

# **Utilization of Federal Technology**

## **National Laboratory and Facility Success Stories for Fiscal Year 2016 and 2017**

**March 2019**

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## Creating Technologies through Engagement at Every Level: The Critical Materials Institute

Ames Laboratory in conjunction with the DOE Office of Energy and Renewable Energy, the Advanced Manufacturing Office, Idaho National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, The Colorado School of Mines, Iowa State University, Purdue, Rutgers, UC Davis, and industry participants

*Engaging industry in every step of research to develop new technologies.*

### Innovation

One successful CMI project involves several National Lab Team Members and Eck Industries. This project produced castable Ce-modified Al alloys that have the ability to fill a vacant spot in the aluminum alloys family. The alloys maintain their mechanical properties to a higher temperature than currently available alloys and thus create a high temperature aluminum alloy with mechanical characteristic improvements upwards of 30% over other Al alloys in similar high temperature applications. Previously existing aluminum alloys which can function at high temperature are too cost prohibitive for widespread application due to their use of elements such as scandium and zirconium. Cerium modification of Aluminum alloys will serve to create an as-of-yet unseen opportunity for Aluminum alloys to be utilized in high temperature applications, such as automotive engines; where before, such an application was limited to much denser and thus heavier alloys.

### Outcomes

#### Technology Advancement

The CMI's emphasis on collaboration at every stage of research and development has produced over 100 invention disclosures since its inception in 2013, resulting in eight patents to date, numerous patent applications, and several technologies licensed.

#### Impact

Several of the research projects being undertaken by the CMI include its Industrial Team Members who are participating in the research every step of the way. Using this approach, the CMI is able to consistently focus on the economic and manufacturing feasibility of the technologies it's developing.



Picture of aluminum-cerium-magnesium engine part cast by Eck Industries.

“There has been tremendous interest from industry due to the unique material properties and low cost of this alloy. This project is a template for rapid development and commercialization. Not only did we bridge the research ‘valley of death,’ we also developed a highway for communication from our customers to us to help guide the project.”

David Weiss, Vice President of Engineering/R&D, Eck Industries

### Timeline

- 2013:** DOE establishes the Critical Materials Institute (CMI) headquartered at the Ames Laboratory to develop solutions to domestic shortages of rare earth metals and other materials critical for U.S. energy security.
- 2015:** Several National Lab CMI Team Members and Eck Industries invent *Castable High-Temperature Ce-Modified Al Alloys*.
- 2017:** Eck Industries exclusively licenses the technology.
- 2018:** Patent issues.

<sup>1</sup> U.S. Dept. of Energy, Ames Laboratory mark new era in critical materials research with new Energy Innovation Hub (September 10, 2013 Ames Laboratory Press Release)

<sup>2</sup> Eck Industries exclusively licenses cerium-aluminum alloy co-developed by ORNL (June 7, 2017 ORNL Press Release)

## Fundamental Advances for High Quality/Low Cost Feedstock Powders

Ames laboratory

*Increasing the quality of gas atomization for powder production.*

### Innovation

Fundamental process modeling and simulation enables precise gas atomization to produce highest quality additive manufacturing (AM) feedstocks by high volume/low cost manufacturing method. Conventional gas atomized powders, even those produced by aerospace-qualified powder makers, are far from ideal feedstock powders for either laser or e-beam melted (EBM) methods of AM. Also, EBM powders tend to have “satellite” projections and poor flowability for build layer spreading and high internal porosity (20-30%) that causes harmful porosity in AM builds. Atomization process modeling, verified by experiments, demonstrated efficiency and effectiveness at solving these problems.

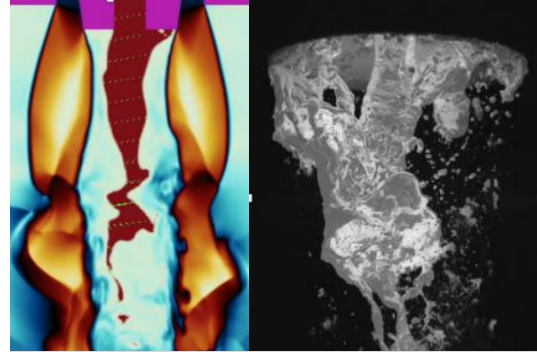
### Outcomes

Technology Advancement

Adaptation of compressible flow modeling to incorporate high density liquid metals permitted ground-breaking simulation of supersonic gas atomization of molten metal in full 2-D to analyze melt break-up into droplets that solidify into spherical powders for use in AM. 2-D break-up simulations compared well with high speed video imaging of comparable gas atomization experiments (see Figure), permitting selection of modest gas velocities for producing EBM powder feedstock with extremely low interior porosity (4%), compared to 20-30% for typical commercial powder. While further 3-D simulation of droplet breakup will permit powder size predictions, empirical data allowed a greatly enhanced (3x) powder yield (50-60%) to be achieved in experiments performed with AMES gas atomizer, compared to commercial practice.

Impact

With sufficient industry adoption of the methods and controls for precision gas atomization from this project, the cost for highest quality powder (500-1000/kg), from plasma rotating electrode process (PREP), can be reduced by about 10 times.



Comparison of simulated liquid nickel breakup by argon atomization gas (left) and experimental liquid nickel gas atomization spray high speed video frame (right).

**“One of the highest barriers to broad adoption of additive manufacturing will tumble down if precision gas atomization becomes common industrial practice.”**

Dr. Iver Anderson, Senior Metallurgist,  
Ames Laboratory

### Timeline

**2017:** Ames shipped re-designed MAR-M-247 powder to ORNL for AM trials where the EMB powder yield was 56%.<sup>1,2</sup>

<sup>1</sup> Hernandez, F.H., Riedemann, T., Tiarks, J., Kong, B., Anderson, I.E., Ward, T., Regele, J.D. “Simulation of primary breakup in planar close-coupled gas atomization,” in proceedings of 14th International Conference on Liquid Atomization and Spray Systems, 198 (2018).

<sup>2</sup> Hernandez, F.H., Riedemann, T., Tiarks, J., Kong, B., Anderson, I.E., Ward, T., Regele, J.D. “Close-coupled gas atomization and nozzle gas dynamics, part (2): Simulation,” in proceedings of Advances in powder metallurgy and particulate materials, pp. 35–54. Metal Powder Industries Federation (2018), [techstreet.com/standards/advances-in-powder-metallurgy-particulate-materials-2018?product\\_id=2016552](http://techstreet.com/standards/advances-in-powder-metallurgy-particulate-materials-2018?product_id=2016552)

## Ames Laboratory-developed Titanium Powder Processing gains World-Wide Customer Base

Ames Laboratory in conjunction with DOE Office of Science and Office of Fossil Energy, Iowa State University's Research Foundation, the State of Iowa Regents Innovation Fund, and the U.S. Army

*Efficiently processing Titanium powder for multiple manufacturing applications.*

### Innovation

Titanium powder created with Ames Laboratory-developed gas-atomization technology is being successfully marketed by Praxair Inc., which offers fine, spherical titanium powder for additive manufacturing and metal injection molding of aerospace, medical and industrial parts. It marks the first time large-scale amounts of titanium powder are available to industry with a potential for low-cost, high-volume manufacturing.

### Outcomes

#### Technology Advancement

Titanium's strength, light weight, biocompatibility and resistance to corrosion make it ideal for use in parts ranging from aircraft wing structures to replacement knee joints and medical instruments. Using ultra-fine, high-purity spherical titanium powder to 3-D print or mold these parts generates 10 times less metal waste than traditional casting of parts.

#### Impact

Two former Ames Laboratory employees Joel Rieken and Andy Heidloff, created a spinoff company, Iowa Powder Atomization Technologies (IPAT), to exclusively license Ames Laboratory's titanium atomization patents. IPAT scientists worked to further optimize the titanium atomization process and along the way won several business and technology awards for their efforts, including the Department of Energy's Next Top Energy Innovator competition in 2012. IPAT was acquired by Praxair, a Fortune 250 company and one of the world's largest producers of gases and surface coatings in 2014, and Praxair began marketing titanium powder the following year.



A titanium bolt and the corresponding amount of titanium powder necessary to create it.

*"Titanium powder made with this technology has huge potential to save manufacturers materials and money."*

Dr. Iver Anderson, Senior Metallurgist,  
Ames Laboratory

*"Praxair Surface Technologies has chosen to commercialize the titanium atomization technology from Ames and also to hire two of the three investigators (Heidloff and Rieken) that were responsible for this unique titanium atomization process."*

Dean Hackett, Vice President  
Praxair Surface Technologies, Inc.

### Timeline

**2012:** IPAT wins the DOE Next Top Energy Innovator Competition.

**2014:** IPAT is acquired by Praxair.

**2015:** Praxair begins marketing fine titanium powders for the AM Industry.

<sup>1</sup> Ames Laboratory Scientist and Team win Excellence in Technology Transfer in FLC Award Competition (August 25, 2017 Ames Laboratory Press Release)



## Argonne helps Aramco Research Center-Detroit Slash Engine and Fuel Design Time and Cost

Argonne National Laboratory in conjunction with Aramco Research Center-Detroit

*Accelerating engine design through supercomputing.*

### Innovation

In 2017, Argonne scientists and engineers pinpointed engine designs for a given fuel using the Mira supercomputer at the heart of the Argonne Leadership Computing Facility, a Department of Energy Office of Science User Facility.

### Outcomes

#### Technology Advancement

With Mira's supercomputing prowess, Argonne's Virtual Engine Research Institute and Fuels Initiative (VERIFI) team simulated more than 2,000 engine design combinations. The simulations were conducted with design scenarios from the Aramco Research Center-Detroit, one of three U.S.-based research centers operated by Saudi Aramco's North American subsidiary, Aramco Services Company. The work was conducted as part of a Strategic Partnership Project (SPP).

#### Impact

The Argonne approach "reduced design time from months to weeks," said Sibendu Som, group leader and principal computational scientist at Argonne. This significant reduction in design time translated to significant cost savings.



By tapping into Argonne's high-performance computing resources and expertise, Aramco Research Center-Detroit streamlined its engine and fuel design process.

"The simulations performed by Argonne found two optimized fuel-engine concepts that could improve fuel efficiency substantially."

Yuanjiang Pei, Lab Scientist, Aramco Research Center-Detroit

### Timeline

**2017:** Argonne scientists use Mira supercomputer to pinpoint engine designs

## Companies Tap into Argonne's Self-Healing Coating that could Revolutionize Lubrication

Argonne National Laboratory in conjunction with the DOE Office of Science and Lawrence Berkeley National Laboratory

*Developing a self-lubricating film that can greatly improve engine durability.*

### Innovation

Argonne researchers have developed an ultra-durable, self-lubricating tribofilm – a film that forms between moving surfaces – that could have profound implications for the efficiency and durability of engines and other machinery with moving metal parts.

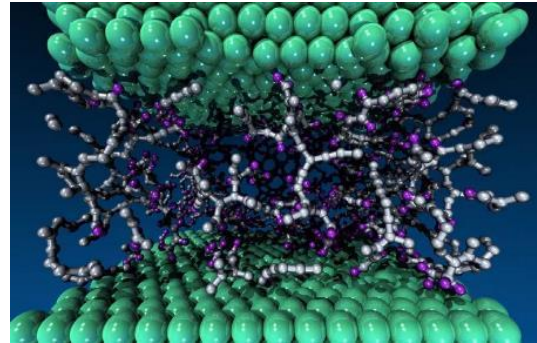
### Outcomes

#### Technology Advancement

The tribofilm reduces friction by 25-40 percent and wear to unmeasurable values. As such, it holds promise for significantly reducing energy consumption in a range of applications and greatly extending the life of hardware. In addition, because the tribofilm regenerates itself as it is worn away, it could greatly reduce the need for maintenance and the associated costs.

#### Impact

In 2017, Argonne entered into Strategic Partnership Projects (SPP's) with Nissan – which has production facilities in Tennessee and Mississippi – and Hyundai – which has a production facility in Alabama – to explore application of the technology in the automakers' engines. Also in 2017, Argonne and Magna Services of America – headquartered in Troy, Mich. – won a Technology Commercialization Fund award from the Department of Energy (DOE) to explore the application of the technology to increase the service interval of automotive powertrain applications.



Argonne researchers have demonstrated that, with the design of catalytically active surface layers, they can crack long-chain hydrocarbon molecules of base oils and turn them into diamond-like carbon tribofilms and other forms of carbon nanostructures on rubbing surfaces.

*"This is a very unique discovery. We have developed many types of diamond-like carbon coatings of our own, but we've never found one that generates itself."*

Ali Erdemir, Argonne Distinguished Fellow,  
Argonne National Laboratory

<sup>1</sup> "Hard, Slick and Ready to Roll." *Automotive Engineering*. March 2017. [anl.app.box.com/s/h51uk609tqoo4vnfxojoibwkz2zpek0i](http://anl.app.box.com/s/h51uk609tqoo4vnfxojoibwkz2zpek0i)

<sup>2</sup> Marotti, Ally. "Oil change, shmoil change: Argonne creates regenerating engine coating." *Chicago Tribune*. August 2016. [chicagotribune.com/bluesky/originals/ct-argonne-scientists-coating-to-protect-engines-bsi-20160804-story.html](http://chicagotribune.com/bluesky/originals/ct-argonne-scientists-coating-to-protect-engines-bsi-20160804-story.html)

<sup>3</sup> Erdemir, Ali, Ramirez, Giovanni, Eryilmaz, Osman, Narayanan, Badri, Liao, Yifeng, Kamath, Ganesh, Sankaranarayanan, Subramanian. "Carbon-based tribofilms from lubricating oils." *Nature* 536 67-71 (August 2016).



## Argonne's NMC Cathode Technology a "Game-Changer" in the Battery Industry

Argonne National Laboratories in conjunction with the Department of Energy

*Improving cathode technology to make lithium-ion battery technology cheaper and more efficient.*

### Innovation

Argonne's Nickel Manganese Cobalt (NMC) cathode technology represents an advancement in lithium-ion battery technology from earlier cathode chemistries. Nickel and manganese are considerably cheaper than cobalt, and batteries with NMC cathodes perform better than those with alternative cathode chemistries.

### Outcomes

#### Technology Advancement

NMC has become a dominant focus for cathode material development in the market, as it improves lithium-ion battery performance while reducing manufacturing cost and environmental impact. Applications for the technology include batteries in personal electronic devices, power tools, and hybrid electric vehicles. Additionally, NMC promises to be a key technology for enabling large-scale energy grid storage.

#### Impact

In 2008, the NMC technology was licensed by Toda Kogyo, a respected supplier of materials in the lithium-ion and nickel-metal hydride battery markets. In 2009, BASF Corporation, the largest affiliate of BASF SE and the second-largest producer of chemicals and related products in North America, with 20,000 employees in the U.S., licensed the NMC cathode technology and has invested in further research and development as well as facilities to produce NMC-based products. Most notable is a 70,000-square-foot plant BASF opened in Elyria, Ohio, in 2012 to produce NMC materials. BASF invested \$50 million in the construction, which was also supported by a \$24.6 million grant from DOE. In 2011, both General Motors and LG Chem licensed the NMC technology. NMC is a key enabling component in the battery that powers GM's Chevrolet Bolt, the 2017 *Motor Trend* Car of the Year and one of *Time* magazine's 25 Best Inventions of 2016.



BASF's NMC battery materials plant in Elyria, Ohio

"NMC has been a game-changer in the industry. People are using this Argonne technology without even knowing it, and we fully expect they will be using it more and more."

Mike Fetcenko, Director of Battery Materials,  
BASF Corporation

### Timeline

- 2008:** NMC technology was licensed by Toda Kogyo
- 2009:** NMC technology was licensed by BASF Corporation
- 2010:** Argonne and BASF received a "Deals of Distinction™" Award in 2010 from the Licensing Executives Society, Inc.
- 2011:** NMC technology is licensed by General Motors and LG Chem

<sup>1</sup> "BASF Cathode Material Production Plant, Elyria, Ohio, US." *Chemicals Technology*. chemicals-technology.com/projects/basf-cathode-materials-plant-elyria-ohio-us/

<sup>2</sup> Scoenberger, Robert. "BASF starts electric car battery materials production in Elyria." *The Plain Dealer*. Nov. 2012. cleveland.com/business/2012/11/basf\_starts\_electric\_car\_batte.html

## Auto-Induction Media

Brookhaven National Laboratory

*Using an auto-inducing media to increase production of expression strains to produce large amounts of life saving proteins*

### Innovation

The T7 protein expression system developed by Dr. Studier from Brookhaven National Laboratory has shaped the field of recombinant DNA technology. The T7 RNA polymerase is so active that a small basal level of T7 polymerase can lead to substantial expression of target protein even in the absence of added inducer. If the target protein is sufficiently toxic to the host cell, then the auto induction of the target protein due to the small basal level of T7 polymerase will pose a substantial challenge in the establishment of the target plasmid in the expression host. Dr. Studier addressed this challenge by formulating growth media recipes and protocols that allow for reliable growth of T7 expression strains to saturation with little or no induction.

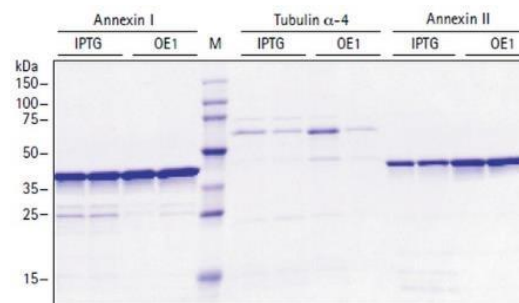
### Outcomes

Technology Advancement

The growth media and protocols developed for use with the T7 expression system, are applicable to other existing expression systems inducible by IPTG or arabinose and potentially to any expression system with an inducer whose action is blocked by glucose. The simplicity of the protocol in using the auto-inducing media allows for efficient screening of many clones in parallel for expression and solubility, as cultures have only to be inoculated and grown to saturation.

Impact

Using the T7 protein expression system, researchers in academia and industry have used E.coli to express several human proteins, including Insulin to treat diabetes. The yields of target protein using the autoinduction media is typically several-fold higher than that obtained by conventional IPTG induction. EMD Millipore is currently manufacturing and selling the auto induction media to academic institutions, biotech and pharmaceutical companies. The media is being used by biotech companies and pharma to express life-saving proteins including enzymes and therapeutics.



Better recombinant protein yields with Overnight Express™ auto-induction (OEI) media compared to manual IPTG induction protocol. Courtesy: EMD Millipore

"Auto-induction simplifies, increases the efficiency, and reduces the cost of producing proteins from cloned genes in the T7 expression system in E. coli (a system previously invented and patented at BNL and successfully licensed for commercial use). It also expands the ability to produce many different proteins in parallel and is applicable to other inducible protein-production systems as well."

William Studier  
Emeritus, Brookhaven National Laboratory

### Timeline

- 2003:** Auto-induction media was licensed by EMD Biosciences and the licensee launched the auto-induction media in the market
- 2007-2008:** Follow-on patent applications were filed
- 2017:** The licensee sublicensed the technology to additional companies
- 2018:** Dr. Studier, the inventor of the technology, was elected as the fellow of the National Academy of Inventors for his work on this technology and the T7 protein expression system that is widely used by scientists to express recombinant proteins in bacteria

## Kilopower Reactor Using Stirling Technology (KRUSTY) System

Consolidated Nuclear Security Y-12/Pantex in conjunction with NASA's Glenn Research Center and the National Nuclear Security Administration

*Developing small scale nuclear power for long term space exploration missions.*

### Innovation

The KRUSTY demonstration, co-funded by NASA and the Department of Energy (DOE) / National Nuclear Security Administration (NNSA), is a milestone in the creation of a small, safe, reliable nuclear power source. The Kilopower concept, a kilowatt-range nuclear reactor using an HEU-Mo metallic fuel core, was a 2013 R&D 100 Award winner (Los Alamos National Laboratory, NASA, and National Security Technologies).

### Outcomes

#### Technology Advancement

With the expertise and creative thinking of Y-12 engineers and fabricators, Y-12 successfully provided depleted uranium-molybdenum prototype components to Glenn Research Center for preliminary thermal testing in November 2016. NASA personnel and other team members, including Y-12 personnel assembled and initiated electrically heated thermal testing of the prototype power system. Based on the prototype test results and fabrication and project lessons learned, Y-12 was able to cast and machine the HEU-Mo components that were delivered to NNSA for testing that resulted in the reactor subassembly (core, reflector, and shielding) achieving criticality on Nov. 16, 2017. With the validation of the reactor subassembly, Los Alamos National Laboratory and NASA engineers/scientists will now integrate the reactor with the power subassembly and proceed toward the full power, full temperature KRUSTY demonstration by the end of the 2nd Quarter FY18.

