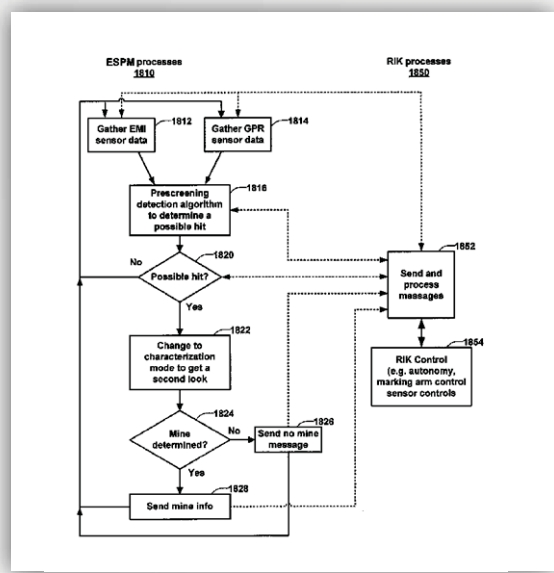
Patent No. 9,206,210 Docket No.: BA-342 - Issued: 2015-12-08
Inventors: Kevin L Gering, Mason K. Harrup, Harry W. Rollins

Methods and Apparatuses for Self-Generating Fault-Tolerant Keys in Spread-Spectrum Systems



In wireless radio communication, spread-spectrum techniques involve increasing a signal's bandwidth for a variety of reasons, including to avoid jamming and reduce the probability of detection or interception. However, secure communication may be compromised if an eavesdropper has already obtained the spreading code being used for transmission of a spread-spectrum signal. This invention advances the deployment of spread-spectrum systems by dynamically selecting the spreading code used by a pair of communicating devices in such a way that it will be inaccessible to an eavesdropper. The channel reciprocity between the communicating parties is used to set up a common secret key (a spreading gain) among them. The self-generated key remains unknown to an eavesdropper whose different physical location, with respect to the legitimate parties, leads to a different set of channel parameters.

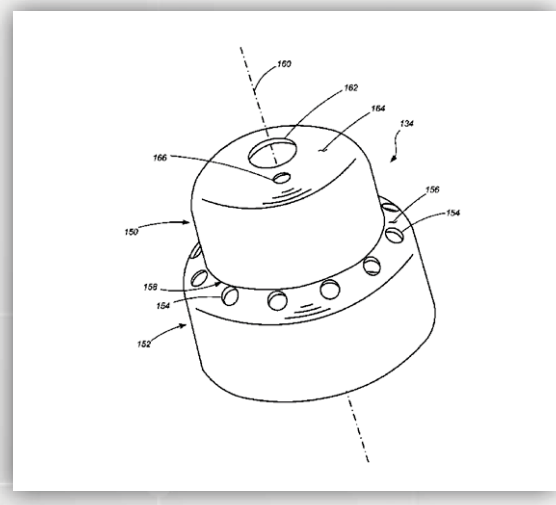
Patent No. 9,215,587 Docket No.: BA-783 - Grant Date: 2015-12-15
Inventors: Hussein Moradi, Behrouz Farhang, Rangam Subramanian



Real Time Explosive Hazard Information Sensing, Processing, and Communication for Autonomous Operation

Robots today generally lack the ability for decision-making, relying on continuous guidance by human operators. For example, land mine detection using robots is performed in teleoperation mode, where the operator controls robotic behavior including locomotion and control of mine sensing equipment — an inefficient and error-prone process. This invention brings hardware components for sensing, motion, manipulation and actions together with software components for perception, communication, behavior and world modeling into a single robot intelligence kernel that can function on a variety of robotic platforms. The robot intelligence kernel can develop a variety of mechanical capabilities, and enable a collaborative human-robot relationship in which the robot can assume varying degrees of autonomy. As robot autonomy increases, the operator can attend to crucial tasks at hand (for instance, locating victims, hazards, dangerous materials; following suspects; measuring radiation and/or contaminant levels) without worrying about moment-to-moment navigation decisions or communications gaps.

Patent No. 9,213,934 Docket No.: BA-476D1 - Grant Date: 2015-12-15
Inventors: Roelof J Versteeg, Douglas A Few, Robert A Kinoshita, Doug Johnson, Ondrej Linda



Bell Column Downtube, Reactors Utilizing Same and Related Methods

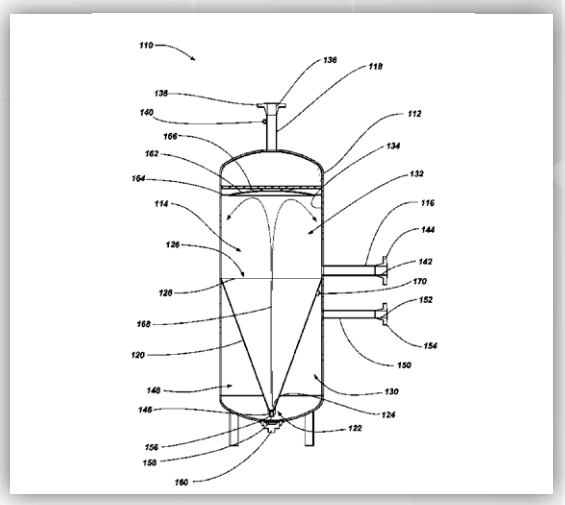
Due to the difficulty of converting some carbon-rich materials into fuels, many sources (often waste products) have been ignored as potential feedstocks for fuel production. This patent describes a chemical reactor to convert such carbonaceous waste materials into fuels and fuel precursors such as hydrogen, and synthesis gas. The reactor tube and bell design control the reaction to enhance the mixing, distribution and residence time of the oxidizing and hydrocarbon materials within a salt bath. Multiple hole geometries may be utilized to facilitate the distribution of the gases and maximize reactor efficiency.

Patent No. 9,216,401 Docket No.: BA-556 - Grant Date: 2015-12-22
Inventors: Terry D Turner, Dennis N Bingham, Bradley C Benefiel, Kerry M Klingler, Bruce M Wilding

Heat Exchanger and Related Methods

Due to relatively high freezing temperature, unwanted concentrations of carbon dioxide cause problems for natural gas liquefaction systems. Current processing of natural gas to liquid form requires the carbon dioxide to be removed first in order to avoid solid carbon dioxide crystal formation. This patent is for a new heat exchanger developed for small-scale natural gas liquefaction that eliminates the need for expensive precleanup of the carbon dioxide and the associated large, expensive and energy-intensive filtration equipment. The carbon dioxide is processed with the natural gas stream, then transferred to the heat exchanger where it separates clean natural gas from the carbon dioxide crystals and changes the waste carbon dioxide back into a gas.

Patent No. 9,217,603 Docket No.: BA-495 - Grant Date: 2015-12-22
Inventors: Terry D Turner, Michael G McKellar



Thermophilic and Thermoacidophilic Metabolism Genes and Enzymes from Alicyclobacillus Acidocaldarius and Related Organisms, Methods

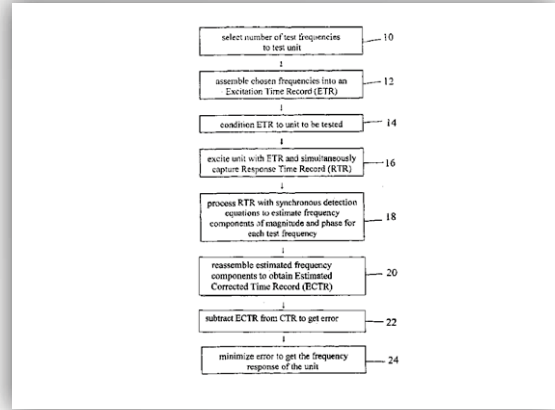
Alicyclobacillus acidocaldarius is a microorganism that produces enzymes that are very active in acidic conditions (pH 1) and at high temperatures (90°C, 194°F). Enzymes with these properties are needed to economically produce fuels and chemicals from plant material such as corn stover and wheat straw. This organism produces a number of enzymes necessary for conversion of biomass to biofuels. This patent describes the genes and the associated proteins related to the metabolism of the bacterium.

Patent No. 9,222,094 Docket No.: BA-293D1 - Grant Date: 2015-12-29
Inventors: Vicki S Thompson, William A Apel, David W Reed, Brady D Lee, David N. Thompson, Francisco F Roberto, Jeffrey A Lacey

Thermophilic and Thermoacidophilic Glycosylation Genes and Enzymes from Alicyclobacillus Acidocaldarius and Related Organisms, Methods

It is recognized that bacteria glycosylate (attach a carbohydrate) their proteins. Glycosylation of a protein has been shown to assist in the protein's stability and activity, modulate physical properties such as solubility, and protect against its destruction. The glycosylated enzymes from Alicyclobacillus acidocaldarius have enhanced activities under industrially relevant conditions such as with acid and at very high temperatures. This patent describes some of the genes responsible for the glycosylation of enzymes in the thermoacidiphilic microorganism Alicyclobacillus acidocaldarius.

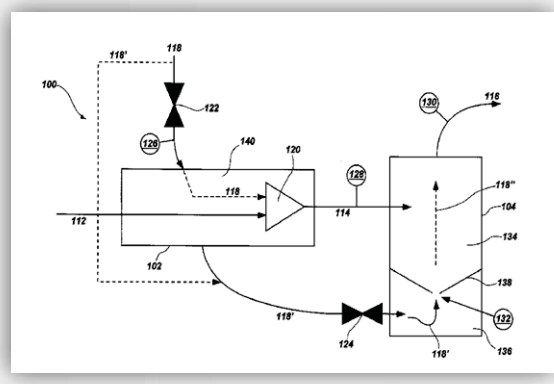
Patent No. 9,234,228 Docket No.: BA-312 - Grant Date: 2016-01-12
Inventors: David N. Thompson, William A Apel, Vicki S Thompson, David W Reed, Jeffrey A Lacey



Method, System and Computer-Readable Media for Measuring Impedance of an Energy Storage Device

Measuring a battery's impedance (internal resistance) allows for control and diagnosis of battery performance. Although effective, the existing well-established technique uses a series (multiple measurements in a row) approach which makes it time consuming. This patent describes a single-measurement parallel approach that allows for real-time acquisition of battery impedance over a specific frequency range without a significant loss of accuracy.

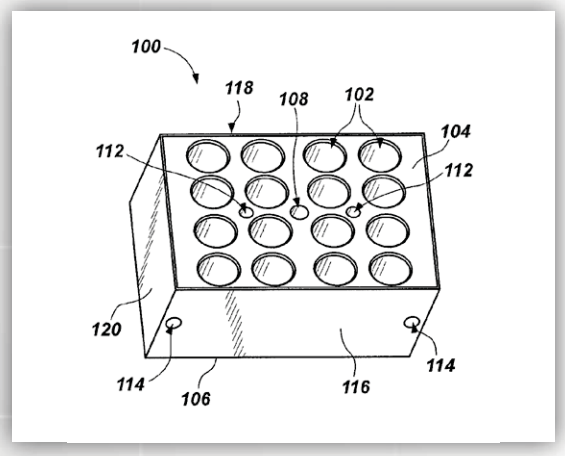
Patent No. 9,244,130 Docket No.: BA-396C1 - Grant Date: 2016-01-26
Inventors: John L Morrison, William Morrison, Jon P Christophersen, C. (Chet) G Motloch



Sublimation Systems and Associated Methods

The production of liquefied natural gas includes a refrigeration step that results in unwanted crystal formation due to carbon dioxide impurities within the methane gas mixture. This technology describes an apparatus for liquid natural gas production. The process includes a series of two heat exchangers and separation techniques that enable most of the liquid natural gas to separate from the crystals, leaving the remaining mixture to be heat processed to vaporize the unwanted carbon dioxide.

Patent No. 9,254,448 Docket No.: BA-496 - Grant Date: 2016-02-09
Inventors: Terry D Turner, Michael G McKellar, Bruce M Wilding



Methods for Determining Enzymatic Activity Comprising Heating and Agitation of Closed Volumes

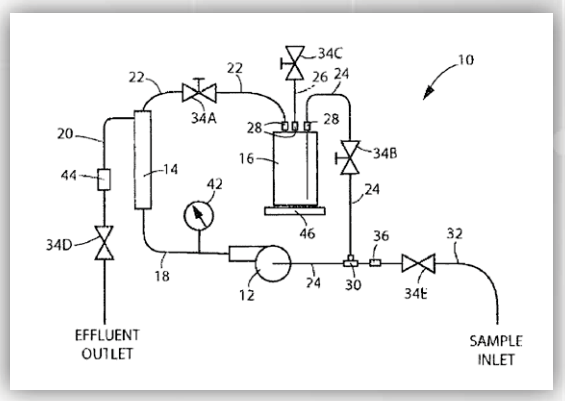
Enzymes are biological molecules that accelerate chemical reactions. Information about how an enzyme will behave in different substrates (reaction mixtures) is obtained by measuring the conversion of one chemical to another by the enzyme over a time. However, multiple factors can impact the reaction rate and product final concentration, including: temperature, how well the substrates dissolve, the types of chemicals present, and how well the chemicals and enzymes mix and interact. This patent describes a technique for more accurately measuring enzymatic activity during which closed volumes of enzymes and substrates are agitated at predetermined reaction temperatures.

