U.S. DEPARTMENT OF ENERGY

Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities

Fiscal Year 2015

Report to Congress
July 2018

United States Department of Energy
Washington, DC 20585

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Message from the Technology Transfer Coordinator and Director, Office of Technology Transitions

The Report on Technology Transfer and Related Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2015 ("*Report*") is prepared in accordance with the requirements of the Technology Transfer and Commercialization Act of 2000:

> *It is the continuing responsibility of the Federal Government to ensure the full use of the results of the Nation's federal investment in research and development. To this end, the Federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector.*
>
> *Each Federal agency which operates or directs one or more Federal laboratories or which conducts activities under sections 207 and 209 of title 35, United States code, shall report annually to the Office of Management and Budget, as part of the agency's annual budget submission, on the activities performed by that agency and its Federal laboratories under the provisions of this section and of sections 207 and 209 of title 35, United States Code.*

Pursuant to the legislative language this report is being submitted to OMB before being released to the public and provided to the following Members of Congress:

- **The Honorable Michael Pence**
  President of the Senate
- **The Honorable Paul Ryan**
  Speaker of the House
- **The Honorable Thad Cochran**
  Chairman, Senate Committee on Appropriations
- **The Honorable Patrick Leahy**
  Vice Chairman, Senate Committee on Appropriations
- **The Honorable Rodney Frelinghuysen**
  Chairman, House Committee on Appropriations
- **The Honorable Nita M. Lowey**
  Ranking Member, House Committee on Appropriations

- **The Honorable Lamar Alexander**
  Chairman, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations
- **The Honorable Dianne Feinstein**
  Ranking Member, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations
- **The Honorable Mike Simpson**
  Chairman, Subcommittee on Energy and Water Development
  House Committee on Appropriations
- **The Honorable Marcy Kaptur**
  Ranking Member, Subcommittee on Energy and Water Development
  House Committee on Appropriations
- **The Honorable Lisa Murkowski**
  Chair, Senate Committee on Energy and Natural Resources
- **The Honorable Maria Cantwell**
  Ranking Member, Senate Committee on Energy and Natural Resources
- **The Honorable Greg Walden**
  Chairman, House Committee on Energy and Commerce
- **The Honorable Frank Pallone**
  Ranking Member, House Committee on Energy and Commerce
- **The Honorable Lamar Smith**
  Chairman, House Committee on Science, Space, and Technology
- **The Honorable Eddie Bernice Johnson**
  Ranking Member, House Committee on Science, Space, and Technology

Technology partnering is an active component of the Department of Energy's (DOE) overall mission to promote scientific and technological innovation that advances the economic, energy, and national security interests of the United States. This *Report* describes these activities and outlines DOE's procedures and organizational management structure for ensuring appropriate management and oversight of such activities, in accord with prevailing policy and authorities. If you have any questions, please do not hesitate to contact Ms. Melissa Burnison, Assistant Secretary for Congressional and Intergovernmental Affairs, at 202-586-5450.

Sincerely,

Chanette Armstrong

Executive Summary

In Fiscal Year (FY) 2015, the Department of Energy (DOE) and its laboratories and facilities managed and executed 17,086 technology transfer-related transactions. These transactions include but are not limited to 734 Cooperative Research and Development Agreements (CRADAs); 2,395 Strategic Partnership Projects (SPP), formerly called Work-for-Others Agreements (WFOs), involving non-federal entities (NFEs); 74 Agreements for Commercializing Technology (ACT); 6,310 active licenses of intellectual property; and 7,571 user projects. In addition, DOE's National Laboratories and Facilities reported 1,645 inventions; filed 949 patent applications (856 U.S. and 93 foreign); were issued 755 patents (632 U.S. and 123 foreign); and reported 577 commercialized technologies.[1] Associated with these activities, DOE's Laboratories and Facilities reported approximately $249.0 million in SPP non-federal sponsor "funds-in," $64.8 million in non-federal sponsor "funds-in" for CRADA's, $30.3 million in non-federal sponsor "funds-in" for ACTs, $33.1 million in licensing income, and over $21.2 million in earned royalties.

DOE is one of the largest supporters of technology transfer within the federal government. The work conducted at its National Laboratories and National Nuclear Security Administration (NNSA) plants and sites has provided the scientific and technical foundation for many technologies in the market today. In addition to that foundational work, technology transition activities support the acceleration of the transfer of federally-funded research from the laboratory to the commercial marketplace. The successes are confirmation of DOE's robust technical enterprise, which is a result of continuous outreach and partnering with the private sector. They contribute to fulfilling DOE's mission and further strengthen the capabilities of DOE's laboratories and facilities. The magnitude of this work is also a reflection of the continued confidence in DOE held by thousands of public and private partners who work with DOE. This *Report* describes DOE's technology transfer activities and outlines how DOE ensures appropriate management and oversight with prevailing policy and authorities.