#### Impact

This nuclear power source is under consideration for NASA as a method for spacecraft and planetary surface power for long-term missions. This experiment also allowed NNSA to obtain valuable benchmark nuclear cross-section data for DOE/NNSA's Nuclear Criticality Safety Program (NCSP).



NASA's "Kilopower Reactor Using Stirling Technology" system, affectionately abbreviated "KRUSTY."

### Timeline

- 2014:** Agreement between Glenn Research and Y-12 calling to support the design of a small nuclear powered reactor for potential use in future space explorations
- 2016:** Y-12 provided depleted uranium-molybdenum prototype components for preliminary thermal testing
- 2017:** Reactor subassembly achieved criticality.
- 2018:** Full power, full temperature KRUSTY demonstration.

## Particle Accelerator Technology for Extending Pavement Life

Fermilab National Accelerator Facility in conjunction with the U.S. Army Engineer Research and Development Center

*Using particle accelerators to strengthen materials.*

### Innovation

Fermilab has partnered with the U.S. Army Engineer Research and Development Center (ERDC) to develop a powerful, compact and inexpensive particle accelerator that can be used to strengthen materials such as plastics, rubber and industrial coatings. The accelerator will direct a high-power beam of electrons at the material, altering its properties. The result would be a higher-durability surface whose extended life could translate into enormous economic benefits. And thanks to the accelerator's portability — less than a meter-and-a-half long — materials can be treated in situ.

### Outcomes

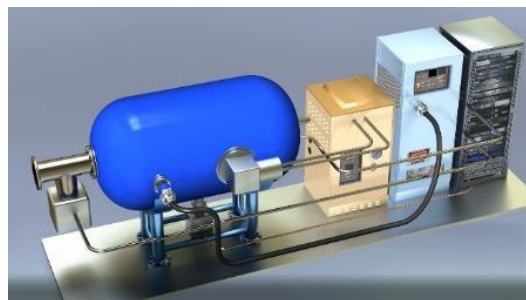
#### Technology Advancement

The accelerator, which is currently in development, is based on high-efficiency, superconducting radio-frequency technology (SRF), which allows it to operate with very low cooling losses. This in turn lets operators dispense with the cryogenics typically used in accelerator operation, dramatically simplifying the system and reducing the machine's size and weight.

#### Impact

One of the areas where such a compact accelerator could have a significant impact is in extending the life of roads and pavement, potentially saving the United States billions of dollars per year on road repair. Small and light enough to be skid-mounted, the accelerator could be taken directly onto the roadways to treat the asphalt. Through an Interagency Agreement between the ERDC and the U.S. Department of Energy, the Illinois Accelerator Research Center (IARC) at Fermilab is working with ERDC to develop the advanced materials and accelerator technologies that will improve the strength, weather resistance, toughness, chemical resistance, and service life of paved surfaces.

And its use would extend beyond industrial materials. Electron beams generated by a compact SRF accelerator could cleanly and cheaply treat wastewater and sterilize medical equipment or build parts and tooling in the additive-metal manufacturing industry, where current machines are limited by beam power.



250-kilowatt skid-mounted compact superconducting accelerator

“The Compact SRF Accelerator technology developed by Fermilab and the IARC team has many applications to ERDC research that could advance technology breakthroughs. We are particularly interested in the Compact SRF Accelerator’s potential application in novel, high-performance pavements. Because it is small and light enough to be truck-mounted, the Compact SRF Accelerator can be used to crosslink or polymerize new pavement materials *in situ*, giving engineers more freedom to tailor the material to the environment and its purpose. We are collaborating with IARC to study a variety of promising materials.”

John F. Rushing, Ph.D., Research Civil Engineer,  
U.S. Army Engineer Research and Development  
Center

### Timeline

**2015:** Provisional patent application filed

**2016:** Fermilab won a TechConnect World National Innovation Award for the innovative use of a compact SRF accelerator for industrial applications.<sup>1</sup>

**2018:** Continuation Filed

**2018:** Patent 10,070,509 issues

<sup>1</sup> “TechConnect Innovation Awards.” TechConnect World Innovation Conference & Expo; May 22-25, 2016; Washington D.C.” Accessed January 25, 2019. [techconnectworld.com/World2016/participate/innovation/awards.html](http://techconnectworld.com/World2016/participate/innovation/awards.html)

## Natural Science, LLC Licenses Fermilab's Electromagnetic Boom and Environmental Clean Up Technologies

Fermi National Acceleratory Laboratory in conjunction with Natural Science, LLC

*Licensing of an electromagnetic mop for potential oil clean up.*

### Innovation

The electromagnetic mop system works because micron-sized magnetite particles will mix with oil more readily than water when these filings are spread on an oil-water mixture. The particles form a unique and preferential bond with the oil due to a combination of forces, forming a loose colloidal suspension. The filings are magnetic, so they can be moved by a typical magnet. This allows one to use magnetic fields to manipulate, trap, and remove the oil in an environmentally safe manner with high efficiency. Natural Science is applying the licensed technology to an electromagnetic boom system that will replace the standard (and inefficient) passive boom and skimmer systems used today.

### Outcomes

#### Technology Advancement

Natural Science, LLC and Fermilab announced an exclusive field-of-use license agreement that grants Natural Science rights to Fermilab's electromagnetic boom and environmental cleanup technologies for use in conjunction with magnetizable oil. The Natural Science team is developing an electromagnetic mop system that may be able to extract over ninety percent of the oil from the surrounding water, a substantial gain over traditional methods. If the technology is successfully commercialized, it could become an industry standard for oil spill remediation.

#### Impact

Natural Science can use and develop electromagnetic oil recovery boom technologies across a broad range of applications, including on- and off-shore oil remediation and control management systems as well as produced water hydrocarbon remediation. Through this exclusive field-of-use agreement, Natural Science customers will now have access to innovative technology that is environmentally safe and outstrips current solutions in terms of efficiency.



Early concept of the electromagnetic boom

"This license agreement, with one of the most recognized laboratories in the world, represents our commitment to finding the best technologies and delivering the best solutions to our customers ... Given the nature of our product, we feel our technology will quickly become an industry standard for oil spill remediation."

David Cathey, Natural Science

### Timeline

**2011:** Non-Provisional patent application filed

**2014:** First patent issues

**2015:** Exclusive field-of-use license executed with Natural Science, LLC<sup>1</sup>

**2016:** Second patent issues

<sup>1</sup>naturalscienceusa.com/



## Unique Software Offers Tool for Securing Transmission Grid at Maximum Efficiency

Idaho National Laboratory

*Using algorithms that incorporate weather monitors, utility system data, and computational fluid dynamics to provide real time ampacity ratings of power lines.*

### Innovation

Coordinating with a CFD program from WindSim<sup>1</sup>, the INL team developed General Line Ampacity State Solver (GLASS)<sup>2</sup>, which offers the ability to blend data from weather monitors and electric utility system data with CFD-enhanced weather analysis algorithms.

### Outcomes

Technology Advancement

Since 2010, INL has collaborated with Idaho Power Company on dynamic line rating concepts, and recently finished a full instrumentation of two test beds with weather stations and line rating software in Idaho. With GLASS, Idaho Power has been gathering weather data and the ability to calculate steady state, transient, and what INL calls “true dynamic liner rating” ampacities.<sup>3</sup> The next step is ramping up the software to calculate forecasted line ampacities and temperatures. INL also has completed a cooperative research and development agreement with AltaLink LLC—Alberta, Canada's largest regulated electric transmission company—on a field study of four transmission line segments in support of a wind project’s expansion request.<sup>4</sup>

Impact

In recognition of its potential to strengthen and secure the power grid, GLASS was named a finalist for the 2017 R&D 100 Awards. INL has also received a Technology Commercialization Fund award from the U.S. Department of Energy Office of Technology Transfer. In 2018 and 2019, INL plans to refine the GLASS software with another industry partner, testing endurance and possibilities for commercialization.

In its seven-year evolution, GLASS has undergone three formal peer reviews and two merit reviews. More than 70 people from around the world, representing the utility industry, academia, and local, state and federal government, came to Idaho Falls Nov. 7–8 for an INL-hosted Dynamic Line Rating workshop.



Idaho National Laboratory researchers are collaborating with partners in industry and academia to use concurrent cooling from wind to make the electrical grid more efficient and secure.

“While WindSim was originally a software program designed to optimize placement and performance of wind turbines, the company’s collaboration with INL has allowed the company to broaden their solutions.”

Catherine Meissner, Software Development Manager, WindSim

### Timeline

**2010:** INL researchers worked with WindSim to start studying how transmission lines cooled by the wind can handle more electricity. INL researches also began collaborating with Idaho Power Company.

**2017:** Finalist for 2017 R&D 100 Awards

<sup>1</sup> “WindSim.” WindSim. Accessed January 25, 2019. [windsim.com/](http://windsim.com/)

<sup>2</sup> “GLASS – General Line Ampacity State Solver.” Idaho National Laboratory. Published April 19, 2017. [youtube.com/watch?v=X8laVYN6tUw&feature=youtu.be](https://www.youtube.com/watch?v=X8laVYN6tUw&feature=youtu.be)

<sup>3</sup> “General Line Ampacity State Solver (GLASS).” Accessed January 25, 2019. [renewable.energy.inl.gov/Conventional%20Renewable%20Energy/Asset%20Library/general-line-ampacity-state-solver.pdf](http://renewable.energy.inl.gov/Conventional%20Renewable%20Energy/Asset%20Library/general-line-ampacity-state-solver.pdf)

<sup>4</sup> “Transmission Line Ampacity Improvements of AltaLink Wind Plant Overhead Tie-Lines Using Weather-Based Dynamic Line Rating.” Office of Science and Technical Information, U.S. Department of Energy. Published July 2017. [osti.gov/biblio/1375207](http://osti.gov/biblio/1375207)



## Public/Private Research Collaboration Leads to Industry Shift toward Efficient Electronic Procedures in Nuclear Plants

Idaho National Laboratory in collaboration with commercial nuclear utilities, electronic work package solution vendors, and other organizations

*Developing improved procedures in nuclear facilities.*

### Innovation

A nuclear industry task force led by INL human factors researcher Johanna Oxstrand is instrumental in ongoing efforts to leverage the efficiency and safety benefits of computer-based procedures and work processes.<sup>1</sup> The industry task force is known as DIRECTOR – an acronym for “Dynamic Instructions Editing Tool Requirements”. The DIRECTOR initiative is a follow-on to the “Nuclear Electronic Work Packages – Enterprise Requirements” task force led by Ms. Oxstrand, 2015-2017. The 110 participants in the DIRECTOR task force represent 19 utilities, 11 research organizations, and 16 vendors as well as multiple standards organizations.

### Outcomes

#### Technology Advancement

The strong industry engagement in both DIRECTOR and NEWPER mirrors an industry-wide attitude shift toward phasing out the use of paper-based work processes in favor of streamlined electronic processes. The main goal of the DIRECTOR and NEWPER initiatives is to define functional and design requirements for electronic work packages (eWP) and computer based procedure solutions, that each utility can use and tailor to their specific needs

#### Impact

NEWPER published a large set of utility-generic functional requirements for eWP solutions. These requirements describe the fundamental functionality needed for all roles involved in the work management process, such as planners, supervisors, craft, and archiving staff. The final NEWPER functional requirements report for advanced and adaptive smart documents was published as a Procedure Professionals Association standard in 2017.<sup>2</sup>



INL Human Factors researchers Katya Le Blanc (left) and Johanna Oxstrand (right) demonstrate the LWRS-developed computer-based procedure system on a tablet computer to Diablo Canyon Nuclear Power Plant operator K.R. Thompson.

“NEWPER is a critical element of a fundamental shift within the nuclear industry away from paper. The implementation of dynamic smart procedures, developed from the craft and operators that use them, can change the way these groups execute work. Gone are the limitations of paper procedures and the results will be better human performance, if the structured approach developed by NEWPER is used.”

Bill Nowicki, Sr. Evaluator, Institute for Nuclear Power Operations

### Timeline

**2015-2017:** The NEWPER initiative

**2016:** TCF 16-12130 Computer-Based Procedures for Field Workers

**2017:** TCF 17-13408 Highly Scalable Computer-Based Procedure System for Field Workers

<sup>1</sup> [inl.gov/article/encouraging-innovation/](http://inl.gov/article/encouraging-innovation/)

<sup>2</sup> [ppaweb.org/documents/ppa-ap-907-005-001.pdf](http://ppaweb.org/documents/ppa-ap-907-005-001.pdf)

## Impedance Measurement Box Offers Battery State-of-Health Data in Near Real Time

Idaho National Laboratory in conjunction with Montana Tech of the University of Montana, Motloch Consulting, and QualTech Systems Inc. with support from DOE Office of Energy Efficiency and Renewable Energy and the Vehicle Technologies Office

*Collecting data and testing the qualities of batteries for a variety of systems.*

### Innovation

In a joint development project with industry and academia<sup>1</sup>, Idaho National Laboratory's Energy Storage Group have developed the Impedance Measurement Box (IMB), a device that can generate battery impedance data in 10 to 15 seconds.

### Outcomes

#### Technology Advancement

As battery technology becomes more complex and users' expectations become more pronounced, there is a pressing need for highly accurate assessment techniques that can give state-of-health readings in conditions approaching real time. Until now, embedded monitoring has relied on passive measurements of voltage, current and temperature, or on impedance methods that can take as long as 10 minutes. In addition to testing electric vehicle batteries, the IMB diagnostic tool can be used to test batteries for many uses including military, telecommunications and critical infrastructure. The latest development is a third-generation device, able to assess a 50-volt system, making it applicable for testing on battery modules. The overarching technological purpose of IMB is the development of smarter and better energy storage and management systems that can more accurately detect pending failures, assist with warranty, and enable smarter management for extended battery life.

#### Impact

INL has teamed with Colorado based Dynexus Technology, Inc., to provide the energy storage industry with this first-of-a-kind technology for advanced battery health diagnostics. Under an exclusive licensing agreement, Dynexus will commercialize IMB as an embedded wideband impedance technology for analyzing and forecasting the health, aging and safety characteristics of advanced energy storage devices<sup>2</sup>.



The Impedance Measurement Box can assess a single battery cell or battery strings, which are commonly used in many consumer applications.

*"This technology could help assess the resale value of a used electric vehicle, or provide remaining life and safety insights for repurposing those batteries into secondary applications. Monitoring battery health and remaining life will help ensure the safety and reliability of repurposed batteries, and will strengthen their viability, insurability and marketability."*

David Sorurm  
CEO, Dynexus Technology

### Timeline

- 2005:** INL researchers begin developing a method to rapidly measure battery impedance
- 2010:** "IMB" prototype system demonstrated for auto manufacturers
- 2011:** "IMB" development team receives R&D 100 award
- 2016:** Dynexus Technologies exclusively licenses technology

<sup>1</sup> [ieeexplore.ieee.org/abstract/document/4839680](http://ieeexplore.ieee.org/abstract/document/4839680)

<sup>2</sup> [chargedevs.com/newswire/dynexus-licenses-embedded-battery-diagnostic-technology/](http://chargedevs.com/newswire/dynexus-licenses-embedded-battery-diagnostic-technology/)

## Small Scale Natural Gas Liquefaction

Idaho National Laboratory

*Small scale liquefaction plants enables LNG to be used near where it is produced.*

### Innovation

As liquefied natural gas (LNG) advances toward widespread commercial use, the prospect of producing it where it will be distributed commercially has become increasingly attractive. An invention by the LNG research team at Idaho National Laboratory has made this prospect a reality by developing a small-scale methane liquefaction plant. Small-scale liquefaction plants are advantageous because their compact size enables the production of LNG close to the location where it will be used. This proximity decreases transportation and LNG product costs for consumers.

### Outcomes

Technology Advancement

The small-scale LNG plant also allows localized peak shaving to occur – balancing the availability of natural gas during high and low periods of demand. It also makes it possible for communities without access to natural gas pipelines to install local distribution systems to supply stored LNG.

INL liquefaction technology is designed to draw natural gas from a transmission pipeline at a point where the pressure is dropped to accommodate commercial distribution. The plant is powered mainly by the energy created through this pressure drop. As the gas enters the plant, some of it is allowed to expand, and as it expands, it cools. This allows the process to use the natural gas as a coolant in the liquefaction process.

Impact

Texas based Nu Blu Energy, LLC exercised their option to license this liquefaction technology and the complementary liquid and compressed natural gas fueling system developed by researchers at INL. Nu Blu is moving ahead to finalize the design and engineering of these systems to enable commercial deployment at a location in Port Allen, LA.



A liquid and compressed natural gas fueling station in Fresno, California.

“We are excited to bring the INL technology to LNG market. The NuBlu facility in Port Allen, Louisiana, is producing cold LNG for all energy markets. We are working to get all the LNG prescribed so we can duplicate our efforts to expand the plant to 90,000 gallons per day.”

Cory Duck, Vice President of Corporate Growth & Development  
NuBlu Energy

### Timeline

- 2000:** INL begins collaboration to build and demonstrate small scale LNG plant in Sacramento, CA
- 2002:** First natural gas liquefaction facility commissioned in Sacramento, CA<sup>1</sup>
- 2005:** C/LNG Fueling system developed at INL deployed in Fresno, CA
- 2006:** INL small scale LNG technology wins R&D 100 Award
- 2015:** INL LNG technologies licensed to Nu Blu Energy

<sup>1</sup> eurekaalert.org/pub\_releases/2002-06/dne-icg062002.php

## Next Generation Radar

The Kansas City National Security Campus with multiple university partners

*Collaborations to develop next generation radar for a variety of applications.*

### Innovation

One of first projects identified as a new priority by The Kansas City National Security Campus (KCNSC) is developing next generation radar. As general university collaborations proved successful, the concept evolved into a more strategic process for maturing technology and university partnerships with the Radar 2021 Consortium. As part of their partnership with the University of Kansas, The KCNSC Radar Consortium recently investigated the snow and ice sheet thicknesses in the Arctic, Greenland, and the Antarctic by testing a KU/KCNSC radar flying over the North Pole. The National Aeronautics and Space Administration (NASA) P-3 plane measured and charted the snow sheet thickness over 89.993° North at an altitude of 1,500 feet.

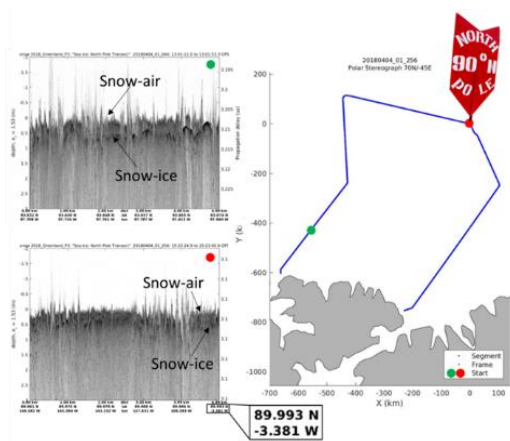
### Outcomes

Technology Advancement

Another university partner designed and fabricated a miniaturized agricultural radar that operates in the 22 – 26GHz range using a laminate substrate material as part of the Technology Demonstration Panel (TDP) philosophy that was created within this consortium. A second university team designed and fabricated miniaturized additively manufactured (AM) electrical shields to achieve isolation between signal lines on this radar

Impact

This flight was a high-priority mission over sea ice and a repeat of a flight line surveyed yearly since 2013 (Fig. 1). NASA was able to benefit from the greatly increased resolution (less than 2cm, Fig. 2) of the KU/KCNSC Radar, while the KCNSC was able to benefit from flight testing and learning more about the application of some of the newly-developed Radar Consortium technology such as miniaturization and increased power. The first iteration included a miniaturized RF section (~5x smaller), increased power (~10x increase), and stretched processing capability for long-range measurements (>12x airplane altitude increase while maintaining high resolution of <2cm).



Flight path charted for the North Pole overflight (right) with the corresponding KU/KCNSC radar scans of the snow thickness at the red and green dot locations (left).

“Current and future work are geared toward the incorporation of novel packaging technologies developed within the Consortium to further increase performance while reducing the instrument’s size, weight, and power requirements.”

Fernando Rodriguez-Morales, Professor at KU

<sup>1</sup>Morales, F. R., Leuschen, C., Feathers, A., McDaniel, J., Wolf, A., Garrison, S. “Packaging and Miniaturization of a 2-18 GHz UWB Radar for Measurements of Snow and Ice: Initial Results,” IMAPS 2017, 50th International Symposium on Microelectronics – Raleigh, NC, Oct. 9-12, 2017.