Patent No. 9,284,596 Docket No.: BA-740 - Grant Date: 2016-03-15
Inventors: David N. Thompson, Emily DeCrescenzo Henriksen, David W Reed, Jill R Jensen

Systems and Methods for the Detection of Low-Level Harmful Substances in a Large Volume of Fluid

There are many applications in which it is desired to detect the presence and concentration of harmful substances in a fluid. One example is monitoring for microbial pathogens in a source of drinking water, such as a lake. However, standard sample methods may not accurately reflect actual concentrations in large sources. Further, certain microbial pathogens may be harmful to human health at levels too low to detect using conventional methods. This patent describes a portable, automated, accurate and repeatable pathogen concentration system that provides detectable concentrations of these pathogens is an accurate and repeatable fashion.

Patent No. 9,285,354 Docket No.: BA-167A1 - Grant Date: 2016-03-15
Inventors: Michael V Carpenter, Lyle G Roybal, Alan Lindquist, Vicente Gallardo



Methods of Combined Bioprocessing and Related Microorganisms, Thermophilic and/or Acidophilic Enzymes, and Nucleic Acids Encoding Said Enzymes

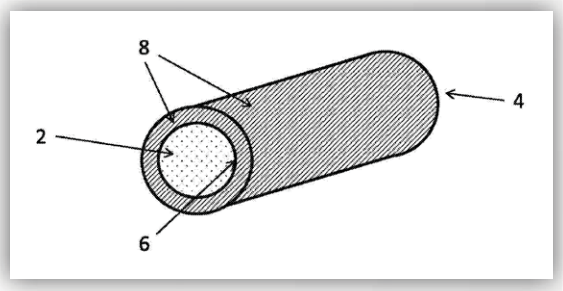
Typical biofuel production requires a multistep process to convert biomass feedstocks starting with water, acid and high temperatures; followed by cooling, pH adjustment and enzyme treatment with a final cooling, pH adjustment and fermentation step to fuels. However, the multiple steps require separate expensive reaction vessels, the high temperatures result in thermal decomposition products that inhibit microbial fermentation and the added cooling and pH adjustment steps are expensive. This patent describes a single step process using heat and acid tolerant Alicyclobacillus acidocaldarius to produce all the enzymes needed to break the biomass into sugars and then ferment those sugars into fuel.

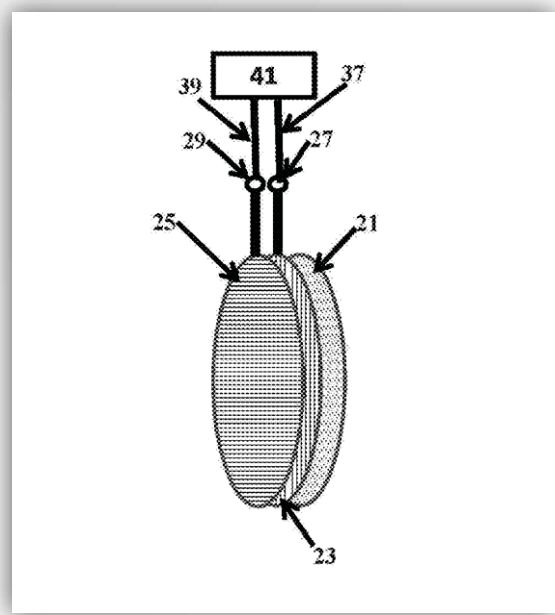
Patent No. 9,290,784 Docket No.: BA-282D2 - Grant Date: 2016-03-22
Inventors: David N Thompson, William A Apel, Vicki S Thompson, Thomas E Ward

Controlled-Release Fertilizer Composition Substantially Coated with an Impermeable Layer

Soil amendments such as compost, manure, bone meal, leaf mold or synthetic fertilizers, provide a primary means for bolstering plant growth, but significant quantities never reach the roots of plants. More nutrients are immobilized by soil than used by crops. The invention uses control-released fertilizer coated with an impermeable layer. The fertilizer composition may further include one or more hollow sections to allow for root penetration and efficient delivery of nutrients.

Patent No. 9,296,661 Docket No.: BA-339 - Grant Date: 2016-03-29
Inventors: Mark D Ankeny

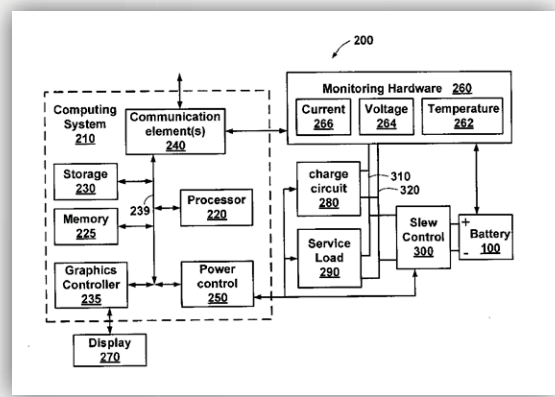




Method and Device for Secure, High-density Tritium Bonded with Carbon

A long-lasting and reliable energy source is essential for many applications including medical devices, extreme environment sensors and longer-term storage (for example, nuclear waste monitoring). Radioactive energy sources such as tritium have been used for many years; however, tritium is a significant health concern unless properly secured. Current methods for securing tritium result in a low-density product with low potential as a significant energy source. This invention provides a device and method for producing secure, high-density tritium bonded with carbon. A precursor of tritium (lithium-6 or boron-10) is inserted between layers of carbon and irradiated with neutrons to form tritium. The result is a secure, high-density, bonded tritium source which can provide long-term power and is capable of operating in extreme environments and under extreme temperatures.

Patent No. 9,305,674 Docket No.: BA-429 - Grant Date: 2016-04-05
Inventors: Alan K Wertsching, Troy J Tranter, Matthias Ebner, Brad C Norby

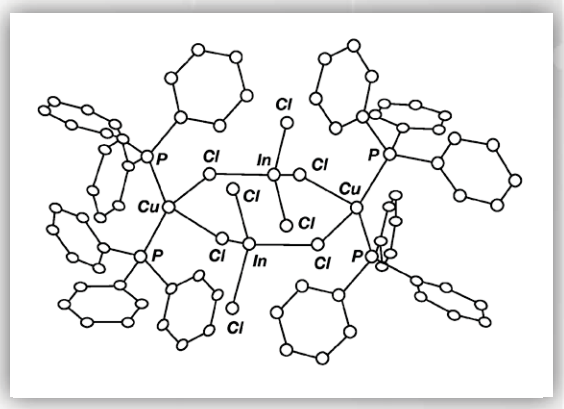


Circuits and Methods for Determination and Control of Signal Transition Rates in Electrochemical Cells

Uncontrolled charge and discharge pulses can damage electrochemical battery cells, increasing excess heat and reducing cell performance and safety. This patented method is configured to detect charge and discharge pulse transition rates of systems coupled to electrochemical cells. The pulse transition rate is then adjusted before it reaches the battery sufficient to reduce degradation caused by transitions greater than a determined rate.

Patent No. 9,312,577 Docket No.: BA-406 - Grant Date: 2016-04-12
Inventors: David K Jamison

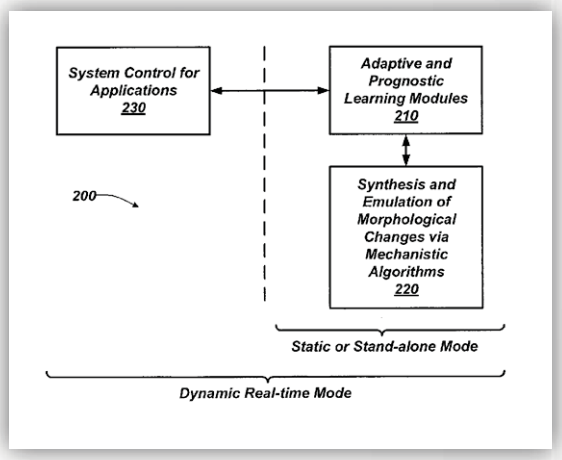
Methods of Forming Single Source Precursors, Methods of Forming Polymeric Single Source Precursors, And Single Source Precursors Formed by Such Methods



Molecules containing all of the elements, and having the correct stoichiometric ratio needed to form the final product are called single source precursors. Nanoparticles arising from thermal decomposition of single source precursors are useful for the manufacture of thin film semiconductors, superconductors, or electrically insulating materials. Such thin film structures have applications in electronics, pharmaceuticals, and as catalysts in the making of advanced materials. There is a need for improved methods to form single source precursors for use in forming multilayered semiconductive nanomaterials. The method described in this patent uses supercritical fluids (carbon dioxide at a pressure and temperature where it has the density and solvent properties of a fluid, but the viscosity and diffusivity of a gas) for controlled thermal decomposition of single source precursors to form nanoparticles having uniform composition and structure.

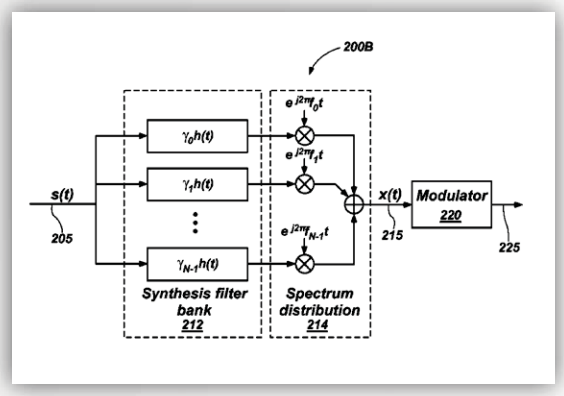
Patent No. 9,315,529 Docket No.: BA-389D2 - Grant Date: 2016-04-19
Inventors: Robert V Fox, Rene G Rodriguez, Joshua J Pak, Chivin Sun, Kelsey Margulieux, Andrew Holland

Methods, Apparatuses, And Computer-Readable Media for Projectional Morphological Analysis of N-dimensional Signals



Classical mathematical morphology, a method for nonlinear processing of images and signals based on filtering the images with simple geometrical shapes, was originally developed in the 1960s for binary images. There is a need for methods and apparatuses that provide a new outlook at mathematical morphological analysis that should be considered supplementary to the more traditional approach. In this patent, the so-called "projection" variant of mathematical morphology was developed. In many cases, it allows generalizing the problem of signal/image analysis and establishing its rigorous mathematical formulation in the form of variational problems. The morphological methods that were developed are applicable to multispectral signals/images or arbitrary dimensionality.

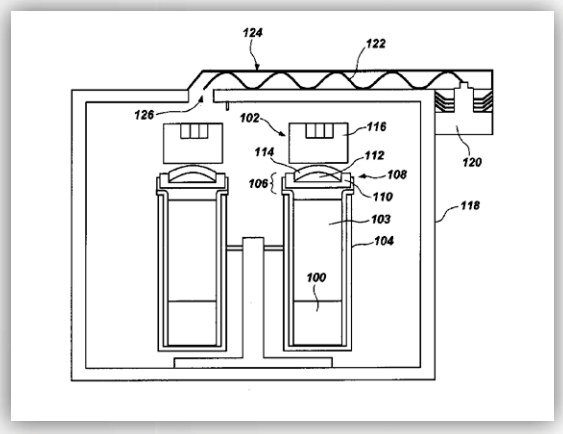
Patent No. 9,342,876 Docket No.: BA-481 - Grant Date: 2016-05-17
Inventors: Michael V Glazoff, Kevin L Gering, John E Garnier, Sergey Rashkeev, Yuri P Pyt'ev



Methods and Apparatuses Using Filter Banks for Multi-carrier Spread Spectrum Signals

Wireless services in harsh and hostile environments must overcome challenges such as intentional jamming (for example, brought about by an enemy during wartime) and unintentional interference (for example, waveform collision in the presence of other devices due to limited spectral resources). Known for their robustness, spread spectrum systems extend information across more bandwidth than is required by the data rate. Multi-carrier spread spectrum is a particular form of spread-spectrum designed to be resistant to narrow or partial band interference. This invention uses filter-bank techniques to generate and detect multi-carrier spread-spectrum signals that can carry information at a very low power level distributed over the frequency spectrum. The signal transmission is kept at or below the noise level of other signals leading to a low probability of detection and interception.

Patent No. 9,369,866 Docket No.: BA-585C1 - Grant Date: 2016-06-14
Inventors: Hussein Moradi, Behrouz Farhang, Carl A Kutsche



Methods for Forming Particles

The growing demand for renewable energy resources continues to drive development of cost-effective and high-efficiency photovoltaic cells for use in solar cells and arrays of photovoltaic devices. A thin-film solar cell (TFSC) or thin-film photovoltaic cell (TFPC) is a solar cell that is made by depositing one or more thin layers of photovoltaic material onto a substrate. The ability to form a material having a dense structure and a large grain size would represent a significant improvement in the development of photovoltaic devices. To obtain a material having a desired particle or grain size, a two-part annealing process is performed. The patented method involves subjecting single source precursors or pre-copolymers to microwave radiation to form particles which create a densely packed thin film.

