INL/EXT-15-36646

Idaho National Laboratory Mission

Accomplishments

- Nuclear Energy
- National & Homeland Security
- Science & Technology Addressing Broad DOE Missions
- Collaborations
- Stewardship & Operation of Research Facilities

INL Idaho National Laboratory

On the front cover:

Silicon Carbide Fibers

On the back cover:

Top: Troy Garn, Research Engineer

Middle: Sr-90 Stuck in Place

Bottom: (Front left) Julian D. Osorio Ramirez (12-month Ph.D. Student), Fulbright Scholar from Florida State University

(Front Right) Sayonsom Chanda, Research Engineer Power & Energy Systems

(Standing) Ren Liu (Ph.D. Student), Summer Intern from Washington State University

CONTENTS

ACRONYMS

AC	Alternating Current
AEM	Advanced Electrolyte Model
AGC	Advanced Graphite Creep
AGR	Advanced Gas Reactor
ANL	Argonne National Laboratory
ANS	American Nuclear Society
ASEE	American Society for Engineering Education
ASME	American Society of Mechanical Engineers
ATF	Accident Tolerant Fuel
ATR	Advanced Test Reactor
ATRC	ATR Critical Facility
ATRC	Advanced Test Reactor Complex
BEA	Battelle Energy Alliance, LLC
BEV	battery electric vehicles
BFNUF	Biomass Feedstock National User Facility
BYU-I	Brigham Young University Idaho
CAES	Center for Advanced Energy Studies
CANDU	Canadian deuterium-uranium
CARB	California Air Resources Board
CES-21	California Energy Systems for the 21st Century
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
CMI	Critical Materials Institute
CRADA	Cooperative Research and Development Agreement
CSET	Cyber Security Evaluation Tool
CWI	CH2M-WG Idaho, LLC
DCFC	Direct Current Fast Charge
DEA	Drug Enforcement Administration
DHS	Department of Homeland Security
DICE	Distributed Information Operations Constructive Environment
DNN	Office of Defense Nuclear Nonproliferation
DoD	Department of Defense
DOE	Department of Energy
DOE-IN	Department of Energy Office of Intelligence and Counterintelligence
DOE-OE	Department of Energy Office of Electricity Delivery and Energy Reliability
DOE-SC	Department of Energy Office of Science
DTRA	Department of Defense Threat Reduction Agency
EBR-II	Experimental Breeder Reactor II
ECIP	Energy Conservation Investment Program
EERE	Office of Energy Efficiency and Renewable Energy
EES&T	Energy and Environment Science and Technology
EFF	Experimental Fuels Facility
EIL	Energy Innovation Laboratory
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EPSA	Office of Energy Policy and Systems Analysis
ESH&Q	Environment, Safety, Health and Quality
ESL	Energy Systems Laboratory
EV	electric vehicle
EVSE	electric vehicle supply equipment

FBI	Federal Bureau of Investigation
FCF	Fuel Conditioning Facility
FIB	Focused Ion Beam
FLC	Federal Lab Consortium
FMF	Fuel Manufacturing Facility
FOA	Funding Opportunity Announcement
GASR	Gas Assay, Sample, and Recharge
GTRI	Global Threat Reduction Initiative
HAZMAT	hazardous material
HEU	highly enriched uranium
HFEF	Hot Fuels Examination Facility
HRP	Halden Reactor Project
IAEA	International Atomic Energy Agency
IASCC	irradiation assisted stress corrosion cracking
ICS	industrial control systems
ICS-CERT	Industrial Control Systems Cyber Emergency Response Team
IEEE	Institute of Electrical and Electronics Engineers
IFSF	Irradiated Fuel Storage Facility
IMCL	Irradiated Materials Characterization Laboratory
IMOM	Improved Many on Many
INL	Idaho National Laboratory
IPL	Integrated Priority List
IRC	Idaho National Laboratory Research Center
ISU	Idaho State University
JFCS	Joint Fuel Cycle Study
KJRR	Ki-Jang Research Reactor
LAMDA	Low Activation Materials Development and Analysis
LDRD	Laboratory Directed Research and Development
LEU	low-enriched uranium
LWR	Light Water Reactor
M3	Material Management and Minimization
MASLWR	Multi-Application Small Light Water Reactor
MFC	Materials and Fuels Complex
MOU	Memorandum of Understanding
MSW	municipal solid waste
N&HS	National and Homeland Security
NAC-LWT	NAC-Legal Weight Truck
NASA	National Aeronautics Space Administration
NE	Nuclear Energy
NEA	Nuclear Energy Agency
NEET	Nuclear Energy Enabling Technologies
NEID	Nuclear Energy Infrastructure Database
NEUP	Nuclear Energy University Programs
NGNP	Next Generation Nuclear Plant
NIAC	National Infrastructure Advisory Council
NNSA	National Nuclear Security Administration
NRAD	Neutron Radiography Reactor
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NS&T	Nuclear Science and Technology
NSUF	National Science User Facility
NUC	Nuclear University Consortium

OECD	Organization for Economic Co-operation and Development
OEM	original equipment manufacturer
ORNL	Oak Ridge National Laboratory
OSIRIS	On-Site Inspection RadioIsotopic Spectroscopy
P&G	Proctor and Gamble
PACOM	Pacific Command
PEV	plug-in electric vehicles
PIE	post-irradiation examination
PINS	Portable Isotopic Neutron Spectroscopy
PNNL	Pacific Northwest National Laboratory
R&D	research and development
RDD	radiological dispersal device
RDD&D	research, development, demonstration, and deployment
RELAP-7	Reactor Excursion and Leak Analysis Program-7
RH-LLW	Remote-Handled Low-Level Waste
RISMC	risk-informed safety margin characterization
ROK	Republic of Korea
RPV	reactor pressure vessel
RTDS	Real-Time Digital Simulator
RTG	radioisotope thermoelectric generator
S&T	science and technology
SACSESS	European Union Safety of Actinide Separation Processes
SAPHIRE	Systems Analysis Programs for Hands-on Integrated Reliability Evaluations
SBIR	Small Business Innovative Research
SMC	Specific Manufacturing Capability
SOCOM	Special Operations Command
SPP	Strategic Partnership Project
SPS	Switchable Polarity Solvent
SPS FO	Switchable Polarity Solvent Forward Osmosis
STEM	Science, Technology, Engineering, and Mathematics
TAC	thermoacoustic sensor
TEM	transmission electron microscope
TPE	Tritium Plasma Experiment
TRISO	tristructural isotropic
U.S.	United States
UI	University of Idaho
UK	United Kingdom
VHTR	very high temperature reactor
VSATT	Vehicle Systems Analysis Tech Team
VTO	Vehicle Technology Office
WNUF	Wireless National User Facility
WSTB	Water Safety Test Bed
ZEV	zero emission vehicle
ZPPR	Zero Power Physics Reactor

Efficient and Effective Mission Accomplishment

1.1: Nuclear Energy

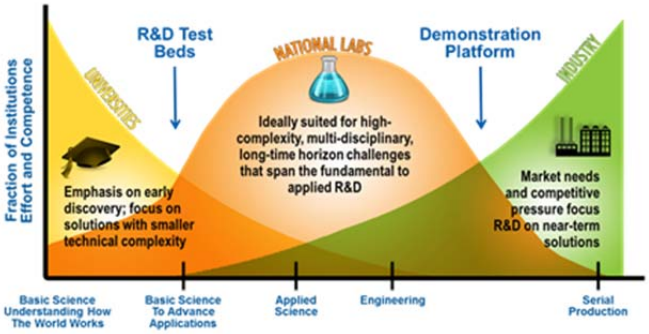
OBJECTIVE 1.1: NUCLEAR ENERGY
Lead and implement relevant, high impact RDD&D programs. Establish the INL as the preeminent, internationally-recognized Laboratory in nuclear energy technologies (including advanced fuel cycles). The primary focus areas include, but are not limited to the following:

- **Engineering driven science-based approach to the development and performance of Nuclear Fuels and Materials applicable to current and future generations of reactors;**
- **Fuel cycle technologies including advancements in pyro and aqueous processing technologies, nuclear materials management and non-proliferation standards, and transient testing capability enabling the design and qualification of fuels and materials;**
- **Reactor Safety, Material Science, and Human Performance for Life Extension of Light Water Reactors; and**
- **Advanced reactor design and optimization.**

Accomplishments

Idaho National Laboratory's (INL's) performance significantly exceeds expectations made toward realizing strategic objectives with significant positive impact on INL's or Department of Energy's (DOE's) mission. INL surpassed the expectations of the research plans through creative, new, or unconventional methods to allow greater scientific and/or engineering reach than expected. In addition, the work conducted at the Laboratory provided major advances that significantly accelerate DOE or other customer mission(s).

INL created a standard on how nuclear energy research development, demonstration, and deployment (RDD&D) is being defined and conducted. In the area of Nuclear Energy (NE) leadership, INL-led efforts have impacted the conversation nationally and internationally on nuclear energy innovation. Under the leadership of INL, a new paradigm is defined for faster and cost-effective deployment of innovative technologies through public-private partnerships executed by a "nuclear energy test bed." The discussions started in April 2014 in the national laboratories Big Ideas Summit. INL organized and led a set of concurrent national workshops on nuclear energy innovation at six different sites. The results are published in a report titled "Nuclear Innovation Workshops" (September 2015). In addition, multiple white papers and presentations were provided to DOE-NE on the Fast Spectrum Test Reactor, Demonstration Reactor studies, Nuclear Energy Test Bed, the Role of National Science User Facility (NSUF), and the Regulatory Considerations. The concepts were also presented in multiple meetings with DOE, industry, and the Organization for Economic Co-operation and Development (OECD)/Nuclear Energy Agency (NEA). The conclusions of the white papers and presentations are being applied to re-organize the DOE-NE programs using the new method.



Bridging the "Valleys of Death" with an R&D test bed and demonstration platform.

The new structure highlights the industry pull in the nuclear energy vision, while preserving the enduring contents of a government-led program. Likewise, INL programs and implementation strategies are being adjusted to realign with the DOE-NE structure. In support of this, an independent budget proposal was also discussed with DOE-NE at the FY 2017 Integrated Priority List (IPL) meeting. This was a joint three-laboratory proposal (INL, Argonne National Laboratory [ANL], Oak Ridge National Laboratory

[ORNL]) and was well received by DOE-NE for the proposed new initiatives to support the new direction. The paradigm shift is not the result of a single RDD&D activity but a culmination of integration and RDD&D activities demonstrating "engineering-driven science-based approach."

The following are RDD&D projects where INL exceeded the expectations of the research plans in significant ways through creative, new, or unconventional methods that allow greater scientific and/or engineering reach than expected. Also, the RDD&D conducted at the Laboratory are of exceptional or outstanding merit and quality. RDD&D conducted at the Laboratory had significant positive impact on DOE or other customer missions. These areas of notable performance either have improved or have the potential to improve the overall mission of the Laboratory.

INL-developed technologies are having a major impact on industrial applications. INL-developed technologies are being demonstrated/made available outside the nuclear energy community, which significantly exceed the research plans:

- The High-temperature steam electrolysis work being performed for Google.
- Strontium (Sr) heat generator trade studies being conducted for Chevron (funded through Jet Propulsion Laboratory).
- INL's Digital Instrumentation and Control and Human Factors research group collaborated with industry generating new work with industry. Industry groups include many of the large utilities and power plant operators (Southern Nuclear and Vogtle, Pacific Gas and Electric and Diablo Canyon, STARS Nuclear Alliance, Paolo Verde, Duke Energy, etc.).
- Uranium extrusion process was demonstrated to support the TerraPower metallic fuel design.

First extrusions completed in Experimental Fuels Facility.

- INL's strong technical support for NuScale Small Modular Reactor licensing applications is continuing and extending to other technical and logistical areas (e.g., siting of the first reactors). The RELAP5-3D team at INL released NRELAP5 for specific NuScale applications.
- MOOSE-based applications and risk-informed safety margin characterization (RISMC) methodology is being adopted by the industry at an increasing rate. INL also had several inquiries for collaborations with industry on specific applications. Specific examples are Canadian deuterium-uranium (CANDU)-owners group and GE Hitachi.
- A Strategic Partnership Project (SPP) agreement was signed between James Fisher Nuclear Ltd. and INL. The work involved reviewing technologies to perform in-core inspections of graphite using EDF Energy's existing refueling machine for the United Kingdom's (UK's) fleet of advanced gas reactors.

INL demonstrated the use of science-based approach for fuel development on nuclear fuel thermal conductivity measurements activities. Through the conduct of activities conducted under Notable Outcome 1.1.B, a scientific approach and methodology was developed for studying nuclear fuel system thermal properties to be used for future nuclear fuels and materials research and development at INL. This science-based method connects advanced multi-scale, multi-physics modeling with multi-scale experimental measurements significantly improving the understanding of advanced nuclear fuel system thermal performance and behavior. INL expects this methodology will be adopted and utilized worldwide by leading research institutions in the field. The multiple approaches developed for measurements at different length-scales and the connection made with modeling and simulation activities were beyond the expectations of the notable outcome (Ref: Thermal Properties Measurement Report).

INL staff developed modern and creative risk analyses methods that will potentially have a wide-ranging impact. The previous success of INL's creative modeling and simulation and associated validation and verification efforts continue to have a major impact as they are being combined with probabilistic approaches. RISMC methodology, which combines the deterministic analyses methods with probabilistic considerations, continues to grow in its recognition outside INL.

Third Meeting of the Civil Nuclear Energy Research and Development Working Group of the Bilateral Commission on Civil Nuclear Cooperation.

An example of this recognition includes the inclusion of the RISMC approach as one of the key topics involved in the United States (U.S.)-Japan Bilateral Commission on Civil Nuclear Cooperation. INL's technical lead of RISMC, Dr. Curtis Smith, was asked to represent DOE on several international activities, including the International Atomic Energy Agency 19th Meeting of the Technical Working Group on Advanced Technologies for Light Water Reactors (LWRs). The RISMC work on External Events was recognized when DOE selected Dr. Smith to participate with the Committee on the Safety of Nuclear Installations—a subgroup of the NEA's OECD-sponsored group. INL's participation on the Working Group is directly tied to the newly formed Working Group on Natural External Hazards, which was established to improve the understanding and treatment of external hazards that would support the continued safety performance of nuclear installations, and improve the effectiveness of regulatory practices.

Recently, the CANDU Owners Group expressed interest in leveraging the tools and technologies developed at INL related to the RISMC Toolkit—the CANDU Owners Group agreed to fund a project at INL such that they can train their staff on the MOOSE-based framework and next generation tools such as RELAP-7 and RAVEN. Interest has also been raised from vendors, such as General Electric Hitachi, on the topic of low-temperature hydrostatic testing of boiling water reactor pressure vessels and modeling/simulation of this in Grizzly/RAVEN and Westinghouse on the topic of advance risk assessment methods, specifically application of RAVEN for dynamic modeling. Use of the RISMC Toolkit has seen applications outside current reactor design with ANL using the RISMC approach for modeling/simulation for small modular reactors. Related to advanced seismic applications, the RISMC team has been interacting with industry through case studies and working with partners, such as the Vogtle nuclear power plant. The visibility and interaction with our Electric Power Research Institute (EPRI) partner increased during FY 2015. INL interacted with EPRI on investigating the next generation

of tools for use at EPRI and they have also proposed to start a new EPRI/INL group solely focused on using the RISMC Toolkit for enhanced modeling of external hazards such as flooding and high winds.

In the following areas, INL's performance exceeds expectations of performance as set within Performance Objectives with some notable areas of increased performance identified. There are important examples where the Laboratory exceeded the expectations of the research plans. Significant areas of RDD&D conducted at the Laboratory are of exceptional or outstanding merit and quality. RDD&D conducted at the Laboratory positively impacts DOE or other customer missions, while enhancing the international reputation of INL and global recognition of the DOE-NE programs.

INL's international reputation continues to grow through enhanced participation in international activities and collaborations on research results. INL scientists and engineers are strong contributors and leaders in many of the OECD/NEA working parties, expert groups, and task forces. These include Accident Tolerant Fuels, Fuel Recycling Chemistry, Innovative Fuels, Thermodynamics of International Fuel Database, Innovative Structural Materials, Advanced Fuel Cycle Scenarios, Reactor and Criticality Benchmarks, Halden Reactor Project, Validation Center, etc. A detailed list of OECD/NEA groups and INL's participation is available upon request. The INL participants are major contributors to the publications resulting from these groups.

INL organized and hosted the *5th International Pyroprocessing Research Conference* in October 2015 at the Energy Innovation Laboratory (EIL), in Idaho Falls. This 3-day conference hosted approximately 100 registered attendees, with 50 presentations and 12 posters. International participation included researchers from Republic of Korea, Japan, China, France, Italy, Austria, Germany, as well as a number of researchers from the U.S. The conference boosted INL's international reputation as the leading research institute on pyroprocessing.

International Pyroprocessing Research Conference.

INL hosted an international workshop on radiation chemistry (*Radical Behavior-2015*) on July 20-22, 2015. The workshop was organized and chaired by INL Laboratory Fellow Bruce Mincher, an internationally recognized authority on radiation chemistry. The 3-day workshop involved numerous U.S. participants from national laboratories and universities, as well as participants from Germany, UK, France, and the Czech Republic. Attendees were given a tour of the INL's separation and radiation chemistry research laboratories, which demonstrated INL's capabilities and opportunities for future engagement.

On September 8, 2015, INL and the National Nuclear Center of the Republic of Kazakhstan signed a "Memorandum of Understanding (MoU) for Technical Cooperation Concerning Nuclear Science and Technology." This MoU was concluded within the framework of the 1997 agreement of cooperation between the U.S. and the Republic of Kazakhstan concerning peaceful uses of nuclear energy. Possible areas of cooperation are developing and improving the properties of advanced nuclear fuel and materials, including testing based on research reactors; measuring techniques and approaches for in-pile

experiments; developing destructive and non-destructive post-irradiation examination (PIE) of fuels and materials; validating modern simulation tools; and training and education, including possible student or personnel exchanges.

INL's Giovanni Pastore is on assignment at *OECD Halden Reactor Project* (HRP, Halden, Norway). This assignment is strengthening the collaboration between INL and HRP and enhancing BISON development efforts through availability of Halden data. Interaction with HRP experts is also promoting new research directions for BISON (e.g., modeling of burnable absorbers in LWR fuel).

INL completed a number of solvent irradiation tests in the INL radiolysis/hydrolysis test loop in support of the Fuel Cycle Technologies Program and in support of international collaborations with the European Union Safety of Actinide Separation Processes (SACSESS) Program. The INL test loop is a one-of-a-kind research capability in the world and has drawn significant attention from the European research community. The U.S. (INL) was invited to participate in the EU Framework Separations Program (SACSESS), which is the first time in over 20 years the U.S. has been allowed to participate. INL is testing solvents of interest for the U.S. Fuel Cycle Technologies Program (for Advanced TALSPEAK and ALSPEP processes) and for the EU program (innovative SANEX process).

In the following areas, INL's performance meets the identified expectations as set within Performance Objectives. Minor deficiencies, if any, identified are offset by other exceptional performance and have little-to-no potential to adversely impact the mission of the Laboratory.

The majority of the major milestones were completed on or ahead of schedule. In addition to the notable outcomes discussed later in this report, in FY 2015 the majority of the milestones were completed on or ahead of schedule and within budget; with a few exceptions. Some milestones at the Materials and Fuels Complex (MFC) were impacted by workload at MFC and delays in the Advanced Test Reactor (ATR) schedule. Some of the earlier missed milestones were subsequently completed in FY 2015. Identified delays have been managed, resulting in no major impacts to the national programs (e.g., the missed milestone on Americium metal production will not impact the programmatic needs until the end of FY 2016). While there was considerable risk in completing all the milestones at MFC in FY 2015, careful planning and prioritization early in the fiscal year enabled INL to achieve completion of the most impactful milestones on or ahead of schedule.

The milestones status is tracked and reported on a monthly basis. Below are examples of INL's noteworthy milestones and accomplishments in each mission area to demonstrate the extensiveness of the nuclear RDD&D research conducted in FY 2015.

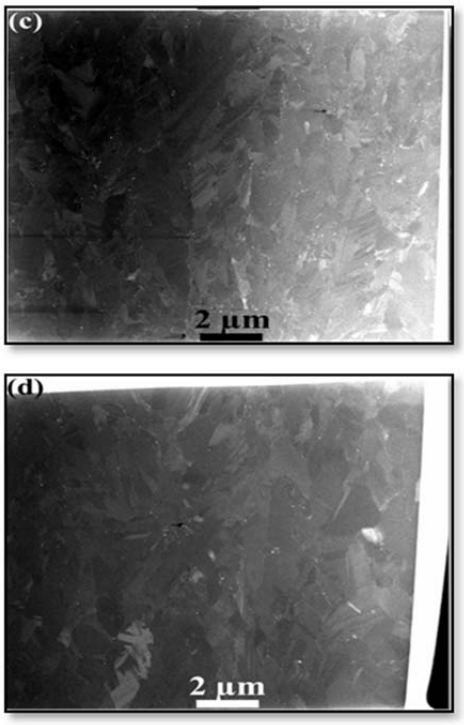
Nuclear Fuels and Materials

Tristructural Isotropic (TRISO) fuel kernel fabrication line was successfully re-started at BWXT. These new kernels are meeting all specifications, and the level of kernel fissures was significantly reduced. Initial evaluations suggest these are the best kernels produced by the program. This research will serve as the foundation for coating and compacting of the final TRISO qualification fuel going forward.

Post-irradiation examination (PIE) for Advanced Gas Reactor (AGR)-1 particles and Advanced Graphite Creep (AGC)-2 second graphite capsule are completed providing new and unique data. PIE and safety testing of AGR-1 compacts and particles was completed. Advanced microscopy on AGR-1 particles is expanding knowledge base on fission product transport within TRISO particles. The graphite program completed PIE of the second capsule, AGC-2. The graphite creep information gathered by INL represents unique data that positions INL as a thought leader in this area and to serve as a focal point for others in the graphite community with which to collaborate.

New innovative Accident Tolerant Fuel (ATF) fuel design is developed, fabricated and demonstrated. INL and Universities Space Research Association staff successfully fabricated an innovative advanced ATF fuel design consisting of annular pellets with inert central cores. This fabrication demonstrates a new capability for fabricating ceramic-based fuels at INL. Additionally, the concept may provide a means for solving technical challenges associated with LWR use of ATF technologies.

Ki-Jang Research Reactor (KJRR) fuel experiment containing the largest amount of fissile material (over 600g of U) ever irradiated in ATR is ready for reactor insertion. The KJRR, currently under construction in South Korea, is in the process of qualifying a new fuel element design. As part of this effort, a prototype KJRR fuel element will be irradiated for several operating cycles in the Northeast Flux Trap of the ATR. The KJRR fuel element contains a very large quantity of fissile material by historical ATR experiment standards; consequently, it was necessary to conduct an extensive set of new physics measurements in the ATR Critical Facility (ATRC) to expand the current validation envelope. Analyses, testing, and validation for inserting the experiment are complete and the experiment is on schedule for insertion into Cycle 158A in mid-October 2015.



Examples of STEM (Scanning Transmission Electron Microscopy) images of a neutron irradiated TRISO particle fabricated with small SiC grain size; (top) SiC layer middle region; (bottom) SiC layer outer region.

A draft Code Case to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code to qualify Alloy 617 for use in construction of nuclear components at high temperatures, up to 1750°F (950°C), for service life up to 100,000 hours was submitted to the Special Task Group on Alloy 617 qualification. Obtaining experimental data and determining allowable stress values based on analysis of those data, to support the high-temperature Code Case, was the focus of the Advanced Reactor Technologies (formerly Next Generation Nuclear Plant [NGNP]) Program high temperature metals program since 2008. It has been more than 25 years since a new material for high-temperature nuclear components has been added to the five alloys that are currently Code-qualified for such use. Qualification of Alloy 617 would enable high-temperature design of components for very high temperature reactors (VHTR).

First set of ATF irradiations started in ATR. In February 2015, the irradiations of the first set of accident tolerant fuel concepts started in ATR, completing the FY 2014 extended notable outcome. These concepts are being tested for the first time and the irradiations continue in ATR.

The first irradiated fracture toughness tests on alloys X-750 and XM-19 were completed in support of the EPRI irradiation and PIE Cooperative Research and Development Agreement (CRADA). The successful completion of the two specimens that were irradiated in the EPRI-2 test train, (to a fluence of 1.93×10^{20} n/cm^2) marks the first time that the newly constructed irradiation assisted stress corrosion cracking (IASCC) test systems were used to conduct fracture toughness tests. The successful accomplishment of these tests also represents the completion of a full suite of mechanical characterization

(tensile, fracture toughness, and IASCC) on material irradiated in the ATR Loop 2A. These fracture toughness tests follow earlier successful completion of the first IASCC tests for the same project. The fracture toughness data collected for the irradiated X-750 specimen confirms irradiation embrittlement in the alloy that was measured by only one other research institution, Studsvik Nuclear in Sweden. The data will be compared to additional new data generated at INL when more specimens are tested at fluences of 5×10^{19} n/cm^2 and 1.0×10^{21} n/cm^2. The collection of data will represent the most complete collection of irradiated mechanical properties data for this alloy.

Fuel Cycle Sciences and Technology

INL completed all critical activities scheduled in FY 2015 and significant progress was made on the Joint Fuel Cycle Study (JFCS) project. This project involves a CRADA between INL and the Korea Atomic Energy Research Institute. Activities in FY 2015 focused on the research, design, fabrication, and qualification of kilogram-scale pyroprocessing equipment for installation into the Hot Fuels Examination Facility (HFEF) hot cell. Unit operations under development include fuel decladding, oxide reduction, electrorefining, and salt distillation/metal consolidation. The JFCS project is a very comprehensive effort that includes expertise in pyroprocessing, fuels, remote systems mechanical engineering, electrical engineering, control systems engineering, drafting, fabrication, nuclear safety engineering, and HFEF facility engineering. Nearly every kilogram-scale unit operation supporting the JFCS is being fabricated in duplicate: one for installation in the HFEF hot cell, and one for "cold testing" in a radiological or non-radiological facility.

A series of experiments were successfully completed for separating transuranics from lanthanides in a molten salt electrorefiner. This research is related to pyroprocessing of fast-reactor sodium-bonded metallic fuels and represents one of the technologies used for separating transuranics from lanthanides and keeping the transuranics in the fuel cycle. The experiments were performed in the HFEF argon hot cell using salt from the Mk-IV electrorefiner located in the Fuel Conditioning Facility (FCF) argon hot cell.