## Polymer Additive Manufacturing (AM) Consortium Rapidly Develops Polyphenylene Sulfide Powders

The Kansas City National Security Campus in conjunction with university and industry partners.

*One of the “game changing” technologies identified for expansion by the KSNSC is Polymer Additive Manufacturing (AM).*

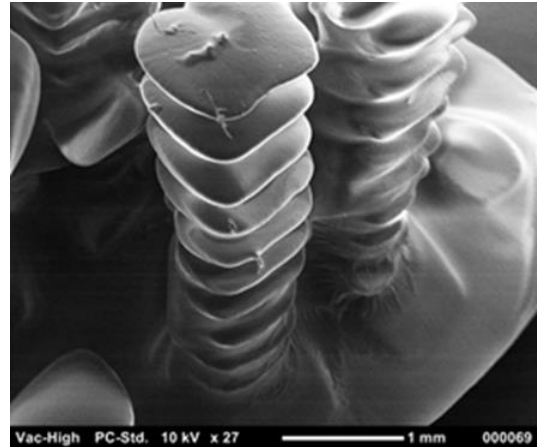
### Innovation

One of the “game changing” technologies identified for expansion by the KSNSC is Polymer Additive Manufacturing (AM). KCNSC strategically selected specific university, laboratory, and industry partners for its Polymer AM Consortium because of the considerable amount of fundamental, basic, and applied research required. Polymer AM provides rapid development from concept to the manufacturing floor with a less expensive alternative to metals in certain circumstances. The KCNSC works with a myriad of polymeric materials that are used in tooling, fixtures, and war reserve parts, and has the ability to rapidly scan objects and use Polymer AM to reproduce these objects on-site and on-demand. Typically referred to as Rapid Prototyping, this technique can be used very effectively to provide quick answers to evolving technical questions about processes or products.

### Outcomes

#### Technology Advancement

KCNSC’s Polymer AM Consortium worked closely with university collaborators and a vendor to develop polyphenylene sulfide (PPS) powders with appropriate particle sizes for use in low-temperature Powder Bed Fusion (PBF, also known as Selective Laser Sintering - SLS) processing. These materials have great potential for use as encapsulant molds including, but not limited to, potting shells, dams, and sealers. The rapid turn-around by the university collaborators to focus heavily on PPS processing and the relationship developed with the vendor has given the KCNSC an unprecedented ability to conduct R&D toward the development and potential implementation of a science-based manufacturing approach using PBF that will allow high fidelity parts to be fabricated for future mission assignments.



Scanning electron microscope (SEM) image of pillar microstructure of silicone elastomer printed using stereolithography, a polymer additive process.

*“This Consortium, while highly focused on various aspects of Polymer AM, is also a conduit to rapidly enhance our knowledge and capabilities as a whole.”*

Jamie Messman, Principle R&D Scientist and  
Polymer Additive Manufacturing Consortium  
Leader

## LBNL Facility Advances Clean, Biobased Products

Lawrence Berkeley National Laboratory with multiple industry partnerships

*An unparalleled resource for companies accelerating biobased technologies to grow the nation's bioeconomy*

### Innovation

LBNL's Advanced Biofuels and Bioproducts Process Development Unit (ABPDU) supports innovation in the United States' growing bioeconomy. The facility offers industry partners the means to optimize, scale up, demonstrate, create prototypes, and validate commercial feasibility of technologies to transform nonfood plant-, algae-, and waste-derived materials into useful products. By partnering with LBNL's ABPDU, companies can dedicate time and resources to quickly moving clean, biobased products to market, not building test facilities.<sup>1</sup>

### Outcomes

#### Technology Advancement

The majority of the nearly 40 companies that have partnered with ABPDU work under a CRADA or SPP. IndieBio, a biotech accelerator, entered into an umbrella agreement with LBNL/ABPDU covering all its startup cohorts.

Many partner companies go on to secure follow-on commercialization funding via DOE Small Business Vouchers, DOE seedling grants, SBIR-STTR Awards, and private financing, thanks to promising ABPDU project results.<sup>2</sup>

#### Impact

Since 2014, almost 40 companies have partnered with Berkeley Lab to develop, scale and validate their technologies at ABPDU in projects valued at nearly \$3 million. Partners reaching the commercial and pre-commercial stages include Ripple Foods, Mango Materials, Greenlight Biosciences, Lygos, and Ginkgo Bioworks, Kalion, HelioBioSys, and Bolt Threads.<sup>3</sup>

According to DOE's Bioenergy Technologies Office, ABPDU has collaborated on more biobased projects with developing companies than all other national labs combined. In addition, research at ABPDU has led to the disclosure of four (4) new inventions with LBNL inventorship.<sup>3</sup>



LBNL's ABPDU enables industry partners to invest their time and resources into moving biobased products to market quickly rather than building pilot facilities.

*"Speed is important to us, and ABPDU has been very helpful to get companies further along toward economic viability."*

Ron Shigeta  
Chief Science Officer  
IndieBio (biotech accelerator)

### Timeline

**2012:** ABPDU established

**2014:** ABPDU expands to handle biotech development projects, not only biofuels development

**2017:** LBNL/IndieBio umbrella agreement provides ABPDU access to all the accelerator's startup cohorts

<sup>1</sup> "Beyond Biofuels: Berkeley Lab Facility a Catalyst for Broader Bio-based Economy," *Berkeley Lab News Center*, October 17, 2017

<sup>2</sup> "Chief Pilot: ABPDU, where the elite meet to defeat petroleum," *Biofuels Digest*, December 14, 2016

<sup>3</sup> ABPDU website, [abpdu.lbl.gov](http://abpdu.lbl.gov)



## Newomics Launches Product, Enters Precision Medicine Market

Lawrence Berkeley National Laboratory

*Developing precise, rapid electrospray ionization mass spectrometry to lower sample testing costs.*

### Innovation

Researchers seeking to cure disease or address environmental and food safety hazards face a bottleneck in electrospray ionization mass spectrometry (ESI-MS), which requires samples be loaded and delivered to the machine one at a time. LBNL researchers Daojing Wang, Pan Mao and Peidong Yang set out to clear this bottleneck with their multinozzle emitter array technology. Their invention, patented by LBNL, delivers a flow of samples for analysis to significantly reduce testing costs. By creating smaller sample droplets, the sensitivity of mass spectrometry is improved 10 to 100 times over conventional emitters.<sup>1</sup>

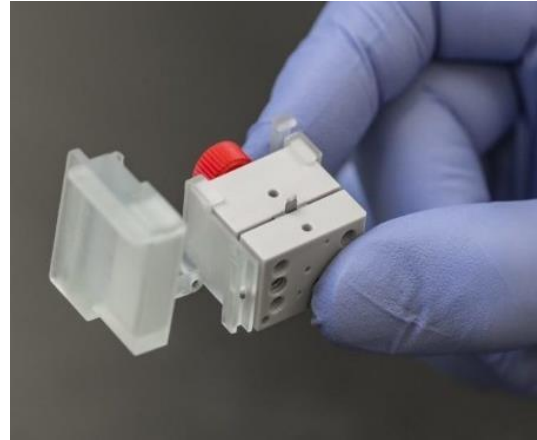
### Outcomes

#### Technology Advancement

LBNL supported technology maturation with a \$100,000 Innovation Grant enabling the researchers to demonstrate the device's use for bioimaging and high throughput ESI-MS. Follow-on funding to develop a commercial product included over \$3 million from SBIR Phase I and II Awards. The endeavor ultimately gained enough funding to launch a researcher startup, Newomics.

#### Impact

The Emeryville, California-based startup employs six people. In 2017, Newomics released its first product, the M3 multinozzle emitter for mass spectrometry.<sup>2</sup> The company offers precision medicine integrated platforms that require very small amounts of blood. Among its products are blood-based assays for diabetes diagnosis and for managing and monitoring manmade chemicals in the environment, such as perfluorinated chemicals (PFCs) that may damage human health. Newomics also provides industry and research organizations with services such as environmental biomonitoring, biomarker discovery and drug screening using its proprietary technologies.<sup>3</sup>



Newomics' M3 emitters provide faster, more sensitive identification of biological sample than competitors to support drug development and environmental biomonitoring.

"If someone wants to look at low abundant species, they can utilize our devices. Improved robustness means the results are more reproducible and reliable."

Daojing Wang  
Newomics Founder and President

### Timeline

- 2011:** Multinozzle emitter array manuscript publishes in *Analytical Chemistry*
- 2012:** Technology wins R&D100 Award
- 2012:** LBNL Innovation Grant awarded
- 2012-16:** SBIR funding
- 2017:** Technology licensed to inventor startup
- 2017:** Newomics releases its first product

<sup>1</sup> "Multinozzle Emitter Arrays for Nanoelectrospray Mass Spectrometry," *Analytical Chemistry*, 83, 15, 2011.

<sup>2</sup> "Screening for Disease or Toxins in a Drop of Blood," *Berkeley Lab News Center*, October 18, 2017

<sup>3</sup> Newomics website, newomics.com

## DIY Energy Monitoring

Lawrence Berkeley National Laboratory

*Home monitoring for energy efficiency and savings*

### Innovation

A stick-on building electricity meter developed at Lawrence Berkeley National Laboratory (LBNL) is entering the market as a do-it-yourself home energy monitoring technology.

LBNL researcher Steven Lanzisera led development of cost-saving adhesive-mounted sensor to replace transformers and in-panel hardware used for building submetering<sup>1</sup>. Lanzisera founded a startup based on the technology. The company, renamed Whisker Labs from the original name, Wattstick, is based in Oakland, California.

### Outcomes

Technology Advancement

In 2014, Whisker Labs participated in the first cohort of Wells Fargo Innovation Incubator (IN2), to advance commercialization<sup>2</sup>. IN2 is co-administered by NREL and made possible through a DOE partnership model, Agreement for Commercializing Technology (ACT).

Impact

Whisker Labs' DIY Home Energy Monitoring Sensor – easily affixed to a homeowner's electrical panel or breaker box – provides real-time power usage and diagnostic information for home appliances including HVAC systems, to identify potential energy waste. When combined with Whisker Labs' Connected Savings<sup>SM</sup> platform, consumers gain a complete home intelligence system supported by a mobile app. A home electrical system monitor, designed to alert homeowners of potential fire hazards, is in development.

Whisker Labs was acquired by Earth Networks<sup>3</sup>, an environmental technology company experienced in weather monitoring devices in December 2016. In May 2017, Whisker Labs' DIY Home Energy Monitoring Sensor received the Electronic House's 2017 Product of the Year Award in the Home Control and Automation category.



DIY Home Energy Monitoring Sensor installed and operational.

"Today, every appliance and every device in the home is connected to the power network. The problem is the network is not accessible and the power data it holds is locked. We are excited to open this power network and connect it to the internet through one simple device."<sup>3</sup>

Bob Marshall  
Earth Networks CEO

### Timeline

- 2014:** Stick-on meter introduced
- 2016:** Technology licensed to inventor startup
- 2016:** Whisker Labs acquired by Earth Networks
- 2017:** Whisker Labs' DIY Home Energy Monitoring Sensor receives Electronic House's 2017 Product of the Year
- 2017:** DIY Technology available to utility, solar, and other companies as well as consumers

<sup>1</sup> "COTS-Based Stick-On Electricity Meters for Building Submetering," *IEEE Sensors Journal*, 14, 10, 2014.

<sup>2</sup> "Why Wells Fargo's cleantech incubator is a hit," *GreenBiz*, March 26, 2018.

<sup>3</sup> "Earth Networks acquires Whisker Labs and launches DIY home energy monitor," *Venture Beat*, Dec. 2, 2016.

## A Cancer Vaccine Delivery Technology

Lawrence Livermore National Laboratory with support from NIH, DTRA, and industry partners

*A vehicle for drug delivery with broad applications.*

### Innovation

A team of scientists at the Lawrence Livermore National Laboratory (LLNL) has developed a technology that has a broad commercial potential as a vehicle for the delivery of drugs and vaccines and certain other applications. The technology is based on the use of synthetic nanometer-sized nanolipoprotein particles (NLPs) that mimic the naturally occurring high-density lipoprotein (HDL) particles in the blood, which are evolved for the transport of cholesterol and other lipid molecules in the body.

### Outcomes

#### Technology Advancement

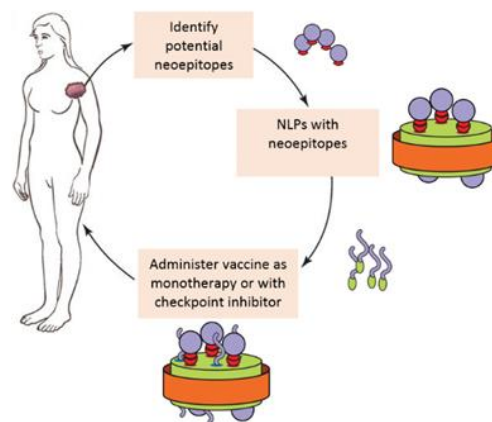
In a personalized vaccine approach, a cocktail of synthetic versions of some of these peptides carrying new antigenic determinants can be used to vaccinate the patient to stimulate a powerful anti-cancer immune response. But, the delivery of synthetic peptides in free form is not very efficient party due to the degradation of peptides in the body. However, such peptides are protected from degradation in the body when they are embedded on the surface of LLNL-developed NLPs.

Moreover, adjuvants required for inducing a strong immune response to destroy cancer cells can also be conjugated on the surface of NLPs carrying peptides. Thus, the use of NLPs enables the co-delivery of peptides and adjuvants to lymph nodes at the same time and in a particulate form for optimum anti-cancer immune response.

#### Impact

The NLP technology has been licensed to Ann Arbor, Michigan-based startup company, EVOQ Therapeutics, for development of a peptide-based human cancer vaccine. EVOQ hopes to start clinical trials using this approach within two to three years.

The NLP technology has many additional applications including the development of vaccines for Francisella tularensis (rabbit fever), influenza and Chlamydia; the in vivo delivery of nucleic acids; formulating drug molecules to enhance their efficacy; and the shuttling of therapeutics across the blood-brain barrier.



A concept of personalized cancer vaccine

“I saw [the development of NLPs] as an important advance for understanding the mechanics of drug transport into cells and potentially as a platform for the development and delivery of vaccines. Without the support of the LDRD Program, the NLPs wouldn’t be where they are today.”

Paul Hoerich  
Bio-organic Chemist and one of the original inventors of NLPs, LLNL

### Timeline

- 2005:** NLP technology development begins at LLNL with internal LDRD funding.
- 2014:** First patent, in extensive intellectual property portfolio, issued.
- 2017:** EVOQ Therapeutics licenses LLNL intellectual property.

## ALE3D for Industry (ALE3D4I): Multiphysics Simulations for Advanced Manufacturing Solutions

Lawrence Livermore National Laboratory

*Software code that simulates process used in advanced manufacturing made available to industry.*

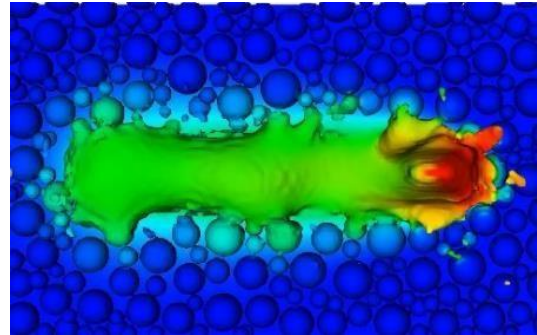
### Innovation

For over 30 years, Lawrence Livermore National Laboratory (LLNL) developed and utilized ALE3D - a unique finite element based, multi-physics software code that simulates processes commonly used in today's Advanced Manufacturing processes. Until recently, ALE3D has only been available for U.S. Government use. LLNL has recently introduced a version of ALE3D modified for industrial use by leveraging internal development funding (LLNL's Innovation Development Fund). The new ALE3D For Industry (ALE3D4I) can now be used on LLNL's HPC systems with non-Governmental U.S. partners to develop solutions to industry's Advanced Manufacturing problems.

### Outcomes

#### Technology Advancement

ALE3D4I, like its parent Government-only software ALE3D, enables simulating several key processes used in Advanced Manufacturing. Through previous Cooperative Research and Development Agreements (CRADAs) with industrial partners, LLNL has used ALE3D to simulate production processes for manufacturing metal parts via laser powder bed fusion additive manufacturing – a field that is growing exponentially. Transitioning metal additive manufacturing from production of prototypes to production of critical parts (like those used in safety-critical systems in automobiles and airplanes) is hindered by a lack of confidence in the quality of the part. Published studies based on the ALE3D code demonstrate the importance of recoil pressure and Marangoni convection in shaping the melt pool flow and how denudation, spattering, and pore defects emerge and become part of a laser bed-fusion process. Now with ALE3D4I, manufacturers interested in using this additive manufacturing process to produce critical parts can simulate their manufacturing process and better understand the effect on their product before they spend significant manufacturing resources and time.



Simulation of laser based additive manufacturing (AM) on the powder scale to determine spattering associated with the AM process.

“U.S. industry is looking for a competitive edge by leveraging HPC...We’re confident that ALE3D-4I is going to fill a need that the engineering software industry can’t currently provide.”

Chad Noble, ALE3D Team Lead, Lawrence Livermore National Laboratory

### Timeline

- 1990s:** LLNL begins publishing research papers on ALE3D
- 2016:** LLNL funds internal development of ALE3D4i to make an industry-usable version of its national security code ALE3D
- 2017:** LLNL launches ALE3D4i for industrial use

## ATOM: A Public-Private Consortium Transforming Discovery

Lawrence Livermore National Laboratory in conjunction with multiple university and industry partners

*Accelerating the development of effective therapeutics.*

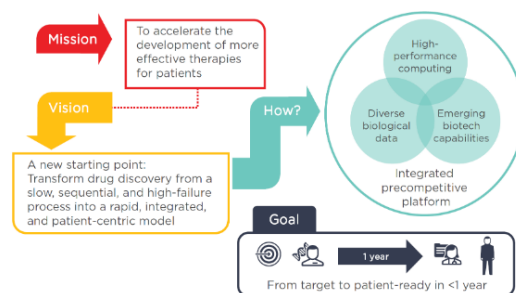
### Innovation

ATOM – Accelerating Therapeutics for Opportunities in Medicine – is a public-private consortium that was formed under a Consortium Agreement signed by Lawrence Livermore National Laboratory (LLNL), GlaxoSmithKline (GSK), the National Cancer Institute’s Frederick National Laboratory for Cancer Research (FNLCR), and the University of California, San Francisco (UCSF). Each consortium member plays an integral part with LLNL contributing its best-in-class supercomputers, as well as its expertise and innovative approaches to modeling and simulation, cognitive computing, machine learning, and algorithm development. GSK’s contribution is chemical and in vitro biological data for more than 2 million compounds, as well as preclinical and clinical information on 500 failed molecules, along with drug development expertise. For its part, FNLCR is contributing from its wealth of scientific expertise in precision oncology, computational chemistry and cancer biology, as well as support for open sharing of data sets and predictive modeling and simulation tools. UCSF provides expertise from a long history of innovation in drug discovery and medicine to improve the lives of patients.

### Outcomes

#### Impact

By leveraging each member’s contributions, the consortium sets out to transform the way cancer drugs are discovered by creating an open and sharable platform that integrates high-performance computing, shared biological data from public and industry sources, and emerging biotechnologies. The ATOM consortium is working to transform cancer drug discovery from a time-consuming, sequential, and high-risk process into an approach that is rapid, integrated, and with better patient outcomes – using supercomputers to pretest many molecules simultaneously for safety and efficacy. ATOM welcomes additional public and private partners who share the vision of accelerating therapeutics for better patient outcomes.



Accelerating Therapeutics for Opportunities in Medicine (ATOM) aims to transform the drug discovery process

*“ATOM is a novel public-private partnership that draws on the lab’s unique capabilities to create a paradigm change in drug development.”*

Bill Goldstein, Laboratory Director, Lawrence Livermore National Laboratory

### Timeline

- 2016:** The Department of Energy, GlaxoSmithKline and the National Cancer Institute announced their intent to create the ATOM consortium as one of the Cancer Moonshot initiatives.
- 2017:** LLNL, GSK, the National Cancer Institute’s Frederick National Laboratory for Cancer Research, and the University of California, San Francisco established the ATOM Consortium.
- 2019:** The ATOM Consortium members publish its first “Year in Review: Our Key Achievements” at [atomsience.org](http://atomsience.org) showcasing major accomplishments as of the one-year anniversary.