Patent No. 9,371,226 Docket No.: BA-469 - Grant Date: 2016-06-21
Inventors: Robert V Fox, Fengyan Zhang, Rene G Rodriguez, Joshua J Pak, Chivin Sun

Alteration and Modulation of Protein Activity by Varying Post-Translational Modification

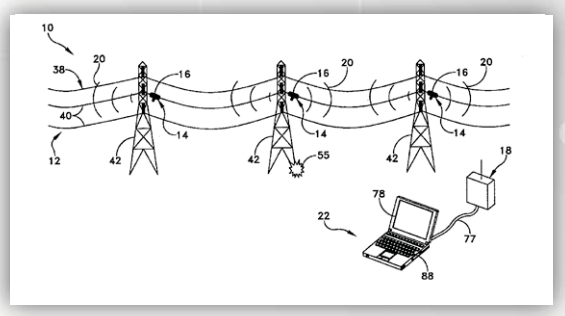
Extremophilic microbes live and thrive under conditions such as acidic or alkaline surroundings and boiling or freezing temperatures. They can be found in features such as Yellowstone National Park hot pots or the deep ocean thermal vents, glaciers, salt flats and radioactive environments. Yet, qualities for extreme survival are what make these microbes useful for turning biomass into biofuel. Current biofuel production processes require elevated temperatures and acidic condition for extended periods of time. This patent describes methods to modify proteins in a microbe that help them withstand extreme environments and be of use in extreme industrial processes.

Patent No. 9,388,398 Docket No.: BA-351D1 - Grant Date: 2016-07-12
Inventors: David N Thompson, David W Reed, Vicki S Thompson, Jeffrey A Lacey, William A Apel

Methods, Apparatus, and Systems for Monitoring Transmission Systems

Electrical transmission systems, pipelines and cell towers are all susceptible to damage. Many are in remote areas where monitoring may be quite difficult, dangerous, and expensive. This patent describes a sensing platform that includes a sensor and a transmitter that sends information to control rooms so problems can be monitored in real time and addressed quickly. A control system connected to the sensor produces output data based on output signals produced by the sensor. A transmitter associated with the control system transmits output data from the control system.

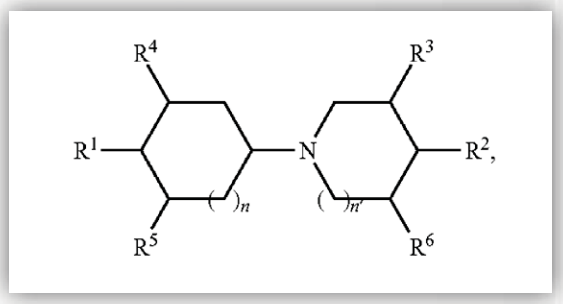
Patent No. 9,398,352 Docket No.: B-566C1 - Grant Date: 2016-07-19
Inventors: Robert E Polk, John M Svoboda, Phillip B West, Gail L Heath, Clark L Scott



Methods for Treating a Liquid Using Draw Solutions

Decreasing water supplies throughout much of the industrialized world has necessitated new methods and systems for utilizing water that contains contaminants or impurities. Additionally, certain industries have a need for safer, more energy-efficient methods and systems for removing water from a target material or solute. Traditional purification methods include thermal flash evaporation and reverse osmosis (RO), a process in which water is separated from solutes through a membrane by application of pressure. Forward osmosis circumvents several of the deficiencies of RO by using a draw solution with a greater osmotic pressure than the feed liquid. The concentrated solution pulls the water through the membrane, leaving the contaminants behind, and the water can be extracted from the solution with low-grade heat. This patent relates to methods and draw solutions for treating a liquid using an N-cyclicalkyl-cycloalkylamine as a switchable polarity solvent.

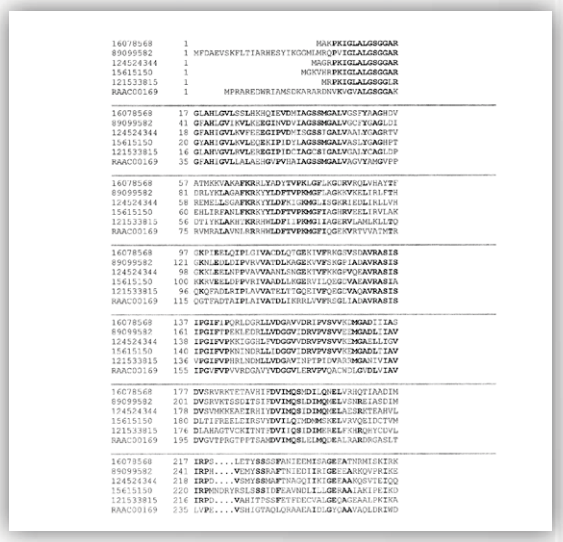
Patent No. 9,399,194 Docket No.: BA-808 - Grant Date: 2016-07-26
Inventors: Aaron D Wilson, Christopher J Orme

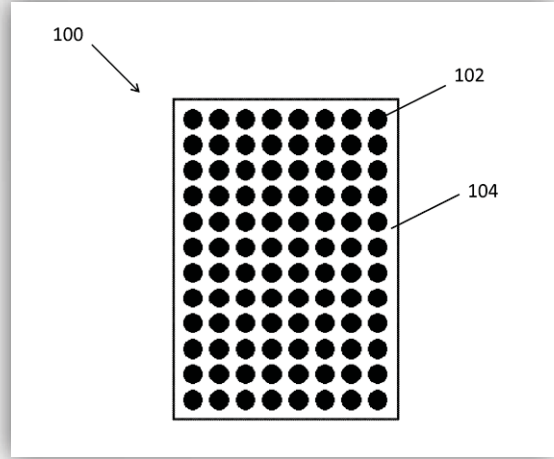


Thermophilic and Thermoacidophilic Biopolymer-Degrading Genes and Enzymes from Alicyclobacillus Acidocaldarius and Related Organisms, Methods

Existing biofuel production pretreatment requires high temperatures and specialized pressure vessels constructed for resistance to acid and high temperature and pressure thereby increasing costs associated with biomass utilization. These current systems can be expensive and generate significant waste products. The addition of acid stable and heat tolerant enzymes to the pretreatment process lessens the need for energy and expensive construction materials, and lowers waste generation. This patent describes the gene sequences and related proteins from Alicyclobacillus acidocaldarius that can be used for improved biofuel processing.

Patent No. 9,404,134 Docket No.: BA-283ACIP1C2 - Grant Date: 2016-08-02 Inventors: David N Thompson, William A Apel, Vicki S Thompson, David W Reed, Jeffrey A Lacey, Emily DeCrescenzo Henriksen

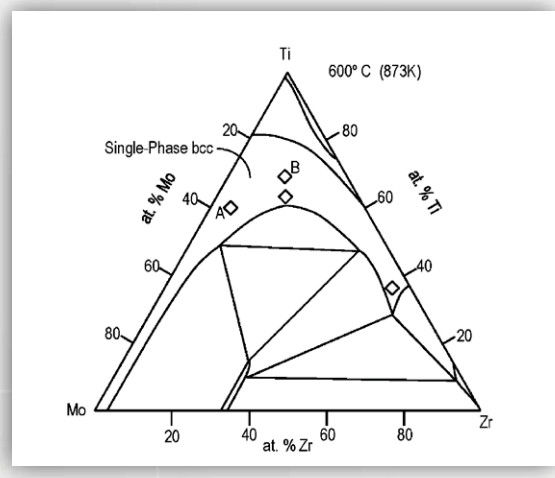




Identification of Discriminant Proteins through Antibody Profiling, Methods and Apparatus for Identifying an Individual

Accurate biological testing is critical for identifying individuals, for example in forensic cases. DNA-based methods have gained acceptance in forensics and paternity testing, yet they are still relatively expensive, require specialized equipment with highly skilled technicians and lengthy analysis times. Antibody profiling has many advantages over conventional DNA-based methods including increased speed, ease of use and decreased costs. This method is based on the discovery that every individual has a unique set of antibodies present in their bodily fluids and can be identified when those antibodies form immune complexes to proteins on a test chip. Currently antibody profiling methods use a complex and ill-defined mixture of proteins for identification and suffer from inconsistent results. This patent identifies a unique set of proteins that is capable of discriminating every person in the world's population. Since each protein for the antibody profile is known, results are consistent and accurate making this test suitable for identification applications.

Patent No. 9,410,965 Docket No.: BA-528 - Grant Date: 2016-08-09
Inventors: William A Apel, Vicki S Thompson, Jeffrey A Lacey, Cynthia D Gentillon



Nuclear Fuel Alloys of Mixtures and Method of Making Thereof

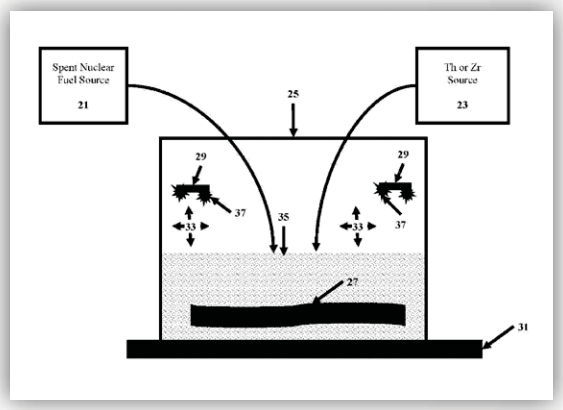
Alloys of various metals are being investigated as ways to increase the melting point of fuel, increase burn-up of fuel, and gain other beneficial chemical, thermal and mechanical properties over pure uranium or actinide fuels such as plutonium. These alloys would have applications for burning transuranic elements to reduce their environmental impact in used nuclear fuel. This patent describes methods for creating nuclear fuel alloys that combine more than two different metals to increase the melting point and resist the tendency of some alloys to allow the component metals to migrate at higher temperatures and the resulting reduction of the alloy's accident tolerance. Fuel alloy mixtures include uranium with molybdenum, tungsten, tantalum, titanium, and zirconium.

Patent No. 9,305,667 Docket No.: BA-555- Grant Date: 2016-04-05
Inventors: Robert D Mariani, Douglas L Porter

Separation of the Rare-Earth Fission Product Poisons from Spent Nuclear Fuel

There are various methods available for recycling used nuclear fuel in order to recover more of the energy potential of a given quantity of fuel. Aqueous and electrometallurgical methods are well-known, but a dry recycling method exists which does not extract plutonium, use toxic chemicals, or produce large volumes of waste. This patent describes a method to improve dry recycling further by providing a way to separate neutron-absorbing fission product poisons – primarily rare-earths – from the used nuclear fuel. Removal of the rare-earth neutron poisons reduces the amount of enriched uranium oxide feed material needed to re-use the fuel, thus improving the efficiency of this used fuel recycling method.

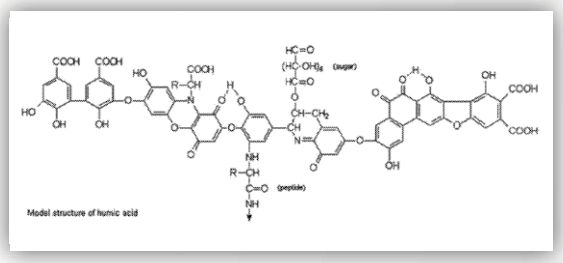
Patent No.9,428,401 Docket No.: BA-286 - Grant Date: 2016-08-30
Inventors: James W Sterbentz, Jerry D. Christian



Remediation Using Trace Element Humate Surfactant

Cleaning up an environment polluted by an intentional release or an accidental spill is difficult and costly and can damage or destroy a fragile ecosystem. The Trace Element Humate Surfactant (TEHS) solution uses indigenous microbes, humic acid, soaplike surfactants, and base elements in a liquid slurry that can be sprayed on oil-contaminated soil and water using standard firefighting equipment. The microbes in the TEHS solution go to work consuming the oil, leaving delicate environments completely cleaned in a very short period of time. With TEHS there is no human exposure to toxic hydrocarbons and no environmentally destructive soil removal equipment.

Patent No.9,427,785 Docket No.: BA-524 - Grant Date: 2016-08-30
Inventors: Catherine L Riddle, Steven C Taylor, Debra Fox Bruhn

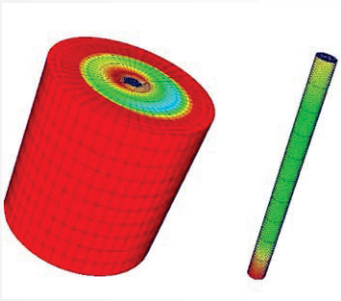


Copyright Assertions

During FY 2016, INL received permission to assert copyright on two software programs. Since 2005, INL has been authorized by DOE to assert copyright protection on more than 85 pieces of software.