A collaborative research project involving INL, Forschungszentrum Jülich in Germany, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) in Spain, and the Laboratory of Molecular Nanofabrication in the Netherlands was completed. The manuscript for publication on Dissolved Gas Analysis extractant radiolysis was submitted to Dalton transactions ("Gamma-radiolytic Stability of New Methylated TODGA Derivatives for Minor Actinide Recycling").

A new multi-column capability for Kr and Xe capture research was established at INL. This capability allows for the study of the selective capture of Kr and Xe from used nuclear fuel recycling off-gas simulants to support the DOE Fuel Cycle Technologies Off-Gas Sigma Team.

Nuclear Safety and Regulatory Research

Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) risk assessment software Version 8.1.2 was released in December 2014. This software suite is the primary risk assessment tool in use at the Nuclear Regulatory Commission (NRC) and National Aeronautics Space Administration (NASA). Major functionality was added to the cut set viewer. Analysts are now better able to sort and view cut sets when assessing a plant's risk from various contributing basic events and initiators. SAPHIRE, Version 8.1.3, was completed and released in September 2015.

The capabilities in RISMC methodology were expanded, enhancing the utility of the methodology. The FY 2015 activities include:

- For margin analysis, adaptive sampling techniques were developed that greatly reduce the number of samples required to perform RISMC stochastic analyses.
- For human interactions modeling, human models were developed that can be employed in a simulation-based probabilistic risk assessment environment as well as initial development of human dynamic interactions for inclusion in the RISMC analysis.
- For external event modeling, the research team performed modeling of plant response when flooding and seismic events occur.
- For component aging modeling, the research team developed finite element-based methods to investigate how reactor pressure vessel (RPV) (steel) and containment (concrete) thermo-mechanical properties change with time.

Nuclear Systems Design and Analyses

ATR low-enriched uranium (LEU) conversion physics team moved the LEU fuel design from the conceptual design phase to preliminary design. Two candidate configurations are based on the conceptual Enhanced LEU Fuel design. Core safety analysis also ramped up, with the physics team providing data to assess effects of LEU fuel on N-16 systems, instrumentation, beryllium reflector lifetime, accident release source terms (core and cooling pond), and a number of other safety-related functions. The INL physics team is coordinating and working closely with contractor MPR Associates for thermal hydraulic analysis and Atkins Global for source term work.

Tritium Plasma Experiment (TPE) upgrades nearing completion to boost TPE power by a factor of three and provide a new control center outside of TPE's radiation enclosure. The TPE is a unique experiment that can accommodate neutron-irradiated samples of fusion wall materials and use tritium for material exposure to an actual fusion plasma environment. It is the main International Tokamak Experimental Reactor-supporting facility at INL.

Space Nuclear Technologies

INL successfully established capability to repackage neptunium-237 oxide (NpO_2) in the Fuel Manufacturing Facility (FMF) at MFC. Planning and design activities for this new capability were initiated in early FY 2013. In early FY 2014, MBraun fabricated and installed the new Np Repackaging Glovebox in FMF during the summer of FY 2014. Final acceptance testing and other associated FMF facility modifications were completed in mid-FY 2015, with formal readiness assessments conducted by INL and DOE-ID from April through early July 2015. All corrective actions from the assessments were completed by August 26, 2015. DOE-ID authorized start-up of repackaging operations on September 2, 2015. Initial operations to inspect the 9975 drums into which the NpO_2 will be packaged for shipment to ORNL, were completed on September 3, 2015 and transferred into FMF in preparation for the final repackaging operations, which were scheduled for the week of September 14, 2015. ORNL needs the first batch of NpO_2 to continue

Neptunium Repackaging Glovebox in FMF.

target fabrication operations. The capability to repackage NpO_2 for shipment to ORNL is a critical component to enable restart of production of ^{238}Pu in the U.S.

INL played a substantial role in the year-long NASA-led effort to perform and publish a study to discuss a sustainable strategy and present findings for the provisioning of safe, reliable, and affordable nuclear power systems that enable NASA Science Mission Directorate missions and is extensible to Human Exploration and Operations Mission Directorate needs in the next 20 years. INL's major contributions to the "Nuclear Power Assessment Study" involved assembly, test, and launch operations for nuclear-enabled missions at Kennedy Space Center, both radioisotope power systems and fission power systems, plus security and cost analyses for these operations and systems. Numerous conference presentations and publications were published, which include INL scientists, resulted from this extensive Study, covering ten broad conclusions.

INL completed a sequel book, "Atomic Power in Space II," in September 2015 that presents a history of radioisotope power systems and space reactor power and propulsion systems developed from the early 1980s through 2013. DOE's earlier book, *Atomic Power in Space*, published in 1987, covered the history prior to 1980. Development, review, and approval of this sequel spanned over 2 years and included extensive research, reviews by DOE subject matter experts, and coordination with multiple DOE laboratories.

Cover of "Atomic Power in Space II"

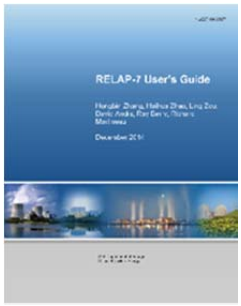
Advanced Instrumentation

Using the acoustic telemetry infrastructure, most of the ATR process states were mapped to the ATR logs to validate the changes in the acoustic signature to a particular phenomenon in the reactor. The laboratory-directed research and development (LDRD) project, "Acoustic Telemetry Infrastructure for In-Pile ATR and TREAT Monitoring," under Dr. Vivek Agarwal supports the NSUF and DOE-NE mission to develop advanced sensors to perform in-pile monitoring. The initial scientific accomplishment of the research is the ability of the ATR acoustic measurement infrastructure to successfully monitor active noise sources emanating from within the reactor. The infrastructure consists of installed accelerometers on the outer shell of the pressure vessel and the system data acquisition system. By utilizing advanced signal processing techniques, it was proven that periodic pulses (frequency harmonics) from the five pump vanes attached to the rotating shaft of the primary coolant pump acted as a virtual thermoacoustic sensor (TAC) signal source. Real-time monitoring of frequency harmonics allowed the team of researchers to develop the first panoramic view of a virtual TAC signal showing different ATR process states from startup to shutdown.

Modeling and Simulation

The multi-year ATR Core Modeling Upgrade Project was completed. Implementation of the software suite consists of two codes, HELIOS and MCNP, which are necessary to develop the Core Safety Assurance Package for ATR. Implementation of the software suite was required for insertion of the KJRR experiment in the northeast flux trap of ATR. This experiment is necessary to allow licensing and startup of a vital new reactor capability in Korea, which will be used for medical isotope production. Validation of the analytical models of the KJRR experiment was performed using measurements in the ATRC. Measurements of reactivity worth and power distribution were compared to analytical models to provide a best-estimate plus uncertainty and appropriate bias in the analytical models. The validation of the analytical models utilized a state-of-the-art validation protocol developed under the Core Modeling Upgrade Project that meets current industry standards. The analytical models were determined to be in good agreement with measured values demonstrating the adequacy of the software suite to allow for safe insertion of the KJRR experiment into ATR. In addition, validation of this code will enhance the ability to insert future fuel types into ATR.

RELAP-7 User's Manual is released allowing external users to start testing the code. Under the Light Water Reactor Sustainability (LWRS) Program, the RELAP-7 (i.e., Reactor Excursion and Leak Analysis Program-7) development team released the RELAP-7 User's Manual and RELAP-7 Theory Manual as part of the December 2015 beta 1.0 release milestone.



RELAP-7 User Manual.

Grizzly developed two new features to support LWR license renewals. The Grizzly development team implemented a coupled thermal and moisture transfer model for concrete in Grizzly. The model was validated against the MAQBETH mock-up experiment data with good agreement. This is an important component for models for multiple types of concrete degradation, including alkali-silica reactions and irradiation damage. Additionally, a new phase field subsystem for the construction of multiphase models with arbitrary number of phases was developed for the RPV version of Grizzly. This system allows the simple development of complex phase field models that are needed to simulate the microstructural evolution of reactor pressure vessel materials. RPV and concrete performance under long-term operation are important topics for second license renewal; Grizzly will provide information important to informing decisions on the second license renewal.

RAVEN team increased simulation speed allowing faster assessments. Under the LWRS Program, the RAVEN team increased the simulation speed (around a factor of 50 speedup) of the RAVEN code by the parallelization of the physical models that were internally evaluated (e.g., surrogate models) on high-performance computing clusters. The team was able to optimize computer capability and improve the data processing speed. A model requiring one million evaluations formerly took 500 minutes. With the new improvements, that same model completes evaluations in 10 minutes.

BISON included gadolinia poisoning as an additional important feature for LWR fuel behavior. Under Nuclear Energy Advanced Modeling and Simulation, the BISON model that computes evolution of the radial power profile with burnup in UO_2 was extended to include gadolinia poisoning. This added capability expands analyses to other fuels in LWRs, increasing the number of possible validation cases.

Recognitions and Awards

First, a summary of the recognitions and awards from the first half of the year is provided for completeness. Details of these may be found in the mid-year report.

Dr. David Nigg was recognized with American Nuclear Society (ANS) Fellow Honor in the Winter Meeting (November 2014).

Dr. Shannon Bragg-Sitton received the Mary Jane Oestmann Professional Women's Achievement award at the ANS Winter Meeting.

Dr. David (Xianming) Bai received The Minerals, Metals and Materials Society Young Leader Professional Development award.

Dr. Brad Merrill received the American Nuclear Society (ANS) Fusion Energy Division Outstanding Achievement Award for his work in the fusion safety.

Dr. Cathy Riddle received the Idaho ANS Section Meritorious Award.

Dr. Cathy Riddle

Additional recognitions and awards in the second half of the year include:

INL's Integrated Waste Screening System has received the 2015 Federal Laboratory Consortium Far West Regional Award for Outstanding Technology Development. INL researchers Doug Akers and Lyle Roybal developed the technology to efficiently assess the nearly 40 million tons of drilling waste generated by fractured wells. These wells often produce significant amounts of Technologically Enhanced Naturally Occurring Radioactive Material, which must be characterized, segregated, and disposed of properly. The system can conduct rapid (3-minute) onsite analyses, reduce costs, and document and certify recommendations for proper environmental disposal.

Dr. Cathy Riddle also received the Partnership for Science & Technology Science, Technology, Engineering, and Mathematics (STEM) Education Advocate Award.

Dr. Krzysztof Gofryk

INL received a substantial research award from Office of Science. INL's **Dr. Krzysztof Gofryk** was selected by the DOE-SC as one of 44 scientists to receive significant funding for research as part of DOE's Early Career Research Program. This award demonstrates the ever-increasing quality of INL's Nuclear Science and Technology staff, their engagement in the community as leaders at various levels, and the research results they produce.

Notable Outcomes

Notable Outcome 1.1.A.

INL and DOE-ID mutually agreed on October 7, 2015 that this notable outcome was achieved. The Nuclear Energy Infrastructure Database (NEID) is available as a searchable database. Currently, the database contains information from significant U.S. nuclear energy research institutions as well as a sample of international facilities, and will continue to be refined and updated based on input from the programmers, the Database Review Panel, and additional research and facility survey results. Additional information is contained in the "Nuclear Energy Infrastructure Database Fitness and Suitability Review" (INL/EXT-15-34453, Rev. 1).

The gap analysis, "NSUF Preliminary Nuclear Energy Research and Development Gap Analysis for FY15," (INL/LTD-15-36581) was comprised of (a) a capability analysis, based on the NEID and (b) an R&D direction analysis based on information drawn from a variety of sources, including community interest and past Nuclear Energy University Programs (NEUP) and Nuclear Energy Enabling Technologies (NEET) R&D awards. The capability gap analysis process is ongoing and recommendations will be updated at least annually in order to inform the infrastructure acquisition processes. The NEID supported the FY 2015 NE-4 Infrastructure awards and the FY 2016 Infrastructure Funding Opportunity Announcement (FOA) process.

1.1 A

As part of the National Scientific User Facility (NSUF), establish a capability and infrastructure database:

- *Identifying a set of major capabilities associated with DOE-NE work across the DOE complex;*
- *Documentation of the major capabilities and identification of the gaps in the capability compared to DOE-NE program gaps;*
- *Establishment of a database review panel; and*
- *Initiation of a searchable database.*

INL and DOE-ID mutually agreed on October 7, 2015 that this notable outcome was achieved. (CCN 236684)

To assist in the development of the NEID, a Database Review Panel was formed in January 2015 with representatives from the various stakeholder communities associated with NSUF, including DOE-NE, university reactors, university researchers, national laboratories, and the nuclear power industry. The Panel was instrumental in the review and improvement of the NEID and the associated web portal. A description of the panel can be found in "Nuclear Energy Infrastructure Management Program - Database Review Panel Charter" (INL/MIS-15-34099).

The database was developed from January to June 2015 by members of the NSUF staff, the INL Information Management staff, the NEID Database Review Panel and DOE-NE staff and was released for use by authorized personnel on June 25, 2015. Incremental improvements will continue to be implemented as feedback is received and in accordance with program direction. Currently, access is available to DOE-NE and INL staff, with a public release planned for December 2015. Instructions for using the database can be found in the "Nuclear Energy Infrastructure Database (NEID) User's Guide" (INL/EXT-15-35485, Rev. 1).

1.1 B

Develop fuel thermal conductivity measurement capability. Demonstrate a new science-based approach to fuels development by performing thermal conductivity measurements on advanced fuel samples (beyond UO_2). Demonstrate how thermal property measurements can be taken on Accident Tolerant Fuel (ATF) concepts to support DOE's evaluation of ATF concepts. FY 2015 scope is limited to capability demonstration using unirradiated or surrogate samples and does not include measurements on irradiated fuel.

INL and DOE-ID mutually agreed on August 25, 2015 that this notable outcome was achieved as a result of the disclosure of the Thermal Properties Measurement Report and the recommendation of a recommended thermal property measurement strategy to the Irradiated Material Characterization Laboratory (CCN 236347).

Notable Outcome 1.1.B.

A new scientific approach and methodology was developed for studying nuclear fuel system thermal properties that will be used for future nuclear fuels and materials research and development at INL. This science-based method connects advanced multi-scale, multi-physics modeling with multi-scale experimental measurements significantly improving the understanding of advanced nuclear fuel system performance and behavior. This methodology will be adopted and utilized by leading research institutions in the field.

INL's "Thermal Properties Measurement Report" (INL/EXT-15-36283) summarizes the research, development, and initial use of significant experimental thermal property characterization capabilities at INL and the subsequent modeling and simulation of the data in Fiscal Year 2015. These new capabilities were used to characterize a U_3SI_2 (candidate Accident Tolerant) fuel sample to be fabricated at

INL. The MARMOT advanced modeling and simulation capability was utilized to illustrate how the microstructural scale data can be used to model and calculate the bulk property characterization data. A scientific method was established for thermal property measurement on fresh and irradiated fuel samples. These activities lead to the recommendation of a thermal property measurement strategy for the Irradiated Material Characterization Laboratory.

Notable Outcome 1.1.C.

The notable outcome was met by demonstrating progress in the highly enriched uranium material recovery project to support a DOE decision on the next phase. The original basis for progress was to complete the detailed design of the ¼-scale fluidized bed chlorination pilot plant; however, based on analysis that revealed several vulnerabilities in the initial concept that was based on a similar pilot plant constructed and operated in the 1960s, it was determined that the initial approach to recover uranium from the fluidized bed was not going to succeed. Using input from INL fluidized bed subject matter experts (including those with experience with the fluidized beds in the Integrated Waste Treatment Unit) and expertise from a commercial zirconium manufacturer, additional capabilities were added to the pilot plant, the most essential of which was the addition of a recycle loop and filter vessel to allow removal of the uranium from the fluidized bed after zirconium removal. Additionally, INL used the opportunity to improve pilot plant operations and provide additional information pertinent to the full-scale demonstration, by adding the ability to recycle one of the chlorinating gases and an additional filter vessel. The final fabrication of the pilot plant vessels and skid will be completed October 30, 2015. The milestones in the approved material recovery pilot plant project execution plan are still on track to complete testing with zircaloy in the ¼-scale pilot plant by the end of September 2016 and the milestone to complete testing with unirradiated fuel by the end of September 2017.

1.1 C

Demonstrate progress in highly enriched uranium (HEU) material recovery project. Complete assembly of the 1/4-scale fluidized bed chlorination pilot plant for testing with unirradiated fuel. This pilot plant will be instrumental in developing engineering data that will be used to support a DOE decision on whether to proceed with a hot demonstration of the technology (likely at full-scale) or not.

The demonstration of progress in the HEU material recovery project demonstrates achievement of this outcome.

Notable Outcome 1.1.D.

The AGR-5/6/7 test train design is unique in several aspects. It combines three different experiments into a single test train to shorten the overall (AGR) program irradiation schedule and reduce the costs of irradiation and related support activities. The test train design also accomplishes the two major objectives of qualifying a TRISO fuel design and performing a margin test to expand the possible operating temperature band for potential use of that fuel in future advanced reactors.

To meet all of the test objectives of the three experiments, the AGR-5/6/7 test train is quite different from previous AGR test trains. The test train will be comprised of five capsules of different lengths and different numbers of compacts per capsule, and will contain compacts of two different packing fractions of TRISO coated particle fuel. Previous AGR experiments were comprised of capsules of the same dimensions throughout the test train and compacts of the same packing fraction. Each of the five capsules has a specific target temperature

1.1 D

Develop a state-of-the-art test train design for the Advanced Gas Reactor (AGR)-5/6/7 tristructural isotropic (TRISO) coated particle fuel irradiation campaign. Evidence would be demonstrated by completion of the final AGR-5/6/7 test train design review documents, issuing them to reviewers, conducting the final design review meeting, and tabulating the comments received prior to or at the meeting. The objective evidence would be the design review meeting agenda, the signed attendance list, and the tabulated list of comments received.

INL and DOE-ID mutually agreed on September 17, 2015 that this notable outcome had been accomplished (CCN 236547).

range to be maintained during irradiation, from a minimum of 700°C to greater than 1350°C. To provide statistically significant data for the test objectives, approximately 520,000 TRISO coated fuel particles will be irradiated in the AGR-5/6/7 test train, which is more fuel than any previous test train. Other design improvements relate to the thermocouples and temperature control. The temperature control gas lines will be run through fewer, but larger, through-tubes to allow the use of larger thermocouples, which are needed to withstand the higher temperatures to which the experiment capsules will be subjected. Also, a larger number of thermocouples from different manufacturers will be used in the test train to more precisely control capsule and compact temperatures during irradiation, and to test different thermocouple designs at a variety of temperatures to determine survivability for future use. Successful completion of the AGR-5/6/7 test train irradiation will meet the primary AGR program objectives of "providing a fuel qualification data set in support of the licensing and operation of a high temperature gas-cooled reactor and supporting deployment of a high temperature gas-cooled reactor by reducing market entry risks posed by technical uncertainties associated with fuel production and qualification."

Publications

The high quality of INL's science and engineering activities are demonstrated through a strong publication record. Research results were published in a diverse set of prestigious journals enhancing INL's reputation as a world-class energy laboratory. INL staff published 154 peer-reviewed articles in prestigious journals in FY 2015. The number does not include many other publications that are accepted but not yet published. The number also does not include many conference proceedings where INL's staff participated and presented in prestigious national and international conferences.

In addition, INL staff contributed to or led the publication of multiple OECD/NEA reports that are highly referenced in international circles (e.g., Innovative Fuels State-of-the Art-Report). INL edited a special section of Volume 77 (November 2014) of the *Journal of Progress in Nuclear Energy* on the "Status of Generation IV Reactor Development." This provides the most up-to-date summary of five of the six advanced reactor systems being developed under the Generation IV International Forum. Also noteworthy is a high-impact DOE report that was completed under the leadership of INL on "Nuclear Fuel Cycle Evaluation and Screening."

Finally, a provisional patent application was filed for "Methods and Systems for Aluminum Electroplating," which was meant as an alternative to cadmium coating to provide corrosion protection for common fasteners. This technology has a very wide application and the research supporting the patent stemmed from work performed under 2013 LDRD, "Aluminum Electroplating from Low Temperature Molten Bromide Salts."

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Efficient and Effective Mission Accomplishment

1.2: National and Homeland Security

OBJECTIVE 1.2: NATIONAL AND HOMELAND SECURITY

Lead and implement relevant, high impact RDD&D programs. Establish the INL as a major center for national security technology development and demonstration. The primary focus areas include, but are not limited to the following:

- **Critical infrastructure protection technology RDD&D in technology focus areas of industrial control systems cyber security, wireless communications, and grid reliability and security;**
- **Armor production which meets Department of the Army cost, production schedules, and quality requirements for Specific Manufacturing Capability (SMC) and explosives/blast protection;**
- **Nuclear nonproliferation and emergency response technology RDD&D and training including work with special nuclear materials; and**
- **Applied solutions to satisfy requirements for Defense and Intelligence Community customers.**

Accomplishments

INL's science and engineering innovations and the deployment of technology solutions are enhancing the security of the nation's economy and energy supply, building security and resilience into the nation's critical infrastructure, and protecting citizens from the threats of weapons of mass destruction, terrorism, and cyber attack. The achievements described in this annual summary demonstrate INL's significant success in exceeding most of the RDD&D performance goals and strategic objectives for the national security mission, and illustrate multiple stakeholder recognition of INL as a major center for national security technology development and deployment. These achievements have contributed to the mission success of DOE, National Nuclear Security Administration (NNSA), Department of Defense (DoD), Department of Homeland Security (DHS), U.S. Intelligence Community, and Public Safety/Emergency Response organizations.

INL's transformational technology solutions deployed as technical papers, threat analysis reports, prototypes, proof-of-principle scaled-demonstrations, training, limited-quantity advanced technology prototypes and manufactured products are a culmination of innovations in the integration of scientific and engineering expertise with unique and differentiating infrastructure for modeling, experimentation, prototyping, testing, and production. INL is solving complex national security challenges by (a) advancing the fields of science and engineering; (b) influencing the direction of current research and development (R&D) programs and providing a technology basis for the creation of new R&D programs; (c) enabling threat information sharing through public-private partnerships that prepare government and commercial organizations to anticipate, detect, respond, and mitigate cyber and physical threats; and (d) providing the military and emergency responders with analyses and tools for situational awareness, effective command and control, and force-multiplication technologies.

Technology Leadership

INL is nationally and internationally recognized as a preeminent national security technology leader. This recognition was validated during multiple meetings, symposia, visits, and briefings with DOE and U.S. Government national security leaders. Examples include:

- Lt. Gen. Frank G. Klotz, DOE Under Secretary for Nuclear Security and NNSA Administrator; Madelyn Creedon, NNSA Principal Deputy Administrator; Admiral John Richardson, Deputy Administrator for Naval Reactors (now the Chief of Naval Operations); and Anne Harrington, NNSA Deputy Administrator for Defense Nuclear Nonproliferation visited INL on several occasions. These visits provided a strategic leadership basis for highlighting INL's technical capabilities and program

leadership in reducing the threat of proliferation of nuclear weapons in a DOE/NNSA report to Congress "Prevent, Counter, and Respond – A Strategic Plan to Reduce Global Nuclear Threats (FY 2016–FY 2020)." Additionally, INL was invited to serve as the DOE Laboratory Complex co-Chair for the NNSA Office of Defense Nuclear Nonproliferation (DNN) Cyber Security Task Force to identify strategies and prioritize future year investments for the NNSA Assistant Deputy Administrators and their program managers.

- INL provided national security tours and briefings with multiple members and staff of the U.S. Congress, including Idaho Senators James Risch and Mike Crapo, Idaho Congressmen Mike Simpson, other congressional members and staffers from committees, such as the Senate Select Committee on Intelligence, House Select Committee on Intelligence, House Armed Services Committee, and House Energy and Water Development Appropriations Subcommittee. These interactions have resulted in congressional influence upon future R&D investments within DOE, NNSA, DOD, DHS, and Intelligence R&D program for power grid security and resilience, control systems cybersecurity, nonproliferation technologies, and Public Safety communications and emergency response.

"…a visit to INL would provide you with a firsthand look at the cutting edge research being done to protect the grid from cyber intrusion…" Senator James Risch, January 27, 2015

- A visit by Federal Energy Regulatory Commission Chair Cheryl A. LaFleur influenced the release of a Notice of Proposed Rulemaking RM15-14-000, "Revised Critical Infrastructure Protection Reliability Standards."
- Executive meetings between Navy 10th Fleet (FLEETCYBERCOM) Commander Vice Admiral Jan Tighe and INL Lab Director John Grossenbacher, along with research leaders from INL's Mission Support Center, resulted in the development of a framework for a transformational threat analysis program focused on control system security. Commander Tighe referred to INL as a thought-leading organization that truly understands the reality of control systems cyber challenges, and called out INL as the nation's thought leader in providing a path forward for these challenges.
- INL's leadership and researchers, in collaboration with NNSA and Pacific Northwest National Laboratory (PNNL), supported the International Atomic Energy Agency (IAEA) in the successful completion of IAEA's inaugural *International Conference on Computer Security in a Nuclear World*. INL supported the IAEA by providing advanced planning guidance for the conference agenda, identifying and securing commitments for keynote speakers, reviewing over 200 technical papers, presenting five technical papers, and spearheading the preparation and delivery of a live demonstration of the vulnerabilities associated with the cyber and physical security of nuclear energy installations.
- INL successfully hosted and presented talks during the second annual National Geomagnetic Disturbance Workshop attended by national and international representatives from industry, universities, regulatory agencies, and government policy and R&D organizations.
- At the *Industrial Control Systems Joint Working Group Conference* hosted by INL, INL researchers delivered multiple research papers that provided approximately 150 national and international infrastructure security experts with updates on the evolving solutions and available capabilities to protect their critical infrastructure assets from current and future cyber threats.

- Under INL leadership, *Resilience Week 2015* continues to be recognized as the premier international public forum for technology exchange—advertised as "Transforming the Resilience of Cognitive, Cyber-physical Systems." Over 50 papers, eight of which were co-authored by INL researchers, were presented to 180 national and international conference attendees from industry, government, universities, and national laboratories.