The Office of Technology Transitions (OTT) would like to acknowledge the valuable role played by the many professional practitioners of technology transfer throughout DOE's program offices, labs and facilities who are committed to helping technologies transition to the market and foster connections among stages of research, development, demonstration and deployment (RDD&D) that are needed to reach commercial impact. DOE encourages these practitioners and their management to continue this excellent work. The resulting contributions of their work add significantly to our Nation's economic competitiveness and to OTT's mission to expand the commercial impact of DOE's portfolio of RDD&D activities over the short, medium and long term.

[1] Department of Energy Technology Transfer Working Group Reporting and Appraisal Guide for DOE Technology Transfer Activities, energy.gov/technologytransitions/downloads/ttwg-reporting-and-appraisal-guide

Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities

Fiscal Year 2015

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1. Introduction

Technology transfer has been an aim of United States Federal Government (USG) policy since the passage of the Bayh-Dole Act (P.L. 96-517, as amended by P.L. 98-620) and the Stevenson-Wydler Act (P.L. 96-480) during the 1980s. In 1989, the *National Competitiveness Technology Transfer Act* (P.L. 99-502) affirmed this goal by establishing technology transfer as a mission of federal research and development (R&D) agencies, including DOE. Since then, DOE has encouraged its National Laboratories and Facilities[2] to enter into technology partnering activities with non-federal entities, as appropriate, using a variety of mechanisms. Pursuant to 48 CFR §970.5227-3 Technology Transfer Mission Clause (48 CFR Chapter 9, Subchapter I, Part 970, Subpart 970.52), DOE has authorized its Facilities to patent and license intellectual property (IP) resulting from DOE R&D and to collect and make appropriate use of related royalties and fees for Government-funded technology transfer activities.

In FY 2015, DOE and its National Laboratories and other facilities managed and executed 17,084 technology transfer-related transactions, including but not limited to:

- **734 CRADAs**
- **2,395 SPPs involving non-federal entities**
- **6,310 active licenses of intellectual property**
- **74 ACT Agreements**
- **7,571 user projects.**

In addition, DOE National Laboratories and Facilities totaled:

- **1,645 invention disclosures**
- **949 patent applications filed (856 U.S. and 93 foreign)**
- **755 patents issued (632 U.S. and 123 foreign)**
- **577 commercialized technologies**
- **$249.0 million in SPP non-federal sponsor "funds-in"**
- **$64.8 million "funds-in" for CRADAs**
- **$30.3 million "funds-in" for ACT**
- **$33.1 million in licensing income**

It is important to note that, for purposes of this document, the term "technology transitions" incorporates "technology transfer." Technology transitions includes, but is broader than "technology transfer" previously described by former DOE Secretary Steven Chu as, "the process by which knowledge, intellectual property or capabilities developed at the DOE's National Laboratories, single-purpose research Facilities, plants, and other Facilities are transferred to other entities, including private industry, academia, state or local governments."[3]

"Technology transitions" more accurately reflects the wider scope of the efforts to which DOE is committed. The OTT was established, not to simply guide singular acts of technology transfer, but rather to foster multiple handoffs among scientists, innovators and investors that make up the dynamic processes that nurture the Nation's innovation ecosystem. Those activities may take many forms, including but not limited to Cooperative Research and

[2] The United States Department of Energy National Laboratories and Facilities are a system of laboratories and facilities overseen by the United States Department of Energy (DOE) for the purpose of advancing science and technology to fulfill the DOE mission. Sixteen of the seventeen DOE national laboratories are federally funded research and development centers administered, managed, operated and staffed by private-sector organizations under management and operating (M&O) contract with DOE.

[3] *Secretarial Policy Statement on Technology Transfer at DOE Facilities*, The Honorable Steven Chu, Secretary, Department of Energy, 2011 energy.gov/sites/prod/files/gcprod/documents/Policy_Statement_on_TT.pdf.

Development Agreements (CRADAs), Strategic Partnership Projects (SPPs), Agreements for Commercializing Technology (ACTs), User Agreements, and licensing of intellectual property.

As demonstrated in this *Report*, private firms and other non-federal entities continue to realize that DOE's National Laboratories and Facilities can provide valuable and often unique problem solving capabilities to the benefit of their own objectives. In some cases, those entities have built long-term relationships with DOE that yield greater results over time. Technology partnering is also important in furthering technical competencies at DOE's National Laboratories and Facilities as well as in areas such as workforce recruiting and retention. Similarly, DOE's National Laboratories and Facilities can benefit from engaging with others possessing the skills to develop, commercialize, and deploy technology. In FY 2015, DOE participated in 3,203 non-classified ACT, CRADA, and SPP agreements with non-federal entities. Additionally, DOE collaborated with small businesses on 1,046 agreements and supported 31 start-up companies in FY 2015. DOE's laboratories and Facilities have sustained strong rates of invention disclosures and patent awards, with over 1,600 invention disclosures and over 750 patents issued. In addition, the DOE laboratories and Facilities reported 577 commercialized technologies in FY 2015.