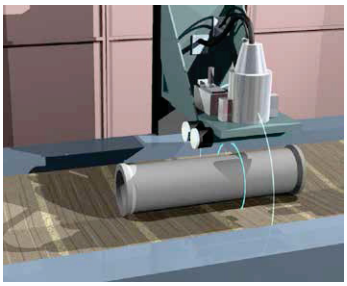
Copyright is a legal right that grants the creators of original work, such as software, exclusive rights for its use and distribution. As a condition of employment, INL employees assign such rights to the company. In accordance with BEA's contract with DOE, all copyright rights are assigned to DOE, unless 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.

Mammoth

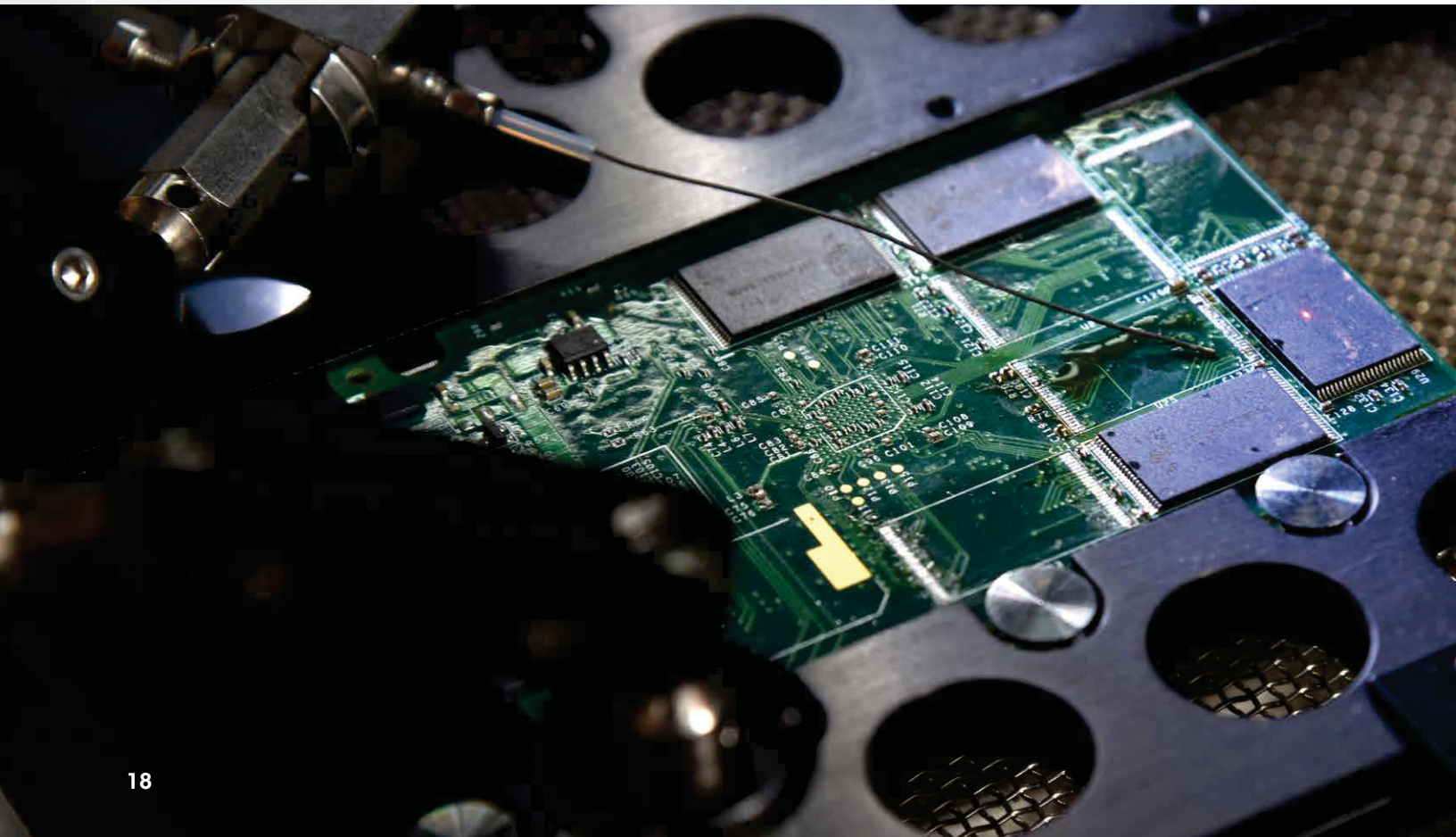


Recent developments in INL's MOOSE framework, specifically the introduction of Multi-Application (MultiApp) capabilities, have created the opportunity for high fidelity multiphysics simulations of nuclear reactors at INL. The MAMMOTH code was designed as a general reactor physics management application that fills this role. It is a reactor physics tool that provides the capability to seamlessly couple other MOOSE applications, such as the neutron transport application Rattlesnake, to the fuels performance application BISON and the thermal/fluids code RELAP-7 to produce a higher fidelity tool for fuel performance simulations under operational and off-normal reactor conditions.

Integrated Waste Screening System Software: IWSS Software



Integrated Waste Screening System (IWSS) technology can efficiently assess the nearly 40 million tons of drilling waste generated annually by the drilling and fracking of oil and gas wells. Wells can produce significant amounts of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) that must be characterized, segregated and disposed of properly. Currently, the industry uses a limited and costly sampling and analysis method that requires extended times for laboratory analysis. IWSS provides immediate on-site analysis and segregation of bulk waste material. It provides a cost-effective approach to characterization and segregation of the waste, as well as documentation and certification that the waste disposal process is monitored and that the waste is being disposed of safely.



Royalties

During FY 2016, U.S. businesses sold roughly $13 million in products, processes, and innovations based on INL patented technologies. Use of INL technologies in domestic and global markets has created jobs and increased U.S. global competitiveness. Commercial markets have been very accepting of INL-developed technologies. From FY 2005 to FY 2016, INL signed 823 licenses to commercialize technologies developed within the laboratory. This success is a result of excellent research and strong laboratory support. INL's support strategy provides for necessary investments that will achieve optimal mission-related returns. Since the inception of BEA's contract, INL has earned more than $17.5 million in royalties. It reflects a strong, expanding portfolio of IP, as well as increased attention to commercialization of INL discoveries, inventions and current IP. During FY 2016, INL received more than $1.3 million in royalty receipts. (Figure 3)

Royalties are an important signal that INL innovations are meeting market needs. It should be noted that it takes time and persistence for inventions to mature into products that generate royalties. INL continues to encourage innovation and to reinvest a significant portion of the royalty revenues to promote development of promising new early-stage technologies emerging from INL's ongoing R&D programs.

Expenditure of royalty funds is governed by federal regulations and the funds must be used in ways that support technology transfer activities. Roughly 30% of royalty funds received by INL are shared with inventors of royalty generating technologies. Additional money is spent to recognize and reward inventors and other employees who have supported technology transfer activities throughout the laboratory, independent of the technology having commercial applications. The remaining funds are reinvested in technology transfer activities throughout the laboratory. Reinvestment is directed from two funds, the Science and Technology Strategic Investments Fund (SIF) and Innovation Development Fund (IDF).

SIF is focused on funding R&D capabilities that will lead to new technology development and increase the potential for INL to generate new business.

A key to the success of these maturation investments will be INL's ability to engage industry whose own resources and expertise are essential in advancing future generations of INL technologies. IDF projects have permitted development of stronger relationships with industry, yielding exceptional return on investment to the U.S. public from INL research. Focusing on commercial results has enabled IDF's success.

In FY 2016, $1.1 million was reinvested into laboratory technology transfer activities. A selected summary of projects is provided in Table 1. INL resources were amplified due to DOE's Technology Commercialization Fund (TCF), which provided matching funds to select mature promising energy technologies with potential for high impact. See the TCF article on page 36.

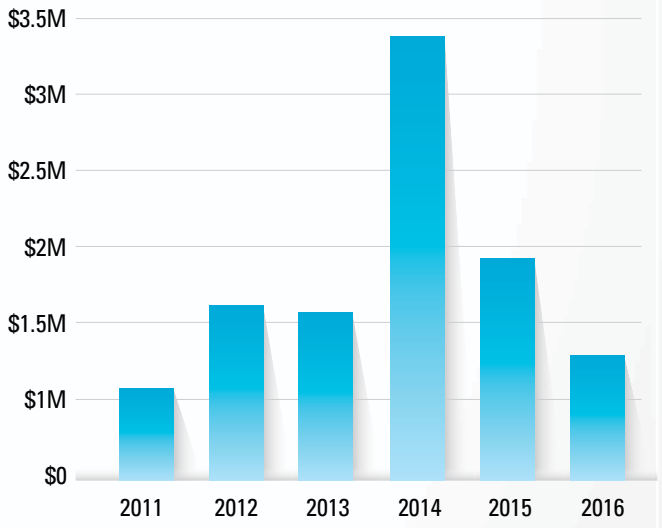


Figure 3. Royalties received FY 2011–2016.

Table 1. Select technologies supplemented with royalty funds.

IDF Projects	PI(s)
Battery Condition Monitor This project supported refinement of a method to derive battery health metrics from impedance data.	Humberto E. Garcia
WSComm Wireless Waveform Integration into the 5G International Standard INL is participating on the Radio Access Network 3GPP-5G Standards Committee to demonstrate the usefulness of the WSComm waveform in next generation mobile phone communication.	Hussein Moradi
Biologic Synthesis for Isobutyrate This project validated the production of isobutyrate from enzymes originating from thermophilic organisms.	Vicki S. Thompson
SHINE This project involved neutron/gamma discrimination testing and data analysis as well as expansion of new detector formulations.	Catherine L. Riddle
Advanced Outage Control Center Dashboard with Predictive Tools This TCF sponsored technology maturation project will further develop a nuclear power plant outage dashboard to graphically represent the current status of the refueling outage and provides predictions for completion of bulk work.	Shawn St. Germain
Change Detection Systems for Nuclear Applications This TCF sponsored technology maturation project will modify the existing INL Change Detection System specifically for use in nuclear facility applications. CDS was developed as an easy-to-use desktop or laptop computer software program for the rapid and precise alignment of digital images.	Troy Unruh/ Gregory D. Lancaster
Computer Based Work Procedure System for Field Workers This TCF sponsored technology maturation project will optimize INL's computer-based procedure system for work execution in the field making it ready for commercial use. This effort will further develop the capabilities needed to increase nuclear power plant efficiency, improve human performance during field work, improve plant design modification processes, and integrate with other plant systems (e.g., component databases, scheduling software, and work management systems).	Johanna H. Oxstrand/ Katya L. Le Blanc/Aaron D. Bly
Enhancing Lithium-Ion Battery Safety This TCF sponsored project will mature a method of detecting precursors for thermal run away in batteries.	Sergiy V. Sazhin
Vibro-acoustic Testing for Microstructure Characterization and Metrology This TCF sponsored technology maturation project will develop a portable scanning infrastructure for a novel material characterization technique called vibro-acoustography that has been developed by INL for nuclear applications to characterize fuel, cladding materials, and structures.	James A. Smith
Additive Manufacturing as Alternative Fabrication Technique for the Fabrication of Uranium Silicide Fuel This TCF sponsored technology maturation project will perform a feasibility study of direct routes to fabrication of dense uranium silicide fuel pellets using an advanced additive manufacturing approach.	Isabella J. Van Rooyan
Development of an In-core 3-Omega Thermal Conductivity Probe This TCF sponsored technology maturation project will adapt the three-omega method for measurement of bulk material thermal conductivity to an integrated probe for eventual use in a material testing reactor.	Vivek Agarwal
Hysys Process Modeling This project was funded to refine the process models for a new system to convert ethane to ethylene using oxidative dehydrogenation.	Anne M. Gaffney

License Highlights

INL negotiates license agreements with businesses and other organizations that allow them to produce, manufacture, sell, or use IP owned by the laboratory. INL licenses its IP on much the same terms as universities, other research organizations and industrial firms.

Since the initiation of BEA's contract, INL has signed 823 licenses that have earned more than $17.5 million in royalty fees. These include 62 patent licenses, 39 license option agreements, 107 copyright licenses with fees, and 615 copyright licenses without fees (Figure 4).