RDD&D Programs for Cybersecurity Protection

In exceeding performance objectives of INL's national security mission, INL has significantly advanced DOE's strategic leadership role in the expansion of RDD&D program objectives for cybersecurity protection of national and international nuclear facilities, and other critical infrastructure sectors. INL's recognized global leadership and innovative approach to threat analysis and vulnerability discovery has significantly contributed to transformational shifts in technical programs and policy discussions. INL's thought leadership influence is demonstrated by:

- INL choreographed a live demonstration during the *IAEA's International Conference on Computer Security in a Nuclear World* depicting a cyber attack against physical security and operations equipment associated with a nuclear power plant. This conference included over 1300 participants from nearly 100 member countries and organizations. Prior to conducting the demonstration, INL coordinated a review with the Office of Science and Technology Policy, DOE/NNSA, DOE Office of Intelligence and Counterintelligence, and the Office of Secretary of Defense to establish an agreement on a common baseline on the threats and technologies that could be shared internationally in support of this conference.

The IAEA's first International Conference on Computer Security in a Nuclear World.

  Research based on an INL researcher presentation at this IAEA conference describing "Cyber-Informed Engineering: The Need for a New Risk Informed and Design Methodology," along with INL's onsite assessment methodologies is included in INL scope for FY 2016 DOE-NE research.

- With the leading support of INL, DOE-NE made significant progress in establishing a new national program to conduct R&D that enhances the availability of advanced and cost effective cybersecurity technology solutions to assure the safety, security, and safeguarding of nuclear energy facilities. The evolving DOE-NE program awarded over $3M for R&D through five grants within DOE-NE NEUP, NEET, and Small Business Innovative Research (SBIR).

- National and Homeland Security (N&HS) Associate Laboratory Director is serving as a strategic advisor to the DOE Deputy Secretary in understanding the requirements for an integrated DOE plan for cybersecurity R&D and critical infrastructure protection sector leadership to secure the nation's power grid. In this advisory role and based on INL's parallel efforts with the U.S. Navy, INL briefed the DOE Secretary and Deputy Secretary, DOE Office of Intelligence and Counterintelligence (DOE-IN) Director, and the U.S. Navy 10th Fleet Commander on the evolution of future requirements to meet DOE's strategic objectives in the protection of the U.S. power grid through the creation or modification of control systems cybersecurity programs within DOE and the U.S. national security community.

"…Secretary Moniz and I have made 'cybersecurity' a high priority – indeed, we're directing nearly $100 million over this year and next year toward cybersecurity for the nation's electric grid…" DOE Deputy Secretary Sherwood-Randall, February 13, 2015, remarks at the White House Summit on Cybersecurity and Consumer Protection.

Critical Infrastructure Protection

Innovations in control systems cybersecurity, power grid security, spectrum sharing wireless communications, and vulnerability assessments have reduced threats to the U.S. Government and the private sector's critical infrastructure, enabled capabilities for enhanced Public Safety, and assured the security of the economy and energy supply. Peer-reviewed experimental results and scientific observations leading to these innovations were disseminated to policy makers, infrastructure asset owners, and research leaders across the globe. Examples include:

- In collaboration with DHS and the Federal Bureau of Investigation (FBI), INL cybersecurity experts participated in a 3-week, 15-city campaign of classified threat briefs and mitigation strategies to over 1,600 federal and private stakeholders and asset owners. This public-private information sharing campaign focused on two sophisticated malware attack campaigns (i.e., Havex and BlackEnergy) against industrial control systems.
- INL's technical leadership support for the DHS Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) resulted in the peer-reviewed production and dissemination of more than 24 alerts, more than 160 advisories, and five onsite incident responses. These public-private information sharing activities and response capabilities, in coordination with the DHS National Cybersecurity and Communications Integration Center continues to build public trust in the security of our national infrastructure.
- INL continued to reset the standard for products that enable the assessment of vulnerabilities and critical infrastructure interdependencies with delivery of the latest version of Cyber Security Evaluation Tool (CSET®) Version 7.0. The comprehensive security program (downloaded and distributed to more than 6000 users) was delivered and deployed as the new standard tool for assisting critical infrastructure asset owners perform guided self-assessments of their cybersecurity defenses. Additionally, INL researchers completed the development, testing, and delivery of improved DHS assessment and analysis tools, including IP Gateway, a Digital Library application, Map Viewer application and the Chemical-terrorism Vulnerability Information application. The delivery of Chemical-terrorism Vulnerability Information enabled DHS Infrastructure Information Collection Division to meet a presidential milestone upon release of a version of the tool to qualified users.

- Control systems cybersecurity experts conducted eleven red/blue team ICS security training courses to over 400 federal, industry, and international security officials, 98 onsite assessments of federal, state and city infrastructure owners, and 11 self-guided online training courses designed to educate cyber officers and operators.
- INL received notification of the second patent award for WSComm from the U.S. Patent and Trademark Office, US 8,861,571B2 "Methods and Apparatuses Using Filter Banks for Multi-Carrier Spread-Spectrum Signal." This award confirms the novelty of the technology and enables the viability for commercial deployment of the intellectual property for both the radio frequency transmission and reception of the spectrum sharing waveform.
- INL's cybersecurity strategists and leading researchers are serving as advisors and are influencing the Grid Modernization Laboratory Consortium's Grid Modernization Program Plan, DOE's Quadrennial Technology Report, and the North American Electric Reliability Corporation GridEx III exercise.
- A leading infrastructure protection researcher is serving as a member of the Board of the Infrastructure Security Partnership and as one of the co-chairs of the Operationalizing Resilience Working Group. By serving in this role, INL collaborates with leaders from government, academia, and the private sector to create a forum to work with communities to instill resilience awareness and best practices for infrastructure protection.
- Upon invitation from the Co-Chairs of the Senate National Laboratory Caucus, INL's Senior Cyber and Energy Security Strategist provided a brief on national challenges in securing the U.S. electric grid to the Caucus during March 2015.
- INL's thought leadership and influence regarding critical infrastructure cybersecurity was recognized internationally through the N&HS Associate Laboratory Director's invitation to speak at the U.S. European Command and George C. Marshall European Center's International Cyber Summit. As a result of this presentation, INL was invited to be a regular participant in future education cybersecurity lectures at the Marshall Center. As described by Joseph Vann, Marshall Center Professor of National Security Studies, "The Marshall Center will benefit from showcasing the Lab's expertise and the Lab fills a much needed academic niche that is currently not being adequately addressed."

Security and Vulnerability Assessments for Critical Infrastructure Asset Owners

Recognition of INL's technical leadership across physical and cybersecurity technology development, breadth of engineering and operations experience, and capability for lab-, prototype-, and full-scale testing has resulted in multiple opportunities for INL to conduct security and vulnerability assessments for critical infrastructure asset owners. These assessments provide the asset owners with opportunities to identify, prioritize, and mitigate security risks that present the potential for unacceptable consequences.

- A team of INL cyber researchers, security specialists, and threat analysts completed a threat-based assessment of a DoD facility's design. The innovations and value-added from the INL methodology resulted in a DoD broad agency announcement for services to assess additional DoD facilities.

- INL physical security subject matter experts are participating in the NNSA Security Conditions Review of all national laboratories and facilities involved in the production and assembly of nuclear weapons. Results from these assessments are used by NNSA to manage and identify future security improvements and upgrades aligned with NNSA and Congressional budget planning and appropriations.

Strategic Growth and Evolution in Critical Infrastructure Mission

Excellence in program performance through product innovation and quality, cost-effectiveness, scheduled delivery, and reach-back support has resulted in significant opportunities for continued growth in ongoing programs and the evolution of new programs. Examples within the Critical Infrastructure Protection mission include:

- INL was notified by DOE-OE of two new project awards for "Ensuring Uninterrupted Energy Flows from Cyber Attacks Targeting Essential Forecasting Data for Grid Operations" and "Secure Cloud Computing in the Electric Grid" from the RC-CEDS-2015 Laboratory research calls. The first project utilizes discoveries within an INL LDRD involving concolic algorithms and collaborations with Brookhaven National Laboratory and Orange and Rockland, a New York utility. The second project is a collaboration with ANL and involves LDRD concepts for resilience metrics.
- INL was awarded a DOE-OE project that expands the Cybersecurity Risk Information Sharing Program, an evolution of an innovative DOE approach to establish an energy sector operational technology networking environment. This pilot program involves collaboration with utilities, national laboratories, and the Electricity Sector Information Sharing Analysis Center.
- Advisory support from INL with the DOE Office of Energy Policy and Systems Analysis (EPSA) in development of the DOE Quadrennial Energy Review has led to a new EPSA-funded project at INL. This project involves an assessment of the international markets for and barriers to nuclear fuel leasing, as well as an assessment of cyber-physical security challenges for electric utilities, which will be used by DOE leadership as a technical basis for existing and prospective energy-related policies.
- Due to experimental results and laboratory demonstrations of developmental spectrum sharing technology prototypes for the Drug Enforcement Administration (DEA), U.S. Special Operations Command (SOCOM), the U.S. Navy, as well as the completion of an onsite review by the Office of Management and Budget, INL has been approved to receive multi-year program extensions for product design, development, and testing. Both DEA and SOCOM intend to deploy the proprietary technology (WSComm) to mission needs for assured communications in a contested radiofrequency spectrum environment.
- INL expanded its RDD&D role in supporting public utilities' capability to secure the national power grid by establishing a Strategic Partnership Project agreement with Southern California Edison. This agreement and the research tasks it includes will be the basis for long-term RD&D collaboration with state-wide California Energy Systems for the 21st Century (CES-21). It will demonstrate the viability of implementing a risk analysis process for evaluation of cyber threat advisories, and will develop and ultimately deliver machine-to-machine automated threat response capabilities for utilities across California and the U.S. INL received a commitment from DOE Office of Electricity Delivery and Energy Reliability (OE) for a significant new collaborative program involving INL and Sandia National Laboratory to assure the national grid's physical protection against an emerging physical threat.

- Substantial innovations in modeling power line properties and High Voltage Transmission Line Electromagnetic Interference have resulted in INL receiving Phase II funding from the Office of the Secretary of Defense to resolve potential interferences from transmission lines on DoD test ranges.
- In recognition of INL's expertise, experience developing assessment methodologies and tools, analytic capabilities, and thought leadership within this mission space, DHS selected INL to lead multiple Regional Resilience Assessment Projects across the U.S. to understand the interdependencies and resilience of regional critical infrastructure.

Nuclear Nonproliferation

INL researchers are exceeding all expectations in the dissemination of leading science, demonstration of national technical capabilities, and deployment of impactful solutions in the field of isotopic measurements. Experimental outcomes demonstrate successful integration of INL's primary missions for nuclear energy and national security in supporting the R&D programs of the NNSA Office of DNN, Department of Defense Threat Reduction Agency (DTRA), and DHS Domestic Nuclear Detection Office. These achievements advanced INL's strategic objectives for broad user facility access to the Nuclear and Radiological Analysis Center and strengthened INL's world class recognition as science and engineering leaders in nuclear and radiological measurements for treaty verification, forensics, emergency response, and proliferation detection. Examples include:

- INL developed a new national capability by demonstrating that a realistic radiological dispersal device (RDD) could be detonated on INL's Radiological Response Training Range. This demonstration, the first-of-a-kind within the U.S., identified the future research needed to model radiological material dispersal and first-responder measurement capabilities. To further prove the benefits of this capability, INL conducted a second RDD test to resolve additional scientific uncertainties. The results of these tests provide DHS, DTRA, and the FBI with an understanding of how experimentation on the fundamental material dispersal and accountability characteristics can assist the nuclear forensic community (including intelligence, law enforcement and policy) in the reconstruction of a detonated RDD. As described in a DTRA press release, this test "demonstrated the robustness of the post-detonation nuclear forensics capabilities to support the U.S. Government's commitment…this commitment, in turn, serves to deter our adversaries from undertaking such attacks." The results of these tests are already gaining interest from the international community for potential use in future exercises.

INL researchers prepare (above) radiation source and conduct (below) a first-of-its-kind radiation dispersal device test.

- In collaboration with University of Hawaii, INL researchers supported first-of-a-kind exploratory measurements examining the feasibility of infrasound measurements to monitor nuclear facilities. A full proposal for continued exploratory R&D was requested after the experimental results demonstrating the potential of this technology for treaty compliance were briefed to the Department of State and the DTRA.

- INL's On-Site Inspection RadioIsotopic Spectroscopy (OSIRIS) proprietary software, which addresses onsite inspection measurement capability requirements for the Comprehensive Nuclear-Test-Ban Treaty Organization was used during the Integrated Field Exercise 2014 (IFE14) in Jordan and described in news reports in *Physics Today* and *Science and Technology Review*.
- In collaboration with Idaho State University (ISU), INL researchers completed experiments demonstrating the feasibility of using photo-nuclear reactions to produce ^{237}U and isotopes of Kr and Xe. As a result, DTRA is funding INL and ISU to further the development of the technology in support national and international measurements for nuclear forensics and treaty compliance.
- INL produced and delivered multiple noble gas standards to the U.S. Government and the Provisional Technical Secretariat of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). These standards are produced and shipped to a global network of national and international laboratories for calibration and quality control tests of treaty compliance measurements. INL's capabilities and experimental results of new methodologies to improve the quality and reduce cost of producing the standards were presented by INL during an invited talk at the Workshop on the Signatures of Medical and Industrial Isotope Production and were published in the proceedings of the *20th International Conference on Radionuclide Metrology and its Applications*.

INL researchers successfully demonstrate the capability of OSIRIS in Jordan during the Integrated Field Exercise 2014.

- Research discoveries in ultratrace and forensic isotope measurements were presented in eight papers during the 2015 International Conference on Methods and Applications of Radioanalytical Chemistry. Additionally, radioanalytical scientific research results were published in multiple peer-reviewed journals.
- Results from INL N&HS and Nuclear Science and Technology (NS&T) LDRDs, "Development of Actinide Halide and Oxy-halides for Isotopic Separations" and "Development of a Simplified Soft Donor Technique for Trivalent Lanthanide Actinide Separations," provided a new understanding and methodologies for synthesis and purification of a neptunium species. Based upon these scientific discoveries, INL was awarded a new DHS project to conduct formative experiments evaluating the basic thermodynamic properties of new actinide compounds that address DHS's needs for a stable supply of nuclear measurement standards.

Safeguards and Security of Nuclear and Radiological Materials

INL researchers are exceeding expectations in the safeguarding and security of nuclear and radiological materials to enable the achievement of national nonproliferation objectives for the future peaceful use of nuclear materials for energy generation, industry/medical/research applications, and national security. Examples include:

- A cross-laboratory INL team in a national effort of federal organizations and national laboratories, coordinated by the National Nuclear Security Administration Off-Site Source Recovery Project, secured 50,000 curies of Cs-137 irradiators from a decommissioned industrial facility in Mexico and transported the irradiators to the Nevada National Security Site for safe and secured storage. INL and

Los Alamos National Laboratory provided expertise in support of the removal of 100 Ci of radioactive isotope Cobalt-60 from an industrial facility in Maryland. Securing the radioactive source, a pencil-sized stainless steel capsule, surpassed the one millionth curie (Ci) milestone for the Off-Site Source Recovery Project in recovering disused and unwanted radioactive sources from domestic sites.

- INL emergency responders, as part of the DOE Region 6 Radiological Assistance Program Team, deployed to 26 training, exercise and national response events. These deployments by personnel from DOE-ID, INL's Lab Protection, N&HS, Energy and Environment Science and Technology (EES&T) and Environment, Safety, Health and Quality (ESH&Q), CH2M-WG Idaho, LLC (CWI) and CH2M included (a) support to the U.S. Nuclear Regulatory Commission, Region 10 Environmental Protection Agency, and the State of Idaho Department of Environmental Quality in the investigation and characterization of a radiologically contaminated residence in Boise, Idaho; (b) training for the Medical Emergency Radiological Response Team in Caldwell, Idaho; and (c) exercise support during the Rocky Mountain Airshow and the Air Force Academy Graduation in Colorado.
- Five INL staff supported the National Technical Nuclear Forensics task force, whose mission supports Annex IV to National Security Presidential Directive-17/HSPD-4, in a field deployment exercise held in Long Beach California. INL supports the task force with radioactive material subject matter experts, field analysts, debris collection, and health physics expertise.
- INL continues to provide expertise and access to facilities and materials to train national and international personnel to perform effectively during nuclear and radiological events and inspections. INL conducted the *5th annual Pre-inspector Course* to prepare participants for assignments at the IAEA; more than 25 courses for radiological dispersal device response training or radiography training to prepare emergency responders within the FBI, DoD, and state hazardous material (HAZMAT) units; and four other federal emergency responders courses/personnel on the operations and system design characteristics in anticipation of an event within nuclear fuel cycle facilities.
- INL's program leadership enabled NNSA to achieve a historic milestone for the Russian Research Fuel Return Program by completing the removal of all highly enriched uranium from Uzbekistan and a program goal for the Global Threat Reduction Initiative with the removal of spent nuclear fuel containing 36 kilogram of highly enriched uranium from the Institute of Nuclear Physics in Almaty, Kazakhstan. In completion of these NNSA programmatic objectives, INL supported NNSA in coordinating several years of collaboration between the host countries, multiple laboratories, Russia, and the IAEA.

Dr. Igor Bolshinsky readying the cask for transport.

- Due to significant contributions from INL program leadership, The Ukrainian National Academy of Sciences, NNSA, and the U.S. Department of State achieved another significant nuclear nonproliferation milestone in establishing the Neutron Source Facility at the Kharkiv Institute for Physics and Technology. The dedication ceremony for this facility significantly advanced the progress of U.S. commitments made during the 2010 Nuclear Summit for joint U.S.-Ukrainian technical cooperation.

- In support of NNSA's Material Management and Minimization (M3) Domestic Reactor Conversion Program, INL made significant progress in the success of science, engineering, and program management for the development and deployment of LEU nuclear fuels. Examples include:
  - For the TREAT Conversion Project, INL successfully produced 1-in. × 1-in. TREAT fuel blocks for demonstrating a viable manufacturing process for potential core conversion to LEU.
  - Accelerated project schedules for the removal of HEU were coordinated for the low-flux miniature neutron source reactor in Ghana and the return of spent nuclear fuels from Uzbekistan, Georgia, and Poland.
  - INL released reports, "The Functional and Operational Requirements for the Low Enriched Monolithic Fuel Plates (FOR-158, Revision 0)," and "AFIP-6 MkII PIE Summary Report" meeting a NNSA Level 1 milestone for the prototypic scale test at bounding power to high burnup of monolithic fuel design; and a briefing to the National Academy of Sciences review committee in support of a study on the current status of and progress toward eliminating HEU use in fuel for civilian research and test reactors.
  - INL supported the resolution of the bilateral information exchange agreement between DOE and the Republic of Korea (ROK) and hosted several technical paper discussion forums for the Joint Fuel Cycle Studies Program. These discussions align with the interests in the U.S. and ROK in advancing the early-stage technical understanding of experimental electrochemical reprocessing, (pyroprocessing) and PIE. INL also hosted the 10th meeting of the Electrochemical Recycling and Safeguards and Security Working Groups as part of the Joint Fuel Cycle Studies between the U.S. and ROK.

Defense and Intelligence Community

INL is achieving primary mission objectives in conducting research and delivering applied solutions and products that meet and exceed the technology requirements for Defense and Intelligence Community organizations. INL's efforts result in information analyses and products that enable regulatory agencies, military planners, and counterintelligence officers to anticipate threats, adjust strategies and tactics, and enhance command and control; deployment of advanced, force-multiplying technologies that result in technical superiority of our military, law enforcement and counterterrorism forces; increased confidence in the effectiveness of our nonproliferation and counterproliferation programs; and improved training and technical capabilities of INL's emergency management and public safety first responders.

Specific Manufacturing Capability

As the Abrams Armor Center of Excellence for the U.S. Army, INL's Specific Manufacturing Capability (SMC) met all production requirements and product quality delivery expectations for the production of heavy armor for Abrams Main Battle Tank Program. SMC's ability to respond and react to unscheduled technical challenges, events and changing boundary conditions from the U.S. Army customer was outstanding.

- The history of SMC production excellence, engineering innovation, unique infrastructure, and process adaptability enabled the U.S. Army to award SMC a Foreign Military Sales contract for 151 armor assemblies for the Moroccan government.
- In anticipation of Abrams commitments for increased armor production for the Engineering Change Proposal 1 program and Foreign Military Sales, SMC developed an aggressive hiring plan to obtain 55 additional employees in FY 2016 increasing personnel by nearly 50%.
- SMC achieved the milestone of 30 years of manufacturing excellence, completion that was recognized during a ceremony attended by SMC employees and leadership and representatives from INL, DOE, and the U.S. Army. In addition to that significant event, the SMC project has been operating for over a year without a lost-time accident.
- SMC is a major component in the effort to provide vital information about war fighter survivability in attacks on the Abram Battle Tank in urban settings. Recently SMC supported an Army Test Evaluation Command request to determine possible advantages and cost savings by providing advanced computer modeling and simulation exercises as a possible replacement to certain aspects of live fire tests and evaluations.

INL's patent-pending transformer protection solution is proven to address current threats and designed for easy modifications of future threats.

- SMC developed two innovations conceived within INL LDRD's program: (1) bainite steel—material capable of withstanding ballistic threats at a reduced weight—was to be included in the *U.S. Army Tank Automotive, Research, Development and Engineering Center's Capabilities Handbook*, a compendium of current and future force capabilities for ground vehicle systems; and (2) transformer protection, a patent-pending armor system capable of protecting electrical utilities substations from ballistic threats, was presented during an invited talk at the *Power Grid Resilience Conference*.

Growth in Support to the Intelligence Community and DoD

INL is enabling the U.S. Intelligence Community and Department of Defense to understand threats and assess the risks to the nation's critical infrastructure. Examples of achievements include:

- Many Intelligence Community programs experienced project expansion of scope and funding to deliver regular and ad hoc threat analyses and expert consultation on evolving national security challenges. These efforts include participation in the development and augmentation of issues reported in the President's Daily Brief. This program growth is a result of INL's novel threat analysis methodologies, including a unique integration of analysts, operations engineers, and cyber researchers.
- INL threat analysts and cyber researchers provided thought leadership in the formation and evolution of exercises and new programs for the DoD Cyber Awakening, 10th Fleet, Pacific Command (PACOM), DoD Control Systems Community of Interest, and others.
- INL's threat analysis capabilities also resulted in new collaborative programs between DOE's Office and Intelligence and Counterintelligence and its peer organizations within DOE (i.e., DOE-OE, DOE-NE, DOE Office of Science [SC], etc.) These collaborative efforts engage multiple DOE national laboratories and private sector companies and organizations.

- INL researchers provided presentations at two national events in support of advancing DOE IN's strategy of building recognition of DOE's National Laboratory capabilities. These events included (1) a presentation to the Director of National Intelligence's Science and Technology Directorate and National Intelligence Science and Technology Committee; (2) presentations with DOE Office of Intelligence and Counterintelligence and several national laboratories during the Director of National Intelligence's Intelligence Community Science and Technology (S&T) Expo to Congressional leaders; and (3) presentations at the *NSA Power Grid Security Workshop* to assist in the creation of a new threat analysis and information sharing framework between utilities.

Research Products deployed to the Military

Other examples of products that were developed by INL and fielded for military solutions include:

- INL successfully implemented innovations in data integration and visualization, communication linkages and machine-to-machine interfaces into multiple products delivered to the 453rd Electronic Warfare Squadron and other military organizations. With delivery of the Improved Many on Many (IMOM) Versions 7.7.1, 7.7.2, and enhanced version builds, the U.S. Air Force has deployed enhanced air combat mission planning capabilities that protect mission assets while meeting critical information assurance objectives. Other products and upgrades that were delivered include the Survivor Broadcast Overlay Tool, the Tactical Display Framework, and Distributed Information Operations Constructive Environment (DICE) Version 3.8. In addition to mission planning and mission operations capabilities for the U.S. Air Force, INL's innovations have enabled the successful transition of these products into new applications for military communities responsible for special operations and combat search and rescue.
- INL delivered two versions of Change Detection System products to U.S. Government organizations for use in the field during military surveillance and tactical operations. INL followed-up delivery of these systems with training and is supporting the end users' field testing and evaluation. The sponsoring organizations have provided positive feedback of the performance of the systems and intend to support follow-on projects for additional applications and system enhancements.
- INL's Portable Isotopic Neutron Spectroscopy (PINS) research team provided real-time reach-back response to the U.S. Army for the identification of suspect chemical munitions. Expert consultations supported Army responses for the safe disposition of materiel identified at Tooele Army Depot, Utah; Dover Air Force Base, Delaware; Fort Ord, California; the Spring Valley neighborhood of Washington, DC; and the former Indiana Army Munition Plant, Indiana. At Fort Ord, an engineered innovation of the PINS stand was used to assist the operator to avoid touching the munition under test and producing a chemical release. At Dover Air Force Base, a prototype of the PINS-3 DT system was used to better characterize an artillery shell recovered from the ocean.

Recognitions and Awards

Recognitions and awards from October 2014 through September 2015 are provided below. Details from the first half of the year may be found in the mid-year report.

Dr. Ron Fisher

- Admiral Rogers, Commander USCYBERCOM/Director National Security Agency, publically thanked INL for its unique and significant contributions to national security during the summer meeting of the Industrial Control Systems Joint Working Group.
- Dr. Ron Fisher was commended by the National Infrastructure Advisory Council Chairs, Constance Laue and Dr. Beverly Scott, for his contributions to the National Critical Infrastructure Security and Resilience Research and Development Plan Working Group.
- Jennifer Turnage and the N&HS Emergency Response and Readiness staff was applauded for successful radiological response training by the U.S. Army Medical Department, Chief of Chemical, Biological, Radiological, and Nuclear Science Branch.
- Dr. Igor Bolshinsky received a special medal for contributions in establishing the Neutron Source Facility at the Kharkiv Institute for Physics and Technology.