This *Report* is the successor to the *DOE Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories for Fiscal Year 2014*. As such, it satisfies requirements under federal statutes, in a context of DOE's broadened focus on technology transfer as one component of DOE's overall technology transitions activities, which broadly address the commercialization and economic impact of technology developments under DOE's programmatic activities. This *Report* does not account for classified technologies developed, patented or transferred as part of national security programs, including SPPs and Strategic Intelligence Partnership Projects; however, it does present unclassified technologies from those programs. Section 2 provides an overview of the nine guiding principles of DOE's technology transfer policy. Section 2 also describes DOE's organization, how DOE currently manages and oversees its technology transfer activities, and how legislative requirements and activities are managed under OTT. Section 3 presents reporting metrics for technology transfer along with analysis of multi-year trends of technology transfer activities from FY2010 to FY2015. Additional analyses may be found in Appendix B. Section 4 introduces DOE's technology transfer and commercialization activities and other initiatives to support commercialization along with highlights of the FY 2015 R&D 100 awards summarized in Appendix D. DOE researchers won 33 of the 100 awards in FY 2015.

DOE has implemented a number of programmatic initiatives designed to improve the procedures for collaborating with its National Laboratories and Facilities and to provide greater visibility of the opportunities to work with the private sector. This section describes in depth the initiatives that DOE has implemented to engage and partner with the private sector to commercialize technologies. These initiatives include ACTs, Lab-Corps, and the Small Business Technology Transfer (STTR) Program to name a few.

Industrial engagement with DOE's Scientific User Facilities and shared R&D Facilities enhances DOE's technology transfer efforts. Sections 5 and 6 of the *Report* describe how DOE's Office of Science (SC) supports energy technology through funding in basic science research and development (R&D) of experimental and computational capabilities. Section 5 outlines the structure of SC's User Facilities, while Section 6 describes SC's research programs with significant industrial engagements such as the Energy Innovation Hubs, Bioenergy Research Centers, Energy Frontier Research Centers, and Accelerator Stewardship Research and Development Program. Both of these sections highlight the unique capabilities that enable discovery through science and technology R&D and the open-access and capabilities made available to researchers, scientists and technologists to accelerate the transition from scientific discovery to application to technology deployment.

The DOE brings some of the best scientific minds and capabilities to address the Nation's scientific and engineering challenges and implement a strategy for growing our economy and ensuring our national security. The *Report's* final section, Section 7, introduces some of DOE's applied energy R&D partnerships and initiatives and resulting commercial impacts of research, development, demonstration, and deployment (RDD&D) of energy technologies stemming from initiatives and programs at DOE National Laboratories and Facilities. Commercialization of these technologies by the private sector can enable job creation and the long-term economic growth. Technical descriptions of a subset of these technologies are also presented in this section, including a discussion on the Advanced Research Projects Agency–Energy (ARPA-E), which has supported technology transfer through its technology-to-market program – moving technology to the next stage of development.

DOE's Laboratories and Facilities support sustained technology transfer and commercialization activities and engagements with the private sector. A complete list of the DOE Laboratory Technology Transfer offices and key points of contact can be found on OTT's homepage at "Who Do I Contact at the Labs?".

For FY 2015 highlights of DOE's technology transfer and commercialization activities see Appendix E. The success stories therein as reported to OTT during FY 2015 are a testament to the breadth of technological innovation by DOE's National Laboratories and Facilities in addressing the nation's energy, nuclear security, and environmental challenges while meeting DOE's mission to enhance U.S. security and economic growth through transformative science and market solutions.

There have been two notable developments since the end of FY 2015. First, in June of 2016 DOE issued its first department-wide selections for the Technology Commercialization Fund (section 2.2.1) which is administered by OTT. Second, OTT is now an established office within DOE, with a dedicated staff including a senior career official deputy director.