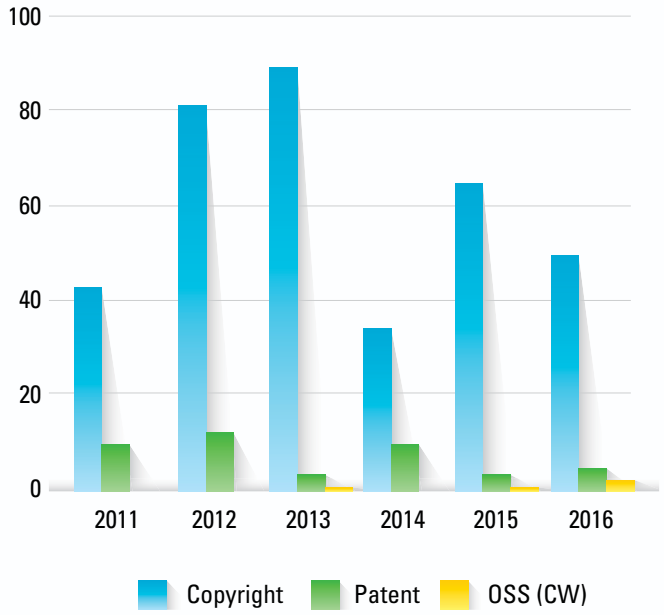


Figure 4. New licensing activities during FY 2011–2016.

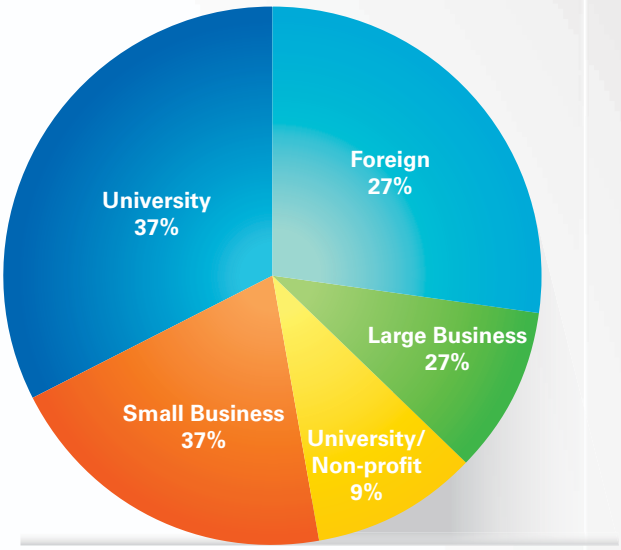


Figure 5. Licenses executed FY 2016.

SRT

Idaho Falls based SR Technologies (SRT) executed a new license agreement with BEA to commercialize a natural gas fueling system developed at INL. The system is capable of dispensing both compressed and liquefied natural gas, depending on the requirements of the vehicle or machinery being fueled. This technology is expected to further reduce the cost of natural gas as a transportation fuel and closely complements the small scale natural gas liquefaction technology developed at INL, which has also been licensed by SRT.

Antibody Profile Analysis System and Method

Identity Sciences, Inc. (IDS) executed a new license agreement with BEA to continue with the development and commercialization of an Antibody Profiling technology initially developed at INL. This technology provides a new method to identify individuals (human & animal) for use in various applications including law enforcement, security and food safety. The technology is complementary to DNA fingerprinting but costs less and allows for more rapid analysis.

LNG

Nu Blu Energy, LLC exercised its option to license the small-scale natural gas liquefaction technology and a natural gas fueling system developed by researchers at INL. Nu Blu is moving ahead to finalize the design and engineering of these systems to enable commercial deployment within the next 12 months.

Topology-Generator

Released as an open source project under a GPL2 license on GitHub.

Code-Generator

Released as an open source project under a GPL2 license on GitHub.

AICS

Two software evaluation license agreements were executed for the AICS (Autonomic Intelligent Cyber Sensor). One license went to Diamond Offshore Co. and one to Telos Corp. The Autonomic Intelligent Cyber Sensor (AICS) provides autonomous cybersecurity and state awareness for Ethernet based industrial control networks. It employs Autonomic Computing techniques and a Service Oriented Architecture to: 1) automatically discover network entity information, 2) automatically deploy deceptive virtual hosts, and 3) automatically identify anomalous network traffic with very high accuracy.

BISON

INL licensed BISON software to 12 universities and commercial entities. BISON is a finite element-based nuclear fuel performance code applicable to a variety of fuel forms, including light water reactor fuel rods, tristructural-isotropic fuel particles, and metallic rod and plate fuel. It solves the fully coupled equations of thermo-mechanics and species diffusion, and includes important fuel physics such as

fission gas release and material property degradation with burnup. The BISON application is based on the MOOSE framework. Licensees include:

University of Illinois

KEPCO International Nuclear Graduate School

Rensselaer Polytechnic Institute

University of Utah

Khalifa University

OECD – Nuclear Energy Agency (NEA)

Defense Academy of UK

AREVA FEDERAL SERVICES, LLC - MD

Korea Advanced Institute of Science

TECHNICAL RESEARCH CENTRE OF FINLAND

Japan Atomic Energy Agency (JAEA)

RNET Technologies Inc.

Grizzly

Grizzly is a simulation tool for assessing the effects of age-related degradation on systems, structures, and components of nuclear power plants. Grizzly is built on the MOOSE framework, and uses a Jacobian-free Newton Krylov method to obtain solutions to tightly coupled thermo-mechanical simulations. Grizzly runs on a wide range of hardware, from a single processor to massively parallel machines. Licensees include:

University of Arizona

UT Battelle, LLC

Bechtel Marine Propulsion Corporation

PHISICS

PHISICS was licensed to North Carolina State University as a software package intended to provide a modern analysis tool for reactor physics investigation. PHISICS is designed to maximize accuracy for a given availability of computational resources by using several algorithms and meshing options to optimize computational resources and desired accuracy levels.

RAVEN

INL issued 11 licenses for the RAVEN software. RAVEN is a software code that provides a graphical user interface for three principal applications. These include the pre- and post-processing of the RELAP-7 input and output, a capability to model nuclear power plants control logic for RELAP-7 code and dynamic control of an accident scenario evolution, and a general environment to perform probability risk analysis for RELAP-7, RELAP-5, and any generic MOOSE-based applications. Licensees include:

Ohio State University

University of Michigan

North Carolina State University

University of Illinois

University of New Mexico

Boccini University

Institute of Nuclear Safety System

Westinghouse Electric Company, LLC

Bechtel Marine Propulsion Corporation

Electricity De France (EDF)

FPoliSolutions, LLC

RELAP5-3D

Industry and universities continued to request access to the RELAP5-3D code. In FY 2016, more than 18 new license agreements were executed. RELAP5-3D is widely used in the international nuclear community to support research and nuclear studies, safety analysis, and evaluation of innovations. As it has for decades, INL continues to cooperate with the International RELAP Users Group, and last year released the latest in the RELAP5-3D code series to analyze transients and accidents in water-cooled nuclear power plants and related systems. Immediately prior to this year's annual International RELAP Users Group meeting in Idaho Falls, Idaho, 31 individuals participated in an advanced training class conducted by INL. This training assists utilities and other companies using RELAP5-3D in performing systems safety analyses. Licensees include:

University of Idaho

Dipartmento Energia – Politecnico D

Tokyo City University

University of South Florida

Ansaldo Nucleare SpA

VUJE, a.s.

Ustav jaderného vyzkumu Rez, a.s (U)

ESI France, Parc D'Affaires SILIC

U.S. Naval Research Laboratory

Toyko Institute of Tech

FPoliSolutions, LLC

Industrial Leak Detection, Inc.

Mitsubishi Heavy Industries, LTD.

Universitas Gadjah Mada

Karlsruher Institut für Technologie

Studiecentrum Voor Kernenergie Cent

AREVA NP Inc. - VA

TerraPower, LLC

Sophia

INL issued two nonfee government use agreements for Sophia software. INL licensee, NexDefense, Inc., is licensed to provide Sophia software to commercial customers.

Sophia is an INL-developed industrial control system fingerprinting software tool, which passively monitors infrastructure and informs management about anomalies for further investigation or protective action. This innovative technology was made commercially available after extensive beta testing by dozens of enterprises. INL issued licenses to:

Department of Defense

Naval Facilities Engineering Command, Command Information Office

Ridgetop Group

Tucson, Arizona-based Ridgetop Group, Inc., executed a patent and copyright license with BEA to commercialize a battery life cycle assessment product based on the R&D 100 Award finalist CellSage technology developed at INL. Ridgetop will apply CellSage battery modeling capabilities to create a battery health analysis tool for developers of high reliability electronic systems.

Ridgetop Group, Inc.

Contracts Management

The Contracts Management organization serves as an integral facilitator in the development, negotiation and management of agreements necessary to advance INL's mission objectives. By establishing working relationships with the three INL mission organizations, Nuclear Science and Technology (NST), National and Homeland Security (NHS) and Energy & Environment Science and Technology (EES&T), Contracts Management is responsible for strategically identifying the best partnering mechanism(s) to meet their research and partnership objectives.

The Science & Technology directorates' agreement activity in 2016 consisted of advancing INL's nuclear energy strategy by bringing together industry with national laboratories. Contracts Management plays a significant role in enabling S&T directorates to be successful in achieving the laboratory's Lab Plan. These commitments with industry are upheld through research and development agreements which establish partnerships with the private sector plus fulfill INL's commitment to offer the public access to the national laboratory's talent, facilities and experience. These initiatives will continue into FY17 with increased scrutiny on expediting agreements to meet the demands of business. Agreement highlights below are examples of just a few relationships that were executed to support the NE Voucher Program, and to increase collaborative relationships with our strategic foreign partners.

In FY 2016, INL's partnership with TerraPower was re-energized with new management oversite and both parties are now working to re-activate tasks. INL will continue to perform RD&D and will look for opportunities to expand our collaborative research.

Research and Development Agreement Activity

INL uses Cooperative Research and Development Agreements (CRADA) to meet the R&D needs and resources of the participating parties. INL's CRADA portfolio includes agreements with short periods of performance to agreements lasting several years; all of which are necessary to align mission objectives and deliver outcomes. The number of agreements executed and commitments made vary considerably from year to year based upon INL's Lab Plan.

During FY 2016, INL continued to optimize its collaborative research opportunities. Figure 6 highlights the booked value and number of CRADAs executed last fiscal year. The estimated total value of the FY 2016 portfolio was just over $11.0 million, including $3.2 million of funds-in, $3.6 million of in-kind contributions, and approximately $4.1 million in government contributions.

Historically, SPP's portion of the INL budget varies between 15 and 35 percent, depending on the research needs of our sponsors. Figure 7 highlights the diverse makeup of our FY 2016 SPP portfolio. U.S. sponsors who use INL's SPP program include the Army, Navy, Air Force, the Nuclear Regulatory Commission, NASA, the Environmental Protection Agency, and the Departments of Defense, Homeland Security and National Security.

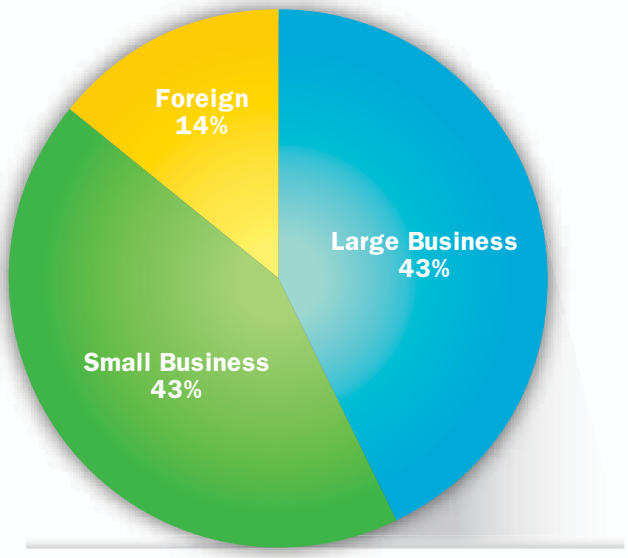


Figure 6. FY 2016 executed CRADAs by stakeholder.

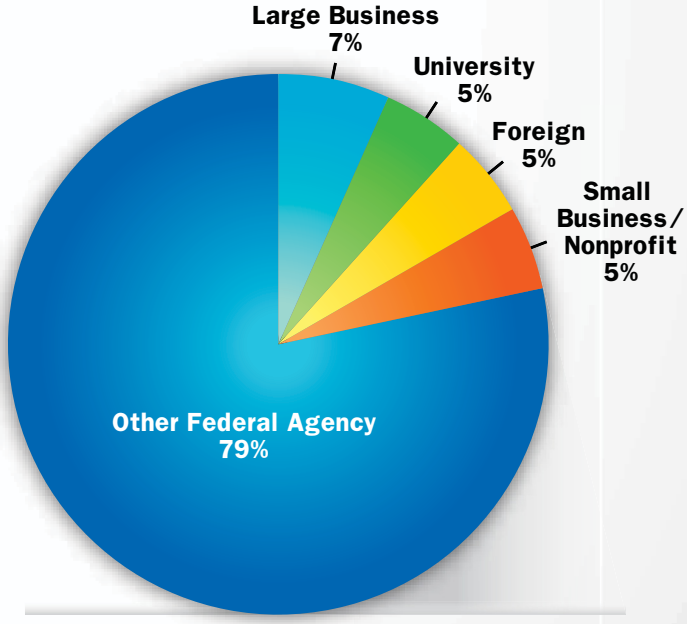


Figure 7. FY 2016 executed SPP by stakeholder.