Dr. Igor Bolshinsky

- INL's "dedication, capabilities, and expertise" were acknowledge by the Director of the Idaho Bureau of Homeland Security, Brigadier General, Brad Richy in a November 2014 letter supporting INL's request to deploy Band 14 on the Wireless Test Bed:

> *"The wireless range, and the lab, has demonstrated their commitment to public safety in Idaho and across the nation…they maintain extensive experience in wireless, cyber security [sic], and disaster management. This commitment and expertise uniquely enable the lab to be an asset to the national effort to bring dedicated wireless broadband to public safety users across the country."*

- DOE Deputy Secretary Elizabeth Sherwood-Randall recognized INL's unique infrastructure during the February 2015 *White House Cybersecurity Summit*:

> *"…Our National Labs also conduct cutting-edge research on cybersecurity questions – I recently visited Idaho National Laboratory, where we have a test bed with real equipment, grid-scale, where we test equipment for use in the energy sector, and we conduct live, real-time exercises as trainings for private-sector security experts…"*

- Paul Moskowitz was assigned to lead a mutli-laboratory team for NNSA aimed at developing new/alternative design basis threats needed for source protection and prioritization activities. In addition, Paul was presented a certificate of appreciation by the DOE-IN Deputy Director for Cyber, Vergle L. Gipson:

  > *"Your initiative, subject matter expertise, and collaboration have categorically benefited DOE's cyber intelligence efforts in protecting critical national assets from cyber threats."*

- Cherrie Black was recognized by National Infrastructure Advisory Council (NIAC) Transportation Resilience Working Group Chair, Dr. Beverly Scott, and NIAC Transportation Resilience Study Group Chair, Mr. Ted Basta, for her contributions to the NIAC Transportation Resilience Study Group, the findings from which informed the final report delivered to the White House in July 2015.
- Brent Stacey was assigned to assist the Idaho Cybersecurity Cabinet Taskforce created by Idaho Governor C. L. "Butch" Otter. The taskforce will support the development of policies, programs, and strategies to detect vulnerability, prevent attacks, and protect state governmental networks.
- INL was recognized by Federal Energy Regulatory Commission Commissioner Cheryl A. LaFleur in her press statement on "Development of Supply Chair Cyber Controls in New Reliability Standards."

  > *"I would like to recognize the Idaho National Laboratory…the trip highlighted the important research and development work done at the Department of Energy, as well as the opportunities for collaborative work between public and private sectors to protect critical grid assets."*

- Dan Elmore became a senior member of the Institute of Electrical and Electronics Engineers (IEEE). Senior Member is the highest professional IEEE grade that reflects the experience and professional accomplishments of the member – only 9% of IEEE nearly half a million members receives this high recognition.
- Dr. Daniel Devasirvatham was selected to participate in the Association of Public Communications Officials International's Awards Committee and the National Spectrum Consortium's Testing Assessment Working Group.

Cherrie Black

Brent Stacey

Dan Elmore

Notable Outcomes

Notable Outcome 1.2.A.

DHS renewed the Strategic Partnership Program Agreement for INL to provide programmatic and technical leadership supporting operations for DHS ICS-CERT. The DHS National Protection and Programs Directorate Office of Cybersecurity and Communications recognized the impact of INL's programmatic achievements and world-class control systems security capabilities by issuing an Interagency Agreement for central management and oversight of the ICS-CERT Program. This 5-year agreement enables the continuation of the mutual mission success of DHS, DOE, and INL in assuring the cybersecurity, resiliency, and reliability of the nation's power grid and other critical infrastructure.

1.2 A

INL will secure continued collaboration with the Department of Homeland Security and advance its leadership role in protecting the nation's critical infrastructure through a renewal of the Work for Others Agreement to operate the Industrial Control Systems-Cyber Emergency Response Team (ICS-CERT).

INL and DOE-ID mutually agreed in the May-June PEMP Monthly report that this notable outcome was achieved as a result of the renewal of the 5-year Inter-Agency Agreement/renewal of its Work For Others agreement with the Department of Homeland Security that covers the efforts of the Industrial Control Systems-Cyber Emergency Response Team (ICS-CERT) (CCN 235512).

Publications

Research results were published in a diverse set of prestigious journals enhancing INL's reputation as a world-class energy laboratory. INL staff published 25 peer reviewed articles in prestigious journals in FY 2015. The number does not include many other publications that are accepted but not yet published, publications in conference or workshop proceedings, or reports and presentations that were approved for limited distribution.

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Efficient and Effective Mission Accomplishment

1.3: Science and Technology Addressing Broad DOE Missions

OBJECTIVE 1.3: SCIENCE AND TECHNOLOGY ADDRESSING BROAD DOE MISSIONS

Lead and implement relevant, high impact RDD&D programs. Establish the INL as a multi-program National Laboratory with world-class nuclear capabilities. The primary focus areas include, but are not limited to the following:

- **Science based performance assessment for energy storage and bioenergy systems;**
- **Clean energy integration design, test, control, and validation; and**
- **Energy critical materials.**

Accomplishments

Overall, INL Science and Technology Addressing Broad DOE Missions significantly exceeded expectations resulting in clear, positive impact for INL, DOE, and industry. INL made a positive impact on DOE's mission to improved U.S. energy security and industrial competitiveness. In doing so, INL demonstrated significant innovation leveraging the Laboratory's core capabilities and competencies with science and technology achievement to accelerate the deployment of advanced transportation technology, providing U.S. industry a competitive advantage with new and improved water reuse/recycle technology, illustrating new technology and methods for cost effective energy system integration, and helping mitigate the impacts of energy/energy-water activities on the environment. As a result, INL is recognized by industry as a leader in electric vehicle (EV) system performance science, diagnostics, and testing and continues to be a recognized national leader in the development of hybrid energy integration and renewable energy systems.

INL's technical expertise in clean energy integration helped the DoD deploy over 1,000 megawatts of renewable solar and wind energy at defense sites around the world. INL completed studies on the value of nuclear based Hybrid Energy Systems with high renewable energy use for Utah, Wyoming, Texas, and Arizona. INL also performed the first-of-a-kind geographically dispersed Real-Time Digital Simulators (RTDS) tests with the National Renewable Energy Laboratory (NREL) simulating the impact of renewable energy systems on power grid performance. Wireless vehicle charging test capabilities were also successfully integrated with the INL/NREL real-time simulator capabilities.

Wireless charging test for Chevy Volt.

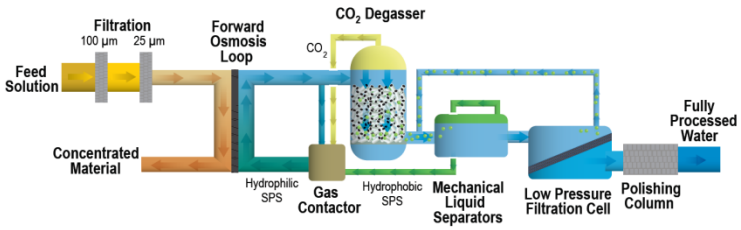
Examples of industry and national impact include the issuing of over 90 vehicle test report fact sheets based on this research that lower the barriers to advanced vehicle deployment by informing DOE and industry of the latest "on-road" testing results of vehicle technologies. INL's science-based performance assessment activities were recognized by USCAR as a "top accomplishment" for improving the understanding of new transportation technologies and the National Academy of Science cited INL's research numerous times as a leader in energy storage technology assessment.

INL's "Plugged In: How Americans Charge their Electric Vehicles" was issued in September, 2015. Performing the research that led to the report required unprecedented collaboration with automotive original equipment manufacturers (OEMs). None of the OEMs had ever shared proprietary data before and the fact that they shared that data with INL exemplifies outstanding merit, confidence, and trust industry has with INL. Technologically, the data sharing required the development of special, high quality, and first-of-a-kind secure data transfer methods.

EERE's depiction of Biomass to Fuels.

The Biomass Feedstock National User Facility (BFNUF) completed key technology demonstrations for industry including the 200 ton bioenergy byproduct process test for DuPont and the 20 ton process test of post-sorted municipal solid waste (MSW) for InnerPoint Energy Corporation. In keeping with DOE's national laboratory impact goals, these demonstrations helped validate and significantly accelerated the deployment of new technology by industry.

INL's R&D 100 Award winning technology, Switchable Polarity Solvent Forward Osmosis (SPS FO), was licensed to industry for recycling waste water from industrial processes. In collaboration with an industry partner, a new Forward Osmosis-Reverse Osmosis process module was installed at EIL. This system represents a new capability at INL and is the first step in scale-up of the SPS FO process to purify industrial waste water at a fraction of the cost of today's conventional technology.



Switchable Polarity Solvent Forward Osmosis process schematic.

The Critical Materials Institute (CMI) continued to demonstrate significant technology based leadership. For example, INL researcher Yoshiko Fujita led a *Goldschmidt 2015 Conference* session on "Strategic metals: New insights into the biogeochemistry of the Rare Earth Elements." In addition, INL researchers developed a creative new technology that aids in the recycling, recovery, and extraction of rare earth minerals licensed to U.S. Rare Earths, Inc.

Testing of a novel new radon detection method for the Environmental Protection Agency (EPA) was completed. The method simplifies the detection of active subsurface fractures that transport radon gas to the earth's surface. INL also completed the design analyses for the Remote-Handled Low-Level Waste (RH-LLW) Disposal Facility. If approved, the facility would be the first capital asset project built under the new DOE Order 435.1, "Radioactive Waste Management," at INL.

Science-based Performance Assessment for Energy Storage

INL is accelerating technology development and deployment by the automotive industry by lowering barriers to advanced vehicle deployment. Research accomplishments, capability enhancement, and industry impact in this area of important technology exceeded expectations. This is illustrated by the fact that INL received the Office of Energy Efficiency and Renewable Energy (EERE) - Vehicle Technology Office (VTO) **"Distinguished Achievement Award"** this year. The award was given for the work with industry and multiple other stakeholders to collect, evaluate, and disseminate independent real-world data on the benefits of plug-in electric vehicles (PEV) over the past several years. This award was presented at the national *VTO Annual Merit Review and Peer Evaluation Meeting* in front of over 2000 participants from other national laboratories and industry collaborators. Other specific examples of impact include:

National Academies of Science cited INL's PEV research. The National Research Council of the National Academies of Science released the report, "Overcoming Barriers to Deployment of Plug-in Electric Vehicles." This report resulted from a 2-year study conducted by the NRC for DOE and makes recommendations to the federal government on actions to take or to avoid to enable the adoption of PEVs by the mass market. INL's research related to PEVss and charging infrastructure was cited 17 times in the report.

INL held the first national EERE "Tech-to-Market (T2M)" Workshop. The workshop showcased the performance science-based work that INL provides when validating the performance of energy storage devices. Numerous industry representatives attended the event, including automotive manufacturers (Ford, General Motors and Fiat-Chrysler), energy storage companies/suppliers, utilities, academia, and the Society of Automotive Engineers.

Two INL-developed industry standard battery test manuals were published. The manuals provide standardized test procedures for different automotive energy storage applications and provide a centralized point that can be used for evaluating different battery technologies. As the primary author of the manuals, INL serves a key role in driving the path of energy storage testing and maintains a leadership position when it comes to independent evaluation of emerging technologies.

INL's electric vehicle research broadly supported U.S. government agency deployment across the country. This research and subsequent reporting focused on agency transportation fleets to identify daily operational characteristics of select vehicles and reported findings on vehicle and mission characterizations to support the successful introduction of PEVs for agency deployment. For example, for the Navy, INL published the report "AVTA Federal Fleet PEV Readiness Data Logging and Characterization Study for the U.S. Department of Navy" (INL/EXT-15-36439) and provided it to Pentagon officials. The report covers the evaluation of data from 73 internal combustion engine federal fleet vehicles operating in four Marine Corps fleets in Southern California and will be used to validate the introduction and use of advanced battery electric vehicles (BEV) in fleet applications.

INL significantly expanded the capability to evaluate and characterize PEVs and charging infrastructure. Following an FY 2015 third and fourth-quarter facility upgrade, INL's Electric Vehicle Infrastructure laboratory has increased the capacity to concurrently evaluate and characterize charging infrastructure for system efficiency, electrical power quality, electro-magnetic field, cybersecurity vulnerabilities, and integration with renewable energy resources. Researchers at Electric Vehicle Infrastructure laboratory are supporting industry codes and standards development in an effort to accelerate the adoption of PEVs.

INL's new Electric Vehicle Infrastructure Laboratory.

INL supported the California Air Resources Board (CARB) about zero emission vehicle (ZEV) credits. At the request of the CARB, INL presented analysis results of PEV driving data at multiple CARB meetings to support deliberations with automakers how ZEV credits could be redefined. A revision to ZEV regulations on cars sold in compliant states (California – lead, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, and Vermont) would potentially shift billions of R&D dollars at the various automakers.

California Environmental Protection Agency
Air Resources Board

Data collected by INL provided insight regarding real-world usage of electric vehicle supply equipment (EVSE). The data and lessons learned were captured in two INL whitepapers entitled, "Analyzing Public Charging Venues: Where are Publicly Accessible Charging Stations Located and How Have They Been Used?" and "Categorizing EVSE Venues: Describing Publicly Accessible Charging Station Locations." Stakeholders interested in providing Alternating Current (AC) Level 2 EVSE units and Direct Current Fast Charge (DCFC) look to INL to analyze data collected from Blink, ChargePoint, and AeroVironment EVSE installed around the U.S. as part of PEV charging infrastructure demonstrations.

Chevy Volt "plugged in" charging test.

Important research and analysis results of the **Chevrolet Volt** and **Nissan Leaf** testing helped fill gaps in industry knowledge, and provide help for those promoting PEV technologies including DOE, auto makers, and electric utilities. The reports included:

- "What Kind of Charging Infrastructure Did Nissan Leaf Drivers in The EV Project Use and When Did They Use It?," and "What Kind of Charging Infrastructure Did Chevrolet Volt Drivers in The EV Project Use and When Did They Use It?" helped fill a gap between how much EV charging infrastructure is needed to support wide-spread EV adoption, and what existing EV owners are using. The papers summarize real-world EV charging behavior of over 6,000 vehicles across the U.S.

Car show unveiling of advanced electric vehicle.

- "Driving and Charging Behavior of Nissan Leaf in the EV Project with Access to Workplace Charging," (INL/EXT-14-33700) was published for DOE as technical guidance to industry partners of DOE's Workplace Charging Challenge. The paper draws conclusions from data collected from privately owned BEV whose drivers charge their vehicles at home and work. This study found that workplace charging infrastructure enables BEV owners to complete long daily commutes that would otherwise be impossible. Workplace charging is also an effective range-extending tool to allow drivers to run errands and meet other travel needs above and beyond their normal commute using only electricity. The DOE Workplace Charging Challenge is a high-profile initiative for DOE and the administration.

INL provided an invited presentation and facilitated panel discussions at the **DOE Workplace Charging Challenge Summit** focused on workplace charging lessons learned through the nation's largest PEV charging projects. The summit provided the opportunity for industries such as Google, Coca-Cola, Facebook, 3M, and many others to exchange best practices. This provided INL an opportunity to build the Laboratory's reputation as experts in understanding the PEV technology and the national leader for real-world performance science data collection and analysis programs.

INL posted over 90 accelerated testing, maintenance, and overall cost of ownership fact sheets to the **Advanced Vehicle Testing Activity** website (avt.inl.gov) to update DOE's Vehicle Technologies Office and test report readers with the latest results of continuing on road testing of serval different vehicle technologies. These at-a-glance updates show monthly and cumulative mileage, fuel economy, and operating costs for each group of vehicle make and model under test. Trends in fuel consumption for internal combustion engine powered vehicles (Hybrid Electric and Alternative Fuel) can be seen, and the progress toward completion can be monitored. The primary goal is to provide data for technology modeling, and R&D programs, by benchmarking and validating the performance of vehicles that feature one or more advanced technology such as plug-in hybrid electric vehicle technologies. By benchmarking the performance and capabilities of advanced technologies, INL supports and accelerates the development of industry and DOE technology targets.

Science-based Performance Assessment for Bioenergy System

The INL Biomass Program and the BFNUF conducted numerous proof-of-concept and demonstration tests for U.S. industry and DOE, providing advances that are significantly accelerating DOE missions to establish a sustainable U.S. bioenergy economy. BFNUF research activities accelerated the understanding of biomass technologies and refined industrial performance of feedstock supply systems, including the following key accomplishments:

For **DuPont**, BFNUF generated over 200 tons of prototype product for a follow-on test action supporting DuPont as they deploy a co-product production process at their cellulosic ethanol plant in Nevada, Iowa. INL received very positive feedback on user facility capabilities and the opportunities provided to industry to access these capabilities. David Wood, DuPont's Cellulosic Ethanol Program Manager said, "We greatly appreciate the support and expertise of the INL team. INL's facility offered a unique opportunity to scale up some portions of our process to enable key learnings."

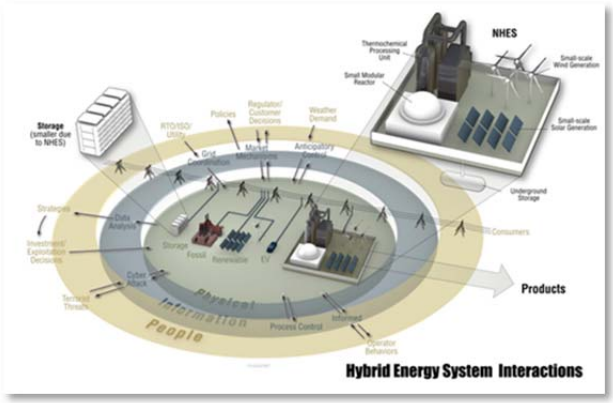
For **InnerPoint Energy Corporation**, BFNUF processed approximately 20 tons of post-sorted MSW. Preprocessing MSW at this scale and with Process Demonstration Unit-based processes is a first for the INL BFNUF, the data and materials generated from this project will provide R&D impact to the DOE Bioenergy Technologies Office and the industry collaborator.

For **COGENT Energy Systems**, BFNUF identified correlations between feedstock quality attributes and feedstock performance in downstream energy conversion processes. The project leveraged INL's feedstock formatting and characterization expertise with COGENT Energy System's modular gasification process.

For **Procter and Gamble (P&G)**, BFNUF established a funds-in CRADA to develop an actionable business case for renewable resource utilization first for P&G's Box Elder facility and then for P&G in general. The scope includes resource assessments of biomass feedstocks and wind/solar, biomass conversion options for heat and power, and an overall logistics model for the region.

Clean Energy Integration Design, Test, Control, and Validation

INL continued to demonstrate significant and sustained strategic leadership producing the influential results needed to advance the future foundations for clean energy integration research. Performance during this period supported development hybrid energy systems concepts and technology development connecting nuclear energy as an integral part of those systems.



Schematic of a hypothetical hybrid energy system.

INL researchers successfully established communication between geographically distributed RTDS at NREL. This new inter-lab capability enables the modeling of power grids in greater detail by allowing software and equipment anywhere in the world to establish a real-time connection to the unique facilities and capabilities available within the DOE national laboratory complex. Researchers also successfully integrated RTDS with the wireless vehicle charging capabilities at Energy Systems Laboratory (ESL). This one-of-a-kind capability enables the integration of vehicle charging patterns based on actual hardware in analyzing impacts on electric grids. RTDSs interact with the wireless vehicle charging equipment via a "Grid Emulator" that acts as an amplifier creating the necessary simulated "grid events." This capability enables INL to analyze dynamic impact of large number of vehicles on practical networks under real-world conditions.

INL proposal the top pick by the California Energy Commission (CEC). The proposal titled, "Demonstrating a Secure, Reliable, Low-Carbon Community Microgrid at the Blue Lake Rancheria," was the winner of the "Demonstrating Secure, Reliable Microgrids and Grid-Linked Electric Vehicles to Build Resilient, Low-Carbon Facilities and Communities" (PON-14-301) proposal. The proposal team members are Humboldt State University, Siemens-Energy Management Division, Blue Lake Rancheria Indian Reservation, Pacific Gas and Electric Co., Tesla Motors, and INL.

Real-Time Digital System installed at the Energy Systems Laboratory.

A new leadership class Dynamic Modeling & Simulation Tool Set was developed. INL has established new dynamic energy systems integration modeling and simulation capabilities that previously were not available. These tools are the basis for cross-cutting DOE programs addressing nuclear energy utilization in hybrid energy systems, grid modernization, and hydrogen production on a national scale. This accomplishment has resulted in a nationally distributed modeling team comprised of INL, NREL, ORNL, ANL, North Carolina State University, and Georgia State Institute of Technology.

Two dynamic energy systems modeling case studies were completed. The studies are summarized in the report entitled, "Nuclear Hybrid Energy Systems Regional Studies: West Texas and Northeastern Arizona" (INL/EXT-15-34503). The case studies relied on the INL programming and analysis capability of the **Modelica Modeling Language** to analyze two regional case studies: one combining a Pressurized Water Reactor with wind and natural gas resources in the Texas Panhandle to produce electricity and gasoline in response to time-dependent market trends, and a second case combining a Pressurized Water Reactor with solar photovoltaic (PV) in Arizona to produce electricity and fresh water from brackish aquifer in northeast Arizona. Modelica was used to simulate process details with component and systems supervisory control logic and algorithms that optimize solutions according to economic and technical design criteria and goals. The effort caps several years of effort to develop and apply Modelica-based dynamic codes to the design, operation, optimization, and assessment of realistic hybrid energy systems.

INL provided significant renewable energy/grid integration technical expertise to DoD. INL renewable energy and power systems experts provided technical input at varying levels for over 25 of the Army, Navy, and Air Force Energy Conservation Investment Program (ECIP) projects performing systems integration, electrical/economic modeling analyses, and performance design/requirements development. INL serves as a major technical advisor and contributor to these ECIP and R&D projects that will total over $200M when completed.

Interaction with renewable energy and traditional grid infrastructure.

INL rescued DoD Solar Power Project. INL researchers helped get a $9 million solar power project at Tooele Army Depot in Utah back on track. The 1.5 megawatt concentrated solar project started up in FY 2014 and operated a few months before weather, moisture, and some design issues caused the control modules to fail, idling power generation. INL's experts developed a design fix for the control module enclosures and electronics, which was implemented in early FY 2015. Those eight are operating consistently and the U.S. Army plans to use INL technology on the remaining solar modules.

INL completed the report titled, "Field Test Results on INL Test of ZBB Battery for U.S. Navy Hybrid Power System Applications," (INL/MIS-14-33472) for the Office of Naval Research (Navy). The Navy has several ongoing projects (such as ZBB Energy's new concept flow battery project) where they are testing various battery and other energy storage technologies in application-based environments. INL is supporting the Navy in regards to usages within microgrids or island grids with higher levels of renewable energy generation and penetration. INL provides independent, third-party technical expertise, advise, testing, and verification/validation for components and systems integration. We also assist with system modeling, system development and integration considerations.

Schematic of geothermal energy system.

INL was selected for Phase 1 Observatory for Research in Geothermal Energy (FORGE) award. The INL/Center for Advanced Energy Studies (CAES) led Snake River Geothermal Consortium (SRGC) was selected by DOE- EERE's Geothermal Technologies Office (GTO) for FORGE award funding. The award allows the SRGC team to study the feasibility of establishing an enhanced geothermal system (EGS) field laboratory at INL.

A 3-year project to test a novel application of CR-39 to determine conditions impacting ground water quality was completed. The tests conducted for EPA Regions 1 and 10, evaluated the application of inexpensive, off-the-shelf technology CR-39 radon detectors to identify active subsurface fractures capable of transporting contaminants to the surface.

A Geothermometry study has been completed that enables more accurate estimates of geothermal reservoir temperatures. This work is important to better understanding of the availability of the geothermal reservoir as a potential clean energy source.

Energy Critical Materials

INL worked with DOE-EERE and industry to provide U.S. manufacturers a competitive advantage in rapidly evolving global clean energy and energy-efficient manufacturing markets. INL's expertise in chemical and materials separations science addresses critical resource availability, reuse, substitution, and security challenges. INL's process systems science and engineering coupled experimental validation, modeling/simulation, and applied high-performance computing will create technology advancements needed for "net-zero" manufacturing capabilities. Also, INL's expertise in materials performance in harsh environments and expertise in membrane science will lead to 80% reductions in manufacturing water consumption in the future.

All Critical Materials Institute (CMI) projects are on schedule and all deliverable were completed as planned this performance year. INL continued to demonstrate science leadership and research that is helping resolve key technology issues critical to U.S. energy security.

INL hosted the Critical Materials Institute (CMI) Annual Review Meeting. INL hosted more than 100 researchers from universities, industry, and laboratories for the CMI's annual review meeting. Over the past 2 years, CMI researchers have filed 34 invention disclosures and nine patent applications.

New metal oxide reduction technology capability established. CMI researchers established a new metal oxide reduction research capability as a "shared use facility" located at the CAES. This is an excellent example of EERE/NE collaboration and leveraging of mutual capabilities with CMI. With the new system, researchers will work with industry to evaluate lower energy methods of performing the oxide reductions—one step for producing rare earth element metals that continues to be a challenge from an energy and chemicals consumption perspective.

Dr. Ted Lister, Critical Materials chemist.

New technology that aids in the recycling, recovery and extraction of rare earth minerals was developed and licensed to industry. The membrane-based solvent extraction technology was invented by CMI, INL, and ORNL collaborators and is the first commercially licensed technology developed via CMI. The new technology aids in the recycling, recovery, and extraction of rare earth minerals has been licensed to U.S. Rare Earths, Inc. The technology uses hollow fiber membranes, organic solvents and neutral extractants to recover rare-earth elements such as

neodymium, dysprosium, and praseodymium, which are used in permanent magnets for cars, cell phones, hard disk drives, computers, and electric motors.

Researchers from INL, ORNL, Ames, Lawrence Livermore National Laboratory (LLNL), and Colorado School of Mines recently traveled to Japan to deepen and broaden U.S./Japanese collaborations to jointly develop recovery and recycling technologies for the rare earth elements. Each country has goals to minimize material losses by recovering and effectively recycling the materials/elements from waste streams. The visit and associated meetings with academic, industrial, and national laboratory personnel furthered collaborations between the countries. Discussions were held with the Japanese Ministry of Economy Trade and Industry, Sendai (Tohoku University); the Japanese Association for Iron and Steel Technology; Nippon Magnetic Dressing Co., Ltd.; Japan Recycling Light Technology and System Company, Ltd.; Kitakyushu Metal Industry Co., Ltd.; and Tokyo Eco Recycle Co., Ltd.

U.S. Rare Earths
MINING THE FUTURE

The Global Threat Reduction Initiative's Off-Site Source Recovery Project has now recovered more than 1 million curies of radioactive materials cumulatively from sites throughout the United States. About 100,000 nationally significant dirty bombs worth of material was recovered. This effort is part of the National Nuclear Security Administration Office of Global Material Security's Off-Site Source Recovery Project.