2. Technology Transfer and Partnering Policy and Management

Building on earlier 2007 policy, the FY 2011 Secretarial Policy Statement on Technology Transfer at DOE Facilities emphasizes that all DOE National Laboratories and Facilities and programs have a responsibility to ensure robust technology transfer activities and research partnerships with industry that result in commercialization and deployment and underscores nine principles that guide DOE's technology transfer programs:

1. Commit to continuously improve policies and procedures for effective technology transfer in support of its mission and for the Nation's benefit.
2. Empower innovators who discover and develop technologies at DOE National Laboratories and Facilities.
3. Fairness of opportunity to promote domestic economic interests with due consideration for securing the benefits of globalization, while balancing U.S. competitiveness considerations.
4. Facilitate commercialization by involving partners that have viable business plans for expeditious technology development and deployment.
5. Assure visibility of DOE National Laboratories and Facilities to promote access to capabilities and intellectual property by all, including small businesses and entrepreneurs.
6. Leverage resources in partnering transactions that complement DOE's mission, goals and objectives and demonstrate benefits to the United States.
7. Continuously improve impact using effective incentives and metrics that indicate success.
8. Apply policies that promote predictability, streamlined processes, transparency, and appropriate flexibility in technology transfer activities.
9. Share best practices and lessons learned throughout the DOE complex to advance technology transfer at DOE, enhance collaboration in commercialization, maximize flexibility, and eliminate and avoid unnecessary barriers to achieve positive impact.

2.1 National Laboratories and Facilities Engaged in Technology Transfer

Federal statutes authorize the DOE National Laboratories and Facilities listed below to conduct technology partnering activities. Most of these National Laboratories and Facilities have established formal technology transfer programs with staff dedicated to the facilitation of the administrative and negotiating processes involved in entering into agreements with non-federal partners.[4]

[4] Office of Technology Transitions. U.S. Department of Energy. "Who Do I Contact At The Labs?" energy.gov/technologytransitions/who-do-i-contact-labs

Office of Science

- Ames Laboratory (Ames)
- Argonne National Laboratory (ANL)
- Brookhaven National Laboratory (BNL)
- Fermi National Accelerator Laboratory (FERMI)
- Lawrence Berkeley National Laboratory (LBNL)
- Oak Ridge National Laboratory (ORNL)
- Pacific Northwest National Laboratory (PNNL)
- Princeton Plasma Physics Laboratory (PPPL)
- SLAC National Accelerator Laboratory (SLAC)
- Thomas Jefferson National Accelerator Facility (JLAB)

Office of Energy Efficiency and Renewable Energy

- National Renewable Energy Laboratory (NREL)

Office of Fossil Energy

- National Energy Technology Laboratory (NETL)

National Nuclear Security Administration

- Lawrence Livermore National Laboratory (LLNL)
- Los Alamos National Laboratory (LANL)
- Sandia National Laboratories (SNL)
- Savannah River Site
- National Security Campus (formerly the Kansas City Plant)
- Y-12 National Security Complex
- Pantex Plant
- Nevada National Security Site (formerly the Nevada Test Site)

Office of Nuclear Energy

- Idaho National Laboratory (INL)

Office of Environmental Management

- Savannah River National Laboratory (SRNL)

2.2 Organization, Management, and Oversight

DOE's oversight, management, and administration of its technology transfer and partnering activities are evolving to address the broader scope of the Secretarial Policy and DOE's mission. OTT was created to lead these efforts, with the Director of OTT also serving as DOE's Technology Transfer Coordinator (TTC) as defined in the Energy Policy Act of 2005 (EPAct 2005), Title X, Section 1001[5]), acting with the Technology Transfer Working Group and the Technology Transfer Policy Board. In this role, the Director serves as the principal advisor to the Secretary on all matters relating to technology transfer and commercialization.

2.2.1 Office of Technology Transitions

In February 2015, OTT was established with the mission to expand the commercial impact of DOE's portfolio of RDD&D activities over the short, medium and long term. OTT is responsible for developing and overseeing delivery of the DOE strategic vision and goals for technology commercialization and engagement with the business and industrial sectors across the U.S., such as manufacturing, energy and technology.

"Through technology transfer, commercialization, and deployment activities, the Department of Energy has made significant contributions to economic growth in the United States. The Office of Technology Transitions will give the Department the opportunity to increase the American people's return on investment in federally-funded science and energy research." - Energy Secretary Ernest Moniz, February 2015.

OTT serves as a DOE-wide functional unit that coordinates the commercial development of DOE's research outputs and is responsible for the statutorily-created Energy Technology Commercialization Fund (TCF), which leverages the R&D funding in the applied energy programs to pursue high

[5] Public Law 109-58, Energy Policy Act of 2005, Title X - Department of Energy Management - gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf

impact commercialization activities. Established as part of the Energy Policy Act of 2005, the fund uses 0.9 percent of the funding for DOE's applied energy RD&D, and commercial application budget for each fiscal year.[6] This provides matching funds with private partners to promote promising energy technologies for commercial purposes. Additionally, OTT is responsible for delivering a Technology Transfer Execution Plan[7] to Congress and reporting annually on DOE's technology transfer and partnership activities[8].