Nuclear Science & Technology

The mission of the Department of Energy, Office of Nuclear Energy (DOE-NE) is to advance nuclear power as a resource capable of meeting the nation's energy, environmental and national security needs by resolving technical, cost, safety, proliferation resistance, and security barriers through research, development and demonstration (RD&D).

The CRADAs listed below support the DOE-NE voucher program under the GAIN initiative and are intended to help accelerate the commercialization of innovation that supports advanced nuclear technology.

Creare, LLC: the participant aims to develop and advance a continuous casting technique that will be applicable to metallic nuclear fuels, such as uranium-10wt% zirconium (U-10Zr). As part of this system, the fuel alloy will remain molten in a crucible for up to eight hours. Due to the reactive nature of U-10Zr, many of the standard crucible materials (Al2O3, MgO, etc.) will react with the melt, contaminating the fuel alloy and causing a crucible failure in the equipment. Developing a successful casting system requires an inert material identified and tested under prototypic conditions.

Ceramic Tubular Products, LLC: the participant is developing an accident tolerant fuel cladding for commercial pressurized water reactor (PWR) fuel based on a multilayered silicon carbide (SiC) material, known as TRIPLEX cladding, which offers major improvements in the safety of LWRs during severe accident conditions. To improve the economics and the corrosion resistance of this clad under normal operating conditions, participant has refined the technology to include advanced fabrication processes, lower cost SiC fibers, and an improved corrosion resistant surface coating. Before proceeding to full commercial application of this improved product, an irradiation test of the product with these new features under typical PWR chemistry and radiation conditions is needed. The MIT Nuclear Reactor Lab will perform this irradiation test in the MIT reactor clad test loop. INL will provide project oversight.

In FY 2016, INL entered into two separate SPP Agreements with ITER that support the International Fusion Energy Organization Agreement. The significance of this collaboration and implementation is identified in the contractor's M&O contract with the Department of Energy.

The ITER ("the way" in Latin) project intends to advance fusion science to maintain fusion for long periods of time to supply fusion power plants. This international agreement is in concert with the following members of the ITER Project: China, the European Union, India, Japan, Korea, Russia and the United States to collectively conduct fusion research. The U.S. government's oversight organization for this project is the Department of Energy's Office of Fusion Energy Sciences.

The purpose of this agreement is to conduct the benchmark study of the MAGARC code as a supplementary activity to the ITER contract 'Electromagnetic Assessments of ITER Magnets in Safety-related Fault Conditions' which is currently being conducted in the UK. The goals of this agreement are 1) to benchmark and to validate the MAGARC code that performed previous analysis for ITER coils fault events; 2) to collaborate with CCFE on benchmarking and validating the analysis package developed for the assessment of ITER magnets arcing safety. Public benefit: The ITER International Agreement is a project between seven entities (U.S., EU, Japan, Russia, India, Korea and China) to build a 500 MWt fusion tokamak reactor, designated as ITER, at Cadarache, France. The INL Fusion Safety Program (FSP) has been OFES's lead laboratory in magnetic fusion energy (MFE) safety for more than 35 years. FSP has supplied many of the safety analysis codes used to license ITER in France.

For ITER Agreement 2, INL is the lead laboratory for magnetic fusion safety in the U.S., as designated by the U.S. DOE in 1979. The INL Fusion Safety Program (FSP) is the group at INL developing fusion safety analysis tools, performing fusion reactor safety analyses and performing safety related materials experiments. Computer codes developed by the INL FSP have been used, and are still being used, to license the ITER device, in particular the code called Tritium Migration Analysis Program (TMAP) and the MELCOR computer code modified for fusion applications. The principal investigator (PI) involved in this agreement developed these computer codes, and has been involved with the safety assessment of the ITER reactor through its various design phases from 1994 to present. This PI serves on the ITER Test Blanket Module (TBM) Program Committee as the U.S. representative safety expert. This agreement supports the ITER IO in safety analyses required to design, license and operate the ITER nuclear facility.

Energy & Environment Science and Technology

INL is conducting testing and evaluation of the WiTricity wireless vehicle charging system, the Qualcomm Halo TM wireless vehicle charging system and the Nissan wireless vehicle charging system to determine the charging efficiency, power quality and electromagnetic field emissions. This testing and evaluation is in support of the development of the Society of Automotive Engineers' draft standard J2954.

The Biomass Feedstock National User Facility at INL is working with the Idaho State Department of Agriculture (ISDA) to assess the viability of biofuel utilization of approximately 8,000 tons of eastern Idaho hay adulterated with unexpected residues of methyl bromide. The hay must be disposed of as it is not eligible for use as feed. Biofuel utilization may be an effective option, but insufficient data exist to assess safety, combustibility and other factors. The Biomass Feedstock National User Facility has expertise in preprocessing and densification of biomass to meet the specifications of biomass burning. Under this Strategic Partnership Project, INL will work to verify a fuel market pathway for the contaminated hay. This analysis being performed at INL is the first of its kind in the area of burning agricultural commodities affected by high levels of inorganic bromide.

As part of the Energy Efficiency & Renewable Energy (EERE) Small Business Voucher program, INL is assisting two small businesses with further development of technologies. Mithra is being assisted with new particle transport manifold-reactor assembly in a research setting using Mithra's Temporal Analysis of Products system. INL is assisting e-Materials Recovery in taking the next steps leading to a stand-alone technology that safely recovers the precious and electronic metals from printed wiring boards without the use of toxic chemicals or high temperature processing and is economically viable.

Illinois Rocstar was awarded a Small Business Innovation Research (SBIR) grant, titled "Integrated Computational System for Electrochemical Device Design and Simulation," and is working with INL. INL is providing support in integrating/ implementing it's Advanced Electrolyte Model. The focus of this work is building computational tools that will accelerate the process of simulating battery performance, enabling the design of cheaper, more powerful, safer advanced batteries with decreased time to market.

CF Technologies, Inc. has been awarded a Small Business Technology Transfer (STTR) grant. The proposal, titled "Hydrothermal Liquefaction of Brown Grease from Wastewater Treatment Plants to Biodiesel using Supercritical Fluids," was co-authored by INL staff and is based upon INL technology and intellectual property. INL staff has teamed with CF Technologies staff to examine a heterogeneous catalytic conversion technology useful for synthesizing ASTM D6751 quality biodiesel from fats, oils and greases.

National & Homeland Security

INL is a leader in and internationally recognized for industrial control systems (ICS) security at the confluence of cybersecurity, wireless, embedded protocols, and threat assessments. The critical infrastructure protection facilities utilize specialized environments spread across the INL landscape. INL also maintains strong ties with control systems vendors and infrastructure owners/operators. In FY16, INL established new partnerships for researching ICS security, while maintaining and expanding existing partnerships.

In FY16, a public power company teamed with INL to explore new and innovative methods for securing its industrial control systems from targeted cyber attacks. The project includes an in-depth engineering evaluation of the company's ICS operational environment for the purpose of identifying high-consequence attack scenarios. This consequence-based risk analysis of the ICS environment will be leveraged by INL to propose new engineering/design options, operational procedures, and active defense methods/alerts/safeguards. INL may use the results of the project to validate a Consequence-driven Cyber-informed Engineering (CCE) framework and identify key lessons learned that can be applied to the broader energy sector.

Strategic Partnerships Community and Deployment

A true reflection of customer satisfaction is returning back for more support. This positive reflection demonstrates the uniqueness and quality of work performed by INL. Here are some significant partnerships that extended their relationship with INL for another fiscal year and beyond.

In its third year of partnership, INL continues to provide network engineering support to Wyle Laboratories in order to facilitate and fulfill the recurring network engineering support required to operate and maintain a reliable National Wireless Network Range capability with multiple technologies and multiple frequencies. Support includes engineering, maintenance, and procurement in order to maintain this advanced communications network.

Southern California Edison continues its second year of partnership with INL to implement a risk analysis process for evaluation of cyberthreat advisories, as well as research to pursue a "Machine-to-Machine Automated Threat Response" capability. INL is conducting a risk analysis pilot project to demonstrate a viable operational risk analysis process and to spiral the development of a prototype software tool suitable for operational use. This research will educate and support the member utilities of the California Energy Systems for the 21st Century (CES-21), who are striving for a proactive and agile response to today's dynamic threat environment characterized by the targeting of critical infrastructure with exploits, vulnerabilities, and malware.

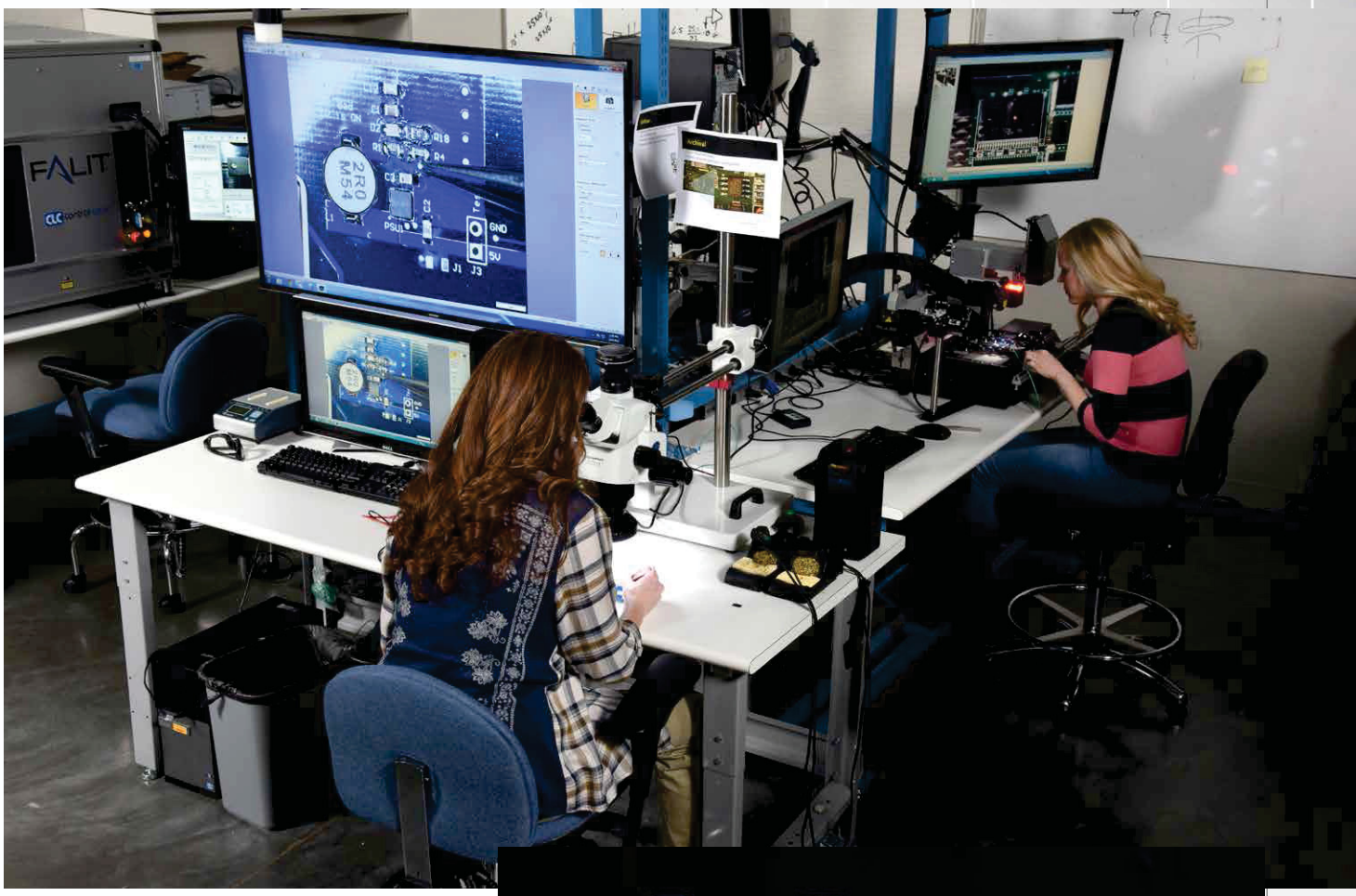
GAIN
Gateway for Accelerated Innovation in Nuclear

iter

IDAHO STATE DEPARTMENT OF AGRICULTURE

e-materials recovery, llc

ILLINOIS ROCSTAR


FALIT
GND
5V


ASP·ID
SENSITIVE
REFRIGERATE!

Technology-Based Economic Development Highlights

The Technology-Based Economic Development (TBED) program is providing value by proactively impacting Idaho and the surrounding regional economy, igniting innovation, and strengthening regional workforce and partnerships.