Recognition and Awards

Dr. Anne Gaffney received the *2015 Eugene J. Houdry Award* of the North American Catalysis Society, which recognizes and encourages individual contributions in the field of catalysis with emphasis on the development of new and improved catalysts and processes representing outstanding advances in their useful application. The award was presented at the 24th North American Meeting of the Catalysis Society to be held in Pittsburgh, Pennsylvania.

Dr. Anne Gaffney.

INL is recognized for "Pressure Vessel Code Case" technical leadership by the American Society of Mechanical Engineers Boiler. Richard Wright leads the code case (standard) development effort for Alloy 617 for elevated temperature nuclear applications and participating in related nuclear materials committees. Jill Wright is leading the code case development effort for Alloy 617 for low-temperature nuclear applications. Tim Roney serves as a committee member for the special working group on reliability and integrity management to support development of requirements for a reliability and integrity management program for nuclear power plants. This leadership will lead to the first new nuclear materials application code case in the U.S. in 25 years. When approved by ASME, Alloy 617 will be just the sixth material, and first nickel alloy, to be qualified for Code use in high-temperature nuclear components. It will increase the design limit above the current highest allowed temperature of 750°C, and will enable construction of components for high-temperature gas-cooled reactors for conditions that are currently impossible.

Demonstrating INL's leadership in science based energy storage testing and analysis, United States Council for Automotive Research (USCAR) presented the *2014 Research Partner Award* to Dr. Jon Christophersen for "excellence in leadership and innovation." The USABC chair (Ron Elder, Chrysler) nominated him for this award and acknowledging a DOE researcher in this way is for the most part unprecedented. In addition, INL's report on the 12-V Auxiliary Load study for the U.S. DRIVE Vehicle Systems Analysis Tech Team (VSATT) was selected as one of the top yearly VSATT accomplishments.

INL's research on the 12-V auxiliary loads was called out as a top accomplishment this year. The study was performed by Barney Carlson for the U.S. DRIVE Vehicle Systems Analysis Tech Team (VSATT) was selected as one of the top yearly VSATT accomplishments. This is noteworthy recognition from industry as represented by USCAR who published the final version of the summary.

INL battery diagnostic tool named as R&D 100 finalist. INL's CellSage technology has been named as a finalist for the 2015 R&D 100 Awards. Developed by researcher Kevin Gering, the advanced software diagnostic tool assesses batteries currently in use. Known as CellSage (or Cell's Age), this technology characterizes battery performance, diagnoses the health of a battery in use, and predicts how much longer it will be able to function in specific conditions and scenarios. Gering won an R&D 100 award in 2014 for his Advanced Electrolyte Model (AEM) technology.

Dr. Gering also received the regional 2014 Idaho Innovation Award for his award-winning technology, Advanced Electrolyte Model (AEM).

The paper "Decontamination Methods Testing for the Waste Isolation Pilot Plant," co-authored by Environmental Engineering and Technology staff member, Steve Reese and Rick Demmer, was awarded the **"Superior Paper" distinction at the Waste Management 2015 conference.**

Notable Outcomes

Notable Outcome 1.3.A

INL issued "Plugged In: How Americans Charge their Electric Vehicles" on September 25, 2015. This report summarizes the largest collection of light-duty PEV and charging infrastructure demonstrations in the world. The huge data collection effort included 130 million miles of driving and six million charging events, providing the most comprehensive view of PEV and charging usage to date. Exceeding expectations, INL developed new, innovative capabilities and systems to collect data, ensure data quality, perform analysis, and generate appropriate reports. Demonstrating the importance of this work to accelerate the deployment of new technology, the $462 million project was collaboratively funded with a 50/50 industry cost share. None of the industry collaborators had ever shared their proprietary performance data before. For the OEMs to share their data required significant confidence with the INL, our Nondisclosure Agreement process, and our specially developed secure data transfer methods.

1.3 A

Collaborating with U.S. automotive industry, INL will quantify plug-in electric vehicle and advanced technology vehicle systems performance and charging infrastructure use patterns by: Issuing a report that summarizes DOE's national light duty plug-in electric vehicle (PEV) and infrastructure programs that documents the results and lessons learned from plug-in electric vehicles and charging infrastructure projects.

INL issued "Plugged In: How Americans Charge their Electric Vehicles" was issued in September, 2015. Performing the research that led to the report required unprecedented collaboration with automotive original equipment manufacturers (OEMs).

The key finding was that ubiquitous public charging infrastructure is not needed to enable PEV adoption. The report documents data accumulation, "Time-of-Use" rate impacts on charging, petroleum reduction potentials and lessons learned.

Publications

Research results were published in a diverse set of prestigious journals enhancing INL's reputation as a world-class energy laboratory. INL staff published 73 peer reviewed articles in prestigious journals in FY 2015. The number does not include many other publications that are accepted but not yet published, or publications in conference or workshop proceedings.

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Efficient and Effective Mission Accomplishment

1.4: Collaborations

Accomplishments

Demonstrating Innovation in Regional Workforce Advocacy

INL is exceeding expectations to provide advancement of regional and national STEM efforts to attract and retain the best and brightest students to scientific endeavor. The following accomplishments demonstrate INL has delivered creative, new and unconventional methods for DOE, industry, and our academic collaborators.

OBJECTIVE 1.4: COLLABORATIONS

Foster new academic, industry, government, and international collaborations to produce the investment, programs and expertise that assure the DOE Vision/Mission for INL is realized. The primary focus areas include, but are not limited to the following:

- **Demonstrating innovation in regional workforce advocacy to attract and retain "best and brightest" in areas of relevance to regional industry, including workforce development, university outreach, and K-12;**
- **Developing human resource pipelines to ensure the Laboratory is connected with universities whose educational programs align with the critical staffing needs of the INL;**
- **Demonstrating progress, impact, and leadership deploying INL capability and through regional partnerships identify and solve regional and industry challenges associated with national clean energy, environmental sustainability, and security challenges;**
- **Enrich the national research, development, and deployment of advanced science-base technologies through the sharing of Laboratory facilities through a user facility model;**
- **Establish and maintain long-term partnerships/relationships that maintain appropriate relations with the scientific and local communities; and**
- **Broadly deploy Laboratory capabilities, intellectual property, and technologies to support and impact industry and other key non-DOE customer needs through Cooperative Research and Development Agreements (CRADA), Work for Others (WFO) Agreements, Agreements for Commercializing Technology (ACT), user facility access, and technology based economic development and Intellectual Property (IP) management and licensing.**

INL planned and implemented innovative STEM educator professional development initiatives, fostered broader understanding of STEM workforce needs, and involved key STEM stakeholders in activities to attract and retain the "best and brightest" as demonstrated through a myriad of local, state, regional, and national student outreach programs and opportunities, including:

- INL led the *2015 i-STEM Summer Institutes* for teacher professional development across the state reaching over 650 educators, administrators and their students, and providing professional development, training, curriculum, resources, and materials for STEM educators.
- INL reached over 3,000 teachers and 60,000 students through outreach including: STEM Nights, career fairs, science bowls, Native American STEM exploration, community events, Idaho Falls Mayor's Energy IQ Summit, Discovery Camps, INL tours, and many more events.

A teacher sharpens her science skills to better understand the STEM concepts students need for success in the future INL workforce.

- INL led and hosted the *Native American STEM Exploration Day* at CAES and co-led and sponsored the 40th North West Indian Youth Leadership Conference bolstering over a 1,000 Native American students' interest in pursuing a STEM degree, motivating and bolstering Native Americans and Hispanics students STEM skills and interest in future STEM careers at INL, and strengthened the Shoshone-Bannack Tribes-INL collaborative relationship.
- INL led seven grant proposal development and writing teams to develop state, university, and federal grants, garnering over $750,000 to support STEM education regionally.

Students in the bus simulator at CAES as part of the Native American STEM Exploration Day.

- INL awarded $60,000 in scholarships, mini STEM grants, and classroom makeover's across Idaho.
- INL served on the review panel for the 2015 Presidential Award for Excellence in Math and Science, provided leadership to write the Idaho State Science standards in alignment with the Next Generation Science and Engineering Standards, led teacher professional development at the Idaho Science Teachers Association annual conference, provided leadership for the *2nd Idaho STEM Summit*, and assisted with development of a statewide STEM strategy.
    - INL's involvement in these executive committees, including the Idaho Regional Mathematics Board of Directors and the Idaho Executive Science Committee, has great potential for positively influencing STEM in Idaho's K-12 schools and preparing Idaho's youth for the future STEM workforce.
- Researcher Tim McJunkin developed a multi-player video game to teach people how to maintain and operate their own electrical power grid and protect it from a cyberattack. McJunkin created "The Grid Game" as a classroom simulation to show college students how the electrical grid functions and the need to balance load and generation. It was later expanded to include cyber attacks. He recently spoke at the *Idaho Professional Technical Educators Conference* about the Grid Game, and students at Meridian Technical Charter High School are piloting it this fall.

User interface of The Grid Game.

- INL played a major role in educating industry and lawmakers of the need for advancing STEM education for Idaho's future workforce and economic prosperity, and supported creation of the new "Idaho STEM Action Center," that will coordinate schools and industry to promote STEM while improving the STEM literate workforce talent pool.
- INL K-12 staff provided leadership, outreach, and presentations at the National Science Teachers Association, STEMx, American Society for Engineering Education (ASEE), U.S. News STEM Solutions, STEM Tech, and the Northwest Council for Computer Educators.

- Additionally, K-12 staff participated and provided input at the *National Energy Education Summit*, (sponsored by CEREL and EERE). The Summit is a national forum for energy educators, subject matter experts, and leaders in the field of energy education to increase attention on the improvement and expansion of energy education across the nation's K-12 schools, community colleges, and universities.
- INL K-12 staff met members of the University of Alaska's Alaska Native Science and Engineering Program board to collaborate and participate on how to leverage the resources of INL and provide outreach for Alaska Native Science and Engineering Program Science and Engineering programs. INL is seen as regional leader in the development of the future STEM workforce and a committed partner in affecting systemic change in education and improving hiring patterns of Native Americans in science and engineering.
- INL K-12 STEM staff is a recognized leader of regional business, industry, and education partners in innovative STEM education and workforce development solutions and received the following awards at the National ASEE Conference for Industry and Education Collaboration:
  - Cooperative and Experimental Education Division: Best Session Award
  - Cooperative and Experimental Education Division: Best Division Presenter.
- INL's yearly My Amazing Future event was held on March 13, and included approximately 150 8th grade girls from across eastern Idaho, including the Shoshone-Bannock tribe—a 50% increase from last year. The girls engaged in over 17 hands-on science, engineering and math workshops to help bolster their interest in choosing STEM careers. INL included several community sponsors for the event and utilized outside grant funds.

My Amazing Future participants exploring STEM at INL.

Developing Human Resource Pipelines

INL is exceeding expectations to cultivate relationships to develop human resource pipelines through education programs, access to experts, strategic and key hires, postdoctoral appointments, and career enhancement through graduate research. Examples of achievements demonstrating success with these approaches include:

- ***Interns:*** In addition to almost doubling INL's intern employment in 2015, increased emphasis was placed on student intern enrichment activities. New items, such as seminars on how to apply for graduate school, interviewing, and resume writing, mentoring from INL Associate Lab Directors, a movie night and discussion on Pandora's Promise, and community outreach activities, were added to INL's intern program. A concerted effort was placed on making the interns feel valued and appreciated by the laboratory and exit survey responses reflect that significant improvement has been made. In addition, INL piloted an option for an art component as part of their final project and intend to continue and expand this practice as it was positively received by the participants and public.
- INL's Internship Program was again profiled in the national internship publication, *Vault*, which recognizes prestigious internship programs and ranks programs based on intern's feedback of the programs.

- ***Postdoctoral Researchers:*** INL continues to increase the number of postdoctoral researchers at the laboratory and anticipates having over 40 (compared to 24 last year) appointees in FY 2015, with almost as many different universities represented. Postdoctoral researchers are a key part of building INL's talent pipeline, as they are often converted to regular employees upon competition of their postdoctoral assignment. In FY 2015, eight postdoctorals were converted to regular hires.
- INL's 38 post-doctoral appointees are performing research across programs in EES&T and NS&T. Highlights of their research include:
  - INL's JunSoo Yoo is working under the mentorship of Yong-Joon Choi on verification and validation of RELAP7 and will participate in the Consortium for Advanced Simulation of Light Water Reactors computational boiling heat transfer study using Computational Fluid Dynamics simulations.
  - INL's SuJong Yoon is working under the mentorship of Carl Stoots and is participating in the Consortium for Advanced Simulation of Light Water Reactors to develop the multi-physics thermal hydraulic code HYDRA-TH. He is also working with an LDRD on designing a new thermal hydraulic/advanced heat exchanger performance flow facility.
  - INL's Congjian Wang is working under the mentorship of Cristian Rabiti developing tools and methodologies for uncertainty quantification and validation of multi-physics nuclear fuel performance simulations.
  - INL's Chandu Bolisetti is working under the mentorship of Justin Coleman developing the next generation of non-linear seismic soil-structure interaction analysis tools.
  - INL's Ahmad Al Rashdan developed and demonstrated an initial automated work packages prototype under the Light Water Reactor Sustainability Program and developed an automated SiC post-processing measurement system for irradiation temperature.
  - INL's Josh McNally—under the mentorship of Aaron Wilson and working in collaboration with both chemist Frank Weinhold, at the University of Wisconsin and Roger Klein, scientist-at-large—discovered evidence supporting the existence of the anti-electrostatic hydrogen bond through x-ray crystal structures while studying Switchable Polarity Solvents, as well as Nuclear Magnetic Resonance Spectroscopy data and freezing point data from the Switchable Polarity Solvents research. This work at INL has the potential to impact both fundamental and applied science.
- INL has initiated a new named post-doctoral opportunity designed to attract, recruit, develop, and inspire early career researchers who have the potential to develop into INL's future scientific and technical leaders. This appointment is highly competitive and is intended to recognize and provide Distinguished Postdoc Associates with a competitive award, research experience, mentorship, and training to develop their capabilities.
- ***Attracting International Researchers:*** There was a 50% increase this year in the number of international researchers at INL as a part of the DOE Exchange Visitor Program and growth in these exchanges is anticipated to continue to increase. The Multicultural Employee Resource Group was initiated this year and has been instrumental in championing initiatives to make INL a more inclusive work environment for foreign nationals. For example, foreign national employees now have the ability to perform research in INL facilities beyond standard work hours and have expanded access to laboratory wide documents.

- An R&D international collaboration is on-going with European Commission's Institute for Transuranium Elements (ITU, Germany) and Politecnico di Milano University (Milan, Italy). This collaboration has led to student internships at INL and developments for the BISON program in fission gas modeling.
- ***Joint Appointments:*** INL's 17 joint appointment agreements provide collaboration with University of Idaho, Boise State University, Idaho State University, California State University – Long Beach, Indiana University, North Carolina State University, Oregon State University, and the University of Nevada – Las Vegas. A noteworthy addition this year is the recent appointment of Dr. Don Roth of University of Wyoming who joined INL as an Associate Director of CAES. Additional joint appointment agreements in process include Penn State, Virginia Commonwealth University, and Florida State University. These new joint appointments are a good indication of INL's increasing regional and national reputation with academia.
- A new joint appointment contracting mechanism instituted in August 2015 reduces costs to universities for joint appointments of INL employees. The new blanket master contract streamlines the process for establishing incoming and outgoing joint appointments with outside entities.
- ***Emeritus Program***: INL has developed an Emeritus program to enable continued valuable research relationships with retired or departed laboratory employees. The title of "Emeritus" is conferred on the most distinguished contributors to the Laboratory and denotes an honorary unpaid status whose recipients are expected to engage in continued research, activities beneficial to the Laboratory (such as internal or external committee work), and/or mentoring of junior staff members. Factors considered are educational level, career grade level at time of departure from INL, years of service at the laboratory, scientific/engineering accomplishments, and recognition by the national and international scientific community as evidenced by awards received. Dr. James Delmore, a newly retired Laboratory Fellow is the first approved Emeritus assignee. Dr. Delmore has four decades of INL service including key studies in chemistry of ion emission, isotope ratio measurements, surface ionization mass spectrometry and ion optic modeling, R&D 100 awards, and staff mentoring.
- ***Expanding Talent Pipeline:*** INL has a long history with Energy Systems Technology and Education Center (ESTEC) and Eastern Idaho Technical College (EITC) and works closely with them on a variety of energy-related activities, programs, and projects. INL continues to support Energy Systems Technology and Education Center with monetary and in-kind support to ensure the vitality of their training programs to prepare students for job opportunities in the energy field. INL has recently provided monetary and in-kind support for Eastern Idaho Technical College to restart and implement the Radiological Control Technician program. The proposed curriculum is of interest to INL, AMWTP, CWI and other companies. INL will continue to act as advisors in order to ensure that graduates from the program possess the necessary training and skills to perform as a Radiological Control Technician.
- INL is partnering with Boise State University to develop a postdoctoral program for computer science, cybersecurity, and computational science, and to develop a graduate certificate in Energy Analysis. The Energy Analysis curriculum would provide graduates an understanding of energy systems, markets, and policy beneficial for scientists, engineers, and non-technical industry personnel.

BOISE STATE UNIVERSITY

- INL, in coordination with the DHS ICS-CERT Program and Brigham Young University Idaho (BYU-I), has developed a Cybersecurity "301" college-level course, which is being piloted this fall semester at BYU-I. The course focuses on cybersecurity for industrial control systems and contains both lectures and hands-on laboratory-type materials. The goal for INL and DHS from this pilot is to develop curriculum that can be used as a foundation for cybersecurity courses at other universities, which in turn may provide the necessary skillset for control systems cybersecurity researchers.
- In FY 2015, INL implemented quarterly meetings with ISU and University of Idaho (UI) to improve dialogue and collaboration to ensure INL's needs are well-met by INL's partner universities. UI has hired additional professors with backgrounds in cybersecurity and is seeking to better understand current and future workforce needs. ISU continues to attract faculty to support university nuclear programs.

Demonstrating Progress, Impact, and Leadership Deploying INL Capability through Partnerships:

Notable Outcome 1.4.A.

INL is surpassing expectations by demonstrating leadership in several key partnerships and developing and deploying technologies for energy security.

As a regional and national leader, INL is making a difference in developing strategies to improve U.S. energy security. Consistent with INL's objectives to establish partnerships with private sector energy system stakeholders, INL continues to build collaborations through regional outreach. These efforts demonstrate INL's growth in leadership and influence in the integration of national energy needs with security requirements across the U.S.

INL helped established a lasting DOE-NE/EERE collaboration and relationship. In June, INL hosted a joint visit by Assistant Secretaries David Danielson (Danielson's second visit to INL this year) and John Kotek. Danielson and Kotek met with INL EES&T industry partners and researchers as well as state of Idaho officials to discuss ways to enhance and promote better relationships between national laboratories, academia, and the private sector.

<u>Technology-based Economic Development</u>

The INL Technology-based Economic Development program targets projects aimed at spurring regional economic development, technology-based economic development, entrepreneurship, and innovation in the region using BEA corporate funds for grants. In FY 2015, a new strategy was implemented to focus the grant awards on larger, higher impact projects with industry cluster development and closer alignment to the laboratory's mission space. Select awards are detailed below:

1.4.A

Expand leadership in regional energy and environment matters increasing regional partnerships with industry, establishing the Center for Advanced Energy Studies (CAES) as a regional industry portal, and expanding workforce development and education outreach to new customers by:

• Establishing a CAES industry outreach advisory committee;
• Adding at least two regional industry collaborations or partnerships; and
• Expanding the regional workforce pipeline and Science, Technology, Engineering and Math (STEM) education outreach in at least two states.

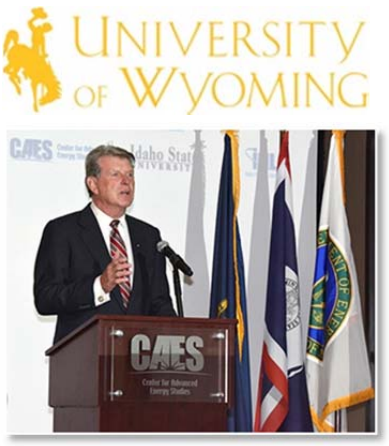
Assistant Secretaries David Danielson and John Kotek visit INL.

- INL awarded a technology-based grant to Idaho Technology Council with E-Center, BYU-Idaho- Broad-based statewide organization with mission to help technology companies in Idaho start, grow, and thrive. They focus on three key areas: Energy, Agriscience, and Software. Projects include: Voice for Idaho technology companies, Idaho tech map, identify Idaho wireless technology companies for potential INL Wireless User Facility, Deal flow report, and Idaho Tech Based Talent/Workforce flow report. The information gathered for these reports will benefit the entire state and drive industry cluster growth in the technology space.
- INL awarded a technology-based grant to Regional Economic Development Corp for East Idaho (REDI)- Newly formed two-county (Bingham and Bonneville), five-city region to support a key cluster development strategy, including R&D in physical, engineering and lab sciences, food-related and value-added manufacturing, hazardous waste treatment, chemical manufacturing, machinery manufacturing, and heavy and civil engineering construction. They plan to build upon the Business + Innovation + Growth, BIG entrepreneurial educational competition. They worked with local, state, and federal leaders and agencies to express support for INL R&D mission in relation to TREAT and FORGE in the past year.
- INL awarded a technology-based grant to Region IV Development for the Investing in Manufacturing Community Partnerships designation for Twin Falls, Idaho, as a new manufacturing community. In July, U.S. Secretary of Commerce Penny Pritzker announced the award and INL's Battelle Energy Alliance, LLC (BEA) corporate funding was used as matching for the designation. The program aims to accelerate the resurgence of manufacturing and create a competitive climate for communities to attract manufacturing jobs and investment. Communities with the Investing in Manufacturing Community Partnerships designation are provided elevated consideration for federal assistance across 10 agencies.
- INL has organized and provided support for two EERE Lab-Corps pilot teams to develop and commercialize products/services leveraging DOE-developed technologies and/or INL capabilities. The project will lead researchers through the commercialization process, and help spur a change in the INL culture to place greater emphasis and value on entrepreneurial activity. The INL Lab-Corps pilot will leverage the technology development, testing and demonstration capabilities at INL and among CAES partner institutions, and will draw upon the educational and entrepreneurial resources in both Idaho and the surrounding region to pilot the focused Lab-Corps commercialization process. The project will also expose improvement opportunities in policies and business processes, and teach INL researchers how to increase industry impacts of research and capabilities through customer discovery methodology and market pull mechanisms.
- INL's Tech Based Econ Dev program sponsored, coordinated, and hosted the *2015 Business + Innovation + Growth (BIG)* event on February 12–13, 2015, at the EIL. BIG is an educational business pitch competition designed to education entrepreneurs, inventors, and students in eastern Idaho about early stage financing. Twelve teams presented their BIG idea to a panel of judges in the community and diversity track and first and second place awards were announced during the awards ceremony.

- INL's Technical Assistance Program is a federally mandated program that authorizes INL to provide knowledge and specialized equipment to be used for promoting U.S. competitiveness. Through the program, laboratory scientists and engineers can provide assistance up to 40 hours of support, which is not normally available to a community or small business, without fees. Technical Assistance Program offers highly skilled experts and laboratory resources to the region. During the past year, INL has dedicated more than 304 hours to nine Technical Assistance Program projects, which were focused on increasing INL's goodwill and community outreach in the region in projects that intersect and support the laboratory mission areas.

Progress, Impact, and Leadership through Regional Partnerships:

- On October 10, 2014, Governor C.L. "Butch" Otter announced the University of Wyoming was joining CAES, making it the first university outside of Idaho to become a CAES partner. The University of Wyoming provides a valuable strategic fit for the consortium by strengthening the competitiveness of CAES in developing sustainable research grants, expanding educational and workforce development opportunities, and more effectively engaging regional energy industries.



Governor C.L. "Butch" Otter speaking at CAES.

- **INL and CAES provided leadership in assisting in designing the *2015 Intermountain Energy Summit*.** Support included selecting high-level panelists, moderators, and keynote speakers. In addition, a large number of meetings and tours at INL/CAES were held with selected summit guests. This year's summit focused on the energy-water nexus, an area of keen interest to INL and DOE leadership. Several public acknowledgements and a written acknowledgement in the program were offered recognizing INL's role: (1) the Mayor of Idaho Falls Rebecca Casper and Roger Plothow of the Post Register publicly stated their appreciation to INL for providing panelists to ensure a successful summit, (2) front remarks of the program acknowledged INL as a sponsor, and (3) Post Register credited INL and CAES in numerous stories and it was aired on KISU public radio.
- **Leadership in Nuclear Energy (LINE 2.0).** CAES Director Steve Aumeier was selected to lead the LINE Commission's Subcommittee on Research, Education, Workforce, and Infrastructure.
- INL was the DOE national laboratory lead on the Pacific Northwest Louis Stokes Alliance for Minority Participation board of directors meeting, an initiative funded by the National Science Foundation involving Idaho, Washington, and Oregon; to enable educators and advocates from science centers, national laboratories, pre-college programs, community colleges, and four-year institutions to leverage resources and relationships to increase minority participation in STEM, exemplifying INL's ability to serve as a regional leader in STEM education.

- High school students from Marysville, Washington recently visited INL and learned about its bioenergy research as part of *BioenergizeME*, a STEM initiative sponsored by the DOEs Bioenergy Technologies Office. The Marysville students were selected for the tour after winning the biofuels category of Imagine Tomorrow, a five-state competition that challenges high school students to seek new ways to help the country transition to alternative energy.

Marysville, WA students observe a Microgrid Control System in ESL.

- National University Consortium-support of an early career assistant professor at Oregon State University (J. Tucker) provided the groundwork necessary for a new NEUP research grant, awarded in FY 2015, which includes partnership with a researcher at INL.
- The Idaho Department of Commerce, in partnership with INL and CAES, announced the establishment of the Idaho Autonomous Systems Center of Excellence. CAES provides technical leadership for Autonomous Systems Center of Excellence and brings to the partnership expertise in data science, systems engineering, and policy and regulation. This Center, which began operation in May 2015, offers developers, researchers, and unattended autonomous system users access to INL's test ranges, facilities, and the equipment and personnel to acquire, analyze, and visualize large complex data sets.
- INL's Associate Laboratory Director for N&HS, Brent Stacey, was appointed to the Idaho Cybersecurity Taskforce by Idaho Governor C.L. "Butch" Otter. The recently announced cybersecurity Taskforce will support the development of policies, programs, and strategies to detect vulnerabilities and prevent cyber attacks.