2.2.2 Technology Transfer Working Group

In accordance with EPAct 2005, Title X, Sec. 1001(d), DOE has a Technology Transfer Working Group (TTWG) consisting of representatives from DOE's site offices and each of the National Laboratories and single purpose research Facilities. Currently, the role of the TTWG is to:

(1) Coordinate technology transfer activities occurring at National Laboratories and single-purpose research Facilities;

(2) Exchange information about technology transfer practices, including alternative approaches to resolve disputes involving intellectual property rights and other technology transfer matters; and

(3) Develop and disseminate, to the public and prospective technology partners, information about opportunities and procedures for technology transfer with DOE, including opportunities and procedures related to alternative approaches to resolution of disputes involving intellectual property rights and other technology transfer matters.

2.2.3 Alternative Dispute Resolution/Ombudsman

DOE's Office of Conflict Prevention and Resolution (OCPR) provides guidance on the use of Alternative Dispute Resolution (ADR) techniques to DOE National Laboratories and Facilities for any technology transfer issues.[9] OCPR also coordinates with the Office of the Assistant General Counsel for Technology Transfer and Intellectual Property in working with the individual ombudsman at sites throughout the DOE complex to address any IP disputes at the earliest possible stage.[10]

2.2.4 Technology Transfer Policy Board

The Technology Transfer Policy Board (TTPB) supports the TTC. Its members are designated from DOE's major program and staff offices engaged in technology transfer, including the National Nuclear Security Administration (NNSA), the Office of Science (SC), and the applied research programs of Energy Efficiency and Renewable Energy (EE), Nuclear Energy (NE), Fossil Energy (FE), and Electricity Delivery and Energy Reliability (OE), as well as the Offices of the General Counsel (GC), Management & Administration (MA), and Energy Policy and System

[6] P.L. 109-58, Sec. 1001(e) Technology Commercialization Fund - energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf

[7] Technology Transfer Execution Plan 2016-1018, energy.gov/sites/prod/files/2016/10/f33/TTEP%20Final.pdf

[8] Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014, energy.gov/sites/prod/files/2016/06/f33/Technology%20Transfer%20Report%20to%20Congress%20FY14.pdf

[9] DOE Office of Conflict Prevention and Resolution. energy.gov/oha/services/applications-exceptions/alternative-dispute-resolution/technology-transfer-ombudsman

Analysis (EPSA) and others at the request of the TTC. These members serve on the Board in addition to their other full-time duties within DOE. The Board representation is intended to ensure continuity of functions that are essential to sustaining effective implementation of technology transfer policies and practices throughout DOE and across administrations.

The TTC assigns individual members of the TTPB responsibilities for the various deliverables of DOE's central technology transfer management. These include issues of technology transfer policy and procedures, ombudsman activities, oversight and reporting. Members also serve as needed in cross agency groups such as the Federal Laboratory Consortium (FLC) for Technology Transfer and the Interagency Working Group for Technology Transfer (IAWGTT).

2.2.5 Interagency Working Group for Technology Transfer

DOE participates in the IAWGTT, led by the U.S. Department of Commerce's Technology Partnerships Office in the National Institute of Standards and Technology (NIST). The IAWGTT serves as an interagency forum for the exchange of information and as a vehicle for raising and addressing issues and concerns related to technology transfer across the Federal Government. The Director of Technology and Innovation in the Office of Science and Technology Policy and The Director of OTT co-lead cross-agency efforts which aim to increase the economic impact of federally-funded R&D by accelerating and improving the transfer of new technologies from the laboratory to the commercial marketplace. Some key DOE milestones met by the last quarter of FY 2015 included: finalizing the curriculum for the Lab-Corps program; holding the first competition for the Small Business Voucher Pilot, which was established to increase access to DOE National Laboratory resources for clean energy projects; and holding a National Lab Day on the Hill, to highlight the achievements of DOE's National Laboratories.

2.2.6 Federal Laboratory Consortium on Technology Transfer

The Federal Laboratory Consortium for Technology Transfer (FLC-TT) was organized in 1974 and formally chartered by the Federal Technology Transfer Act of 1986 to promote and strengthen technology transfer nationwide. Its membership draws from about 250 Federal laboratories, including DOE's 17 National Laboratories and 5 production Facilities. FLC-TT is supported by a contract between NIST and the Universal Technical Resource Services, Inc., of Cherry Hill, New Jersey.

As required by law, DOE contributes 0.008% of its R&D funding at Federally Funded Research and Development Centers to support FLC-TT. This funding provides support for FLC-TT's operational costs such as website maintenance, publications, conference and meeting support/management, and staff support. DOE's contributions are listed in the table below:

Table 1. Federal Laboratory Consortium - Technology Transfer Contribution from DOE (FY 2009-2015)

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
DOE Contributions	$463,000	$476,000	$499,000	$488,000	$479,000	$539,000	$555,000

3. Summary of Fiscal Year 2015 Transactions

DOE participates in the annual collection of technology transfer metrics (as required by 15 U.S.C. § 3710(f)(2)) that is coordinated by NIST in the Department of Commerce. Table 2 is a subset of metrics collected for fiscal years 2010-2015. Other metrics are tabulated in Appendix B. It should be noted that these metrics are used as indicators of the health of the activities, not as goals to be maximized in their own right. The 2011 Policy Statement explicitly notes: "The goal is to ensure the widespread deployment of technologies developed by DOE, and as such royalties and equity interest shall not be the primary consideration in licensing transactions. Financial returns are intended as an incentive to the scientists and Facility to actively participate in technology partnering and to promote a continuing substantive business commitment by the licensee."