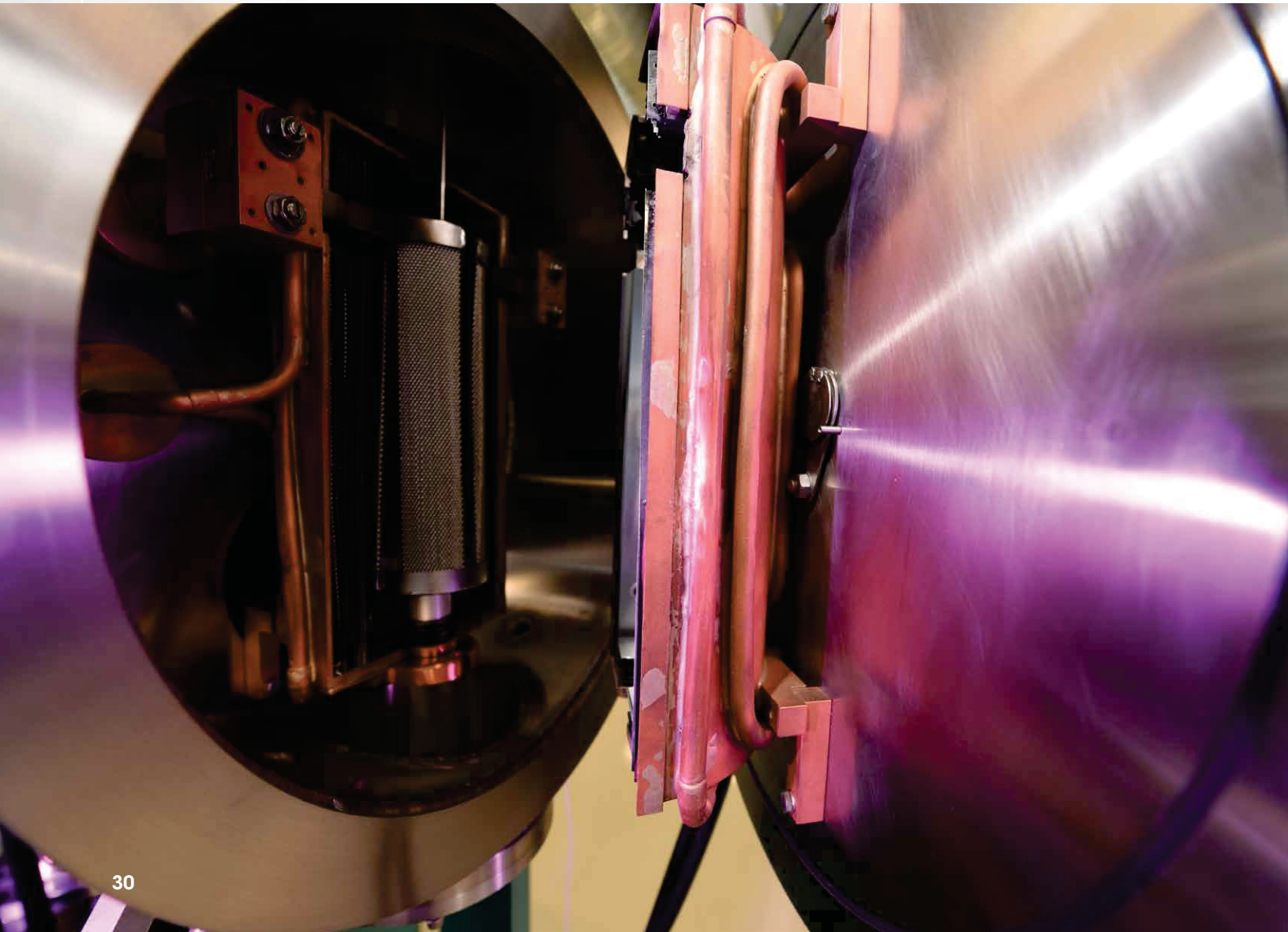
Driving Economic Impact across the Region

INL is one of the largest employers in Idaho and therefore provides a significant economic impact on the state's economy. During FY 2015, INL employed more than 3,700 people, making it the state's fifth largest private employer and the state's tenth largest employer when compared to all public and private businesses.

The economic impact identified in the study only included INL operations managed by BEA and thus, is R&D focused. The study did not include the impact of other DOE contractors, the DOE itself or the Naval Reactors Facility.

Combining INL operations with additional indirect and induced impacts, the laboratory adds nearly $1.6 billion to the state's total economic output and almost 9,300 positions to the Idaho job market. Other important impacts include the following:

- INL's total output impact increased by $170 million from FY 2014 to FY 2015 – a 12% increase.
- INL increased personal income in the state by nearly $703 million.
- Average base salary of an INL employee is $88,635 annually.
- INL subcontracted nearly $130 million to Idaho subcontractors.
- BEA's corporate office contributed $622,500 to charitable giving.
- INL directly employed 3,771 workers in Idaho.
- Secondary effects in Idaho accounted for an additional 5,522 jobs for a total of 9,293 jobs.
- INL accounted for nearly 2.5% of statewide economic output – up from 2.3% in FY 2014.



Leading in International Economic Development Achievement

Stephanie Cook, Idaho National Lab economic and workforce development program manager (l), Jan Rogers, CEO of Regional Economic Development Eastern Idaho (c), and Amy Lientz, director of Partnerships, Engagement and Technology Deployment at INL.

REDI and INL were recognized by the International Economic Development Council with a Bronze Award for the region's promotional video, *Living Life Now. Working for Tomorrow. Eastern Idaho.* The video was developed by REDI as part of its larger regional talent attraction campaign. REDI and INL partnered with other local technology industries on the video to attract employees and businesses to eastern Idaho. The video was developed with the support and cooperation of INL and regional businesses as a way to join together and promote eastern Idaho's employment and business climate, and unique lifestyle. IEDC's Excellence in Economic Development Awards recognize the world's best economic development programs and partnerships, marketing materials, and the year's most influential leaders. These awards honor organizations and individuals for their efforts in creating positive change in urban, suburban, and rural communities.

Building the Talent Pipeline for the Future

INL was honored at the Bannock Development Economic Symposium in recognition of improvements of high school students' awareness and interest in high wage, high tech, and high-demand careers in southeast Idaho for YourFIT program. YourFIT is a technical careers awareness campaign that reaches rural high-school students, with an emphasis on minority populations. INL, along with other local technology companies, partnered with Idaho State University College of Technology instructors, Bannock Development, 4CASI, and Great Rift Business Development to host hands-on learning expositions in seven eastern Idaho high schools. The technology expos showcased high-wage, high-demand technology careers that require only a two-year degree or certification. The project provided a forum for students and their parents to talk with ISU CoT instructors and representatives from local technology-based companies.

American Falls high school students learn about high tech, high wage, high demand jobs requiring only a two-year degree or certification at Your Future in Technology, YourFIT event.

Connecting to Community

INL was pleased to partner with Arco, Idaho, in support of the Atomic Days event in July. INL provided a hands-on event for children to demonstrate INL's tie to space missions and shared ways the community and businesses can partner with the laboratory. An INL fire truck joined the festivities and participated in the grand parade.

INL supported Atomic Days in Arco, Idaho, and taught children about INL's tie to space missions by creating paper straw rockets.

REDI

Regional Economic Development Eastern Idaho, REDI, the 14-county economic development group, was awarded an INL Tech-Based Economic Development grant to establish the eastern Idaho brand by highlighting the distinct assets and opportunities of the region, establishing industry clusters, supporting the role of education in building the right talent pipeline, and developing a regional economic development hub to help both business and talent.

Back row, left to right: Scott Reese, Dan Ordyna, Park Price and Teri Tengaio. Front row, left to right: Stephanie Cook and Jan Rogers, Regional Economic Development Eastern Idaho, received a Tech-Based Economic Development grant to develop a brand and marketing plan for the 14-county eastern Idaho region.

Activities for the project entailed developing a national and international regional brand campaign, including a brand logo, marketing materials, advertising, regional and media relations; partnering with IDOL and industry to develop two talent symposiums; winning the talent attraction game; collaborating with support efforts for a community college feasibility study to enhance educational opportunities in eastern Idaho for technical-based talent; and collaborating and supporting the INL R&D missions that enhance opportunities for regional, TBED and talent attraction and development.

Lab-Corps

DOE's Lab-Corps is a market-driven training program designed to facilitate the transfer of clean energy technologies to commercial use. The seven-week curriculum provides scientists with a better understanding of the commercialization process. In the words of one participant, it teaches scientists to apply the scientific method to business by developing a hypothesis, a business value proposition(s) for their innovation, and testing it through the Customer Discovery process in the marketplace. The program's goal is to strengthen business culture at national laboratories by focusing on private sector needs and validating the significance of research. By engaging inventors in entrepreneurial endeavors, they can focus their efforts on industry-relevant challenges. The researchers are, forevermore, better equipped to discover market needs and research relevance when they start their next project.

INL has participated in the DOE Energy Efficiency and Renewable Energy Lab-Corps program since its inception. As one of one of 11 laboratories participating in program, INL has trained more researchers (10 teams) than any other participating laboratory. For FY 2016, INL had five entrepreneurial teams consisting of three people each: a principal investigator, entrepreneurial lead, and an industry mentor. Each team focuses on one new technology. Listed below are the five teams and their technologies.

Advanced Renewable Aerial Inspections

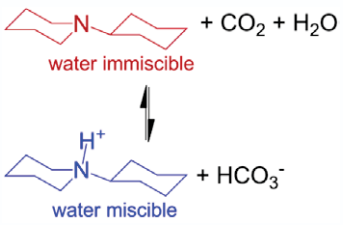
Principal Investigator: Matthew Balderree

Entrepreneurial Lead: Corey Smith

Industry Mentor: Wendolyn Holland

The Advanced Renewable Aerial Inspections (ARAI) technology utilizes unmanned aircraft systems (UAS) to perform safer, more economical inspections on multiple types of wind turbines, including off-shore wind turbines, to collect data. The UAS data can be used to help determine maintenance requirements and detect issues and trends to help wind farm operators, public utilities, turbine manufacturers, and maintenance companies make rapid, informed decisions in how they manufacture, build, deploy, and maintain their products. Through its participation in Lab-Corps, the team hopes to better understand the challenges of taking innovative ideas from concept to commercialization and, ultimately with the help of their commercialized technology, help industry provide additional U.S. energy jobs.

Switchable Polarity Solvent Forward Osmosis



Principal Investigator: Aaron Wilson

Entrepreneurial Lead: Carter Fox

Industry Mentor: Shawn Perkins

Industry Mentor: David Noack

Switchable polarity solvents (SPSs) are an exciting new class of materials that undergo a polarity shift upon being exposed to a chemical agent. The switch leads to profound changes in solubility and phase behavior, and SPSs display many of the beneficial characteristics of room temperature ionic liquids without the cost or difficulty of recycling. This team envisions a range of possible applications for this technology, but their initial target areas will be industrial water treatment and biomass fractionation. The use of SPSs in water treatment processes has the potential to cost-effectively obtain high water recoveries from high-salinity and high-fouling industrial waters. The team's biomass project will use SPSs to fractionate biomass such that it can be merchandized, allowing the biomass industry to compete with the petrochemical infrastructure. With the help of Lab-Corps, the team hopes to explore various paths forward, demonstrate the processes, and bring the technology to market.

High-Moisture Pelleting Process

INL has developed a high-moisture pelleting process that decreases the drying cost and manages the feedstock moisture more efficiently. Through this process, the biomass is pelleted at moisture contents greater than 25 percent. The pellets are partially dried during production by the frictional heat developed in the pellet die during compression and extrusion. Additionally, a short preheating step replaces the conventional, energy-intensive steam conditioning. This step helps reduce the feedstock moisture content as well as activate biomass components, like lignin. Techno-economic analysis indicated the process reduces energy and production costs by about 40 to 50 percent compared to a conventional pelleting method. Currently, scale-up of the high moisture pelleting process from lab to pilot and commercial scale is in progress.

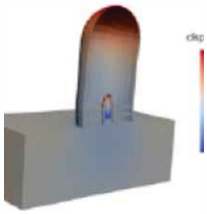
Principal Investigator: Jaya Shankar Tumuluru

Entrepreneurial Lead: Erica Belmont

Industry Mentor: Art Baker

QUAKE

DOE and the nuclear industry perform seismic analysis using equivalent-linear numerical analysis tools. For large levels of shaking, where soil strains are high, these tools are likely inaccurate for seismic and flooding probabilistic risk assessment (PRA) calculations. This proposed technology, with advanced seismic methods and tools, will minimize uncertainty and reduce quantified safety margins and costs required to mitigate seismic hazards.