## Electrochemical Solid-State NOx Sensor

Lawrence Livermore National Laboratory in conjunction with EmiSense Technologies

*A low cost NOx sensor with multiple potential applications.*

### Innovation

Over the past six years, through a CRADA and license, Lawrence Livermore National Laboratory (LLNL) and EmiSense Technologies, LLC developed and commercialized LLNL's novel NOx sensing technology. Existing sensors are both expensive and fragile, limiting adoption in applications looking to keep costs down. The combination of smart electronics and simplified ceramics results in a more sensitive and durable sensor that is easier and more cost effective to produce.

### Outcomes

#### Technology Advancement

The sensor is comprised of a rugged probe designed to survive the harsh environment of an exhaust pipe, connected to a sensor-control module, which performs the signal processing and enables signal extraction. A novel measurement principle sometimes referred to as multi-wave time differential sensing, simplifies the ceramic sensing element contained in the probe, uses impedance spectroscopy to simultaneously differentiate various gas species, including NO, NO<sub>2</sub>, and O<sub>2</sub>. The technology fit was good for EmiSense, which develops commercially-viable advanced automotive sensors from laboratory-scale technologies by developing and validating material sets, designing circuits, selecting components that are cost-effective and approved for automotive applications, and by coding embedded software that delivers selectivity, accuracy, and robust self-diagnostics.

#### Impact

Over time, the solid-state NOx sensor may become as inexpensive as \$50 per unit, lowering many of the biggest barriers to adoption in new vehicles, stationary engines, generators, port equipment, and combined heat and power systems. Such advantages open the door to a projected \$2.5 billion-dollar industry by 2023, as regulation of diesel engines expands to light passenger vehicles, commercial and marine vehicles, locomotives, and construction and mining equipment.



Prototype NOx sensor cross section

### Timeline

- 1999:** Scientists at LLNL start working on NOx detection
- 2009:** EmiSense was formed
- 2011:** EmiSense executed an exclusive license agreement for the LLNL NOx sensor portfolio, followed with a 30 month CRADA



## Revolutionary Suppressor for U.S. Soldiers and Law Enforcement

Lawrence Livermore National Laboratory

*The first-ever practical suppressor for single-shot and automatic weapons on the battlefield*

### Innovation

Lawrence Livermore National Laboratory (LLNL) developed a revolutionary technology that upends the previous century of firearm suppressor design. The key feature of the technology is a flow-through design that simultaneously limits blowback, flash, noise, and temperature, lasting the lifetime of the barrel on single-shot and fully automatic weapons. In addition, the flow-through design requires only minimal maintenance. These features result in the first practical suppressor for battlefield use.

### Outcomes

#### Technology Advancement

Developed in partnership with the U.S. military, this novel suppressor design simultaneously limits weapon blowback, flash, noise and temperature to a degree previously thought impossible by leading manufacturers. With these benefits, the suppressor will also help reduce one of the most prevalent injuries to the modern warfighter: long-term hearing loss.

#### Impact

The LLNL suppressor design exceeded USSOCOM's contractual expectations. Lewis Machine Tools Inc. licensed this technology and in conjunction with LLNL created a commercial version. This new suppressor addresses the six key areas of modern suppressors:

- Reduced peak sound levels
- Lower operating temperatures
- Reduced backpressure
- Flash reduction
- Increased suppressor life
- Minimal increase in bolt carrier velocity

LLNL scientist leveraged high performance computing and 3D printing of titanium prototypes, creating a patented revolutionary suppressor. The innovative design enables soldiers and first responders to accomplish their missions while safeguarding their long-term health thereafter.



LMT brochure of LLNL Suppressor Technology

"It solves all the problems that have plagued suppressors since the suppressor was invented."

Willy Moss, Physicist, Lawrence Livermore National Laboratory, paraphrasing statements from Lewis Machine and Tool Company

### Timeline

- 2014:** Suppressor inventors invite Lewis Machine and Tool Company for onsite demonstration.
- 2015:** Demonstration license period at SHOT Show gun convention.

## Towards Certifying Additively Manufactured Parts for High-Value Applications

Lawrence Livermore National Laboratory in conjunction with Oak Ridge National Laboratory and Unite Technology Research Center

*Gaining a further understanding of materials used for additive manufacturing.*

### Innovation

To this end, researchers at Lawrence Livermore National Laboratory (LLNL) and the Oak Ridge National Laboratory (ORNL) teamed with United Technology Research Center (UTRC) via a Cooperative Research and Development Agreement (CRADA) project funded by the Department of Energy's High-Performance Computing for Manufacturing (HPC4Mfg). The HPC4Mfg project aimed to better understand the material properties of metal objects made using additive manufacturing technology. The joint research team simulated the crystal structure of metals grown during the melting and freezing processes that metal powders experience as they are added layer by layer to the part being built. Material properties can be derived from knowledge of the crystal structure. The team focused on a nickel-iron-niobium alloy, an approximation for the IN 718 alloy used in the aerospace industry.

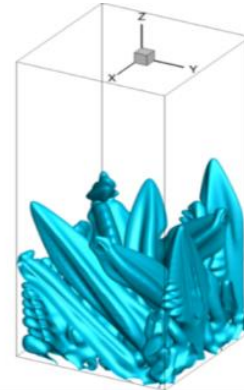
### Outcomes

#### Technology Advancement

The project utilized parallel phase-fields codes at ORNL and LLNL, along with the high-performance computing (HPC) capabilities existing at the two labs to demonstrate the simulation of multiple dendrite growth in three-dimensions (3-D). The computational results were compared with experimental results obtained through work at UTRC.

#### Impact

The project is the first step towards the full 3-D implementation of the integrated microstructural modeling framework for AM envisioned by UTRC. Continuing efforts will further improve the predictions so that the goal of in-process additive manufacture control can be achieved to ensure reliable use of high-value components for aerospace and automotive customers of the future.



High Performance Computing Simulations Predict Crystal Growth in Metal Additive Manufacture

“Access to supercomputers in the DOE’s labs will provide a resource to American firms inventing and building clean energy technologies right here at home that no international competitor can match”

David Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy, DOE Press Release dated March 18, 2016

### Timeline

- 2015:** DOE forms the High Performance Computing for Manufacturing (HPC4Mfg) Program
- 2016:** UTRC is awarded an HPC4Mfg program project and begins work with LLNL and ORNL
- 2017:** The HPC4Mfg project successfully concludes. The published final report envisions the UTRC-ORNL-LLNL research team working together in the future on grand challenge problems applicable to additive manufacturing.

## Saving Energy in Spray Dryers: Modeling Helps Update Established Processes

Lawrence Livermore National Laboratory in conjunction with ZoomEssence

*Improving the efficiency of spray dryers.*

### Innovation

Using commercial and state-of-the-art research codes, LLNL researchers identified the major sources of turbulence production in ZoomEssence dryers and characterized the turbulence intensity throughout the dryer. LLNL researchers chose two separate methodologies to simulate the drying physics in the ZoomEssence system. This work provides a direct characterization of the impact of turbulence on drying and provided guidelines for increase the impact of turbulence on drying rates.

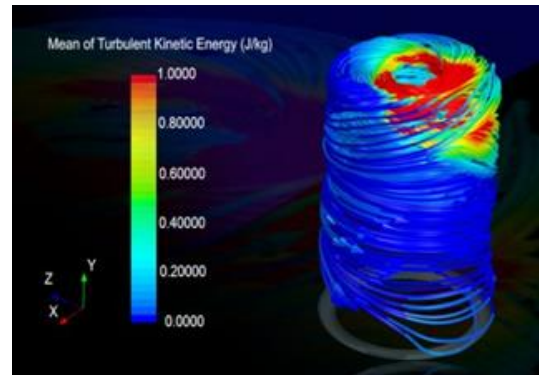
### Outcomes

Technology Advancement

ZoomEssence developed the DriZoom spray drying technology, which uses less energy and results in a higher quality product than traditional spray drying. However, the optimal design of this new method relies on a deep understanding of the fluid dynamics and thermodynamics of the drying process that is not captured by the currently available analysis methods. Advanced CFD codes which can accurately model both major flow structures simultaneously with fine turbulence structure were used to diagnose the flow conditions in the dryer. Researchers found that turbulence aids in mixing the fluid, and that if it is increased further, it could greatly enhance particle drying. The results from the commercial and research turbulence simulations were consistent with these results. Further, in low turbulence environments, the lower fidelity simulations provide an effective tool for studying the particle drying dynamics.

Impact

A very conservative estimated reduction of the energy requirements which could be achieved by this study through implementation of turbulent mixing with no-heat spray drying reduces the energy required to evaporate a ton of water from 4.8 GJ/ton to ~240MJ/ton of evaporated water energy savings per spray dryer. This gives an estimated domestic energy savings on the order of 114,000 GJ just in spray dried food products.



HPC modeling and simulation shows the turbulent kinetic energy in the flow of an industrial scale drier.

“Research partners can use these high-performance computing systems to work on modeling, simulating, and analyzing cutting-edge industrial products and processes, giving them a resource that no international competitor can match.”

Mark Johnson, Director, DOE’s Advanced Manufacturing Office, speaking about the HPC4Mfg Program in a 2016 published interview

### Timeline

- 2015:** DOE announces the new High Performance Computing for Manufacturing (HPC4Mfg) Program.
- 2016:** The HPC4Mfg program announces 10 new projects, including the collaborative research partnership between LLNL and Zoomessence, Inc.
- 2017:** LLNL and Zoomessence complete work under the Cooperative Research and Development (CRADA) agreement; the published poster summarizing the project shows tangible benefits, including “Design guidance at costs of ~\$100Ks as opposed to pilot plants running costs of ~\$10M.”

## High-Repetition-Rate Advanced Petawatt Laser System (HAPLS)

Lawrence Livermore National Laboratory in collaboration with the European Extreme Light Infrastructure Beamlines facility (ELI Beamlines)

*A “game changing” capability to push the frontiers of science and technology revolutionizing research in fields from medicine to astrophysics to clean energy.*

### Innovation

The High-Repetition-Rate Advanced Petawatt Laser System (HAPLS), was developed at Lawrence Livermore National Laboratory (LLNL) located in Livermore, California, for the European Extreme Light Infrastructure Beamlines facility project (ELI Beamlines) in the Czech Republic under an Agreement to Commercialize Technology (ACT) collaboration mechanism. Twenty years ago, LLNL pioneered the first petawatt laser, the NOVA Petawatt, representing a quantum leap forward in peak power. Today, HAPLS leads a new generation of petawatt lasers, with capabilities not seen before.

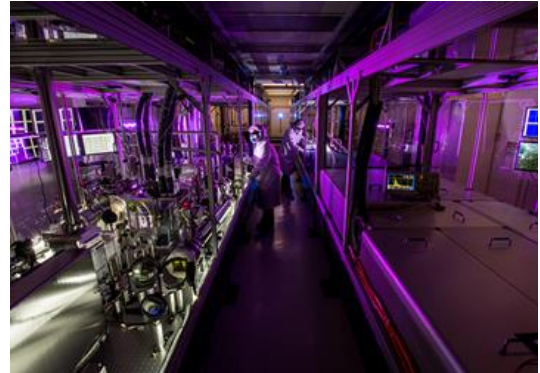
### Outcomes

#### Technology Advancement

HAPLS represents a new generation of application-enabling diode-pumped, high-energy and high-peak-power laser systems with innovative technologies originating from the Department of Energy’s fusion laser research and development. Advancements include HAPLS’ ability to reach petawatt power levels while maintaining an unprecedented pulse rate; development of the world’s highest peak power diode arrays include a pump laser generating up to 200 J at a 10 Hz repetition rate; a gas-cooled short-pulse titanium-doped sapphire amplifier; a sophisticated control system with an auto-alignment capability, performance tracking and machine safety; a gigashot laser pump source for pumping the short-pulse preamplifiers and more.

#### Impact

HAPLS is available to the international science user community to study laser-matter interactions, generate secondary radiation sources enabling a variety of research areas, including time-resolved proton and X-ray radiography with medical applications for cancer treatments, industrial applications such as nondestructive evaluation of materials, and basic science applications such as laboratory astrophysics and laser fusion.



HAPLS has set a world record for diode-pumped petawatt lasers, with energy reaching 16 joules and a 28-femtosecond pulse duration (equivalent to ~0.5 petawatt/pulse) at 3.3 times per second repetition rate.

### Timeline

- 2013:** European scientific community engages with LLNL to design and construct what would become HALPS
- 2017:** HAPLS was transferred to ELI Beamlines
- 2018:** HAPLS made available to the international science user community to conduct the experiments



## Spack: An Open Source Recipe for Success

Lawrence Livermore National Laboratory

*Spack is minimizing time spent coding by allowing developers build software for multiple configurations and share them with others.*

### Innovation

Spack's key usefulness is that it lets developers build software for many combinations of compilers, architectures, dependency libraries, and build configurations, all with a friendly, intuitive user interface. Other LLNL developers quickly recognized this tool's value, and development became a grassroots effort as part of LLNL's Advanced Simulation & Computing (ASC) program work for the National Nuclear Security Administration. The tool really caught on after LLNL publicly released Spack under the Lesser GNU Public License (LGPL) as an open-source project in 2014 and Gamblin presented a paper on the technology at the 2015 Supercomputing conference.

### Outcomes

Technology Advancement

Spack is a very successful example of how LLNL actively building and engaging with open-source communities enables the Laboratory to stay at the forefront of HPC advances, save time and effort, recruit and retain valuable computer scientists and engineers, and collaborate with organizations around the world.

Impact

Spack is now a flexible, configurable, Python-based HPC package manager, automating the installation and fine-tuning of simulations and libraries. It operates on a wide variety of HPC platforms and enables users to build many code configurations. Software installed by Spack runs correctly regardless of environment, and file management is streamlined. This success has led to Spack's adoption in the open source community as well as for efforts such as Department of Energy's Exascale Computing Program, in which Spack will be used to manage software releases for DOE's entire exascale software stack. Spack is a widely-adopted, open-source tool that continues to grow and mature in the open.



Spack (Supercomputer PACKage manager)  
A flexible package manager that supports multiple versions, configurations, platforms and compilers

“Lawrence Livermore’s active participation within the open-source community creates a symbiotic relationship in which staff can collaborate with external users, including other government agencies, to produce cost-effective solutions to complex problems and bolster software to its full potential.”

Bruce Hendrickson, Associate Director for Computation, Lawrence Livermore National Laboratory Timeline

**2013:** Todd Gamblin develops Spack

**2014:** Spack is released as open source.

**2015:** Spack is presented at the annual Supercomputing Conference (SC15).

**2016:** Spack averaged 100 downloads per day

**2017:** Spack averaged 400 downloads per day

**2018:** Spack becomes the deployment tool for the Exascale Computing Project’s software stack. The code is relicensed under Apache and MIT open source licenses. Adoption statistics reach over 150K downloads in the year, 1,100 monthly active users, and over 350 contributors from around the world.

## Rapid and Sensitive Pathogen Detection System

Lawrence Livermore National Laboratory

*System that quickly detects pathogens on site without skilled technicians being required.*

### Innovation

The Rapid and Sensitive Pathogen Detection System is a fully-automated instrument that quickly detects multiple pathogens with sensitivity and specificity. Current instruments need the services of a skilled technician in a centralized lab, and the results are not available for one to three days. The breakthrough microfluidic technology utilizes single-use disposable cartridges to concentrate and purify generic material from samples to perform molecular analysis. Each sample is screened using twelve tri-plex TaqMan® reactions. Included in the test are twelve positive and two negative controls, so the operator has confidence in the generated results. This open-access feature will empower end-users to target any pathogen of interest, as they can load their own real-time PCR assays onto the instrument for customized pathogen detection.

### Outcomes

Technology Advancement

The original research for this technology started during the early 2000s when there was an urgent need to provide onsite medical diagnostics in military facilities where there were not enough medical personnel, e.g., forward military bases, deployed sea vessels, or even poorly-staffed hospitals. Labeled the “Diagnostic Kiosk”, it built upon previous LLNL technologies like the Autonomous Pathogen Detection System (APDS) that processed air samples.

Impact

This instrument enables on-site testing without the need of a skilled technician, and the results are available in an hour, which is ideal for point-of-care diagnostics. LexaGene expects to target the food safety, veterinary diagnostics, water quality monitoring, and aquaculture pathogen surveillance markets. This disruptive technology meets the critical needs of underserved markets throughout the world.



LexaGene LX6 detects many pathogens at once and has great sensitivity and specificity

### Timeline

- 2015:** Bionomics Diagnostics Inc. licensed the technology from LLNL, hired the inventor John Regan as CEO, and partnered with Boston Engineering
- 2017:** LexaGene prototype was completed
- 2018:** LexaGene unveils new prototype system for the Veterinary Market, including a new panel for detecting urinary tract infection (UTI) in small animals.
- 2018:** LexaGene was voted as one of the “10 Most Promising Food and Beverage Solution Providers 2018” by CIO Review for its detection of E.coli in romaine lettuce, which resulted in a widespread multi-state recall and food safety alert from the Centers for Disease Control (CDC) in November 2018.



## Spray-on DNA Bar Codes Trace Source of Tainted Food

Lawrence Livermore National Laboratory

*A new method to track tainted food back to the source.*

### Innovation

Lawrence Livermore originally designed the technology, known as DNATrax, to safely track indoor and outdoor airflow patterns. One of the unexpected capabilities of DNATrax its application to food products. The technology was first developed for biosecurity applications, but has now found another application as a cost-effective and highly efficient method to accurately trace contaminated food back to its source.

### Outcomes

#### Technology Advancement

DNATrax are particles comprised of sugar and non-living and non-viable DNA that can serve as an invisible barcode. It's an odorless and tasteless substance that's been approved by the Food and Drug Administration as a food additive, safe for consumption. Think of it as a microscopic barcode that's sprayed on food at the farm or processing plant. If the food turns out to be contaminated when it reaches the store or dinner table, DNATrax can be lifted off the food and analyzed in the lab using polymerase chain reaction (PCR) to identify the source.

#### Impact

Other applications beyond its potential tracking tainted food for DNATrax possible include assisting in training to determine if personal protective equipment (PPE) such as hazmat suits used by emergency responders and health care workers to treat Ebola patients have been breached. The Defense Department's Defense Threat Reduction Agency (DTRA) funded this SPP research project.



DNATrax sprayed on food

“One of the unexpected capabilities from DNATrax was being able to apply it to food products. You can spray it on food products in the field to identify and track the source of the food.”

George Farquar, Physical Chemist who led a team of researchers that developed the technology for biosecurity applications, Lawrence Livermore National Laboratory

### Timeline

- 2013:** SafeTraces, Inc. founded and DNATrax intellectual property licensed from LLNL.
- 2015:** SafeTraces awarded NSF and FDA grants.
- 2016:** SafeTraces reports sales to its first pilot customer.
- 2017:** SafeTraces reports sales to its first commercial customers and raises \$6.5 million Series A financing.

## Descartes Labs Platform

Los Alamos National Laboratory

*Using machine learning to understand patterns in satellite imagery.*

### Innovation

Kernels of important information can be buried deep in visual data. Yet pinpointing these kernels, particularly in huge datasets is challenging. A new machine-learning vision platform that employs sparsely coded, hierarchical, and lateral linkages within a neural network modeled on the human neuro-visual system is helping to parse out this dense data to find those critical kernels of information. Developed by a team of scientists at Los Alamos National Laboratory, this Video Analysis and Search Technology—or VAST—teaches itself. The more training data it consumes, the better it becomes at identifying patterns, detecting objects, mitigating risk, and solving problems for its end users. Descartes Labs, an artificial intelligence company, uses VAST technology with satellite imaging for commercial purposes.

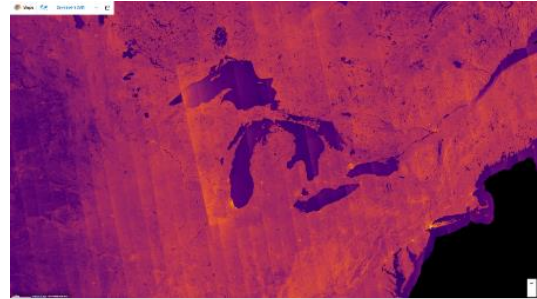
### Outcomes

#### Technology Advancement

Descartes Labs interprets satellite imagery to enable real-time global awareness—whether it is food production, energy infrastructure, the growth of cities, or environmental impacts. Using machine learning and remote sensing technology, the satellite pictures can be converted into maps, which can be sequenced into a time-lapse video to show changes on the Earth's surface. Today, Descartes Labs ingests and processes petabytes of image data into its cloud-based infrastructure from numerous publicly and privately owned satellites, including those belonging to NASA, USGS, Landsat, and ESA.

#### Impact

Descartes Labs has raised \$38.3 million in private equity capital and recently received a \$1.5 million award from the Defense Advanced Research Projects Agency (DARPA) using their satellite imagery and intelligence platform to analyze food security in the Middle East and North Africa. The company has grown to over 40 with offices in San Francisco, Los Alamos, Santa Fe, and New York City.