The Office of the Governor

EXECUTIVE ORDER NO. 2015-07

ESTABLISHING THE IDAHO CYBERSECURITY CABINET TASKFORCE

Cybersecurity Cabinet Taskforce Executive Order.

- Partnership with Oregon State University has provided access to operational data from the Multi-Application Small Light Water Reactor (MASLWR) facility that will be used to validate computational models of small modular reactors that are being studied as a possible component in a hybrid energy system. MASLWR is a 1/3-height scaled model of the NuScale reactor design, which is cooled via a natural convection design. MASLWR test data included steady operation (natural circulation) at various core powers; transition from one steady operation to another at different power levels; and loss of feed water accident, including reactor blowdown, containment condensation, and cooling pool heat exchange.
- INL supported ICS-CERT in delivering 29 onsite cybersecurity assessments and two onsite incident responses to resolve cybersecurity threats within 14 states; including Arizona, Colorado, Utah, and Wyoming. INL's unique cybersecurity expertise and methodology supports the DHS mission, both at a national level and regionally.
- As described in Section 1.2, INL participated in a national effort to transfer irradiators from a decommissioned facility in to secure storage. The effort to recover the irradiators was supported by an INL team including personnel from EES&T, N&HS, ESH&Q (Rad Control), and Facilities and Site Services (Logistics and Property). Government agencies included the Department of Agriculture, Defense Threat Reduction Agency, U.S. Air Force, and other laboratories participating included Los

Alamos National Laboratory, Lawrence Livermore National Laboratory, and Savannah River National Laboratory.

Enrich National Research, Development, and Deployment through the User Facility Model:

- INL is surpassing expectations by advancing national research, development, and deployment, and evolving science-based technologies through the sharing of Laboratory facilities as validated in INL's partnerships and leadership of the NEUP, NEET, NSUF, and National University Consortium (NUC) programs and creative unconventional implementation methods of these programs demonstrate INL is reaching the greater scientific communities and is accelerating paradigm shifts. As demonstrated in the accomplishments below:
- ***Center for Advanced Energy Studies (CAES):*** The CAES CAVE enables collaboration and provides an effective introduction into some of the INL's technologies and capabilities. These capabilities have been highlighted and included in publications such as the second edition of "Handbook of Virtual Environments: Design, Implementation, and Applications."
- INL's HPC staff is collaborating regionally with Ben Nickell serving as a Regional Champion of Extreme Science and Engineering Discovery Environment. Mr. Nickell is engaged in enabling collaborative HPC work in the six northwestern states as part of this national organization.

Demonstration of INL's CAVE.

- ***Nuclear University Consortium:*** The NUC universities continue to do well in obtaining NEUP funding winning 10 awards in 2015, with five of those awards including INL as a collaborator. INL also collaborated with them through subcontracted work on 31 new contracts in 2015—more than any other year since the inception of INL. They also engaged successfully in 11 of 12 LDRD submissions (only four of which were NUC LDRD projects). This diversification of effort allows INL to leverage the capabilities of the NUC universities to increase our capabilities to engage in innovate scientific endeavors.
  - Ed Blandford at University of New Mexico is building void fraction measurement sensors as a capability for TREAT testing and will collaborate on an NEUP Integrated Research Project involving TREAT.
  - Julie Tucker at Oregon State University has developed a supercritical CO_2 system for studying corrosion that does not exist elsewhere in the laboratory complex.
- The NUC LDRD project led by Bob Youngblood titled, "Development and Validation of a Societal Risk Goal for Nuclear Power Plant Safety," supported two graduate students (50% on NUC funds and 50% university funding). The result of the work in NUC project was published as a summary and presented in the ANS Meeting and as part of one student's Master's thesis. These students continued their work as summer interns at INL.
- NCSU faculty and INL staff co-authored an invited Opening Plenary lecture, "Perspectives on Nuclear Power Safety," at the *10th International Conference on Nuclear Reactor Thermal-hydraulics, Operation, and Safety (NUTHOS-10)* (Okinawa, Japan, December 2014).

- ***Nuclear Science User Facilities:*** In FY 2015, the NSUF conducted three solicitations for Rapid Turnaround Experiments and for the first time, integrated its annual call into NE-4's 2015 Consolidated Innovative Nuclear Research FOA. The RTE solicitations drew 48 proposals and resulted in 30 awards to researchers from 16 different institutions. The FOA drew 41 letters of intent that were down-selected to 17 proposals and resulted in four awards. Since inception, NSUF has provided 133 access awards to the unique capabilities available at INL and the other NSUF partner facilities.
- In July 2015, NSUF completed processing samples that were irradiated in ATR as part of a NSUF access award given to Dr. George Imel at ISU. The overall objective of the experiment (Measurement of Actinides Neutron TRAnsmutation) was to measure the neutron cross-sections (probability of interaction) of various actinides important to fuel cycle and used nuclear fuel disposition activities. The experimental process involved irradiation of high-purity actinide samples in the ATR and, after a given time, determination of the amount of the different transmutation products. Comparison of the nuclide densities before and after neutron irradiation allows the effective neutron capture cross-sections to be inferred. The list of actinides that were irradiated is the following: ^{232}Th, ^{233}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{244}Pu, ^{241}Am, ^{243}Am, ^{244}Cm, and ^{248}Cm. Precise knowledge of these interaction probabilities is important to many fields within nuclear energy, specifically (1) fission reactor design, (2) nuclear fuel cycles, (3) nuclear safety, (4) nuclear safeguards, (5) reactor monitoring and neutron fluence determination, and (6) waste disposal and transmutation. The measurements of the isotopic ratios in the irradiated samples were carried out at the MFC using the newly acquired Multi-Collector Inductively Coupled Plasma Mass Spectrometer. Specially prepared sample holders containing the irradiated actinides were also shipped to the Argonne Tandem Linac Accelerator System for comparative measurements.
- In August of 2015, irradiated X-750 nickel alloy specimens were examined in collaboration with Atomic Energy Canada Limited in support of the CRADA (11-CR-16) goal to address the root cause of a material performance issue in CANDU reactors. The sample material was harvested from irradiated spacer springs that separate the fuel bundle from coolant channel (callandria tubes) in the CANDU reactor. Transmission Electron Microscopy (TEM) foils were prepared from the spring sections with a Focused Ion Beam (FIB) microscope. The purpose of this joint project is to examine microstructural changes of alloy X-750 as a function of neutron irradiation and temperature and to characterize the hardness of the irradiated spring sections with potential correlation to helium content.
- ***Wireless National User Facility.*** INL shared WNUF opportunities and capabilities through publications and invited talks such as, "Spectrum Sharing and Critical Infrastructure Protection: Opportunities and Challenges," in the *Proceedings of WinnComm-Europe 2014*; "Dynamic Spectrum Sharing Annual Report 2014," issued by the Wireless Innovation Forum; "The Role of Context in Cognitive Systems," in the *Journal of Signal Processing Systems*; "Context Aware Cognitive Communications for Public Safety," at the *International Wireless Communications Expo*; "Security Aspects of Spectrum Sharing," at the *Wireless Innovations Conference*; "Building Partnerships for Advanced Wireless," at the *Federal Communications Commission Model Cities Workshop*.
- INL provided expert consultation during regional wireless technology meetings with the Idaho Bureau of Homeland Security, Idaho's FirstNet advisory group, and Oregon's FirstNet advisory board to assist in developing the plans for the design and implementation of the National Public Safety Broadband Network.

- **Biomass Feedstock National User Facility (BFNUF).** INL's BFNUF completed the 200-ton bioenergy byproduct process test for DuPont and the 20 ton process test of post-sorted MSW for InnerPoint Energy Corporation.
- For COGENT Energy Systems, BFNUF identified correlations between feedstock quality attributes and feedstock performance in downstream energy conversion processes. The project leveraged INL's feedstock formatting and characterization expertise with COGENT Energy System's modular gasification process.

Establish and Maintain Partnerships and Relationships with Scientific Communities

In FY 2015, INL exceeded expectations in establishing and maintaining long-term partnerships that maintain appropriate relations with the scientific and local communities. INL has continued to deliver technical expertise to scientific and local communities that heighten industry knowledge in nuclear energy, critical infrastructure, and energy security. The following are examples of achievements that meet this objective:

- Rory Kennedy, Jim Cole, and Todd Allen co-chaired the *NuMat 2014* conference. NuMat is one of the largest international conferences in the topical area of fuels and materials for nuclear systems.
- Anita Gianotto was instrumental in forming a new Conduct of Research Community of Practice to improve R&D processes across the BEA laboratories.
- INL researchers' experimental discoveries were reported through the presentation of eight papers/posters during the *2015 International Conference on Methods and Applications of Radioanalytical Chemistry*. These papers describe programmatic R&D and LDRD breakthroughs in ultratrace and forensic isotope measurements utilizing INL's unique capabilities at MFC, ATR, and Idaho Falls-based laboratories. The discoveries in mass spectrometry, radioisotope separation, and isotope measurements also resulted in journal publications: "Iron Fluoranions and Their Clusters by Electrospray Ionization of a Fluorinating Ionic Liquid" in the *Journal of the American Society for Mass Spectrometry*; "Electrodeposition as an alternate method for preparation of environmental samples for iodide by AMS" in *Nuclear Instruments and Methods in Physics Research*; "Production of highly-enriched 134Ba for a reference material for isotope dilution mass spectrometry measurements" in the *Journal of Radioanalytical and Nuclear Chemistry*; and "OSIRIS – Gamma-ray spectroscopy software for on-site inspections under the Comprehensive Nuclear-Test-Ban Treaty" in *Nuclear Instruments and Methods in Physics Research A*. The authors in these papers include collaborators from several national laboratories and international organizations in Switzerland and Japan.
- INL provided technical and scientific leadership at a number of key conferences this year. Details regarding these conferences and associated publications can be found in Sections 1.1, 1.2, and 1.3 of this document.

Broadly Deploy Laboratory Capabilities through Intellectual Property, and Technologies

As noted by the large increase in invention disclosures, INL is increasing exceeding expectations to develop and deploy Intellectual Property and technology. Selected significant achievements are highlighted in the following bullets:

- In FY 2015, 52 new invention disclosures were received, more than doubling the total from FY 2014 and 60% higher than FY 2013. Twenty-two U.S. Patent Applications were filed and 24 U.S. Patents were issued, which is on par with historic numbers, and 10 copyright assertions were granted, an increase of eight over FY 2014. Royalties received from commercial licenses totaled $1,457,558 in keeping with historic averages. In FY 2015, $2,190,545 of the FY 2014 Royalty Income was authorized for re-investment in Laboratory R&D through the Innovation Development Fund. Of this amount, ~80% was invested in new or improved laboratory capabilities or in technology maturation for licensing, with the remainder rolled over to FY 2016. A total of 61 licenses were executed in FY 2015, all representing the deployment of INL technology in some way.
- In FY 2015, BEA executed 71 license agreements for software developed by the NS&T directorate, all of which represent deployment of INL technology within the U.S. and worldwide. The following software products were licensed: BISON (24), RAVEN (8), PHISICS (1), RELAP5-3D (36) - RELAP5-3D license agreements generated $651,792 in FY 2015, RELAP-7 (2).
- A license with 5D Robotics was modified granting exclusive rights to commercialize the INL-developed Robotics Intelligence Kernel software enabling autonomous control of robotic systems.
- A Colorado-based start-up company has executed a license option agreement to the Impedance Measurement Box technology. The Impedance Measurement Box is capable of rapidly measuring the impedance spectra from electrochemical storage devices to assess battery health in real time.
- Illinois Rocstar has been granted a government-use license agreement to develop a stand-alone software module from the R&D 100 Award winning AEM code developed at INL. The license has been granted in conjunction with a Phase II NASA SBIR award received by Illinois Rocstar. The outcome is to develop a set of computational tools that will accelerate the process of optimizing battery performance. At the conclusion of the SBIR period of performance, Illinois Rocstar will have an opportunity to negotiate a commercial license for AEM source code.
- BEA licensee Cogent Energy Systems has built a pilot scale plasma gasification system in Idaho Falls based on plasma technologies developed at INL. Cogent has also engaged with the Biomass Feedstock National User Facility at INL to characterize candidate feedstocks and reactor products.
- INL is expanding the deployed Sophia software tool and CSET for evaluation to a DOE-NE SBIR grant recipient for inclusion in a developmental product destined to determine a nuclear power plant's compliance status with NRC cybersecurity requirements.
- **Dynexus Technology, LLC**, and INL entered into an agreement to exclusively license the Impedance Measurement Box and Battery Health Assessment Intellectual Property. Dynexus Technology was granted a 6-month option to execute an exclusive license for the technology, the development of which was funded largely by DOE's Vehicle Technologies Office. Dynexus is exploring a number of potential markets to apply this technology where improved visibility of battery health could result in substantial cost savings.
- Montana Tech of the University of Montana and INL executed an agreement to bundle intellectual property rights for Impedance Measurement Box Technologies. Montana Tech granted INL exclusive rights to license Montana Tech ownership interests in the equipment patents and copyrights developed under subcontract agreements. Finalizing this agreement has been several years in the making and will improve INL's ability to deploy this technology. Energetic material science research, LDRD and programmatic R&D, in collaboration with Texas Tech University, has resulted in multiple peer-reviewed publications and patent disclosures describing discoveries and innovations in the safer

use of exothermic materials. Journal publications during FY 2015 include "Controlling the Electrostatic Discharge Ignition Sensitivity of Composite Energetic Materials Using Carbon Nanotube Additives," in the *Journal of Electrostatics*; "Desensitizing Nano Powders to Electrostatic Discharge Ignition," in the *Journal of Electrostatics*; "Ignition Sensitivity and Electrical Conductivity of an Aluminum Fluoropolymer Reactive Material with Carbon Nanofillers," in *Combustion and Flame*; "Synthesis and Characterization of Flexible, Free-standing, Energetic Thin Films," in *Surface & Coatings Technology*; and "Development of Flexible, Free-standing, Thin Films for Additive Manufacturing and Localized Energy Generation," in *AIP Advances*. Two FY 2015 collaborative patent disclosures describe unique material compositions for improved control of the energetic reaction. Part of the research, development, and demonstration collaboration included establishing safety protocols for Texas Tech that make this higher risk R&D possible.

- NexDefense (an INL software licensee) announced commercial availability of Sophia, an INL proprietary Industrial Network Anomaly Detection system. This first-of-its-kind cybersecurity sensor for industrial control systems (ICS) was originally developed by INL cybersecurity researchers and showcases INL's advanced technical perspective on ICS cybersecurity. First funded through a DOE-OE research project, this successful technology deployment makes laboratory research outcomes available to a wide audience within industry.
- A new SPP agreement with Southern California Edison helped expand INL's RDD&D role in supporting public utilities in securing power grid infrastructure. This agreement establishes a long-term research, development, and demonstration collaboration with California Energy Systems for the 21st Century (CES-21), a consortium of Pacific Gas and Electric, Southern California Edison, and San Diego Gas and Electric. This SPP is an example of a private-sector deployment of INL's unique vulnerability assessment tools developed through the DOE Office of Electricity Distribution and Energy Reliability (Risk Evaluation Nexus for Digital Age Energy Reliability, Attack Technology Analysis & Characterization, and Response Analysis Characterization Tool).
- Switchable Polarity Solvent (SPS) Technology Holdings secured an option license agreement for INL's intellectual property associated with SPS FO. SPS Technology Holdings' current interest in the SPS FO technology is using it to upgrade and recycle treated wastewater to a state that will allow the water to be used in industrial processes.

Recognitions and Awards

- **Integrated Waste Screening System (IWSS) Federal Lab Consortium (FLC) Award**. BEA's Integrated Waste Screening System has received an FLC Award for 2015 Outstanding Technology Development. The FLC supports technology deployment efforts for its nationwide network of federal laboratories. BEA researchers Doug Akers and Lyle Roybal developed the technology to efficiently assess the nearly 40 million tons of drilling waste generated by fractured oil and gas wells. These wells often produce significant amounts of Technologically Enhanced Naturally Occurring Radioactive Material, which must be characterized, segregated, and disposed of properly. The system can conduct rapid (3-minute) onsite analyses, reduce costs, and both document and certify recommendations for proper environmental disposal. BEA is in the process of negotiating a license agreement to commercialize this intellectual property.
- INL's CellSage and Integrated Waste Screening System were nominated for Idaho Innovation Award's Early-Stage Invention of the Year. Recipients will be announced on October 21, 2015.

- INL submitted two nominations to the R&D 100 Awards Program and one nomination, CellSage, was accepted as Finalist. INL's CellSage technology, developed by Kevin Gering, is an advanced software diagnostic tool to assess batteries currently in use. Known as CellSage (or Cell's Age), this technology is able to characterize battery performance, diagnose the health of a battery in use, and predict how much longer it will be able to function in specific conditions and scenarios. R&D 100 Award winners will be announced November 13, 2015, at an awards dinner in Las Vegas, Nevada.

Notable Outcomes

DOE has acknowledged achievement of the three elements of the Notable Outcome relating to expanding leadership in regional energy and environment matters, increasing regional partnerships with industry, establishing CAES as a regional industry portal, and expanding workforce development and education to new customers.

Adding at least two regional industry collaborations or partnerships:

Various industrial collaborations have been expanded in FY 2015. These collaborations focus on extending the capabilities of CAES and INL to improve U.S. industrial competitiveness. Key examples include our involvement with: McCain Foods, Rare Earth Element Resources', CMI's shared use facility at CAES, Idaho Autonomous Systems, and Center of Excellence.

Establishing a CAES industry outreach advisory committee:

The CAES Industry Advisory Board has been established. The purpose of the Advisory Board is to provide strategic guidance for CAES that will guide the Consortia's engagement with and impact for regional industrial competitiveness and advise on related resource, investment, and partnership development and deployment. The core Advisory Board, chaired by Dr. Howard Grimes, is comprised of 8–10 members to be nominated by the CAES Steering Committee. The Advisory Board's first official meeting was held on April 7, 2015, and engagement has continued throughout FY 2015.

Expanding INL K-12 STEM Education Programs:

INL K-12 STEM education programs met and exceeded all applicable requirements for PEMP Objective 1.4.A, Notable Outcome(s), to expand STEM education outreach into two new regional states. K-12 STEM staff worked with regional industry, education institutions, agencies, STEM organizations, and state departments of education to transfer and replicate the INL i-STEM program and deliver industry-specific STEM educator professional development into two new states: Utah and Wyoming. K-12 STEM staff implemented STEM outreach and teacher professional development in Utah and Wyoming ahead of schedule. Numerous examples of engagement with Utah and Wyoming have been provided to DOE separately.

Efficient and Effective Stewardship and Operation of Research Facilities

2.4: Utilization of Facility(ies) to Provide Impactful S&T Results and Benefits to Internal and External User Communities

OBJECTIVE 2.4: UTILIZATION OF FACILITY(IES) TO PROVIDE IMPACTFUL S&T RESULTS AND BENEFITS TO INTERNAL AND EXTERNAL USER COMMUNITIES

Ensures Laboratory facilities are being used to perform influential science and generating impactful S&T results, pushes the envelope of what the facility can do and/or are among the scientific leaders of the community, while balancing both internal and external user communities.

As noted in the INL's Laboratory Plan, facilities are one of three critical capabilities needed for the laboratory to achieve its goals. INL facilities are home to nationally unique capabilities to conduct relevant and impactful scientific RDD&D of solutions that enable the success of INL's missions. The Laboratory's facilities are used for experimentation that delivers transformational results for excellence in program performance, advance the viability of INL's investments in future capabilities and missions, enable external user communities to advance knowledge through science, and enhance national economic competiveness through accelerating deployment of technologies.

Nuclear Energy Research at INL Facilities

INL has added significant capability to ATR, MFC, and CAES to expand the services available to enable cutting-edge research in nuclear energy, communications and cyber-security research, and clean energy and environmental sciences. These capabilities are already enabling new scientific outcomes and moving INL forward in the accomplishment of strategic objectives for the future.

INL Employees Celebrate Role in Successful New Horizons Flyby of Pluto

In this year, one of the most powerful demonstrations of INL's impact on world-changing science was demonstrated when, after a journey of three billion miles lasting more than 9 years, NASA's New Horizons mission finally flew by Pluto and its mysterious moons. The craft is powered by a radioisotope thermoelectric generator (RTG) that was assembled, tested, and prepared for launch by researchers at DOE's INL. New knowledge and scientific discoveries have been flowing from New Horizons since its closest approach to Pluto on July 14. The bounty of data will continue to trickle back to Earth for the next 16 months, and the craft's long journey will continue deep into the Kuiper belt—the vast region of icy objects and remnants of the formation of the solar system dating from more than 4 billion years ago. These vital scientific outcomes depended on INL's performance of cutting edge science under tight technical and schedule constraints. INL's technology has continued to function under the harshest of conductions to fulfill mission requirements.

INL delivered leading S&T accomplishments through the Laboratory's facilities, and by expanding these facilities to support new research capabilities, proving once again that INL is among the scientific leaders of the community in our unique research focus areas. INL's breakthroughs in R&D associated with securing and modernizing critical infrastructure were achieved through the use of unique capabilities at MFC, ATR, and Idaho Falls facilities and laboratories.

(a) **(b)** **(c)**

(*a) Artist's concept of the New Horizons spacecraft reaching Pluto. Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI). (b) NASA technicians prepare the New Horizons spacecraft for launch in 2006. The black, finned RTG assembled at INL protrudes from the left side of the spacecraft in this NASA photo. (c) Pluto is seen in a new image taken using one of New Horizons' long-range instruments.*

Advanced Test Reactor Complex

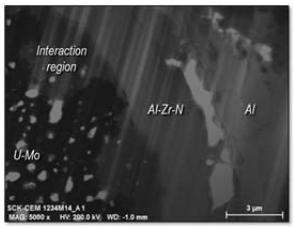
- ATR restarted Cobalt-60 production. Production of Cobalt-60 in ATR marks the beginning of a collaborative production agreement between ORNL's Isotope Business Office and ATR. Cobalt production in ATR is forecasted to increase from an initial five core positions to 22 core positions over the coming 3 years.
- As reported in Section 1.1, the multi-year Core Modeling Upgrade Project to transition ATR from using the legacy software suite PDQ to the software suite HELIOS/MCNP (Monte Carlo Nth Particle) for Core Safety made significant strides and is in the final stages of completion. A robust team effort across INL produced documents to support quality assurance activities including software verification, validation, and ATR Reactor Engineering personnel training on the new software suite. The completion of this work and transition to HELIOS/MCNP for Core Safety Assurance Package development in the near future will allow for experiments like the planned KJRR insertion to be successful.
- In support of the KJRR experiment, Advanced Test Reactor Complex (ATRC) completed flux runs in support of the ATR's N-16 system calibration. In addition to the benefits of calibration, these flux runs will provide data that may support reducing the uncertainty range of the N-16 indication system, which will relax some of the currently tight design requirements for ATR experiments. Completing this test plan was an essential prerequisite to performing KJRR physics testing in ATRC and subsequent irradiation in ATR. The KJRR experiment physics testing in ATRC began in March 2015.
- As initially reported in INL's mid-year accomplishments report, ATR initiated placing the Battelle Energy Alliance Research Reactor (BRR) cask in service this fiscal year. Placing the BRR cask in service at ATR increases the throughput capacity for shipment of irradiated material payloads from the ATRC to MFC. At MFC the experiments will undergo PIE. Increasing ATR's shipping capacity translates into the ability to smoothly increase ATR's business volume. Near-term usage of the BRR cask for shipments between ATR (irradiation) and MFC (PIE) will support the Global Threat Reduction Initiative (GTRI) experiments within the High Performance Research Reactor fuels development program.

Materials Fuel Complex

In addition to the NE research being performed at ATR and its adjacent facilities, nuclear fuel fabrication research is pushing the envelope at facilities within MFC.

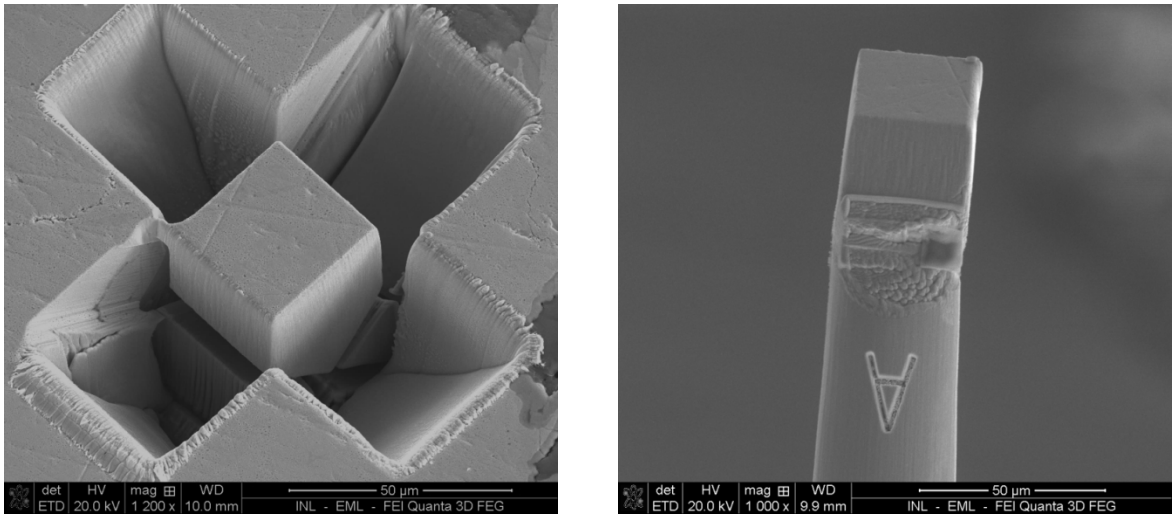
Irradiated Materials Characterization Laboratory (IMCL)

- INL continued with the buildout of capability at IMCL, including fabrication of the IMCL Shielded Transfer Cell, which will mate the glovebox, hood, and transfer port to the Shielded Sample Preparation Area and provide a transfer path via shielded container for highly irradiated materials from HFEF and to the Sample Preparation Laboratory (SPL).
- INL initiated radiological work on the Electron Probe Micro-Analyzer conducting analysis on irradiated fuel and characterizing an unknown sample from the Naval Reactors Facility. INL began cold work using the dual-beam FIB in preparation for mating to shielding and confinement in FY 2016.
- Two Belgian atomic research laboratory (SCK-CEN) researchers spent a week working with MFC researchers to prepare and examine a fuel specimen irradiated in Belgium's BR2 test reactor. Samples were prepared using MFC's FIB capability. The fuel is a coated particle system consisting of a U-Mo kernel coated with zirconium nitride and embedded in an aluminum matrix. Characterization of the specimen was performed using TEM. This analysis is only possible at INL, and highlights use of MFC's world-class capabilities to understand and solve nuclear fuel performance challenges



A micrograph of the prepared specimen at 5,000X magnification.