Principal Investigator: Justin Coleman

Entrepreneurial Lead: Chandrakanth Bolisetti

Industry Mentor: Mark Kaczor

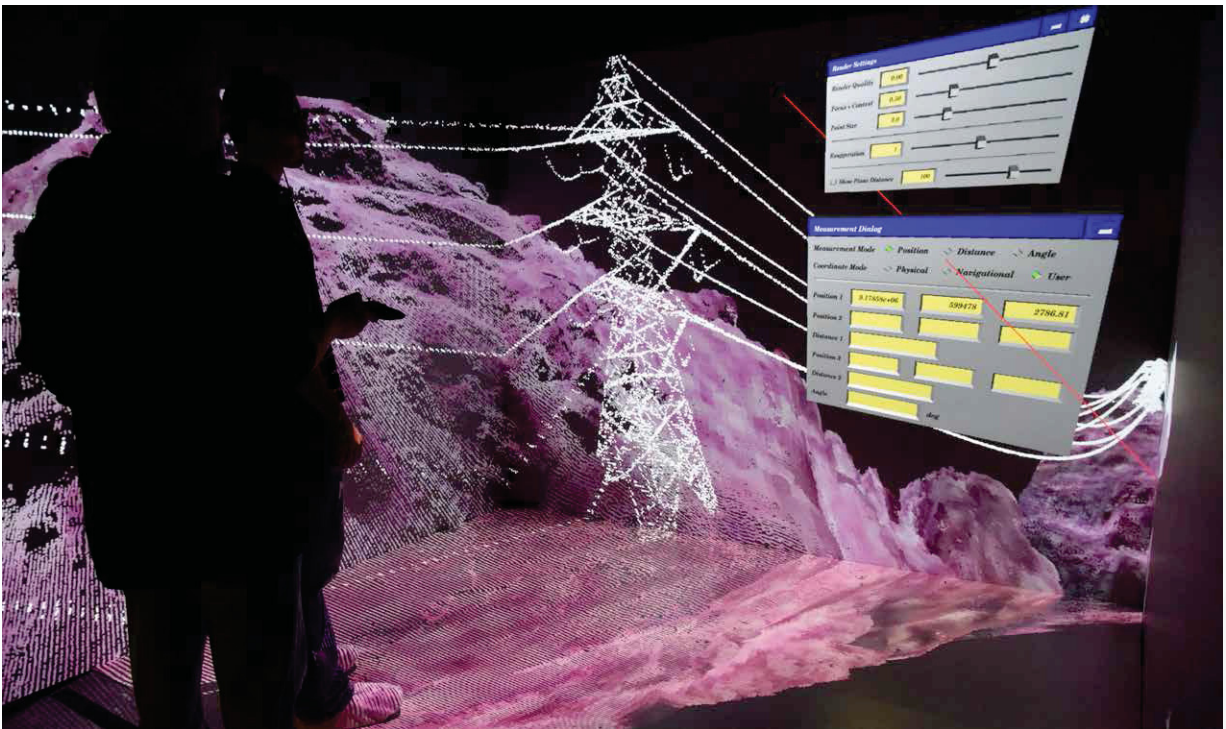
General Line Ampacity State Solver

The General Line Ampacity State Solver (GLASS) software package provides utility companies with the ability to use dynamic line rating to adjust power production through their grid network and allow for deferment of costly transmission line upgrades or new installations. GLASS calculates real-time ampacity and thermal conductor limits, helping the end user determine, in real time, the limiting ampacities and thermal ratings for any given transmission line segment.

Principal Investigator: Jake Gentle

Entrepreneurial Lead: Donna Rennemo

Industry Mentor: Dale Douglass



Technical Assistance Program

INL's Technical Assistance Program (TAP) works to assist job creation and enhance the entrepreneurial climate for emerging innovation-based businesses. TAP's contribution to strengthening and growing innovation-based economies is to offer technical assistance of up to 40 hours to provide support and technical expertise that is not available in the private sector within the region (i.e., INL cannot compete with the private sector).

Between 2005 and 2016, TAP has sponsored 9,100 hours of assistance to entrepreneurs and small businesses. During the past year, INL has dedicated 240 hours to six TAP projects focused on increasing INL's goodwill and community outreach through projects that intersect and support the laboratory's mission areas.

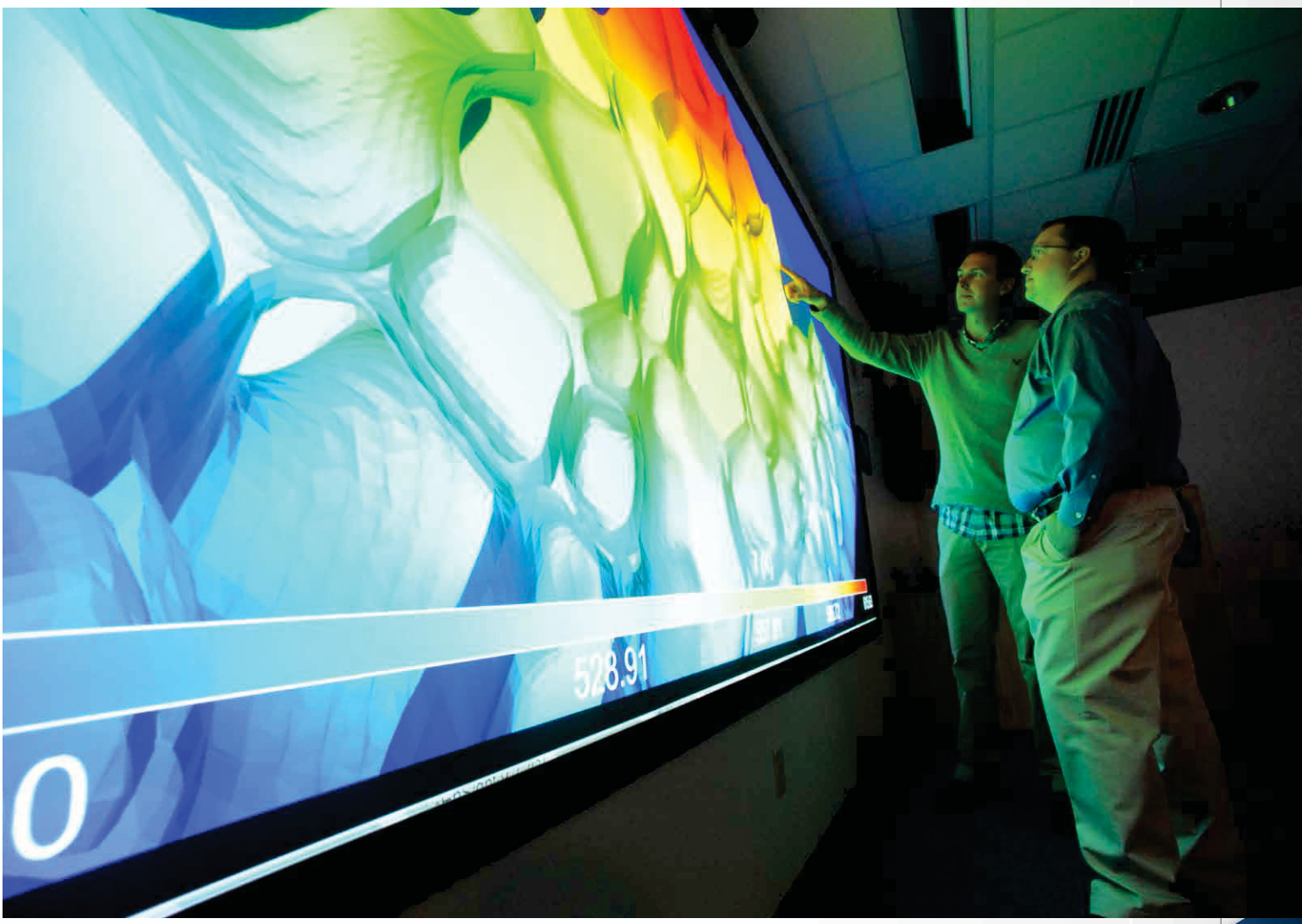
Select TAP projects from 2016 include:

- Lincoln County, Nevada – INL researchers evaluated biomass potential for land managers and performed biofeedstock, proximate and ultimate testing.
- MJ3 Graphite Battery – Small Business Innovation Research support for new battery electrodes development.
- Chief Dull Knife College – Tire pyrolysis, waste to energy project with aim of understanding the value chain from harvesting of tires from the dump, transporting to the location to go through the pyrolysis process and selling of the byproducts like kerosene, diesel fuel, and metals.
- PRIMO Farms – Biofeedstock, proximate and ultimate testing to develop a new market for high protein feed based on ability to harvest, dry and densify the feedstock.
- Shoshone Bannock – INL geophysical equipment was used for subsurface detections.

Success Story: New Open Source Software Program

With the huge success of the MOOSE framework, TD expanded its effort around releasing open source software (OSS). To facilitate this effort, Technology Deployment recruited Paul Berg, a software licensing manager specializing in open source licensing. The program began with defining and refining INL's process of releasing software and determining an overarching strategy around open source and commercial releases to capitalize on the strengths of each. The first project included a high-priority open source software release for the Topology Generator project. Using the team's new capabilities in software licensing, INL was able to release the software to GitHub within hours.

Throughout the process of developing this initiative, INL was able to uncover a variety of ways to streamline and refine the software release process, enabling more efficient and faster future releases. INL commenced the process of releasing many software projects from around the lab both as commercial and open source offerings. This included interfacing with external open source projects and improving the code bases in mutually beneficial open source partnerships. TD greatly expanded the variety of options available to research programs to bring their research to market effectively to ensure maximum impact. Additionally, this increased the quality of software releases and expedited development by utilizing third-party assets, with the confidence that INL can comply with the respective licenses. This is the beginning of many planned improvements and a rapidly accelerating pace of software releases as the program continues to gain momentum.



Successful start for Technology Commercialization Fund

In October 2015, DOE announced a new Technology Commercialization Fund (TCF) that would award nearly $16 million to help move promising energy technologies from national laboratories through industry partners to the marketplace. The TCF program is administered by DOE's Office of Technology Transitions (OTT), which works to expand the commercial impact of DOE's portfolio of research, development, demonstration and deployment activities. The first Call for Proposals went out in February 2016 and resulted in OTT receiving 104 applications from across the laboratory system for projects in two topic areas:

- Topic Area 1: Projects for which additional technology maturation is needed to attract a private partner.
- Topic Area 2: Cooperative development projects between a lab and industry partner(s), designed to bolster the commercial application of a lab-developed technology.

INL was awarded funding for an outstanding nine out of the 15 proposals the lab submitted. Each project promises to advance Idaho's role as an innovation hub for international nuclear energy, other clean energy and national security.

Project	DOE funding amount
Additive Manufacturing as an Alternative Fabrication Technique for the Fabrication of Uranium Silicide Fuel. *Partner: Westinghouse Electric Corp* Perform a feasibility study to determine direct routes to the fabrication of dense uranium silicide fuel pellets using an advanced additive manufacturing approach.	**$150,000**
Advanced Outage Control Center Dashboard with Predictive Tools. The dashboard was tested at the Palo Verde Nuclear Station in April.	**$60,500**
Commercialization Research and Development of Change Detection Systems for Nuclear Applications. Aid workers at nuclear and industrial facilities by more easily and accurately tracking changes in a wide variety of workflow situations through a laptop or desktop computer software program.	**$60,500**
Computer-Based Procedure System for Fieldworkers. The goal of this project is to further develop INL's computer-based procedure for fieldwork for commercial use. This effort will help private-sector companies increase plant efficiency, improve human performance during fieldwork, improve plant design and modification, and integrate with other plant systems.	**$130,000**
Development of In-Core Three-Omega Thermal Conductivity Probe. *Partner: Radiation Detection Technologies, Inc.* Provide a way to quickly and cost-effectively test the thermal conductivity of new materials. This technology may be of high interest to industries developing new materials for high-temperature applications.	**$74,911**
Enhanced and Miniaturized Wireless Valve Position Indicator Prototype. *Partners: Analysis and Measurement Services Corp.; Rolls Royce; Westinghouse Electric Corp.; Electric Power Research Institute.* Enhance the wireless valve position indicator technology concept by designing a miniature prototype, ensuring robust, secure and reliable communication, understanding the impact of interfaces on communication and demonstrating capabilities in actual operating conditions.	**$149, 600**
Enhancing Lithium-Ion Battery Safety for Vehicle Technologies and Energy Storage. Enhance the safety of lithium and other battery systems for increased deployment in transportation and stationary applications. INL has worked on technologies that can identify short circuits in batteries and provide the opportunity to decrease catastrophic failures in batteries in use.	**$119,005**
Vehicle Controller Area Network (CAN) Bus Network Safety and Security System. *Partners: Mercedes-Benz Research and Development North America, Inc.* The goal is to enable a device for use in vehicles that can detect anomalies, potential intrusions or exploitation attempts directed at the vehicle's onboard computer system.	**$150,000**
Vibro-Acoustic Testing for Microstructure Characterization and Metrology. Expand application areas for a novel material designed at INL to characterize nuclear fuel, cladding material and structures.	**$150,000**

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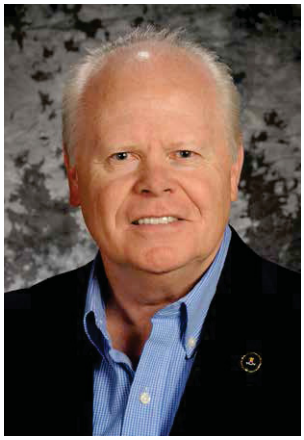

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