View of the Great Lakes using Synthetic Aperture Radar (SAR) through the Descartes Labs Platform

### Timeline

- 2014:** Descartes Labs spun out of Los Alamos National Laboratory with the technology and expertise to turn satellite imagery into high-level business intelligence.
- 2015:** The company started tracking agriculture around the globe through satellite imagery data.
- 2017:** Released a 3.1-trillion pixel, cloud-free Landsat 8 composite image of the world along with two others based on the European Space Agency's Sentinel satellites. The Descartes Maps site allows the public to access this trove of data in a digestible way, opening up new views of the earth for unique insights.
- 2018:** Los Alamos National Lab worked with Descartes Labs to come up with systems for analyzing on-the-ground conditions in Brazil in order to forecast dengue. The hope is to expand the work around the world.

## dfnWorks

Los Alamos National Laboratory

*Transforming simulations of flow and transport through fractured rock.*

### Innovation

More than 85% of the world's energy and 50% of drinking water in the United States is harvested from beneath the Earth's surface. Although critical for many industrial, civil, and governmental applications, the inherent complexity of flow through subsurface fractured systems makes it difficult for conventional subsurface simulation software packages to provide trustworthy results. dfnWorks (short for discrete fracture network) toolkit overcomes technical barriers by combining novel computational meshing techniques and massively parallel computational implementations to realistically and accurately represent flow and chemical transport within fracture networks.

### Outcomes

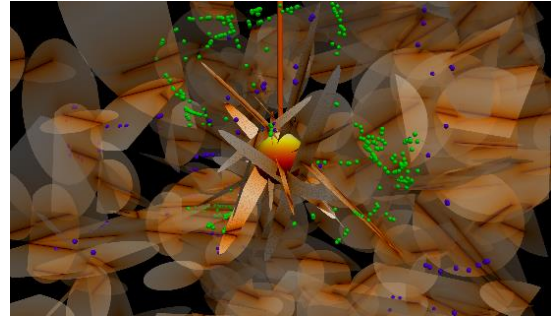
#### Technology Advancement

dfnWorks is open-source software.

- Models flow and transport in fractured rock at scales ranging from millimeters to kilometers
- Uses unique meshing algorithms to represent realistic and accurate fracture networks
- Runs on laptops and supercomputers
- Enables safer nuclear waste disposal, greener hydraulic fracturing, and more efficient mitigation of greenhouse gases

#### Impact

The team is working with Golder and Associates through a Department of Energy (DOE) Technology Commercialization grant to link dfnWorks with the market's leading fracture characterization software FracMan. Golder and Associates have matched DOE funds to make this grant possible. Other leading users of dfnWorks include Chevron, to help oil and gas operators optimize production from hydrocarbon reservoirs and increase our fundamental understanding of subsurface multiphase flow and transport. Also, Swedish Nuclear Fuel and Waste Management Company to specifically address the effects of internal-aperture variability.



These fractures connect up with naturally occurring fractures in the background rock (shown in orange). The green and blue spheres represent different radioactive gases as they transport from the cavity to the surface through fractures.

### Timeline

- 2016:** dfnWorks receives DOE Technology Commercialization grant to move promising energy technologies from DOE's National Laboratories to the marketplace.
- 2017:** Los Alamos National Laboratory and dfnWorks Win R&D 100 Award.

## Success Stories

### Moving Innovative Technologies from DOE National Laboratories to the Marketplace

## Viome

Los Alamos National Laboratory

*Insight is the only cost-effective microbiome platform that offers metatranscriptomic sequencing.*

### Innovation

There are approximately 40 trillion microorganisms living in a human's gut. They help digest food, produce beneficial and harmful chemicals, control infections by pathogens, regulate immune system, and even control emotions.

Enters Viome, a bacteria-analysis company that examines the microorganisms in users' guts and counsels them on how to keep harmful bacteria at bay. Harnessing technology developed at the Los Alamos National Laboratory in New Mexico, Viome employs artificial intelligence to analyze the digestive tract and its effects on the body's immune and metabolic systems.

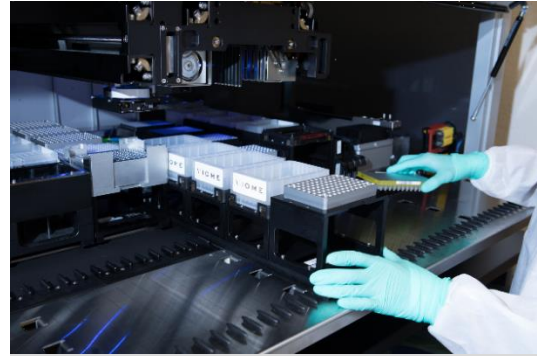
### Outcomes

#### Technology Advancement

Viome was launched with a team of leading entrepreneurs, scientists, and physicians. Viome's Insight kit, the first direct-to-consumer microbiome analysis that sheds light on the active members of a gut microbiome community. Insight can analyze our gut microbiome and provides personalized recommendations for nutrition, supplements, and probiotics, with the goal of improving health and wellness. The at-home Gut intelligence® Test kit uses a stool sample: By analyzing RNA in the stool sample, Viome can get a species-by-species read on the microbial communities in a person's gut including bacteria, viruses, yeast, mold, fungi and parasites. Customers can review the results of the analysis via the Viome app. These results are also factored into a personal wellness profile, using the company's machine learning model (artificial intelligence) for massive and complex biological data.

#### Impact

Viome is the first company to offer wellness as a service, deploying the first direct-to-consumer microbiome analysis that can shed light on the active members of your gut microbiome. Without setting foot in a medical office, a consumer can easily collect the personal samples needed for analysis in the comfort of their own home.



The Viome automated laboratory environment is able to efficiently process 90 samples at a time without cross-contamination.

### Timeline

- 2017:** Los Alamos National Laboratory entered into a cooperative research and development agreement (CRADA) and later an exclusive license with BlueDot. BlueDot created a wholly-owned subsidiary, Viome, the company that would commercialize SPIDR-WEB for personalized healthcare.
- 2018:** Viome and Los Alamos National Laboratory recognized as R&D 100 Award finalists.
- 2019:** Viome is expanding its reach into the world of personalized nutrition with the purchase of Habit Food Personalized, LLC (Habit) — a Campbell's Soup Company business that uses human biology to create highly customized nutrition plans.

## Precious-Metal-Free (PMF) Catalysts

Los Alamos National Laboratory

*A fuel cell catalyst that has no precious metals which lowers the overall cost of fuel cells.*

### Innovation

Fuel cell technology has the potential to upend the energy industry by providing an efficient, clean, powerful energy source. However, the high cost of platinum required to make fuel cells has historically hindered widespread adoption. Pajarito Powder, LLC, manufacturer of advanced engineered supports for fuel cell catalysts, licensed the world's leading precious-metal-free fuel cell catalysts developed at Los Alamos National Laboratory (Los Alamos).

### Outcomes

#### Technology Advancement

The Los Alamos patents lay the groundwork for future development of entirely precious-metal-free (PMF) catalysts. Pajarito Powder is producing commercial PMF catalysts that provide a near-term, low-cost solution for low and moderate power density applications, such as back-up power. Manufactured with the proprietary VariPore™ process, these PMF catalysts achieve unprecedented activity, stability, and reasonable durability under real-world operating conditions, all at material and production costs that are dramatically lower than Platinum-based catalysts.

#### Impact

Pajarito Powder currently employs 15 people and is growing rapidly to meet its goal to fundamentally change the economics of fuel cells by enabling better performance and greater durability at a lower cost. Pajarito Powder received an award from the Department of Energy's Small Business Vouchers pilot program to work with Los Alamos National Laboratory to test and validate their technology. Pajarito Powder is also leading a team on an Advanced Research Projects Agency-Energy (ARPA-E) project to create a reversible hydrogen electrode that would enable cost-effective hydrogen production and reversible fuel cells.



Pajarito Powder PMF catalysts achieve unprecedented activity, stability, and reasonable durability under real-world operating conditions, all at low material and production costs that are dramatically lower than Platinum-based catalysts.

### Timeline

- 2016:** Pajarito Powder entered a licensing agreement with Los Alamos to commercialize PMF catalysts.
- 2016:** Pajarito Powder, LLC awarded Small Business Voucher Pilot (SBV) program for Phase 2 funding with partner, Los Alamos National Laboratory.
- 2017:** Pajarito Powder announced that it had completed the 100th shipment of its Engineered Carbon Supports (ECS) and precious-metal-free (PMF) catalyst materials to customers.
- 2017:** Pajarito Powder and Los Alamos National Laboratory Win R&D 100 Award.



## Geovisualization Technology for Improved Spatial Data Analysis and Risk Assessment

National Energy Technology Laboratory

*New method and tool to support quantification and visualization of spatial data uncertainty to improve accuracy and value of spatial data products (e.g. maps)*

### Innovation

Developed by the U.S. Department of Energy's National Energy Technology Laboratory (NETL), the Variable Grid Method (VGM) is a novel approach to data visualization that employs a novel, innovative spatial analytical approach simultaneously quantify and visualize data trends and underlying uncertainty. The method has been implemented, as well, in a user-friendly, flexible, and reliable tool for use in geographic, map-based, analyses. Ultimately, the VGM method and tool can be used for small and big data analyses to provide more valuable information to end users and decision makers. By providing both the conventional spatial data output along with variations in that data's uncertainty, as a single, unified product.

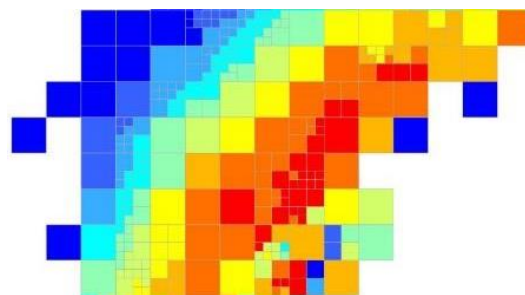
### Outcomes

Technology Advancement

VGM can be incorporated into existing software packages or used as a post-processing workflow. The intuitive approach of the VGM helps communicate the relationship between uncertainty and spatial data to effectively guide research, support advanced computation analyses, and inform management and policy decisions. The method, which is applicable to a wide range of end users, can reduce risks, improve decision-making and reduce costs, particularly in this era of data computing and data analytics where uncertainties may be aggregated and/or ignored by conventional spatial data visualization tools.

Impact

In 2016 the VGM method was an R&D100 Finalist. In 2018 the VGM method was licensed by Texas-based startup, VariGrid Explorations, LLC and was recipient of a DOE Technology Commercialization Fund award. The focus of that award is to facilitate more rapid commercialization of this technology into targeted markets in particular subsurface energy and mineral applications.



The Variable Grid Method communicates both data trends and data uncertainties simultaneously in a single layer (data values (colors) and uncertainty (grid cell size)).

“The VGM Tool is an intuitive visual for consistent communication of uncertainty and risk across an organization - from engineers and scientists acquiring data to top management making investment decisions. VariGrid Explorations’ collaborative efforts with NETL to further develop the Tool(s) for various commercial applications are quite exciting!”

Paul Wanjau, CEO, VariGrid Explorations

### Timeline

- 2015:** Invited, keynote talk at annual Esri User Meeting<sup>1</sup>
- 2015:** VGM approach published in special issue of the journal *Transactions in GIS*<sup>2</sup>
- 2015:** Version 1 of VGM tool developed
- 2016:** Finalist for 2017 R&D 100 Awards<sup>3</sup>
- 2018:** Selected for DOE Technology Commercialization Fund award in partnership with VariGrid Explorations
- 2019:** VGM method and tool copyrighted

<sup>1</sup> Bauer, J. and K. Rose, 2015. Variable Grid Method: an Intuitive Approach for Simultaneously Visualizing Spatial Data and Uncertainty. Esri International User Conference, July 20-24, 2015.

<sup>2</sup> Bauer, J., and Rose, K., 2015, Variable Grid Method: an Intuitive Approach for Simultaneously Quantifying and Visualizing Spatial Data and Uncertainty, *Transactions in GIS*. 19(3), p. 377-397

<sup>3</sup> rd100conference.com/awards/winners-finalists/year/2016/

# NETL-Led Team Creates First-Ever Global Database of Natural Gas Infrastructure Using Custom Big-Data Machine Learning Tools

National Energy Technology Laboratory

*First open-source dataset on oil and natural gas infrastructure provides opportunities for new and rapid insights*

## Innovation

The first-ever database inventory of open-source oil and natural gas infrastructure information from the top hydrocarbon-producing and consuming countries in the world is now available online. The database, known as the global oil and gas infrastructure (GOGI) inventory, identifies more than 6 million individual features like wells, pipelines, and ports from more than a thousand individual datasets in 193 countries. The database, which was assembled over a three month effort, was born from a massive big-data, machine learning driven information acquisition, evaluation, and resource integration project led by the Office of Fossil Energy's National Energy Technology Laboratory (NETL).

## Outcomes

Technology Advancement

One of the key objectives of the work is to help identify and monitor methane leaks from natural gas infrastructure to prevent future leaks and mitigate the associated economic and environmental impacts. Methane is the primary component of natural gas and is a greenhouse gas when released into the atmosphere. Methane leaks from natural gas infrastructure are also a lost opportunity for producers to sell the commodity to consumers.

Impact

Since its release, the GOGI database has been utilized by researchers at Harvard, the Environmental Defense Fund (EDF), and the United Nations Environmental Programme (UNEP) in high profile studies focused on assessing and reducing future global and local methane emissions.

The GOGI inventory offers an economic, environmental, and health and safety resource for researchers, industry representatives, and government regulators to help prevent infrastructure failures, improve economics of energy production, and address fugitive methane emissions.



Pipelines are a common component of oil and gas infrastructure and are one element tracked in the GOGI database

“The new database integrates and standardizes the varying data sets into a global, open-access assessment and inventory of oil and gas infrastructure—a critical tool for predicting and assessing global methane emissions risks, identifying information gaps, evaluating economic costs, and supporting a range of critical decision-making needs.”

Kelly Rose, Data Science Researcher, National Energy Technology Laboratory

## Timeline

- 2017:** GOGI CRADA with EDF and UNEP
- 2018:** GOGI database released on Energy Data Exchange (EDX)<sup>1</sup>
- 2018:** GOGI technical report released on EDX<sup>2</sup>
- 2018:** GOGI web mapping tool, Geocube, on EDX<sup>3</sup>
- 2018:** Invited GOGI seminar at Harvard University<sup>4</sup>
- 2019:** GOGI team selected for Carnegie Science Award<sup>5</sup>

<sup>1</sup> [edx.netl.doe.gov/dataset/global-oil-gas-features-database](https://edx.netl.doe.gov/dataset/global-oil-gas-features-database)

<sup>2</sup> [edx.netl.doe.gov/dataset/development-of-an-open-global-oil-and-gas-infrastructure-inventory-and-geodatabase](https://edx.netl.doe.gov/dataset/development-of-an-open-global-oil-and-gas-infrastructure-inventory-and-geodatabase)

<sup>3</sup> [edx.netl.doe.gov/dataset/global-oil-gas-infrastructure-features-database-geocube](https://edx.netl.doe.gov/dataset/global-oil-gas-infrastructure-features-database-geocube)

<sup>4</sup> Rose, K., 2017. Six Million Deep Wells – Insights into 158 Years of Hydrocarbon Operations thru Machine Learning and Geospatial Analytics. October 6th, 2017, Harvard University, School of Engineering and Applied Sciences, invited seminar. [seas.harvard.edu/directory/djj](https://seas.harvard.edu/directory/djj)

<sup>5</sup> [carnegiesciencecenter.org/carnegie-science-awards/](https://carnegiesciencecenter.org/carnegie-science-awards/)

## NRELS 3-D Visualizations and Analysis Inform Largest Net-Zero Energy District in the U.S

National Renewable Energy Laboratory in conjunction with multiple industry partners and the City of Denver

*Data visualizations and analysis of the United States' largest net-zero energy district.*

### Innovation

NREL developed the foundational software that enabled comprehensive energy district design and planning among cities, land developers, and energy companies. The software integrates building energy load modeling with distribution system modeling for the first time in a tool that utilizes URBANopt and OpenDSS.

### Outcomes

#### Technology Advancement

NREL combined its building energy system model, URBANopt, with grid modeling software, OpenDSS, to model the interaction of the district with the grid. NREL then developed a variety of load and power flow scenarios using a range of technology options, including varying solar photovoltaic penetrations, energy efficiency scenarios, distributed energy storage capacities, and district heating and cooling.

#### Impact

Xcel Energy is integrating the data into its modeling tools to create a cost-effective design framework for what will be its first microgrid in Colorado. The utility and developer can then plan distributed energy resources (DERs) and innovative rate structures before the Denver, Colorado development, Peña Station NEXT is constructed. The project will also result in several tools that others can use to replicate this project across the country. That includes an enhanced version of URBANopt and a developer's handbook created by Panasonic. The district will demonstrate the combined use of multiple DERs and decrease their net integration costs by addressing the hardware, software, and business aspects of district planning and development. The upcoming district will serve as a proven, demonstrated model for smart city design.



NREL and partners collaborated under a CRADA project to analyze the least cost and most scalable net-zero energy infrastructure development in the United States.

Illustration from LC Fulenwider, Inc.

### Timeline

- 2016:** URBANopt (Urban Renewable Building and Neighborhood optimization) model developed by NREL.<sup>1</sup> Used in conjunction with EPRI's open source OpenDXSS electrical power system model.<sup>2</sup>
- 2017:** Cooperative Research & Development Agreement with Panasonic and Xcel signed under which NREL conducted a solar power/battery storage/grid integration study to inform the Peña Station NEXT energy master plan<sup>3</sup>
- 2017:** Solar & storage microgrid installed.

<sup>1</sup> [nrel.gov/buildings/urbanopt.html](http://nrel.gov/buildings/urbanopt.html)

<sup>2</sup> [nrel.gov/docs/fy17osti/68998.pdf](http://nrel.gov/docs/fy17osti/68998.pdf)

<sup>3</sup> [nrel.gov/news/press/2017/nrel-announces-partnership-with-panasonic-and-xcel-energy.html](http://nrel.gov/news/press/2017/nrel-announces-partnership-with-panasonic-and-xcel-energy.html)

## NREL I-Corps Team's Nitrilation Process Could Lead to Renewable Carbon Fiber from Biomass

National Renewable Energy Laboratory in conjunction with multiple industry partners

*Developing a cheaper, more sustainable way to produce high quality carbon fiber.*

### Innovation

An ongoing research effort at the National Renewable Energy Laboratory (NREL) could lead to a cleaner method to transform acrylonitrile (ACN) into carbon fiber, replacing petrochemicals with biomass as the starting point. They did this using nitrilation, a renewable alternative to the petrochemical method which eliminates toxic byproducts, requires less energy, uses inexpensive catalysts, and can be performed in a simple reactor configuration with no explosion hazards.

### Outcomes

#### Technology Advancement

NREL managed to successfully produce 50 grams of bio-derived ACN in a reactor similar to those used in industry today. That capped the first phase of the program. The second phase, now under way, calls for the production of 50 kilograms of ACN that will be converted into carbon fiber and tested.

#### Impact

Driven in part by the interest in using carbon fiber for lightweighting vehicles and aircraft that will save money on fuel costs, the demand for carbon fibers is projected to increase 11% to 18% annually. And given that the carbon fiber industry is especially sensitive to price fluctuations in their base chemical ACN (it takes roughly 2 pounds of ACN to generate 1 pound of carbon fiber), there is a clear need to develop alternative cost-competitive processes.

NREL estimates the new process could put the selling price of biomass-derived ACN below \$1 per pound from cellulosic biomass or starch-based sugars. This target was deemed necessary for cost competitiveness with conventionally produced acrylonitrile. The process produced a 98% yield of ACN. The yield from the petroleum-based method ranges from 80%-83%



Violeta Sánchez i Nogué is a member of the NREL Energy I-Corps team that received Bioenergy Technology Office funding to pioneer a nitrilation-to-acrylonitrile process.

### Timeline

- 2014:** NREL launches and collaborates with partners on the Renewable Carbon Fiber Consortium.
- 2015:** NREL researchers develop sustainable nitriles technology and submit an invention record.
- 2016:** NREL files a U.S. provisional patent application that is ultimately converted to an international (PCT) patent application.
- 2018:** Federal Laboratory Consortium Notable Technology Development and CO-Labs Governors award.
- 2018:** the nitrilation technology wins a R&D 100 award.<sup>1</sup>
- 2019:** NREL partners with Zoltek (Toray) to submit a Technology Commercialization Fund full proposal scale up the nitrilation chemistry.