- MFC staff used FIB techniques to prepare tiny cube-shaped sampled of irradiated fuel—approximately 50 micrometers across, or less than the thickness of a human hair—that will be shipped to ANL for further irradiation in their Argonne Tandem Linac Accelerator System facility. The tiny samples will then be analyzed using ANL's Advanced Photon Source.



Images of a sample during and after preparation using the Focused Ion Beam.

Fuel Manufacturing Facility (FMF)

- INL's FMF team processes completed an FY 2015 milestone to treat at least 2,000 un-irradiated sodium-bonded fuel elements using the sodium separation system, 3 months early. The system separates metallic sodium to recover enriched uranium fuel slugs for offsite shipment and beneficial reuse.

Zero Power Physics Reactor (ZPPR)

- INL's ZPPR team transferred 10 drums containing more than 1,500 inspected and repackaged un-irradiated sodium-bonded Experimental Breeder Reactor II (EBR-II) fuel elements to FMF. This effort helps maximize utilization of vault space and minimize need for new rack storage as part of the documented safety analysis implementation activities, and represents successful completion of an FY 2015 milestone, 4 months early.
- INL dismantled the last of the 11 Sandia National Laboratory sodium debris canisters down to the primary containment vessels was completed in the ZPPR Hot Cell. This NNSA customer milestone was achieved 3 months early and shows that INL can accelerate dismantlement of these canisters to complete this phase of the overall disposition activities in FY 2015.

Remote-Handled Low-Level Waste Disposal Facility

- The RH-LLW Disposal Project is the Laboratory's first line-item construction project of more than $20M approved for final design/construction under the BEA contract and the first line item construction project authorized to proceed to final design/construction by the DOE-NE in 23 years. The disposal facility will provide replacement disposal capability for RHLLW generated in support of Nuclear Energy and Naval Reactors programs at the Idaho site. Construction began in June and is expected to continue throughout 2016.

Sodium Components Maintenance Shop

- The MFC project team developed a new capability to safely handle large sodium-contaminated objects approaching 40 feet in length and 1,200 pounds in weight. The Sodium Components Maintenance Shop team reduced the backlog of mixed low-level waste by 4.6 cubic meters, exceeding the 2015 minimum commitment of 4.0 cubic meters. Most of the components processed were legacy equipment from EBR-II, with some components dating back to the 1960s.

Neutron Radiography Reactor (NRAD)

- NRAD was restarted April 2 after completion of a nearly 14-month overhaul-and-upgrade project. This milestone enabled final calibration of key components and a resumption of radiography to provide researchers with a critical nondestructive tool for conducting examination of irradiated samples by allowing them to see inside the samples to evaluate performance and identify features or flaws that may require further study. Upgrades included a complete replacement of the control panel with a modern digital system, replacement and upgrade of most of the sensors used for operation of the reactor, replacement of the control rod drive systems, and an update of the reactor's Documented Safety Analysis. The overhaul builds on previous improvements, including a conversion to low-enriched fuel in 2010, and a core expansion in 2013 to increase operational durations, which means more time available to support radiography.

Analytical Lab

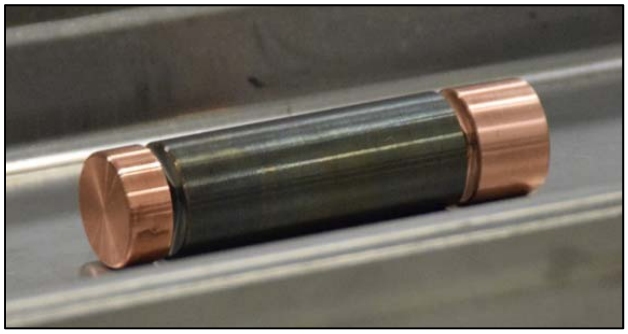
- Researchers began hot operations in the Fresh Fuels Glovebox in MFC's Analytical Laboratory. The latest addition further expands the wide range of nuclear R&D capabilities hosted at INL's MFC. The Fresh Fuels Glovebox houses several new instruments for collecting high-quality data on the thermophysical properties of fuel and material samples prior to irradiation in INL's ATR.

Hot Fuel Examination Facility (HFEF)

- HFEF employees completed another important step in their efforts to prepare for receipt of used commercial fuel for research. They completed a dry run using an NAC-Legal Weight Truck (LWT) cask to test payload handling equipment and verify operating procedures and other equipment. In-cell activities involved removal of the shipping basket from the cask and a dummy fuel element from the basket. NAC-LWT refers to a commonly-used NAC International-designed Legal Weight Truck shipping cask used for transporting used fuel on public highways.
- HFEF employees completed examination of the first elements using the recently-upgraded Element Contact Profilometer in the HFEF hot cell. This first set of Profilometry measurements supported INL's cooperative work with TerraPower, and gathered important data from Fast Flux Test Facility fuel elements. The resumption of Profilometry measurements followed an operational checkout of upgrades to the measurement sensors, stage axis stepper motor drives, and the data acquisition system. HFEF personnel also validated the revised operating procedures that reflect operation of upgraded subsystems.
- As part of a CRADA with TerraPower, INL is performing additional post-irradiation examinations on 1990s FFTF experiments using metal fuel (MFF series) and mixed oxide fuel (ACO-3) to investigate high-dose swelling and creep on HT9 cladding material. Profilometry was completed on 9 of 15 MFF pins in HFEF and cladding and wrapper wire density has been measured on samples obtained from an ACO-3 pin in the Analytical Lab. Three (3) MFF pins were punctured in the Gas Assay, Sample, and Recharge (GASR) apparatus in HFEF to measure fission gas release
- Fuel Cladding Chemical Interface experiments on irradiated TRIGA fuel reached a major milestone wherein two irradiated TRIGA fuel elements were loaded into the BRR cask at the Irradiated Fuel Storage Facility (IFSF) at the Idaho Nuclear Technology and Engineering Center and shipped to the HFEF at the MFC using the BRR shipping cask. The accomplishment is significant because of the considerable efforts involved with preparing the facilities by developing two new Safety Analysis Reports and the various associated supporting engineering analyses, designing and fabricating several pieces of equipment, developing and dry-running four new technical operating procedures (one for IFSF, one for the BRR cask, and two for HFEF), completing two Contractor Readiness Assessments, and then completing all of the necessary final paperwork to authorize the shipment.

Experimental Fuels Facility (EFF)

- INL completed the first extrusion of depleted uranium in EFF to support cooperative research.
- Fuel fabrication employees completed the first extrusions of depleted uranium in MFC's EFF, completing a series of successful tests of fabrication equipment. The tests serve to restore a metallic fuel fabrication capability that has not been used in the United States since the 1980s, and to introduce new capabilities.
- INL is working cooperatively with TerraPower to demonstrate the ability to use extrusion as a way to produce fuel slugs. TerraPower is working to develop a Traveling Wave Reactor concept—a fast reactor that uses metallic fuel similar to the EBR-II pioneered at MFC.



(*ABOVE) A billet of depleted uranium in between copper blocks before being subjected to a 650°C salt bath and 250,000 pounds of force through the extrusion press. (BELOW) EFF employees show the extruded uranium rod to visiting TerraPower representatives.*

Security and Nonproliferation Research Facilities

INL achieved the objectives of its national security mission through innovative use of the Laboratory's unique and differentiating national security and nuclear energy RDD&D expertise and infrastructure. Investments in expertise and infrastructure continue to create new national technical capabilities to perform discovery science and engineering along with addressing current and future national security technology challenges. These new experimental and product production capabilities have resulted in technology deployment that have advanced the fields of science and engineering through technical publications and patents; reduced the threat of proliferation of weapons of mass destruction by delivering measurement standards and providing experimental access to facilities and materials; enhanced the protection of the nation's power grid, nuclear energy facilities, and critical infrastructure through conducting full-scale tests and supporting public-private information sharing of cybersecurity threats and mitigations; increased the technology superiority of US warfighters through production and delivery of advanced armor, threat analyses and mission planning tools; and prepared emergency responders by providing realistic training, expert consultation, and 24/7 reach-back. Examples that demonstrate noteworthy achievements in aligning with DOE expectations for technology deployment are described in the following subsections.

INL Research Center (IRC)

- IRC 603 Lab A-16, A-17; and A-18 were remodeled for the installation of a 0.5 million volt accelerator mass spectrometer, providing the nation with new capability for isotopic ratio measurements that support nuclear materials research and international nonproliferation treaty verification measurements. INL scientists have completed measurements validating ultratrace measurement of iodine isotopes and have demonstrated the capability to increase, by approximately 20-fold, the national capability to analyze samples.
- INL completed the initial series of measurements of iodine on the new accelerator mass spectrometer, installed within the INL Research Center (IRC). INL experimental discoveries were presented during the *2015 International Conference on Methods and Applications of Radioanalytical Chemistry*. These papers describe programmatic R&D and LDRD breakthroughs in ultratrace and forensic isotope measurements utilizing INL's unique capabilities at MFC, ATR, and Idaho Falls-based laboratories. INL scientists have completed measurements validating ultratrace measurement of iodine isotopes and have demonstrated the capability to increase, by approximately 20-fold, the national capability to analyze samples.
- Concurrently, IRC Lab A-19 was modified to include a class 100 clean room and chemistry fume hood for continued support of preparation of ultra-pure mass-separated stable isotopes (e.g., Se-82) for the Super NEMO double beta-decay collaboration studies of neutrino properties; purified stable isotopes for nuclear forensics studies, prior to their irradiation in a reactor or atom smasher; and simulant standards for PINS in-field measurements of uncovered chemical or explosive munitions.

Wireless Test Bed

- Testing communication capabilities were enhanced between INL Wireless Test Bed cell site locations at Gate 1, EBR-1, and CFA-609 with the installation of 144 fiber optic cable. This capability, used for increased data collection and transfer, enables INL to conduct 4G wireless technology tests and has been highlighted as a differentiating testing capability in proposals to FirstNet and the DoD National Spectrum Consortium.
- Additionally, fiber cable was extended to several CFA locations (e.g., Fire Station, Fire Trainer and Medical) to enhance INL emergency response communications.
- Modification to C112 and C117 laboratories within EIL and upgrades to the physical, power, HVAC, fire alarm, and lightning protection at the Fillmore Test Facility have expanded experiment and testing capabilities for wireless communication technologies. The EIL enhancements, including a 3-node software defined radio test configuration, are enabling the advancement of spectrum sharing technology from proof-of-principle to demonstration prototypes for the DEA and United States Special Operations Command. The Fillmore enhancements will assure the integrity of experimental protocols by protecting equipment and operators from environmental extremes and protect the confidentiality of test data and system configurations.

Systems Analysis Facility

- The installation of a high-frequency radio communications system adjacent to the Systems Analysis Facility, secured video teleconferencing in Critical Infrastructure Protection and Resilience Building, and the Mission Operating Environment network into the Cyber Security and Intelligence Building has enabled DHS and the ICS-CERT Program to have more efficient and reliable response communications between Idaho Falls and DHS Washington, DC facilities, as well as the west-coast region of the U.S.

Specific Manufacturing Capability

- SMC, the lead manufacturer of armor packages for the U.S. Army's Abrams main battle tank since 1984, celebrated 30 years of manufacturing excellence and has been operating for over 1 year without a lost time accident. The personnel, facilities, equipment, and processes at SMC continue to meet all production requirements and product quality delivery expectations for the Abrams tank heavy armor.

Critical Infrastructure Protection and Resilience Facility

- With experimental capabilities in a vehicle-cyber testing laboratory and a recently established cyber hardware engineering laboratory, INL cybersecurity researchers are evaluating a patent-pending prototype and unique software package that will enable the user of an automobile to detect a cyberattack on the vehicle's Controller Area Network (CAN Bus) system. These innovative outcomes are the basis for a paper at the IAEA International Conference on Computer Security in a Nuclear World and initial negotiations for industry R&D agreements with U.S. auto manufacturers.

INL Clean Energy Facilities

Energy Systems Laboratory

- INL researchers at the Real Time Power and Energy Systems Innovation Test Bed successfully established high-speed communication links between geographically distributed RTDS at INL and NREL. INL's RTDS computers are interfaced directly to NREL's grid simulator, allowing the simultaneous simulation of complex power systems with many electrical buses and multiple distribution feeds. INL researchers also successfully integrated the RTDS with the wireless vehicle charging capabilities at the Energy Systems Laboratory. This one-of-a-kind capability enables the integration of vehicle charging patterns based on actual hardware in analyzing impacts on electric grids.

Water Safety Test Bed

- INL's EES&T researchers have established the Water Safety Test Bed (WSTB) which replicates a typical municipal drinking water piping system in a roughly 200-foot × 400-foot grid using 30-year old, 8-inch pipes. Water flow, pressure testing, and final operational checkout of the WSTB were completed. The first experiments were conducted at the WSTB with the U.S. EPA to simulate an exposure and decontamination of a biological contaminant—a surrogate for Anthrax spores. This test bed enables INL to address science and technology gaps in experimentation on municipal water supply protection

INL's National User Facilities

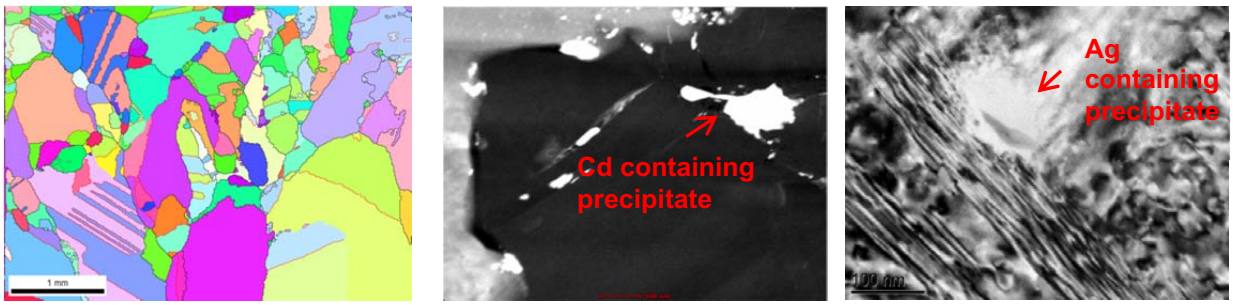
The laboratory has three working national user facilities (ATR National Scientific User Facility, Wireless National User Facility, and Biomass Feedstock National User Facility) that are providing nationally and internationally renowned scientific and technical outcomes and accesses for a variety of users.

Nuclear Science User Facilities (NSUF)

NSUF has served as a successful and important tool for collaboration between DOE, the nuclear industry, and university researchers for nuclear energy research for several years.

- As reported in Section 1.1, the first irradiated fracture toughness tests on alloys X-750 and XM-19 were completed in support of the EPRI irradiation and PIE CRADA in May 2015. These tests demonstrated the flexibility of ATR to provide a wide range of fluences while utilizing the Loop 2A controlled water chemistry facility in the ATR center flux trap.
- In July 2015, NSUF shipped irradiated samples of 172 different RPV steels to the ORNL Low Activation Materials Development and Analysis (LAMDA) facility for examination. The specimens were part of an NSUF access award given to Dr. Robert Odette at the University of California, Santa Barbara. The specimens were irradiated in the ATR in a complex instrumented-lead experiment test train that allowed monitoring and controlling of specimen temperature during irradiation that approached 1020 n/cm^2. The objective of the experiment is to address critical issues key to demonstration that LWR RPVs can maintain large safety margins against sudden fractures over extended lifetimes. A related objective of this experiment is to address the complex effects of neutron flux on new damage mechanisms that may emerge during an extended life. Data from this experiment will fill a critical gap in transition temperature shift plant surveillance data.
- NSUF staff developed analysis procedures and demonstrated capability for TEM analysis of zirconium alloys in support of the CRADA between INL and EPRI (09-CR-06). This CRADA addresses anomalous fuel channel bowing that has been observed in Boiling Water Reactors. The team is trying to measure and understand irradiation and hydrogen-induced strain in zirconium alloys used Boiling Water Reactors. Un-irradiated baseline materials were prepared and examined using the INL's Electron Microscopy Laboratory to optimize preparation techniques and to demonstrate the ability to identify features of interest including a- and c- loop dislocations as well as hydriding. The experiment is providing data on stress-free irradiation growth rate of zirconium alloys as a function of hydrogen content and neutron fluence to investigate a postulated hydrogen-assisted irradiation growth rate mechanism.
- During FY 2015, NSUF researchers significantly enhanced nuclear fuels and materials characterization throughput and data quality through improvements at CAES and INL. The first step in this enhancement was the addition of a Fischione 1040 NanoMill into the sample preparation arsenal. The concentrated, ultra-low energy argon (Ar) ion beam processing available through the Nanomill will set a higher standard for preparation of nuclear fuels and materials for transmission electron microscopy by integrating existing conventional sample preparation and FIB lift-out techniques with the new capability. The NanoMill was purchased through a NEET Infrastructure award and has been installed at CAES. The second part of this effort was the installation of a Topspin ASTAR™ system to greatly expand existing TEM capabilities at CAES.
- **Advanced Characterization of Irradiated Fuel** An advanced imaging system (ASTAR) was procured by MFC staff and installed on the CAES transmission electron microscope. The system provides automated crystallographic indexing and orientation/phase mapping of samples in the TEM to better characterize the microstructure of the samples. It presents a significant technological advancement to the characterization capabilities of the TEM that will result in a dramatically improved performance-to-cost ratio by reducing the labor required for some analyses. The system increases the speed at which data is generated and significantly reduces analysis time. This resulted in

increased research output and increased researcher's efficiency and quality of results. The Topspin ASTAR™ system was purchased through a NEET Infrastructure award. Information on grain boundary character provided by this system is important for analyzing the mechanism behind silver fission product release in TRISO fuel. The images below represent a small portion of this research that is contributing to our knowledge of the performance of TRISO fuels that can be used to fuel an Advanced Gas Reactor.



(a) **(b)** **(c)**

(a) A transmission electron microscope map of grain orientation in a TRISO silicon carbide layer taken using the new ASTAR capability. Each color represents a grain with different orientation. The grain orientations determine grain boundary character, which is being investigated as a cause for different silver transport rates. (b) Silver and cadmium containing precipitates were identified in corroded areas in the TRISO silicon carbide layer. (c) Also for the first time, silver (Ag) was identified inside a SiC grain at a stacking fault. Images were taken by MFC staff at using the Tecnai TEM in CAES.

Wireless National User Facility

The unique capabilities of INL's Wireless National User Facility (WNUF) are available to enable federal, industrial, and academic researchers to accelerate technology deployment of advanced wireless communication technologies—technologies intended to address national challenges within the National Broadband Plan for economic growth, national defense, public safety, infrastructure security, communications interoperability, and spectrum utilization. WNUF-based achievements include:

- Securing INL investments for modernization and expansion of WNUF capabilities such as (1) installation of Long Term Evolution systems to enable all INL Wireless Test Bed and WNUF users to test fourth-generation wireless communication technologies; (2) authorization from the First Responder Network Authority (FirstNet) for the deployment of band class 14 LTE to support future Public Safety communication testing; (3) investigation of cyber vulnerabilities of LTE technologies via LDRD to demonstrate the potential cybersecurity relevance to FirstNet deployment and the benefits of a national capability for Wireless Cyber Emergency Response Team.
- Reaching agreement with the DoD to become a recognized member of the National Spectrum Consortium. This membership positions INL to be one of the primary testing locations for the DoD Rapid Deployment Office to accelerate innovation by permitting collaboration between industry vendors without antitrust concerns holding back spectrum sharing technology development. As a member, INL has submitted a 6-year proposal for infrastructure and operations investments to establish a safe spectrum sharing test bed to enable the testing of spectrum sharing schemes in a controlled radiofrequency environment for fair comparison of communication systems.

- Continued engagement with the Department of Commerce's FirstNet, National Telecommunications and Information Administration, and DHS's Office of Emergency Communications for potential WNUF sponsorship. As a result of a recent visit and capability review, FirstNet approved a Strategic Partnership Project for INL through a 5-year Inter Agency Agreement to provide guidance and technical support in cybersecurity, physical security, compliance, training, and communications engineering. In addition to the SPP, FirstNet donated cell site equipment that enhances the Wireless Test Bed capabilities for testing and training within Band Class 14.
- Broadcasting WNUF opportunities and capabilities through publications and invited talks such as, "Spectrum Sharing and Critical Infrastructure Protection: Opportunities and Challenges," in the *Proceedings of WinnComm-Europe 2014*; "Dynamic Spectrum Sharing Annual Report 2014," issued by the *Wireless Innovation Forum*; "The Role of Context in Cognitive Systems" in the *Journal of Signal Processing Systems*; "Context Aware Cognitive Communications for Public Safety," at the *International Wireless Communications Expo*; "Security Aspects of Spectrum Sharing" at the *Wireless Innovations Conference*; "Building Partnerships for Advanced Wireless" at the *Federal Communications Commission Model Cities Workshop*.
- Providing expert consultation during regional wireless technology meetings with the Idaho Bureau of Homeland Security, Idaho's FirstNet advisory group, and Oregon's FirstNet advisory board to assist in developing the plans for the design and implementation of the National Public Safety Broadband Network.

Biofuels National User Facility

- The INL BFNUF conducted numerous proof-of-concept and demonstration tests for U.S. industry and DOE, providing advances that are significantly accelerating DOE missions to establish a sustainable U.S. bioenergy economy. BFNUF research activities accelerated the understanding of biomass technologies and refined industrial performance of feedstock supply systems.
- For Dupont, INL utilized the BFNUF to perform pilot-scale experiments on materials for project. The flexible configuration of the BFNUF enabled INL to diagnose and mitigate unexpected processing and performance behaviors at very low cost and provide those lessons learned to DuPont for incorporation into full-scale process planning.
- Other key accomplishments of the BNUF are reported in Section 1.3, above.