Table 2. Technology Metrics at DOE National Laboratories and Facilities (FY 2010-2015)

Technology Transfer Data Element	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Transactions and Activities						
CRADAs, total active	697	720	742	742	704	734
New inventions disclosed	1,616	1,820	1,661	1,796	1,588	1,645
U.S. patent applications filed	965	868	780	845	962	856
Foreign patent applications filed	86	192	153	99	182	93
U.S. patents issued	480	460	483	554	693	632
Foreign patents issued	177	143	193	159	129	123
Licenses, total active	6,224	5,310	5,328	5,217	5,861	6,310
Invention Licenses	1,453	1,432	1,428	1,353	1,560	1,336
Other IP (copyright, material transfer, other Licenses)	4,771	3,878	3,900	3,864	4,301	4,974
Active Licenses, income-bearing	3,489	3,510	3,340	3,709	4,215	4,577
New Licenses, income-bearing	357	365	416	330	327	416
Strategic Partnership Project Agreements – NFEs, total active	2,222	2,273	2,519	2,733	2,021	2,395
User Projects, total active	5,819	11,967	9,706	7,396	6,748	7,571
Agreements for Commercializing Technology (ACT)	na	na	2	54	67	74
Reported Income (Thousands of Dollars)						
Total Licensing Income Received	$40,642	$44,728	$40,849	$39,573	$37,885	$33,137
Invention (Patent) Licenses	$37,066	$40,600	$36,103	$36,068	$32,869	$28,966
Copyright Licenses	$2,762	$3,983	$4,075	$3,315	$3,663	$3,939
Other Licenses	$814	$145	$671	$190	$1,353	$232
Total Royalty Income Earned	$25,220	$27,107	$28,735	$27,669	$23,384	$21,245
Other Metrics						
R&D Budget Authority, Basic, Applied and Development *(base, millions of dollars)*	$9,898	$9,915	$10,328	$10,148	$11,203	$13,366
New CRADAs with Small Business	nr	nr	nr	54	66	77
Elapsed Time for License Execution	nr	nr	nr	98 days	98 days	64 days
Total Licenses Granted to Small Businesses	nr	nr	nr	467	297	354
User Projects Awarded to Small Businesses	nr	nr	nr	64	87	83
Total Number of Unique Small Businesses Collaborating with the Labs	nr	nr	nr	764	929	1,476
New Material Transfer Agreements	nr	nr	nr	221	252	268
Active Material Transfer Agreements	nr	nr	nr	1,116	1,226	1,337

Note: nr – not recorded

The results in Table 2 show that DOE's CRADA, non-federal SPP activities have remained relatively stable during the last six years, while licensing activities have increased slightly. This indicates continuing activity as new agreements and licenses are implemented each year at a rate sufficient to compensate for the end dates of earlier agreements.

3.1 Multi-Year Trends

While available data sources vary and span over several periods, they provide insight on trends and patterns that have developed over the recent past. The data selected include licenses, licensing income, CRADAs, SPPs, and User Projects.

Figure 1. Licensing and Licensing Income (FY 2010-2015) presents data on licenses and income from licenses from FY 2010 to FY 2015. The total number of active licenses is divided into three classes: 1) patent (invention) licenses, 2) copyright licenses, and 3) other licenses. Other licenses include biological materials and other forms of intellectual property.

Figure 1. Licensing and Licensing Income (FY 2010-2015)