<sup>1</sup> [nrel.gov/news/press/2018/rd-magazine-honors-duo-of-nrel-innovations.html](https://www.nrel.gov/news/press/2018/rd-magazine-honors-duo-of-nrel-innovations.html)



## NREL Launches Sustainable Mobility Initiative, Joins CDOT Partnership

National Energy Technology Laboratory in conjunction with the Colorado Department of Transportation

*NREL's Sustainable Mobility Initiative aims to use connectivity and automation to optimize mobility and reduce energy consumption*

### Innovation

NREL will draw on the cross-cutting research capabilities under its Sustainable Mobility umbrella to offer solutions that support CDOT's RoadX program to reimagine transportation in Colorado as a crash-free, technologically advanced system. CDOT will rely on NREL's integrated transportation research capabilities, including a deep knowledge of the technology required to connect travelers, vehicles, the grid, and the built environment. NREL will identify meaningful insights from the data collected from CDOT's traffic probes and cameras, public transit records, travelers' smartphone applications, and advanced vehicle systems.

### Outcomes

#### Technology Advancement

The NREL analysis experts will develop models of traveler decision-making patterns within the urban environment using intelligent vehicles and interoperable systems. NREL will develop guidance maximizing efficiencies and pinpointing optimal mobility choices. The RoadX program plans to deploy advanced technology to reduce the cost of transporting goods, improve safety, and alleviate congestion across Colorado's critical transportation corridors. NREL will provide CDOT with systems-level expertise to help the state of Colorado realize this vision for next-generation mobility

#### Impact

The establishment of a true sustainable mobility system will take time. Many questions remain about automated vehicle technology such as what to expect from local and federal legislation, cybersecurity, and the intersection of self-driving vehicles with ride-sharing economy. The state transportation agencies will be guiding how new technologies integrate with the larger transportation system, establishing any necessary rules and regulations, which will inform future research under NREL's Sustainable Mobility Initiative.



Today, transportation operation and energy systems data are generated at an unprecedented scale. NREL's data experts and engineers analyze large sets of complex data—or "big data"—to develop solutions that support the research, development, and deployment of market-ready technologies that reduce fuel consumption and greenhouse gas emissions.

### Timeline

- 2016:** NREL launches its Sustainable Mobility Initiative, with efforts to include collaboration with CDOT's RoadX Program, the ARPA-e TRANSNET initiative Connected Traveler, and DOE's Integrated Network Testbed for Energy Grid Research and Technology Experimentation (INTEGRATE)<sup>1</sup>
- 2016:** CDOT and NREL sign Memorandum of Understanding for the RoadX Program with a goal of leveraging NREL's integrated transportation research capabilities<sup>2</sup>
- 2018:** NREL's Sustainable Mobility Initiative encompasses a wide breadth of projects and technologies, including research on autonomous vehicles, machine learning, connected vehicles, and new models of car ownership.<sup>3</sup>

<sup>1</sup> [nrel.gov/news/features/2016/21622.html](http://nrel.gov/news/features/2016/21622.html)

<sup>2</sup> [nrel.gov/news/features/2016/21622.html](http://nrel.gov/news/features/2016/21622.html)

<sup>3</sup> [nrel.gov/news/program/2018/sustainable-mobility-the-transportation-world-beyond-tomorrow-is-here-today.html](http://nrel.gov/news/program/2018/sustainable-mobility-the-transportation-world-beyond-tomorrow-is-here-today.html)



# Geometrically Enhanced Photocathodes for Improved High-Efficiency in X-Ray Detectors

Nevada National Security Site

*New photocathode technology that may revitalize the U.S. capability to manufacture imaging detector systems for critical national security applications.*

## Innovation

Researchers at the Nevada National Security Site funded through the Site-Directed Research and Development Program (SDRD) have conceived a way to break the limits of detector efficiency and performance in the soft x-ray range, which is largely limited by the total quantum electron yield. Most x-ray detectors operate at normal incidence (i.e., x-ray photons are at a 90° incidence angle to the photocathode) and suffer a loss in quantum efficiency at energies greater than 5 keV. But improvements in yield of up to 20 times have occurred with grazing incidence geometry due to the larger path length of the x-ray photons, which better matches the secondary electron escape depth within the photocathode material.

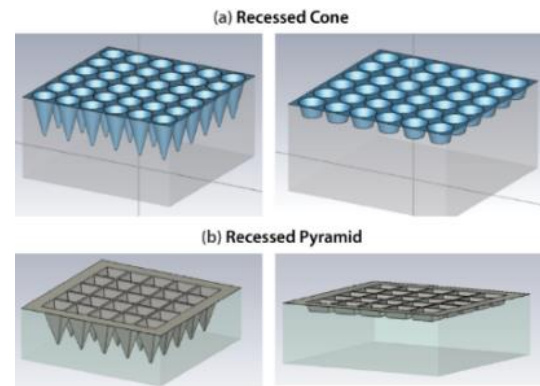
## Outcomes

Technology Advancement

The cathode in the SDRD design can be as large as 5–8 inches in diameter, is free standing, and can be coated with any coating (i.e., Au, CsI, KBr). Also, the cathode can be used at photon energies below 1 keV, with even greater improvement in signal. This design is adaptable to any x-ray detector, allowing for ease of use without compromising performance parameters such as spatial and temporal resolution. The geometrically enhanced photocathode also increases the measured total electron yield by up to 3 times in the 1–12 keV energy range.

Impact

This technology addresses a problem that exists in the stagnating photomultiplier tube (PMT) industry, which is no longer developing the PMTs that were commonplace in legacy testing days. This R&D has spawned more research in semiconductor-based photocathodes and high-density microchannel designs for developing more efficient high-speed imaging systems.



Recessed cone and pyramid structures were considered. Full-length and shallow structures are shown. It was determined that the pyramid structures were more efficient and easier to fabricate; therefore, full-scale and shallow recessed pyramids were made, characterized, and tested in a National Ignition Facility streak camera, SPIDER. Results show an increase in electron yield of up to 3.5x in 7.5 keV.

“The geometrically enhanced photocathode proves that we can push the limits on what we can do in quantum efficiency - that is, improve our ability to see finer detail in the dynamics of fusion experiments. With this geometrically enhanced photocathode, we’re getting better and more data, and it lets us view the dynamics of fusion more clearly.”

Howard Bender, Distinguished Scientist NNS Los Alamos Operations

## Timeline

**2014:** Feasibility study completed under Site-Directed Research and Development

**2016:** Demonstration of first use in streak camera

**2017:** Received R&D 100 award

## NNSS and H3D Partnership Improves Detection of Radioactive Sources

Nevada National Security Site in conjunction with H3D, Inc.

*Improving the ability to detect and identify radioactive sources in order to use unmanned aerial vehicles to measure radioactivity.*

### Innovation

The NNSS Remote Sensing Laboratory (RSL) relies upon state-of-the-art sensors to detect, measure and identify radioactive sources. As part of the research and development efforts, scientists and engineers from the NNSS integrated the H3D sensors with unmanned aerial systems, creating a more flexible and agile vehicle for measuring radiation.

### Outcomes

#### Technology Advancement

The first tests were completed in September 2017 at the Unmanned Systems Inc. (USI) facility in Columbia Falls, Montana and data analysis was finalized in December 2017. The first test provided excellent results that will be used to refine further flights. The CRADA allows NNSS to leverage commercialized radiation detectors and UAS technology, enabling it to deploy them in an entirely new way; the new methods are a new asset for responding to nuclear emergency situations.

#### Impact

H3D's technology grew out of research conducted at the Nuclear Engineering department at the University of Michigan. The technology was further funded in large part by the Defense Threat Reduction Agency (DTRA). The ongoing partnership between H3D and the NNSS will provide research into the trade-offs between sensitivity and resolution of the compact radiation detectors. Integrating the sensor technology with unmanned aerial vehicles has the potential to enhance the next-generation radiation detection capabilities for RSL and other emergency response agencies.



The fixed-wing Sandstorm UAS used in the detection of radiation sources. The UAS is outfitted with a video camera (under nose) and sensor pod (undercarriage), which can be customized for different sensor/detector configurations without changing the overall platform.

"H3D views aerial radiation detection platforms as a key growth area for our organization and we are fortunate to have NNSS as a partner in this effort."

Willy Kaye, Founder and CEO, H3D, Inc.

### Timeline

- 2012:** Development by H3D of CdZnTe as a room-temperature semiconductor high resolution gamma ray detector with DTRA and DOE
- 2017:** First NNSS tests and analysis of H3D radiation sensors for unmanned aerial systems conducted and completed.

## Genetic Regulation in Plants for Improved Biofuels and Forage Crops

Oak Ridge National Laboratory in conjunction with the University of Tennessee and West Virginia University and industry partners

*Researchers identified a gene linked to the synthesis of lignin, a key component of plant cell walls that provides sturdiness but hinders the processing of the plant sugars for biofuel and the digestibility of plants by livestock.*

### Innovation

The BESC research team showed that a key gene can reduce lignin content in plant cells by up to 50 percent in poplar (*Populus trichocarpa*) and plants carrying this variant of the lignin-producing gene showed an increase in sugar release of up to 280 percent. This increase in sugar release resulted in a 250 percent increase in ethanol yield from the biomass that was not chemically or mechanically pretreated.

### Outcomes

#### Technology Advancement

ORNL researchers also applied the same gene altering method used on poplar trees to *Medicago truncatula*, a model system used for alfalfa, which is widely used for animal feed. This resulted in a 25 percent reduction in lignin and a 250 percent increase in flavonoid content. Industry believes this innovation could have a dramatic impact on forage crops by reducing the lignin barrier for improved digestibility while also improving the nutritional quality with increased flavonoids.

#### Impact

ORNL continues to collaborate with both GreenWood Resources and Forage Genetics International as the companies conduct field studies over the next few years to validate this novel plant system in the companies' commercial varieties. ORNL's Technology Innovation Program (TIP) support efforts at ORNL to collaborate with each company during their field trials to provide an accelerated timeline to develop this innovation for the marketplace.



The BESC team, led by Dr. Wellington Muchero at ORNL, identified the key gene for this innovation.

“Incorporating this technology into GreenWood’s poplar breeding program will lead to a new, superior class of bioenergy plantation varieties with which biorefineries can produce transportation fuels at a reduced cost, owing to significant savings during the pretreatment and enzymatic hydrolysis stages. This technology will accelerate GreenWood’s efforts to improve biomass chemical composition that is important in helping move the United States toward energy independence.”

Brian Stanton  
Chief Science Officer, GreenWood Resources, Inc.

### Timeline

**2016:** ORNL researchers matured the intellectual property under ORNL’s Technology Innovation Program (TIP) and licensed the technology to two multiple partners including GreenWood Resources, Inc.

<sup>1</sup> UTB ID 201403346, A Transcription Factor Which Regulates Flavonoid, Phenylpropanoid, Tyrosine, and Tryptophan Pathways, U.S. Patent Application 14/720,023 filed on May 22, 2015.

<sup>2</sup> [ornl.gov/news/greenwood-resources-licenses-ornl-invention-boost-biofuel-yield](http://ornl.gov/news/greenwood-resources-licenses-ornl-invention-boost-biofuel-yield)

## Hyperion: Behavior Analysis Cyber Security Technology

Oak Ridge National Laboratory

*Improving the ability to detect and identify radioactive sources in order to use unmanned aerial vehicles to measure radioactivity.*

### Innovation

Hyperion is a cyber security technology that can alert a user to the existence of sleeper code embedded within executable computer files to thwart malicious activity.

### Outcomes

Technology Advancement

Hyperion's earliest foundations can be traced to work at IBM in the 1990s in functional and denotational semantics followed by additional work in function extraction at Carnegie Mellon University's Software Engineering Institute in 2004. But it was the vision of ORNL researchers who identified the key technical advances that enabled them to take the nascent technology to a deployable form. Work began at ORNL in 2010 on improvements in core algorithms for performance, better semantic handling, and better maintainability, which resulted in today's Hyperion.

Impact

From a cyber security perspective, it is advantageous to understand and analyze the functionality of binary executables of newly developed software or acquired software prior to installing and running these programs on a computer. This is very difficult to do. The Hyperion system was designed to 'look inside' an executable program and determine software's function or 'behavior' without the use of the software's source code. These behaviors can be automatically checked for known malicious signatures and inspected by domain experts to assure correct operation and the absence of malicious content. The closest commercial products start from the perspective of "presumed innocent" code, whereas Hyperion treats all code as a suspect.



Lenvio exclusively licenses ORNL Hyperion technology.

"For us, software with unknown behavior has unknown security, which is problematic for global cybersecurity. Current methods are increasingly overwhelmed by the sophistication of attacks often precipitated by stealthy zero-day or sleeper code vulnerabilities. With Hyperion, we're offering a new class of cyber protection."

B.K. Gogia  
CEO, Lenvio

### Timeline

**1990s:** Work at IBM in functional and denotational semantics sets the foundations for Hyperion.

**2010:** Work at ORNL on what would become Hyperion begins.

- <sup>1</sup> UTB ID201403244, Behavior Specification, Finding Main, and Call Graph Visualizations, U.S. Patent 10,198,580.
- <sup>2</sup> UTB 90000006, Hyperion, U.S. Copyright TXu 1-934-554.
- <sup>3</sup> [ornl.gov/news/lenvio-inc-exclusively-licenses-ornl-malware-behavior-detection-technology](http://ornl.gov/news/lenvio-inc-exclusively-licenses-ornl-malware-behavior-detection-technology)
- <sup>4</sup> [dhs.gov/science-and-technology/news/2017/04/28/news-release-dhs-st-announces-commercialization-malware](http://dhs.gov/science-and-technology/news/2017/04/28/news-release-dhs-st-announces-commercialization-malware)



## Lignin-Derived High-Performance Plastics

Oak Ridge National Laboratory

*Technology enabling the conversion of lignocellulosic biomass, a byproduct from biorefineries and the pulp and paper industries, into plastic resins.*

### Innovation

Researchers at Oak Ridge National Laboratory (ORNL) have developed a high-performance lignin-based thermoplastic that will be useful for industrial plastic resins and commercial materials. The thermoplastic product is an unmodified solvent-extracted melt-stable lignin combined with non-lignin thermoplastic polymer segments. Named ABL, the new material is a drop-in replacement for ABS, providing both performance and cost benefits.

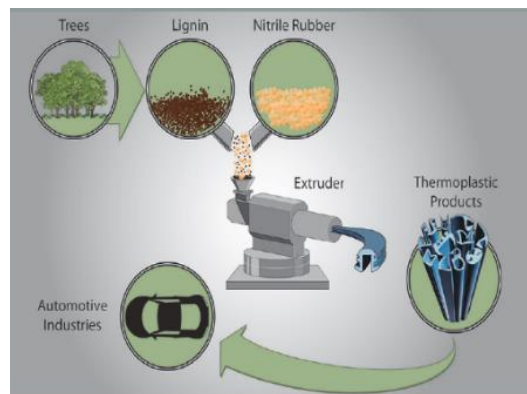
### Outcomes

#### Technology Advancement

To accelerate commercial deployment, ORNL invested a portion of its royalty funds to mature this technology under its Technology Innovation Program (TIP). Under TIP, researchers worked to make the technology more commercially ready while technology transfer office staff members conducted an aggressive outreach campaign. In 2017, upon completion of the TIP maturation project, ORNL competitively selected three commercialization partners and entered semi-exclusive licenses with each. The licensees include Advanced Lignin Biocomposites LLC, a wholly-owned subsidiary of Meridian Waste Solutions based in New London, Minnesota, Prisma Renewable Composites, a Knoxville Tennessee based startup company, and Yangfeng Automotive Interiors, an international Tier 1 producer of vehicle components. All three companies are in the early stages of commercializing the technology.

#### Impact

Potential Applications include conversion of lignin into lightweight materials for vehicles without reducing crash-worthiness, greater fuel economy and reduced CO<sub>2</sub> emissions of vehicles, replacement of fossil-based resins in polymer applications with eco-friendly material, and improved economics of the paper and biofuels industries.



Process of converting lignin into thermoplastic products for the automotive industry.

“The new ORNL thermoplastic has better performance than commodity plastics like ABS. We can call it a green product because 50 percent of its content is renewable, and technology to enable its commercial exploitation would reduce the need for petrochemicals.”

Amit Naskar  
Group Leader and Senior R&D Staff  
Oak Ridge National Laboratory

### Timeline

**2017:** ORNL completed a Technology Innovation Program (TIP) maturation project for this technology to accelerate its commercial development. This was followed with selecting three commercialization partners, entering semi-exclusive licenses with each.

<sup>1</sup> UTB ID 201403426, High-Performance Lignin-Acrylonitrile Polymer Blend Materials, U.S. Patent App. 14/798,729.

<sup>2</sup> [ornl.gov/sites/default/files/documents/201403426.pdf](http://ornl.gov/sites/default/files/documents/201403426.pdf)

<sup>3</sup> [ornl.gov/content/tip-talks](http://ornl.gov/content/tip-talks)



## Method of Producing Carbon Fibers from Multipurpose Commercial Fibers

Oak Ridge National Laboratory

*Cutting both the energy consumption and cost required to produce carbon fiber.*

### Innovation

Researchers at Oak Ridge National Laboratory (ORNL) with support from DOE's Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing, and Vehicle Technologies Offices developed an innovative method to produce low-cost carbon fiber that is poised to revolutionize the composites market. Thanks to their extensive research and development (R&D), ORNL's innovation cuts carbon fiber costs in half and dramatically reduces energy usage, transforming carbon fiber into an affordable material suitable for high-volume, cost-sensitive applications.

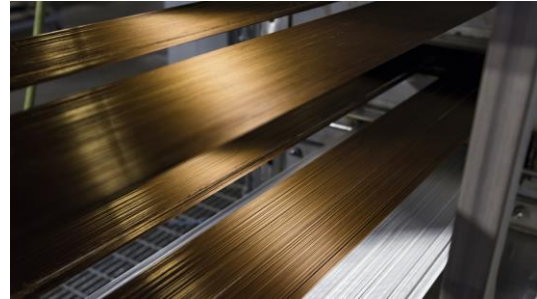
### Outcomes

Technology Advancement

ORNL aggressively marketed the technology through electronic and print media. Following this outreach, ORNL competitively selected four licensees based on their potential for success, commitment to the technology, and willingness to manufacture in the United States. ORNL is now collaborating with two of the licensees to further develop the technology under Cooperative Research and Development agreements. This commercialization activity was recognized by the Federal Laboratory Consortium with a 2018 award for Excellence in Technology Transfer.

Impact

Suitable applications for this technology includes transportation/freight (automobiles, trucks, and marine craft), aerospace (aircraft and spacecraft structures and components), clean energy (wind turbines, tanks for compressed gas storage, and solar panels), infrastructure (buildings, bridges, and other structures made of concrete, steel, masonry, or timber), recreation equipment (bicycles, golf clubs, fishing rods, racquets, and much more), and manufacturing (additive manufacturing, thermoplastics, etc.)



ORNL's scalable process for producing low-cost carbon fiber.

"Our close proximity to ORNL adds a value beyond measure and we are looking forward to future collaborations with them. Additionally, with the input of the University of Tennessee, The Institute for Advanced Composites Manufacturing Innovation (IACMI), and the emerging composites corridor, I believe the Knoxville area will become the world hub for carbon fiber in the future."

Greg LeMond  
Founder, LeMond Composites

### Timeline

**2017:** ORNL signed licenses with multiple companies to further develop technology.

<sup>1</sup> UTB ID 201503583, Method of Producing Carbon Fibers from Multipurpose Commercial Fibers, U.S. Patent Application 62/273,559, filed December 31, 2015.

<sup>2</sup> [compositesmanufacturingmagazine.com/2016/09/cycling-legend-greg-lemond-partners-oak-ridge-national-laboratory/](https://compositesmanufacturingmagazine.com/2016/09/cycling-legend-greg-lemond-partners-oak-ridge-national-laboratory/)

## Qubitekk licenses ORNL Single-Photon Source Approach for Quantum Encryption

Oak Ridge National Laboratory in conjunction with Qubitekk Inc.

*An ORNL developed method to produce quantum light in more controlled deterministic matter which can improve the speed and security of sharing encrypted data.*

### Innovation

Systems that emit single photons typically do so at random times, and it is difficult to generate them as needed, or deterministically. The ORNL team turned to a method known as down-conversion, a process in that yields not one, but two photons. The detection of one of these photons “heralds” the presence of the other. Arranging many photon sources together increases the probability of generating at least one photon pair when needed, even though the individual sources emit at random. This method was licensed to Qubitekk Inc.