Appendix A

CRADAs, Strategic Partnership Projects, Invention Disclosure Records, and Patents

CRADAs

New CRADAs		
Agreement	**Party**	**Title**
15-CR-05	WindSim Americas Inc.	Dynamic Line Rating Development with WindSim
15-CR-02	AltaLink, L.P.	Power Industry Services for Dynamic Line Rating with AltaLink, L.P.
14-CR-14	Procter & Gamble (P&G Utah)	Biomass Feedstock Supply System Logistics Analysis, Densification and Characterization Research
14-CR-13	Idaho Transportation Department	Vehicle to Vehicle and Vehicle to Infrastructure Safety and Fuel Efficiency Research
14-CR-12	Southern Nuclear Operating Company, Inc.	Development of a Control Room Upgrade Strategy for an Operating Nuclear Power Plant

Modified CRADAs		
Agreement	**Party**	**Title**
93-CR-12	Ametek, Inc.	Portable Isotopic-Neutron Chemical Assay System (PINS)
14-CR-12	Southern Nuclear Operating Company, Inc.	Development of a Control Room Upgrade Strategy for an Operating Nuclear Power Plant
14-CR-05	TerraPower, LLC	Idaho National Laboratory and TerraPower Collaboration on Nuclear Hybrid Energy Systems
13-CR-22	Porifera, Inc.	Forward Osmosis-based System for Treatment of Waste Water Generated During Energy Production Using Waste Carbon Dioxide and Waste Heat
13-CR-21	Dairy Research Institute	Integrated Model and Data Platform for the Dairy Industry Operations, Energy and Environmental Analysis
13-CR-15	TerraPower, LLC	Support of TerraPower Fast Spectrum Fuels Tests
13-CR-05	Chevron Energy Technology Company	Water Purification Using Switchable Polarity Solvents and Forward Osmosis
12-CR-22	Progress Energy	Human Factors Engineering for Plant Process Computer Upgrades
12-CR-04	Virent Energy Systems, Inc.	Corn Stover Feedstock Collection and Preprocessing

Modified CRADAs		
Agreement	**Party**	**Title**
11-CR-18	OriginOil, Inc.	Removing Barriers to Algal Biofuel Production
11-CR-16	Atomic Energy of Canada Ltd.	INL-AECL Joint Project for Active FIB and TEM Analysis of Irradiated X-750
11-CR-13	Korea Atomic Energy Research Institute, UChicago Argonne, LLC	Joint Fuel Cycle Studies
09-CR-09	IGE Energy Services, Limited	IGE Energy Services, Limited Assessments - SCADA
08-CR-12	Pebble Bed Modular Reactor (Pty) Ltd - South Africa	PBMR TRISCO Coated Particles in AGR-2 Experiment
07-CR-15	Xtreme Biochemicals, Inc.	Application of Alicyclobacillus to Biomass Processing

Strategic Partnership Projects

New Non-Federal SPP		
Agreement	**Party**	**Title**
15901	Toshiba	Toshiba Diffusion Couple Test
15817	Radiation Monitoring Devices, Inc.	New dual mode sensor for Material Accounting
15815	ATK Launch Systems	Electrosynthesis of Perchlorate: Literature Study and Lab Study
15814	Radiation Monitoring Devices, Inc.	Neutron-Gamma Scintillation Detector for Emergency Response/RIID
15813	Southern California Edison Company	California Energy Systems for the 21st Century (CES-21)
15811	Northrop Grumman Corporation - Aerospace Systems	Electronic Warfare Common Component (EWCC) Maintenance Support In Support of the Miniature Air Launched Decoy (MALD) Jammer (J) FY 2015
15810	GOOGLE	Google Co-Electrolysis
15809	Radiation Monitoring Devices, Inc.	Radiation Imaging Device Testing for RMD, Inc. at INL ZPPR Facility
15806	OneSubSea	Evaluation of battery technologies for drilling platforms

New Non-Federal SPP		
Agreement	**Party**	**Title**
15805	OneSubSea	Feasibility Study of the Potential Effectiveness of Volatile Corrosion Inhibitors to Detect and/or Mitigate Incipient Corrosion in Materials Typical of Pipelines and other Components of Interest to OneSubSea
15803	Electric Power Research Institute (EPRI)	Studying the Ballistic Vulnerability of Transformers
15801	Jet Propulsion Laboratory	Preconceptual Design for SR-90
15509	EDM International, Inc.	Flight Operations for EDM
15506	University of Wyoming	Autonomous Systems Center for Excellence
15505	Idaho Department of Commerce	Autonomous Systems Center for Excellence
15502	Cool Planet Energy Systems	Loblolly Pine Preprocessing for Cool Planet
15501	NuScale Power, LLC	NuScale Power IQ-Station Setup
14905	James Fisher Nuclear Ltd	Fueling Machine Inspection Tool Development
14903	Westinghouse Electric Company, LLC	Westinghouse PIE 2014
14820	The NanoSteel Company, LLC - FL	Support work for the NanoSteel Company
14808	Alliant Techsystems Operations	Simulation and Analysis for Propellant Based Well Stimulation
13908	Electricity De France (EDF)	Reactor Pressure Vessel (RPV) Integrity Assessment Project

Modified Non-Federal SPP		
Agreement	**Party**	**Title**
15810	GOOGLE	Google Co-Electrolysis
15806	OneSubSea	Evaluation of battery technologies for drilling platforms
15801	Jet Propulsion Laboratory	Preconceptual Design for SR-90
15502	Cool Planet Energy Systems	Loblolly Pine Preprocessing for Cool Planet
14905	James Fisher Nuclear Ltd	Fueling Machine Inspection Tool Development

Modified Non-Federal SPP		
Agreement	Party	Title
14901	Canadian Nuclear Safety Commission	Idaho National Laboratory (INL) Support of Human Reliability Analysis (HRA) for the Canadian Nuclear Safety Commission (CNSC)
14818	Electric Power Research Institute (EPRI)	Intelligent Plant Configuration Management Using Wireless Sensors
14816	DuPont Industrial BioSciences	DuPont Cellulosic Ethanol Co-Product
14815	Battelle Memorial Institute (Columbus)	TESTING OF NOVEL CR-39 DETECTOR DEPLOYMENT SYSTEM FOR IDENTIFICATION OF SUBSURFACE FRACTURES, SODA SPRINGS, ID
14814	Wyle Laboratories, Inc.	Wyle Implementations & Test Support
14806	Ford Motor Company	Ford Motor Company Cell Testing
14803	X-Energy, Inc.	Develop Business Plan for X-Energy High Temperature Gas-cooled Reactor Concept
14801	Cumming Investment Company, LLC	Cumming Investment Company Biomass Conversion Work For Others
14505	Clems Custom Gun Works	Clemens Testing Effort
14504	NuScale Power, LLC	NuScale Power LLC Technical Assistance
14502	University of Missouri - Nuclear Research Reactor, The Curators of the	WSU Neutron Beamline Requalification and MU Beamline Design Consulting
13903	Japan Atomic Energy Agency (JAEA)	JAEA Technical Support on Fukushima
13818	Princess Energy Systems, Inc.	Phosphazene Based Electrolyte Additives for Safer Lithiun-Ion Batteries
13816	NuScale Power, LLC	NuScale Hybrid Energy Application Analysis
13811	THOR Treatment Technologies (TTT)	Technical Support for THOR Treatment Technologies (TTT) Steam Reforming Process Startup, Testing, and Operations
13806	NuScale Power, LLC	RELAP5-3D Support for NuScale
13805	Ceramic Cement Corporation	Ceramic Cement Corporation Test Program
13803	Battelle Memorial Institute (Columbus)	Characterization and Decontamination of Surfaces, Structures, Soils, and Other Media
12903	Ontario Power Generator	Integrated Waste Tracking System-Ontario Power Generation

Modified Non-Federal SPP		
Agreement	Party	Title
12820	Materials and Systems Research, Inc.	Development of a Robust, Highly Efficient Oxygen-Carbon Monoxide Cogeneration System
12814	EITC	Firefighter Training Facility Work for Others Utilization
12810	Idaho State University	Specialized Energy Technology and Systems Training
11904	Australian Nuclear Science & Techno (ANSTO)	Review ANSTO, Inc. System Deployment in Radiological Environments
11903	National Nuclear Laboratory, Ltd.	National Nuclear Laboratory in the United Kingdom
11820	TerraPower, LLC	TerraPower - INL Consulting Services for Safety Analysis
11812	Northrop Grumman Information Systems Sector, Defense Systems Division	Northrop Grumman EWCC MPEC II Project
11804	University of Missouri, International Institute for Nano & Molecular Medicine	Extended Testing of Boron Delivery Agents for BNCT

Invention Disclosure Records

No.	Date	Title	Org	Inventors
BA-824	10/8/2014	Portable detector to locate radioactive material in 3D	D	Christopher Riley, Jared Horkley, Kevin Carney, Martha Finck
BA-825	10/13/2014	Non-Linear seismic Soil Structure Interaction (NLSSI) analysis Methodology	C	Justin Coleman, Robert Spears
BA-826	10/27/2014	Reactor Monitoring with Cherenkov Light	D	David Chichester, Sean Morrell, Thomas Holschuh, Wade R. Marcum
BA-827	10/28/2014	Protection of Zircaloy Rods with Yttria-Stabilized Zirconia	B	Brent J. Heuser, Jason Hales, Michael Glazoff, Piyush Sabharwall
BA-828	11/4/2014	Spark ionization system	D	Jared Horkley, Kevin Carney, Martha Finck
BA-829	12/1/2014	Multiple Cutting Surface Boring Bar Head	J	Spencer Wendel, William Fuger

No.	Date	Title	Org	Inventors
BA-830	12/4/2014	Aluminum Electroplating on Metals/Alloys from a Bromide Plating Bath	C	Eric Dufek, Guy Fredrickson, Janes S. Herring, Laura A. Wurth, Prabhat Tripathy
BA-831	12/16/2014	Battery Online Condition Monitoring Methods and System using Active and Passive Measurements	B	Humberto Garcia, Jon Christophersen
BA-832	12/16/2014	Uranium Silicide Pellet Production by Powder Metallurgy	U	Jason Harp, Paul Lessing, Rita Hoggan
BA-833	1/6/2015	Low-cost modular ballistic resistant panels	D	Benjamin Langhorst
BA-834	1/7/2015	Device for Non-destructive quantification of radioactive gases by the Absolute Efficiency Calibration method	D	James C Hayes, Martha Finck, Matthewe W. Cooper, Troy Robinson
BA-835	1/13/2015	Hydriding and Bromination Processes to Recover Uranium from Used Advanced Test Reactor (ATR) Fuel	C	Guy Fredrickson, Prabhat Tripathy, Steven Herrmann
BA-836	1/13/2015	Hydriding-Dehyriding and Chlorination Processes for Recovering Uranium from Used Advanced Test Reactor (ATR) Fuel	C	Guy Fredrickson, Prabhat Tripathy, Steven Herrmann
BA-837	1/19/2015	Electrochemistry Enabled Recovery of Value Metals from Electronics	B	Eric Dufek, Gemma Clark, Jacob A. Parkman, Luis A. Diaz Aldana, Tedd Lister
BA-838	1/19/2015	A One Step Process for the Removal of Metallic (Surface) Coating from the Nd2Fe14B (neo) Permanent Magnets	C	Delon Haggard, Eric Peterson, Prabhat Tripathy, Tedd Lister, William Swank
BA-839	2/5/2015	Mercury Absorbant Fixative	C	Donald Fox, Kip Archibald, Ricky Demmer
BA-840	2/9/2015	Hydriding and Molten Magnesium Treatment Processes for Recovering Uranium from Used Advanced Test Reactor (ATR) Fuel	C	Guy Fredrickson, Prabhat Tripathy, Steven Herrmann
BA-841	2/18/2015	A Pyro/Electrometallurgical Processing Scheme for the Recovery of Uranium from Used Advanced Test Reactor (ATR) Fuel	C	Guy Fredrickson, Prabhat Tripathy, Steven Herrmann

No.	Date	Title	Org	Inventors
BA-842	2/26/2015	Engineering Caulobacter Surface Protein for Rare Earth Element Adsorption	B	Dan Mcfarland Park, David Reed, Mimi Cho Yung, Yongqun Jiao
BA-843	2/27/2015	Desensitizing Ignition of Energetic Materials when Exposed to Accidental Fire	D	Michael A. Daniels, Michelle L. Pantoya, Ronald Heaps
BA-844	3/13/2015	Thermophilic acetylxylanase esterase from Alicyclobacilus acidocaldarius	B	David Reed, David Thompson, Jeffrey Lacey, Vicki Thompson, William A. Apel
BA-845	3/30/2015	Auto Peak-Width Calibration of a Gamma-Ray Spectrm	D	Ann Egger, Augustine Caffrey
BA-846	3/31/2015	Stabilized Phosphoranimines	B	Eric Dufek, John Klaehn, Joshua McNally
BA-847	4/1/2015	A Process for the Recovery of Mercury and Rare Earth Elements from Used Fluorescent Lamps	B	Bruce Mincher, Chien M. Wai, Clive Yen, Donna Baek, Mary Case, Robert Fox
BA-848	4/6/2015	Fast self-discharge measurement and detection of internal shorts in batteries	B	Eric Dufek, Kevin Gering, Sergiy Sazhin
BA-849	4/7/2015	Super Tap	D	Reston Condit
BA-850	4/8/2015	Metallic Aluminum Coating on Zirconium Alloys for Cladding Applications in Advanced Light Water Reactors	C	Guy Fredrickson, Prabhat Tripathy
BA-851	4/8/2015	Recycling of Neo Magnets by HDDR Process-Selection of Process Parameters to Re-fabricate Bonded and Sintered Magnets	C	Delon Haggard, Eric Peterson, Prabhat Tripathy, Tedd Lister, William Swank
BA-852	4/10/2015	A Process for the Recovery of Mercury and Rare Earth Elements from Used Fluorescent Lamps Using Supercritical Fluid Extraction	B	Bruce Mincher, Chien M Wai, Clive Yen, Donna Baek, Mary Case, Robert Fox
BA-853	4/16/2015	Electrochemical Upgrading of Bio-Oils	B	Asanga Padmaperuma, Eric Dufek, Lucia Petkovic, Michael Lilga, Tedd Lister
BA-854	6/2/2015	Membrane Solvent Extraction for Rare Earth Separations	B	Eric Peterson, Ramesh R. Bhave

No.	Date	Title	Org	Inventors
BA-855	5/18/2015	On the use of a Monolithic Platinum Group Metal as an Inert Anode for the Electrochemical Reduction of Metal Oxides in the Fused LiCl-Li2O Electrolyte System	C	Guy Fredrickson, Prabhat Tripathy, Steven Frank, Steven Herrmann
BA-856	6/2/2015	Application of Hydrogen Desorption Disproportionation Recombination (HDDR) Process to Recycle Spent Metal Hydride Electrodes	C	Prabhat Tripathy
BA-857	6/8/2015	An Integrated Process for Supercritical Fluid Extraction and Separation of Lead from Leaded Glass	B	Bruce Mincher, Chien M. Wai, Donna Baek, Mary Case, Robert Fox
BA-858	6/8/2015	Instrumentation to Monitor the Physical Properties of a Serial Network	D	Jared Verba, Jonathan Chugg, Kenneth Rohde, Reston Condit
BA-859	6/16/2015	Thermal Conductivity Microscope	B	David Hurley, Marat Khafizov, Robert Schley
BA-860	6/17/2015	Additive manufacturing of graphite matrixed ceramic fuel blocks.	C	Isabella Van Rooyen, Sean Morrell
BA-861	6/17/2015	Thermocouples Performance Enhancement	C	Ahmad Al Rashdan
BA-862	6/17/2015	Online Geometry Reconstruction and Failure Detection of Nuclear Fuel	C	Ahmad Al Rashdan
BA-863	6/24/2015	Electrochemical treatment of nuclear waste streams	C	Alexander M. Lapides, Bruce Mincher, Christopher J. Dares, Thomas J. Meyer
BA-864	7/8/2015	Universal Pouch Cell Test Fixture	B	Chinh Ho, Clair Ashton, David Jamison, Michael Evans, Randy Bewley, Ryan Jackman, Steven Egan, Taylor Bennett
BA-865	7/8/2015	Catalytic Supercritical Fluid Upgrading of Coal	B	Anne Gaffney, Daniel Ginosar, Lucia Petkovic, Richard Boardman
BA-866	7/13/2015	High Resolution Impedance Measurement Box	B	John Morrison, Jon Christophersen, William Morrison
BA-867	7/22/2015	Dry Cask Monitoring System	C	Ahmad Al Rashdan

No.	Date	Title	Org	Inventors
BA-868	8/3/2015	Thermoacoustic Discrimination of Temperature and Elongation in Fuel Rods	C	James Jewell, James Smith
BA-869	8/17/2015	Protective barriers for electrical power transformers and substations	D	Henry Chu, James Schondel, Michael Bakas, Todd Johnson
BA-870	8/17/2015	Generation of Phase Change Materials	B	Aaron Wilson, Christopher Orme, Daniel Wendt, Gregory Mines, Michael Jones
BA-871	8/18/2015	Branch and Bound Algorithm for Optimization of Dynamic Systems using LENDIT Metrics and S2R2 Sets	C	Joseph Nielsen
BA-872	8/18/2015	Microwave-based fast pyrolysis	B	Rachel Emerson, Tyler Westover
BA-873	8/18/2015	Instrumented hopper with adjustable outlet for characterization flowability of bulk solids	B	Austin Matthews, John Chadron Ryan, Sergio Hernandez, Tyler Westover
BA-874	8/18/2015	Sixteen gamma detector system to characterize neutron flux	B	Christian Jensen, Gene Taylor, John Walter
BA-875	8/18/2015	Method to calibrate non-contact velocity measurements by the Hugoniot elastic limit	D	James Smith, Jeffrey Lacy
BA-876	8/28/15	Method of Brazing Silicon Carbide to Metals	D	Michael Bakas, Henry Chu, Thomas Lillo, Arnold W. Erickson
BA-877	9/30/15	Triple Bubbler System	B	Gregory G. Galbreth, DeeEarl Vaden, Brenda E. Serrano-Rodriguez, Guy L. Fredrickson, Michael R. Shaltry, Tae-Sic Yoo, Maureen P. Chorney
BA-878	9/30/15	Novel Feeder for Biomass Materials	B	Corrie I. Nichol

Patents

ALL INL/DOE US Patents Issued

From: 10/1/14
To: 9/30/15

Docket #	Patent Title				
B-566D1	Methods, Apparatus, And Systems For Monitoring Transmission Systems				
Patent Number:	8,941,491	**Issue Date:**	1/27/2015	**Current Owner:**	Current Contractor
Inventors:	Robert E Polk, John M Svoboda, Phillip B West, Gail L. Heath, Clark L. Scott			**Application Type:**	National, Division, Regular
				Country:	United States
BA-195	Methods Of Forming Boron Nitride				
Patent Number:	8,968,827	**Issue Date:**	3/3/2015	**Current Owner:**	DOE
Inventors:	Tammy L Trowbridge, Alan K Wertsching, Patrick J Pinhero, David L Crandall			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-283ACIP1C1	Thermophilic And Thermoacidophilic Biopolymer-degrading Genes And Enzymes From Alicyclobacillus Acidocaldarius And Related Organisms, Methods				
Patent Number:	9,045,741	**Issue Date:**	6/2/2015	**Current Owner:**	Current Contractor
Inventors:	David N. Thompson, William A Apel, Vicki S Thompson, David William Reed, Jeffrey A Lacey, Emily D. Henriksen			**Application Type:**	National, Continuation-In-Part, Regular
				Country:	United States
BA-322D2	Type Ii Restriction Modification System Methylation Subunit Of Alicyclobacillus Acidocaldarius				
Patent Number:	9,029,114	**Issue Date:**	5/12/2015	**Current Owner:**	Current Contractor
Inventors:	Brady D Lee, Deborah T Newby, Jeffrey A Lacey, David N. Thompson, Vicki S Thompson, William A Apel, Francisco F Roberto, David William Reed			**Application Type:**	National, Division, Regular
				Country:	United States
BA-350	Methods Of Natural Gas Liquefaction And Natural Gas Liquefaction Plants Utilizing Multiple And Varying Gas Streams				
Patent Number:	8,899,074	**Issue Date:**	12/2/2014	**Current Owner:**	Current Contractor
Inventors:	Bruce M Wilding, Terry D Turner			**Application Type:**	National, Original Filing, Regular
				Country:	United States

ALL INL/DOE US Patents Issued

From: 10/1/14
To: 9/30/15

Docket #	Patent Title				
BA-351	Alteration And Modulation Of Protein Activity By Varying Post-translational Modification				
Patent Number:	8,969,033	**Issue Date:**	3/3/2015	**Current Owner:**	Current Contractor
Inventors:	David N. Thompson, David William Reed, Vicki S Thompson, Jeffrey A Lacey, William A Apel			**Application Type:**	National, Continuation-In-Part, Regular
				Country:	United States
BA-386	Identification Of Discriminant Proteins Through Antibody Profiling, Methods And Apparatus For Identifying An Individual				
Patent Number:	8,969,009	**Issue Date:**	3/3/2015	**Current Owner:**	Current Contractor
Inventors:	Vicki S Thompson, Jeffrey A Lacey, Cynthia D Gentillon, William A Apel			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-388	Hybrid Particles And Associated Methods				
Patent Number:	8,951,446	**Issue Date:**	2/10/2015	**Current Owner:**	Current Contractor
Inventors:	Robert V Fox, Rene G. Rodriguez, Joshua J. Pak, Chivin Sun			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-398	Methods For Radiation Detection And Characterization Using A Multiple Detector Probe				
Patent Number:	8,878,140	**Issue Date:**	11/4/2014	**Current Owner:**	Current Contractor
Inventors:	Douglas W Akers, Lyle G Roybal			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-421	Method Of Estimating Pulse Response Using An Impedance Spectrum				
Patent Number:	8,868,363	**Issue Date:**	10/21/2014	**Current Owner:**	Current Contractor
Inventors:	John Morrison, William Morrison, Jon Petter Christophersen, C. (Chet) G Motloch			**Application Type:**	National, Original Filing, Regular
				Country:	United States

ALL INL/DOE US Patents Issued

From: 10/1/14
To: 9/30/15

Docket #	Patent Title				
BA-427	Actinide-ion Sensor				
Patent Number:	8,932,446	**Issue Date:**	1/13/2015	**Current Owner:**	DOE
Inventors:	Shelly X Li, Jan-Fong Jue, R (Scott) S Herbst, Steven D. Herrmann			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-440D1	Methods For Synchronizing A Countdown Routine Of A Timer Key And Electronic Device				
Patent Number:	9,046,268	**Issue Date:**	6/2/2015	**Current Owner:**	Current Contractor
Inventors:	Reston A Condit, Michael Alan Daniels, Gregory P Clemens, Eric S Tomberlin, Joel A Johnson			**Application Type:**	National, Division, Regular
				Country:	United States
BA-454	Radiation Sensitive Devices And Systems For Detection Of Radioactive Materials And Related Methods				
Patent Number:	8,901,507	**Issue Date:**	12/2/2014	**Current Owner:**	Current Contractor
Inventors:	Dale K Kotter			**Application Type:**	National, Continuation-In-Part, Regular
				Country:	United States
BA-467	Method And Device For Fabricating Dispersion Fuel Comprising Fission Product Collection Spaces				
Patent Number:	9,025,722	**Issue Date:**	5/5/2015	**Current Owner:**	DOE
Inventors:	Eric L Shaber, Randall S. Fielding			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-476	Real Time Explosive Hazard Information Sensing, Processing, And Communication For Autonomous Operation				
Patent Number:	8,965,578	**Issue Date:**	2/24/2015	**Current Owner:**	Current Contractor
Inventors:	Roelof J Versteeg, Douglas A Few, Robert A Kinoshita, Doug Johnson, Ondrej Linda			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-500D1	Precursor Polymer Compositions Comprising Polybenzimidazole (as Amended)				
Patent Number:	9,080,052	**Issue Date:**	7/14/2015	**Current Owner:**	Current Contractor
Inventors:	John R Klaehn, Eric S Peterson, Christopher J Orme			**Application Type:**	National, Division, Regular
				Country:	United States

ALL INL/DOE US Patents Issued

From: 10/1/14
To: 9/30/15

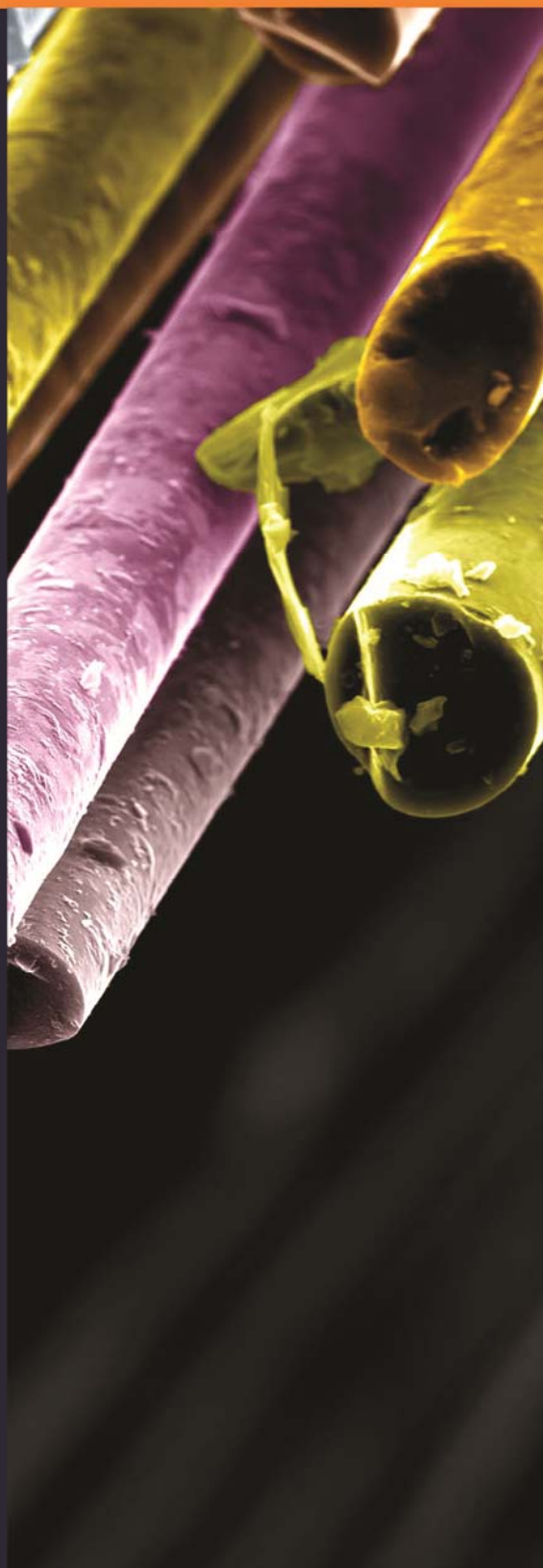
Docket #	Patent Title				
BA-537	Neutron Absorbers And Methods Of Forming At Least A Portion Of A Neutron Absorber				
Patent Number:	8,903,035	**Issue Date:**	12/2/2014	**Current Owner:**	Current Contractor
Inventors:	Donna P Guillen, Douglas L Porter, W. David Swank, Arnold W Erickson			**Application Type:**	National, Continuation-In-Part, Regular
				Country:	United States
BA-558D1	System And Process For The Production Of Syngas And Fuel Gasses				
Patent Number:	9,011,725	**Issue Date:**	4/21/2015	**Current Owner:**	Current Contractor
Inventors:	Dennis N Bingham, Kerry M Klingler, Terry D Turner, Bruce M Wilding, Bradley Curtis Benefiel			**Application Type:**	National, Division, Regular
				Country:	United States
BA-560	Apparatus, System, And Method For Laser-induced Breakdown Spectroscopy				
Patent Number:	8,891,073	**Issue Date:**	11/18/2014	**Current Owner:**	Current Contractor
Inventors:	Andrew J Effenberger , Jill R Scott, Timothy R McJunkin			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-585D1	Methods And Apparatuses Using Filter Banks For Multi-carrier Spread Spectrum Signals				
Patent Number:	8,861,571	**Issue Date:**	10/14/2014	**Current Owner:**	Current Contractor
Inventors:	Hussein Moradi, Behrouz Farhang, Carl A Kutsche			**Application Type:**	National, Division, Regular
				Country:	United States
BA-630	User Interface For A Tele-operated Robotic Hand System				
Patent Number:	8,989,902	**Issue Date:**	3/24/2015	**Current Owner:**	DOE
Inventors:	Anthony Louis Crawford			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-659	Apparatuses For Large Area Radiation Detection And Related Method				
Patent Number:	9,018,586	**Issue Date:**	4/28/2015	**Current Owner:**	Current Contractor
Inventors:	Douglas W Akers, Mark W Drigert			**Application Type:**	National, Original Filing, Regular
				Country:	United States

ALL INL/DOE US Patents Issued

From: 10/1/14
To: 9/30/15

Docket #	Patent Title				
BA-661	System And Process For Upgrading Hydrocarbons				
Patent Number:	9,114,984 B2	**Issue Date:**	8/25/2015	**Current Owner:**	Current Contractor
Inventors:	Dennis N Bingham, Kerry M Klingler, Joseph D. Smith, Terry D Turner, Bruce M Wilding			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-670	Electrodes Including A Polyphosphazene Cyclomatrix, Methods Of Forming The Electrodes, And Related Electrochemical Cells				
Patent Number:	8,871,385	**Issue Date:**	10/28/2014	**Current Owner:**	Current Contractor
Inventors:	Kevin L Gering, Frederick F Stewart, Aaron D Wilson, Mark L Stone			**Application Type:**	National, Original Filing, Regular
				Country:	United States
BA-702	Real-time Monitoring Of Plutonium Content In Uranium-plutonium Alloys				
Patent Number:	9,121,807 B1	**Issue Date:**	9/1/2015	**Current Owner:**	DOE
Inventors:	Shelly X Li, Brian R Westphal, Steven D. Herrmann			**Application Type:**	National, Original Filing, Regular
				Country:	United States

Total Patents Issued:# 25



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