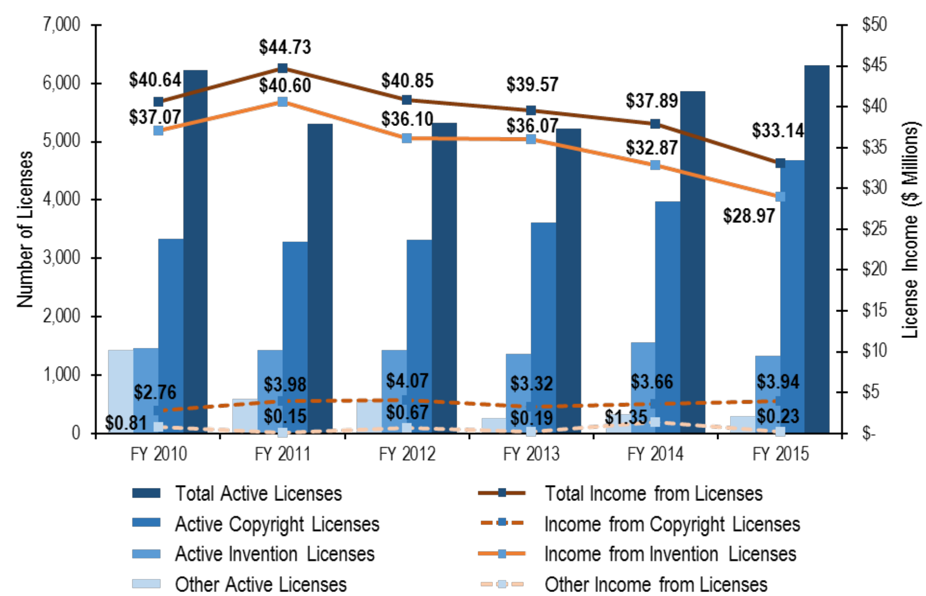
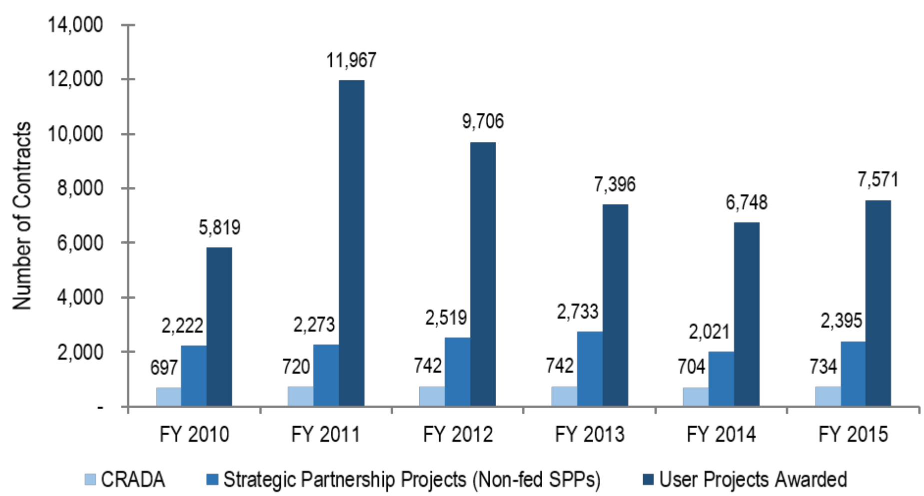


Figure 2. CRADAs, Strategic Partnership Projects, and User Projects Awarded (FY 2010-2015) shows a peak in User Projects awarded in FY 2011. The number of user projects awarded decreased 43.6 percent from FY 2011 to FY 2014 with an uptick in FY 2015. In contrast, SPPs with non-federal entities and CRADAs have remained relatively constant over the last six years. In FY 2015, there were 7,571 user projects compared to 2,395 SPPs

Figure 2. CRADAs, Strategic Partnership Projects, and User Projects Awarded (FY 2010-2015)



and 734 CRADAs, with user projects comprising around 70 percent of agreements at National Laboratories.

4. Technology Commercialization Initiatives and Activities

DOE's technology commercialization activities in FY 2015 involved two focus areas. The primary focus continued to be on new technologies developed at DOE National Laboratories and Facilities. The second focus was supporting and streamlining commercialization of these DOE technologies through a number of initiatives and pilot projects. These efforts demonstrate DOE's department-wide commitment to enabling commercialization as a mechanism to support U.S. economic growth. The following sections provide more detail on each of these areas.

4.1 R&D 100 Awards

An important metric of the success of DOE's technology commercialization activities is the quality and impact of the technologies that reach the commercial sector. It often requires many years, or even decades, to realize the full impact after an initial discovery. In tracking outcomes, we are best able to quantify impact at the point of handover of a specific technology to the commercial sector; therefore, we have to use indirect assessments to follow any continuing impacts thereafter.

The number of R&D 100 Awards illustrates the success and visibility of the DOE National Laboratories' commercialization activities. The R&D 100 Awards are given annually by R&D Magazine to recognize exceptional new products or processes that were developed and introduced into the marketplace during the previous year. To be eligible for an award, the technology or process must be in working and marketable condition – no proof of concept prototypes are allowed – and had to be first available for purchase or licensing during the year prior to the award. The awards are selected by an independent panel of judges based on the technical significance, uniqueness and usefulness from across industry, government and academia.