### Outcomes

#### Technology Advancement

To keep from losing the photon pairs, the team built upon existing ideas of multiplexing, an approach that uses a series of light source systems comprising components common in fiber-optics. The systems switch the speed and frequency of the heralded photon. ORNL’s innovation carries out the switching in the frequency domain that potentially reduces significant single-photon loss. “The goal is to specify and control every aspect of the photon’s quantum state, constraining everything to a single mode so that the photons emitted from the single-photon source are identical – each one indistinguishable from the next,” ORNL co-inventor Nicholas Peters said. The identical photon pairs can be used in developing quantum key encryption technologies that protect information from cyber threats when shared over existing machine-to-machine networks.

#### Impact

Qubitekk has been developing and commercializing quantum cryptography solutions based on its compact and robust entangled photon sources since 2012. The company has focused specifically on the development of quantum key distribution (QKD) systems for machine-to-machine communications associated with distributed control.



ORNL nonexclusively licenses Qubitekk a quantum encryption technology

“The idea of a nearly on-demand, single-photon source can be used to increase the speed, or data rates, and the distance you can send the quantum keys when transmitting encrypted information”

Duncan Earl, President and CTO,  
Qubitekk

### Timeline

- 2012:** Qubitekk starts developing and commercializing quantum cryptography solutions.
- 2017:** Qubitekk partnered with ORNL under a CRADA to collaborate a related project (Scalable Quantum Cryptography Network for Protected Automation Communication) funded by the Cybersecurity of Energy Delivery Systems Program.

<sup>1</sup> UTB ID 201603700, Deterministic Single Photon Source based on Spectral Shift of a Herald Photon, U.S. Patent Applications 15/829,349 filed December 1, 2017.

<sup>2</sup> [ornl.gov/news/qubitekk-licenses-ornl-single-photon-source-approach-quantum-encryption](http://ornl.gov/news/qubitekk-licenses-ornl-single-photon-source-approach-quantum-encryption)

## Cerium Aluminum (Ce-Al) Alloys Provide an Improved Material for Casting

Oak Ridge National Laboratory (ORNL) in conjunction with Ames Laboratory, Lawrence Livermore National Laboratory, and Eck Industries

*A new Ce-Al alloy with multiple beneficial characteristics that allow it to fulfill multiple applications.*

### Innovation

ORNL exclusively licensed Eck Industries for the commercialization of a Ce-Al alloy developed at DOE's Critical Materials Institute that is ideal for creating lightweight, strong components for advance vehicles and airplanes. Researchers at ORNL, Ames Laboratory, Lawrence Livermore National Laboratory, and Eck Industries co-developed this alloy that is easy to work with, lightweight, corrosion-resistant, and exceptionally stable at high temperatures. These characteristics make this alloy ideal for automotive, aerospace, power generation, and other applications.

### Outcomes

#### Technology Advancement

This team has shown that this Ce-Al alloy is stable at a temperature of 500°C. This high temperature material can be incorporated into engines to allow the engine to run hotter for a more complete fuel combustion while being lighter in weight for better fuel efficiency. This alloy also offers improved production methods by not requiring additional thermal processing during the casting process and uses standard aluminum foundry practices without a protective atmosphere. Avoiding the thermal processing and the resulting machining to address thermal distortion will save up to 50-60% of the cost of casting traditional alloys.

#### Impact

Eck Industries sees tremendous interest from their existing and potential customers due to the unique material properties of this low-cost alloy. With this alloy making use of cerium, the U.S. manufacturing sector will benefit from low production costs and suppliers in the U.S. domestic rare earth mining operations will have a new commercial opportunity for an element that make up as much as half of the mined rare earths.



ORNL exclusively licenses commercialization of Ce-Al alloy with Eck Industries

“There has been tremendous interest from industry due to the unique material properties and low cost of this alloy. This project is a template for rapid development and commercialization. Not only did we bridge the research ‘valley of death,’ we also developed a highway for communication from our customers to us to help guide the project.”

David Weiss, Vice President of Engineering and R&D, Eck Industries, Inc.

### Timeline

**2017:** ORNL licenses Eck Industries, Inc. a novel aluminum cerium alloy supported by the DOE's Critical Materials Institute

<sup>1</sup> UTB ID 201503469, Castable High-Temperature Ce-Modified Al Alloys, U.S. Patent Application 15/204,169, filed July 7, 2016.

<sup>2</sup> [ornl.gov/news/eck-industries-exclusively-licenses-cerium-aluminum-alloy-co-developed-ornl](http://ornl.gov/news/eck-industries-exclusively-licenses-cerium-aluminum-alloy-co-developed-ornl)

## Innovative Process for Converting Waste to Jet Fuel Cleared for Take Off

Pacific Northwest National Laboratory in conjunction with LanzaTech working with Virgin Atlantic

*A process for converting carbon-rich pollution into jet fuel*

### Innovation

The Chicago-based company LanzaTech developed a unique carbon recycling technology that operates similarly to traditional fermentation. But, instead of using sugars and yeast to make alcohol, waste carbon-rich gases—such as those found at industrial manufacturing sites—are converted by bacteria to fuels and chemicals, like ethanol. The ethanol can be used for a range of low carbon products, including alcohol-to-jet synthetic paraffinic kerosene (ATJ-SPK), which now is eligible to be used in commercial flights at up to 50 percent blends with conventional jet fuel.

### Outcomes

#### Technology Advancement

LanzaTech turned to the catalytic expertise of PNNL, which developed a unique catalytic process and proprietary catalyst to upgrade the ethanol to (ATJ-SPK). PNNL's catalyst removes oxygen from the ethanol in the form of water, and then combines the remaining hydrocarbon molecules to form chains large enough for jet fuel without forming aromatics that lead to soot when burned.

#### Impact

After PNNL produced five gallons of the desired fuel, LanzaTech then scaled up the entire process. The ethanol was converted to 4,000 gallons of ATJ-SPK at LanzaTech's Freedom Pines facility in Georgia and met all the specifications required for use in commercial aviation. In April 2018, an international standards body approved the ethanol-to-jet fuel pathway for aviation turbine fuel at up to a 50 percent blend ratio with standard, petroleum-based jet fuel based on LanzaTech's Research Report—the culmination of a multi-year collaboration with PNNL. This fuel was used to power a Virgin Atlantic flight from Orlando to London using a Boeing 747.



PNNL researcher Rich Hallen helped develop a process that converts ethanol to jet fuel. In partnership with LanzaTech, which produces ethanol from industrial waste emissions, PNNL's catalytic technology helped to produce 4,000 gallons of ATJ-SPK fuel, some of which was used on a Virgin Atlantic commercial flight from Orlando to London.

"Thanks to collaborative efforts of our friends, partners and governments across both sides of the Atlantic, we are showing the world that carbon capture and utilization are ready today."

Jennifer Holmgren  
CEO, LanzaTech

### Timeline

- 2010:** Imperium Renewables and PNNL begin a Cooperative Research and Development Agreement
- 2012:** PNNL, LanzaTech and Imperium Renewables enter into a three-way CRADA with co-licensing rights
- 2014:** LanzaTech obtains exclusive license rights on PNNL catalytic process
- 2015:** LanzaTech, with support from PNNL, demonstrates successful scale-up
- 2018:** LanzaTech licenses PNNL innovation
- 2018:** Virgin Atlantic test flight



## SLIM: A Breakthrough for Disease Prediction and Diagnosis

Pacific Northwest National Laboratory in conjunction with multiple industry partners

*SLIM represents another step in enabling personalized medicine through high speed analysis of small samples.*

### Innovation

PNNL's Structures for Lossless Ion Manipulations (SLIM) technology brings unprecedented speed and sensitivity for analyzing tiny amounts of biological samples. SLIM's properties—extremely high resolution, high-speed analysis with minimal sample loss in a flexible and low-cost platform—could enable breakthroughs in biological discovery, validation, and clinical diagnostics.

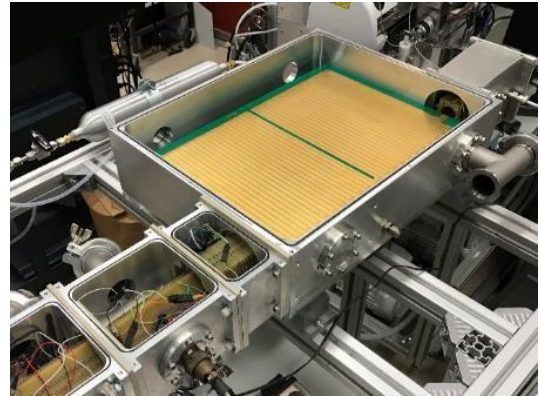
### Outcomes

#### Technology Advancement

The SLIM separations technology provides unprecedented capacity to separate and detect clinically relevant molecules that are indistinguishable by current instruments. It compresses a 40-foot ion path into a device about the size of a small laptop. Using electric fields, SLIM creates conduits that can separate and move ions without losses. This means that researchers can detect and analyze traces of many disease-specific biomolecules, including some that were previously undetectable. It does this in minutes, not hours, enabling population-scale studies in a reasonable amount of time—and equipping scientists, researchers, and clinicians to move faster to detect disease in earlier stages.

#### Impact

Beginning in FY2016 and continuing for the next two years, internationally renowned technology investment company IP Group invested \$2 million through an Agreement to Commercialize Technology (ACT) to further SLIM development and start a new company, MOBILion Systems, Inc., in Exton, Penn. In FY2017, MOBILion licensed the technology from PNNL. MOBILion now is developing a commercial prototype of the SLIM system for demonstration and validation in specific biological applications.



PNNL's licensee, MOBILion, is commercializing this innovative analytical technology to support personalized healthcare decisions.

“Licensing and commercializing PNNL’s SLIM technology enabled MOBILion to provide the most comprehensive, highest throughput analysis of the complement to genomics to advance biomarker discovery and improve productivity of the drug development process through unprecedented characterization of biotherapeutic candidates and the underlying biology of the patients that receive them.”

Melissa Sherman, PhD  
CEO, MOBILion Systems, Inc.

### Timeline

**2016:** IP Group invested \$2million

**2017:** MOBILion Systems Inc. is founded and licenses the technology from PNNL.



## STARS: Harnessing the Sun to Make Gases and Chemicals

Pacific Northwest National Laboratory (PNNL) in conjunction with Southern California Gas Company, STARS Technology Corp., and Oregon State University

*STARS captures sunlight in a parabolic dish and concentrates it to drive a chemical reaction producing chemical energy with 70% efficiency.*

### Innovation

The Solar Thermal Advanced Reactor System (STARS), developed by PNNL, harnesses solar energy to power compact chemical reactors that produce liquids and gases for transportation, electricity generation, and other industrial processes. The U.S. Department of Defense and NASA funded the initial research, followed by the U.S. Department of Energy's (DOE's) SunShot Initiative, which aims to advance American-made solar technologies. STARS team members used DOE's Energy I-Corps training in 2015 to gain insights on marketplace needs and convinced them that a startup was the best way to commercialize the technology.

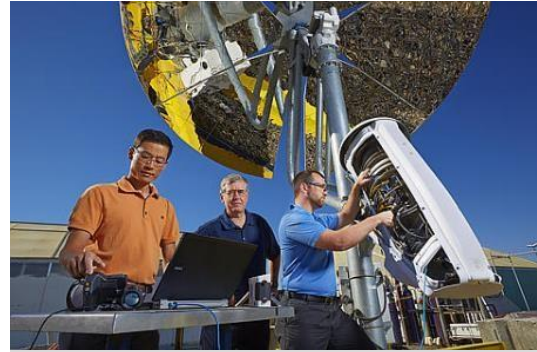
### Outcomes

#### Technology Advancement

An initial CRADA with Southern California Gas Company helped the startup refine and demonstrate the technology. A second CRADA started in FY2017 is enabling STARS Technology Corp., Oregon State University, and PNNL to explore ways to reduce the manufacturing cost of STARS components. The CRADA is being funded by DOE, STARS Technology Corp, and the state of Oregon. A third CRADA also began in FY2017 to further refine and test a prototype STARS system in California, funded by DOE's Technology Commercialization Fund and Southern California Gas, with STARS Technology Corp. providing in-kind contributions.

#### Impact

As the first commercial product, STARS Technology Corp. is pursuing hydrogen production for potential industrial use and fuel cell vehicles, followed by methanol and potentially other chemicals. A commercial partner, SoCalGas, is excited about this opportunity because it serves an estimated 21.6 million customers in Southern California, a region well-suited for solar technologies.



PNNL's STARS technology uses renewable solar energy to produce fuels and chemicals.

*"STARS converts a record-setting 70 percent of renewable solar energy into chemical energy that can be used for transportation or to produce electricity. I co-invented this technology while at PNNL and have since spun off to create a local company now offering STARS to energy-related markets."*

Robert Wegeng

STARS Technology Corporation Principal  
Founder, President & Chief Technology Officer

### Timeline

**2016:** STARS Technology Corporation is founded.

**2017:** STARS Technology Corp. licensed the STARS technology and ran multiple CRADAs to further develop and demonstrate the technology.

## Energizing the Nation

Pacific Northwest National Laboratory

*PNNL has developed a battery which operates in more flexible conditions than other batteries while storing more energy as well.*

### Innovation

Using PNNL's electrolyte chemistry, the vanadium redox flow battery can store 70% more energy and operate over a wider temperature range than similar batteries, making it much more efficient and cost-effective. The inventors at PNNL were so excited about the potential of the new battery that they formed a startup company to commercialize it. UniEnergy Technologies (UET), near Seattle, Washington, was launched in 2012 with a technology license from PNNL. With private funding, the company began building a 60,000-square-foot manufacturing facility to make the battery systems, which are housed in portable shipping containers.

### Outcomes

Technology Advancement

As energy distributors and users realized the value of UET's battery, the company began attracting collaborators. In 2014, Washington State's Clean Energy Fund awarded \$10.5 million in matching grants to two utilities to lead energy storage projects featuring UET's battery. This built on other grid modernization initiatives, including DOE's Pacific Northwest Smart Grid Demonstration Project and Smart Grid Investment Grant funding.

Impact

As of 2016, UET had almost 20MW/80MWh of energy storage systems deployed, ordered, or awarded in the utility, micro grid, and commercial and industrial sectors.

In addition to bolstering the nation's energy system, UET has also attracted \$25 million in private investments to make, demonstrate, and sell its batteries and created 50 jobs.



Avista Utilities Corporation's Energy Storage Project in Pullman, Washington employed UET's energy storage technology to address a large challenge facing today's energy industry: integrating power generated from intermittent, renewable resources, such as wind and solar, into the electrical grid.

"Our partnership with PNNL has been critical in successfully pioneering a new generation of vanadium redox flow batteries from basic chemistry developed at the Lab to field deployment of multi-MW systems in the fast growing, grid storage market. Through this partnership, a technology invented at PNNL has been successfully commercialized by a U.S. company."

Z. Gary Yang  
Co-founder UniEnergy Technologies

### Timeline

- 2012:** UniEnergy Technologies is launched.
- 2014:** Washington State's Clean Energy Fund awarded \$10.5 million in grants to two utilities for energy storage projects utilizing UET's battery.
- 2016:** UET had around 20MW/80MWh of energy storage systems deployed, ordered, or awarded.

## PPPL Physicists Win Edison Award for X-ray Imaging Invention

Princeton Plasma Physics Laboratory (PPPL)

*New extreme ultraviolet (EUV) imaging apparatus that can lead to the manufacture of next-generation integrated circuits*

### Innovation

Three scientists from the U.S. Department of Energy’s PPPL have invented a new extreme ultraviolet (EUV) imaging apparatus for EUV spectroscopy, EUV microscopy, EUV lithography and x-ray imaging. This new imaging apparatus will make significant contributions to EUV lithography at wavelengths in the range from 10 to 15 nm, which is presently being developed for the manufacturing of the next-generation of computer processors and other semi-conductor integrated circuits.

### Outcomes

#### Technology Advancement

EUV lithography uses reflectors to diffract EUV light off a mask that has an image of the information that will be imprinted on the chip. But, current EUV lithography technology, which is still being developed, can only do this by scanning a tiny piece of the image onto the chip at once. The new invention uses a multi-layered structure to reflect the EUV beams to produce a wider beam of light. This captures all the information on the mask and imprints it onto the computer chip without the need for scanning. The new EUV imaging apparatus is expected to lead to substantial advancements and cost savings in the manufacturing process.

#### Impact

The optimization of EUV lithography for the manufacture of the next-generation integrated circuits is a subject of intense research in industry and laboratories worldwide. The new EUV imaging apparatus is considered the next generation of computer chip manufacturing because the EUV light, called soft X-rays, allows designers of computer chips to place 100 times more components, like transistors, in the same area of tiny computer chips. And, the linear distance between components is also 10 times shorter, which means the speed of the chip could be 10 times faster.

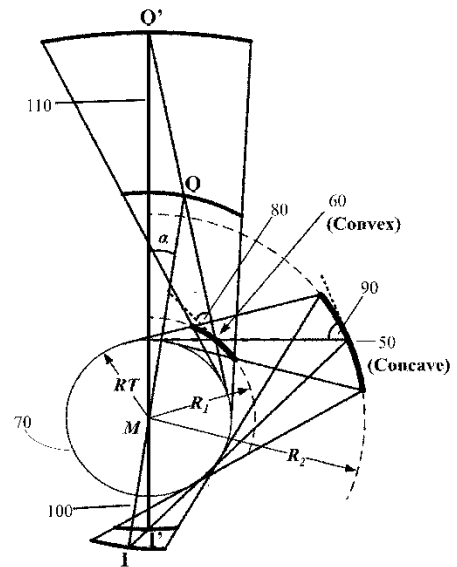


Image from U.S. patent 9,329,487. Example arrangement of the apparatus.

### Timeline

- 2014:** Patent filed for “Objective for EUV microscopy, EUV lithography, and x-ray imaging”
- 2016:** Patent application granted (U.S. 9,329,487)
- 2017:** Manfred Bitter, Kenneth Hill, and Philip Efthimion won Edison Patent Award in the imaging systems category from the New Jersey Research Council for their work<sup>1,2</sup>

<sup>1</sup> pppl.gov/news/2017/11/pppl-physicists-win-edison-award-x-ray-imaging-invention

<sup>2</sup> rdnj.org/news/wp-content/uploads/2017/11/RD-Council-Press-Release-TAEPA-Final-Nov-2.pdf

## Using Large-Scale 3D Printing to Test New Wind Blade Designs

Sandia National Laboratories in conjunction with Oak Ridge National Laboratory and TPI Composites

*Prototyping a 3D printed turbine designed to replicate the wake of a full-scale blade that is one-third the size and costs 5 percent of a standard full-scale blade.*

### Innovation

Sandia National Laboratories, Oak Ridge National Laboratory, and U.S.-based blade manufacturer TPI Composites partnered via CRADA on the production of subscale 3D printed wind turbine blades. Compared to conventional methods, which are very expensive and time-consuming, this production technique allows for rapid, cost-efficient construction of new wind blade designs, reducing the production of custom molds from 16 months to just three.

### Outcomes

#### Technology Advancement

3D printing, or additive manufacturing, is drastically reducing the time and cost associated with building new wind blade designs. It allows blade designs to move directly from computer models to mold production, bypassing some of the expensive and time-consuming steps of more traditional manufacturing. By streamlining the mold-making process, advanced designs can be tested more quickly, accelerating the introduction of new technology and leading to lowered costs for wind energy.

#### Impact

The prototype blades that were printed by ORNL and assembled by TPI Composites are being flown by Sandia at the Scaled Wind Farm Technology (SWiFT) facility as part of an effort to conduct basic science research on wind plant performance. Additionally, this first test of using additive manufacturing is being analyzed by ORNL. With more large 3D printers becoming available in the marketplace, TPI Composites is deciding if 3D printing could be feasible not only for producing molds for subscale blade prototypes, but also for larger scale blade manufacturing.



The ORNL Manufacturing Demonstration Facility Team next to a 3D printed wind turbine blade mold.

“Working with Sandia has been a great experience. We’re excited to see the blades manufactured with the mold we made flying at the SWiFT facility”

Brian Post, Associate Research Staff Member,  
Manufacturing Systems Research Group,  
Oak Ridge National Laboratory

### Timeline

**2017:** Sandia Labs and Oak Ridge won the Far West/Mid-Continent Regional Partnership Award

**2018:** Sandia Labs won the National Federal Laboratory Consortium Technology Focus Award

<sup>1</sup> Sandia National Laboratories’ Partnerships Annual Report FY2016

<sup>2</sup> Albuquerque Journal, April 30, 2018



## Improved Interface for Specialized Radar Systems Benefits War Fighters

Sandia National Laboratories and General Atomics Aeronautical Systems Inc.

*Improving the user interface of a well-established radar system used by the U.S. military.*

### Innovation

Recently, the need arose for improvement to GA-ASI's Lynx® Multi-mode Radar Systems interface, which customers reported was overly complicated and required improvements to enhance usability. Sandia's experts realized that although a steady stream of technical advances had been added to the Lynx, its interface was oriented around engineering requirements. By applying human-computer interaction principles, the GA-ASI team designed an interface that met customer expectations. Making an operator-centric interface improved the system's usability score drastically and enhanced the Lynx radar's usability in high-workload, high-stress mission environments. Enhancements to SAR, beyond those of GA-ASI's Lynx, have been funded through Laboratory Directed Research and Development (LDRD).

### Outcomes

#### Technology Advancement

GA-ASI's Lynx systems operate in the Ku-band, are lightweight, and can detect both small changes in scenery and moving targets. Sandia and General Atomics worked to make Lynx similar to an optical system, in which the radar forms an image covering a large area, storing it in cache memory. The capability allows operators to concentrate on specific areas of interest.

#### Impact

Today, the Lynx systems are built by GA-ASI's Reconnaissance Systems Group. Radar engineering, production, and business activities support nearly 700 employees spread across four buildings in Rancho Bernardo, California, and several other sites.



GA-ASI Field Engineers testing the new Claw interface for the Lynx radar

“Development of Lynx is a shining example of industry-national lab cooperation meeting U.S. and allied airborne surveillance needs. The interface improvements have increased the usage of the radar exponentially. More and more mission successes are being directly attributed to the radar.”

John Fanelle, Senior Director, Radar Systems,  
General Atomics Aeronautical Systems, Inc.

### Timeline

- 2010:** Initial collaboration between Sandia and General Atomics began on the Lynx Radar system
- 2015:** Work began on improving the Lynx interface

<sup>1</sup> Sandia National Laboratories' Partnerships Annual Report FY2017



## Success Stories

### Moving Innovative Technologies from DOE National Laboratories to the Marketplace

## Sandia Opens the Center for Collaboration and Commercialization (C3) in Downtown Albuquerque

Sandia National Laboratories

*Creating a “front door” for access to Sandia’s technology and partnership opportunities.*

### Innovation

Sandia National Laboratories’ Center for Collaboration and Commercialization (C3) is located in the University of New Mexico’s Lobo Rainforest alongside Air Force Research Laboratories and UNM’s tech transfer office in downtown Albuquerque, New Mexico. C3 serves as the public face of Sandia, providing access to the Labs and building relationships with the local community.

### Outcomes

Technology Advancement

This new space allows the local community access to Sandia technologies, expertise, and research. Representatives from Sandia’s tech transfer, economic development, and procurement departments hold regular office hours at C3 to discuss licensing, CRADAs, Strategic Partnership Projects, New Mexico Small Business Assistance, contracting, and other tech transfer opportunities. Additionally, Sandia’s Entrepreneurial Exploration (EEx) program is also run out of C3 and benefits from close proximity to downtown Albuquerque’s vibrant entrepreneurial ecosystem. EEx is designed to inspire potential entrepreneurs within Sandia to either enter the business world or develop an entrepreneurial mindset within the Labs.

Impact

C3 has brought more awareness of Sandia’s tech transfer opportunities to the local community and beyond. Events such as pitch competitions and webinars highlight new and exciting technologies that are ready for transfer outside the laboratories. New relationships have already been established with Fed Tech, Studio G (New Mexico State University), SEAL (University of Texas-Austin), and UNM ICorps.



Sandia’s Center for Collaboration and Commercialization (C3) in downtown Albuquerque, New Mexico

“C3 Downtown brings Sandia’s tech transfer team together with colleagues from UNM and the Air Force Research Laboratory. The three tech transfer organizations working together will collectively increase the impact of our work.”

Susan Seestrom, Chief Research Officer,  
Sandia National Laboratories

### Timeline

**2017:** Sandia’s C3 office opens its doors in downtown Albuquerque, New Mexico

<sup>1</sup> Sandia National Laboratories’ Partnerships Annual Report FY2017

## Biosensors in Portable Virus and Bacteria Diagnostic Devices Improve Healthcare

Sandia National Laboratories and Sensor-Kinesis Corp.

*Using sensor technology to improve early detection of diseases.*

### Innovation

Sandia's R&D 100 award-winning sensor technology, originally developed with the University of New Mexico, can detect bacteria, viral particles, and proteins. Sandia is working with Sensor-Kinesis under a Cooperative Research and Development Agreement (CRADA) to validate the commercial use of the sensor in a range of applications in medical and industrial settings.

### Outcomes

#### Technology Advancement

Sensor-Kinesis, a development stage high-tech company, has developed a medical technology platform to identify pathogens such as E. coli, Salmonella, and Listeria, as well as certain cancer biomarkers. The company is licensing Sandia's shear horizontal surface acoustic wave (SH-SAW) biosensor array technology for use in some of their handheld devices for the early detection of human diseases and environmental pathogens.

#### Impact

While Sensor-Kinesis continues to develop products for a variety of applications, the company can leverage Sandia's technology to help realize its vision of creating portable devices that rapidly produce accurate test results. The company is working to bring its technology to market at a cost point that will make it available to individual doctors, smaller health care institutions, and food and air quality agencies, as well as health providers in remote locations. By creating detection devices that are affordable and easy to use, the company aims to enable individuals to monitor conditions so they can be caught in the early stages, before they require expensive medical care.



Sensor-Kinesis is developing a handheld device for early detection of human diseases and environmental pathogens.

“To improve the standard of care, we must lower the limits of detection for pathogens and biomarkers to one molecule. Sandia's proven technology is helping us move towards that goal with a convenient, label-free handheld device costing a couple hundred dollars.”

Frank Adell, President and CEO,  
Sensor-Kinesis Corporation

### Timeline

- 2010:** Sandia's Acoustic Wave Biosensor technology wins an R&D 100 award
- 2016:** Sandia and Sensor-Kinesis enter into a CRADA to validate the commercial use of the sensor technology

<sup>1</sup>Sandia National Laboratories' Partnerships Annual Report FY2017

## Microspheres for Novel Medical Applications

Savannah River National Laboratory in conjunction with Mo-Sci Corporation, Augusta University, Applied Research Center LLC, SpheroFill LLC, and other industry partners

*Microspheres have potential uses in fields such as medicine, advanced materials, and anti-counterfeiting.*

### Innovation

SRNL's Porous Walled Hollow Glass Microspheres were originally developed as part of an improved system for hydrogen isotope separations in tritium production applications. Hollow glass microspheres have been used for years in lightweight filler material, insulation, abrasives and other applications. The SRNL-developed microspheres are unique because of a network of interconnected pores in the microsphere walls, which allow the tiny microspheres to be filled with, hold and release gases and other materials. Because the glass microspheres provide a protective environment, or cocoon, for their contents, they can be used to hold reactive or flammable absorbents or stored materials, including solids, liquids or gases. This has the potential to provide a safe method of handling, storing or delivering a variety of materials. The microspheres also have an application as part of security inks for anti-counterfeiting purposes.

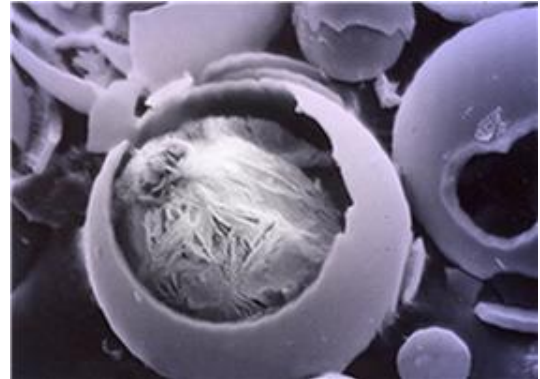
### Outcomes

#### Technology Advancement

A modified version of the microspheres could be used to deliver medication on target, releasing the drug at will and on a schedule. SpheroFill, a biomedical startup, will initially focus on developing microsphere-based treatments for voice disorders in older individuals and as tissue filler for cosmetic surgery. The company also plans to develop the technology for muscle and bone repair for military use.

#### Impact

The long-term goal involves cancer treatment. The microspheres ability to deliver a drug specifically and locally can allow for higher doses of a chemotherapy drug, for example, within a very limited area without having the side effects common in a systemic treatment.



Cross Section of a Porous Walled Hollow Glass Microsphere

"[A] real advantage of being able to do things very specifically and locally, for example treating a tumor, is that we can use higher doses of a chemotherapy drug within a very limited area without having side effects common in a systemic treatment."<sup>1</sup>

Dr. William Hill  
Professor of Cellular Biology and Anatomy  
Augusta University

### Timeline

- 2005:** SRNL pioneers development work creating tritium applications for microspheres<sup>2</sup>
- 2008:** Breakthrough in microsphere technology first published<sup>2</sup>
- 2009:** Announced Mo-Sci Corporation will manufacture microspheres.<sup>3</sup>
- 2011:** Winner of R&D 100 Award.<sup>4</sup>
- 2016:** Anti-counterfeiting strategy for microspheres published<sup>1</sup>

<sup>1</sup>ceramics.org/ceramic-tech-today/biomaterials/patent-opens-up-new-possibilities-for-porous-wall-hollow-glass-microspheres-in-medicine

<sup>2</sup>Wicks, G.G., L.K. Heung, and R.F. Schumacher. "SRNL's porous, hollow glass balls open new opportunities for hydrogen storage, drug delivery and national defense." *Microspheres and Microworlds*. American Ceramic Society Bulletin, Vol 87, No. 6, Pg 23-28.

<sup>3</sup>eurekaalert.org/pub\_releases/2009-12/drnl-mct121709.php

<sup>4</sup>rdmag.com/article/2011/06/2011-r-d-100-award-winners

## Unique Application Specific Integrated Circuit Design for 3D Sensing

SLAC National Accelerator Facility in conjunction with a private manufacturer of LiDAR

*Low cost, high resolution, more efficient, and more compact LiDAR systems.*

### Innovation

SLAC National Accelerator Laboratory's Technology Innovation Directorate partnered with a domestic private Silicon Valley based manufacturer of high-resolution Laser Imaging Detection and Ranging (LiDAR) sensors to develop sensor/ASIC (Application Specific Integrated Circuits) architectures for advanced lidar imaging systems under a Cooperative Research and Development Agreement (CRADA). This project included a licensing agreement with Stanford University which manages intellectual property on SLAC's behalf.

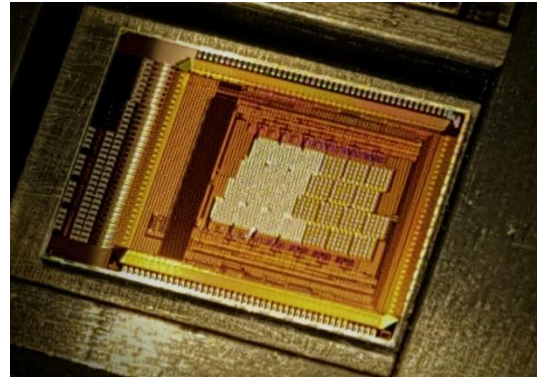
### Outcomes

#### Technology Advancement

This research and development CRADA supported the partner company to develop LiDAR systems that are lower cost, higher resolution, more efficient, and more compact than the current state-of-the-art products that are currently in the marketplace. Continued advances in LiDAR imaging technology will enable innovative domestic industry advances in autonomous vehicles technology and smarter systems.

#### Impact

SLAC and Stanford will continue to collaborate under this CRADA for novel ASIC R&D with benefits for the local industrial partner and for the continued advancement of SLAC's world-leading laboratory research in X-ray and ultrafast science on behalf of the Office of Science.



Time-of-Flight real-time histogramming ASIC with Integrated Single Photon Avalanche Diodes (SPADs)

“SLAC's partnerships with private industry have supported groundbreaking advances that will overcome current constraints faced by autonomous vehicle manufacturers.”

Michael Fazio  
Associate Laboratory Director, Technology  
Innovation Directorate, SLAC

### Timeline

- 2016:** Design, fabrication and characterization of SPAD array begins
- 2017:** SLAC partner receives \$27M in private investment



## Energy Efficient Cryogenic Systems Cut Costs on Earth and in Space

Thomas Jefferson National Accelerator Facility

*An energy-saving technology called the “Ganni Cycle” that reduces energy consumption for cryogenic refrigeration resulting in substantial cost savings.*

### Innovation

An energy-saving technology called the “Ganni Cycle” has been developed at Thomas Jefferson National Accelerator Facility for application to cryogenic refrigeration systems. The Ganni Cycle (named after a cryogenic expert at Jefferson Lab) has been proven to reduce energy consumption for cryogenic refrigeration systems by 20 to 45 percent. Since these systems tend to be very energy intensive, the resulting cost savings are substantial.

### Outcomes

#### Technology Advancement

The portions of the Ganni Cycle that can be used for existing systems have slashed the power requirements of Jefferson Lab’s refrigeration system, while still meeting the Lab’s needs. The cycle has dropped the electricity consumption of the Lab’s cryogenic systems from 6 Megawatts (MW) to 4.2 MW, resulting in a direct savings of \$33,000 each month in electricity costs with cost savings likely to become even more significant in the future.

In addition to energy use reductions and energy costs savings, the Ganni Cycle has the added benefit of reducing maintenance costs, nearly doubling the lifetime of some refrigerator components (a compressor increases its life from 45,000 hours to 74,000 hours) and increasing the time between necessary maintenance periods.

#### Impact

Already, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and the Spallation Neutron Source (SNS) at Oak Ridge National Lab have both benefited from this innovation and now other facilities are expressing an interest in implementing the process in their cryogenic systems. In addition, this technology was utilized by NASA for testing of the James Webb Space Telescope at conditions it will face in space. Jefferson Lab also successfully licensed this technology to Linde.



Jefferson Lab’s Ganni Cycle Cryogenic technology was instrumental in the testing of NASA’s James Webb Telescope.

“The Jefferson Lab technology saves energy and was inexpensive to implement...The Ganni system increases plant capacity very efficiently when we need it and decreases it when we don’t need it, all automatically...”<sup>1</sup>

Roberto Than, head of cryogenics for the Collider-Accelerator Department, BNL

### Timeline

**2007:** Patent Application Granted

**2007:** Received White House Closing the Circle Award “for efforts that resulted in significant contribution to, or have made a significant positive impact regarding environmental stewardship.”

**2008:** Linde BOC Process Plants licenses Ganni Cycle technology.

**2008:** Ganni cycle technology incorporated at RHIC, saving \$50K/week in electric costs<sup>1</sup>

**2012:** Ganni-cycle based system for NASA space chamber used to test components for the James Webb Space Telescope undergoes successful test

<sup>1</sup> [goo.gl/9MK9H2](http://goo.gl/9MK9H2)

<sup>2</sup> [goo.gl/TV8mCW](http://goo.gl/TV8mCW)



## Nuclear Physics Detector Technology is Powerful Tool in Fight Against Breast Cancer

Thomas Jefferson National Accelerator Facility in conjunction with Dilon Technologies

*Non-invasive imaging device for detecting breast cancers*

### Innovation

Known as Molecular Breast Imaging (MBI) or Breast Specific Gamma Imaging (BSGI), the tool is based on gamma-imaging technology developed at the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility in Newport News, VA. MBI is a non-invasive breast imaging procedure that captures the cellular function of breast tissue, complementing mammography in helping to resolve difficult-to-interpret cases.

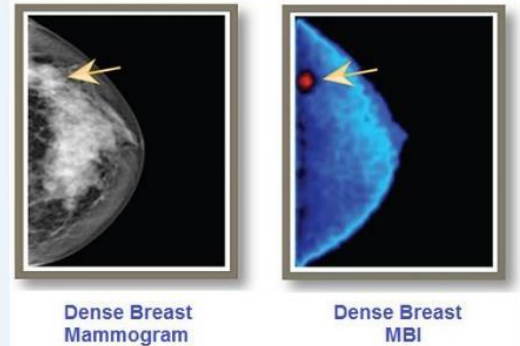
### Outcomes

#### Technology Advancement

MBI is designed for situations where mammography is inconclusive and further evaluation is needed, especially when patients have dense breast tissue, implants, multiple suspicious lesions or clusters of microcalcifications, palpable lesions not detected by mammography or ultrasound, post-surgical or post-therapeutic mass, or if they have been taking hormone replacement therapy. MBI relies on the advanced imaging technology of anatomic-specific detectors to detect early-stage cancers. The compact detector developed by Jefferson Lab captures vital tumor information by viewing the metabolism of cancerous lesions in the breast via radiopharmaceutical uptake.

#### Impact

Dilon Technologies, licensed the high-resolution gamma imaging technology from Jefferson Lab and used it to develop a compact dedicated breast imaging camera. Molecular Breast Imaging is saving lives. Using MBI as an adjunct to mammography results in an almost fourfold increase in invasive cancer detection in women with dense breast tissue. MBI has a higher specificity than MRI and has proven to reduce benign biopsies by 50%. With a negative predictive value of 98%, MBI is the beacon in dense breast tissue. More than 250,000 patients have been screened with BSGI/MBI on a worldwide basis.



MBI provides a valuable tool in breast cancer detection, particularly in dense breast tissue.

"We have been able to make a significant impact by utilizing our licensing agreement with Jefferson Lab to help save lives...More than 250,000 patients have been screened with BSGI/MBI on a worldwide basis."<sup>1</sup>

Bob Moussa  
President and CEO, Dilon

### Timeline

- 1997:** Jefferson Lab's nuclear imaging technology was licensed by 2 local businessmen, who formed Dilon Technologies
- 2004:** Dilon 6800, first production unit for breast-specific gamma imaging sold
- 2009:** Technology recognized with an FLC Technology Transfer Award
- 2011:** Dilon Technologies recognized by DOE as a Top National Innovator<sup>1</sup>

<sup>1</sup> [itnonline.com/content/department-energy-names-dilon-diagnostics-top-national-innovator](http://itnonline.com/content/department-energy-names-dilon-diagnostics-top-national-innovator)

<sup>2</sup> [federallabs.org/node/144254?tab=successes](http://federallabs.org/node/144254?tab=successes)

## Nuclear Physics Accelerator Technology Yields New Process for Producing Boron-Nitride Nanotubes

Thomas Jefferson National Accelerator Facility supported by DOE, Office of Naval Research, and the Commonwealth of Virginia, in conjunction with NASA Langley Research Center and the National Institute of Aerospace

*Process to fabricate high-quality boron-nitride nanotubes (BNNTs)*

### Innovation

Scientists have capitalized on the core technology that powers the Continuous Electron Beam Accelerator Facility (CEBAF) to develop and license a process to fabricate high-quality nanotubes from boron nitride. These BNNTs maintain their strength in air to high temperatures (900°C), efficiently conduct heat but not electricity, can be made to be long and thin, are thought to be non-toxic to living tissues, and may be added to other materials to make composites with enhanced properties.

### Outcomes

#### Technology Advancement

Like carbon nanotubes, boron-nitride nanotubes (BNNTs) are composed of a sheet of atoms that are a single layer thick and are curled up into a tube. These tubes may be composed of one, two, or more rolled sheets of atoms of interlinked boron and nitrogen, with each sheet referred to as a "wall." In 2009, researchers developed a now-patented process to synthesize high-quality BNNTs.

#### Impact

Boron-nitride nanotubes are being explored for their potential in a wide range of scientific, industrial, and commercial applications, such as in composites for unmanned aerial vehicles, efficient solar panel arrays, tough coatings, long-lasting batteries, bright LEDs, effective radiation shielding, neutron detection and rugged aerospace components. The material is also being considered for use in many biomedical applications, such as scaffolding for nerve and bone tissue regeneration, targeted drug delivery, and cancer treatments.



Boron Nitride Nanotubes offer game-changing properties for applications from biomedical to advanced composites to radiation shielding.

"The current world supply of Fibril BNNT™ is under 10 grams, less than the weight of four pennies, but the demand for this material is tremendous. We believe we can sell as much as we can make. When I visit a lab or company, the final question is always—when can we have some?"<sup>1</sup>

Mike Smith  
Chief Scientist, BNNT LLC

### Timeline

- 1994:** Researchers affiliated with DOE's Berkeley Lab theorized that it should be possible to produce nanotubes from a white material called boron nitride
- 1995:** BNNTs were first produced at Berkeley Lab
- 2009:** Researchers developed a now-patented process to synthesize high-quality BNNTs at DOE's Jefferson Lab
- 2010:** Patents for the material developed at Jefferson Lab licensed to a small start-up company, BNNT, LLC
- 2017:** BNNT was named NASA Invention of the Year