DOE researchers won 33 of the 100 awards in 2015, 31 awards in 2014, 36 awards in each of 2013, 2012 and 2011, and 46 in 2010, for a total of 218 from 2010 to 2015. R&D 100 Awards are summarized in Appendix D. Other developed technologies success stories are highlighted in Appendix E. These represent a spectrum of commercial areas including DOE mission areas in basic science, energy efficiency, environment, and security. They also include spin-off applications in areas such as automotive, aeronautical, manufacturing, medical, microwave technology, semiconductor and information technology, and broad applications in cyber security and sensing/control systems.

4.2 Initiatives to Support Streamlined Commercialization

DOE carried out a number of programmatic initiatives in FY 2015 to streamline the technology transfer processes at DOE National Laboratories and Facilities and to communicate better the opportunities for the private sector to engage in commercializing technologies. The following subsections describe illustrative programs: 1) Agreements for Commercializing Technology, 2)

Lab-Corps 3) Small Business Innovation Research/Small Business Technology Transfer, and 4) Other Program and Partnerships for Commercialization.

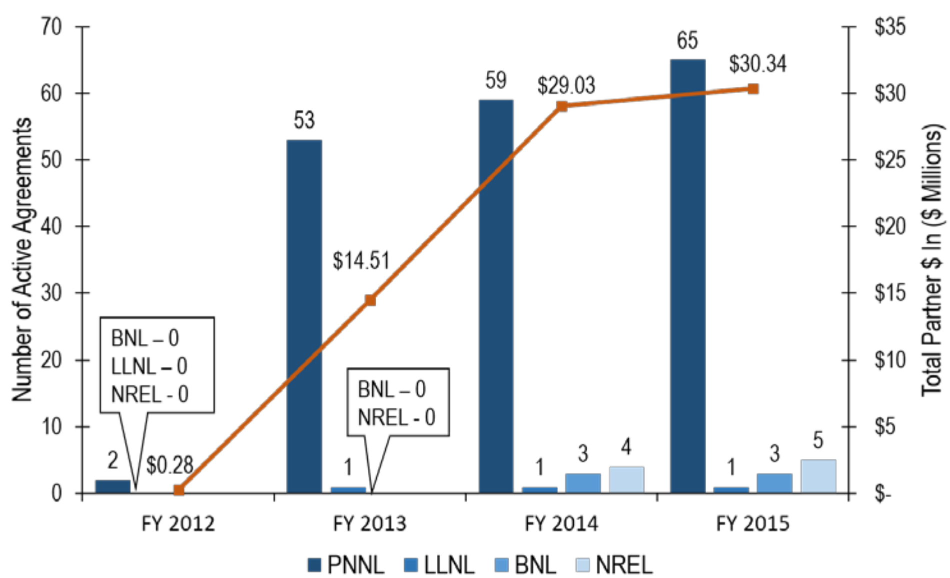
4.2.1 Agreements for Commercializing Technology

The DOE National Laboratories and Facilities have unique scientific capabilities that extend beyond those available to academic and industrial institutions. Each year the DOE spends billions of dollars advancing research in basic and applied sciences. To enhance the impact of federal R&D investments in the National Laboratories and Facilities, the DOE works with industry through various technology transfer mechanisms such as CRADAs, SPPs, and licenses. In February 2012, the then Secretary of Energy announced that eight laboratories would participate in a three-year initiative, the ACT Pilot Program. This pilot mechanism was developed in response to a June 2009 Government Accountability Office (GAO) Report titled, "*Clearer Priorities and Greater Use of Innovative Approaches Could Increase the Effectiveness of Technology Transfer at Department of Energy Laboratories,*"[11] and feedback received from a 2008 *Notice of Inquiry Regarding Questions Concerning Technology Transfer Practices at DOE Laboratories*.[12]

The primary purpose of the ACT Pilot Program was to provide an additional mechanism with unique flexibilities to address barriers that have hindered non-federal access to National Laboratory capabilities.

On February 7, 2015, the DOE extended the ACT Pilot Program until October 31, 2017. Extending the pilot provided the opportunity for DOE to accumulate more data, benchmark, and evaluate outcomes for FY 2014 to FY2016, to better inform a decision on how to proceed with the ACT mechanism. For more information on the ACT Pilot Program– background, participating National Laboratories' implementation strategy, agreement terms and flexibility

Figure 3. Agreements for Commercializing Technology (FY 2012-2015)



[11] See GAO Report No. 09-548, gao.gov/assets/300/290963.pdf

[12] See Notice of Inquiry published on November 26, 2008 entitled "Questions Concerning Technology Transfer Practices at DOE Laboratories," federalregister.gov/articles/2008/11/26/E8-28187/questions-concerning-technology-transfer-practices-at-doe-laboratories.

go to OTT's homepage at energy.gov/technologytransitions/frequently-asked-questions-about-act.

4.2.2 Lab-Corps (Pilot)

EERE launched the Lab-Corps Pilot in FY 2014 to help increase the rate at which National Laboratory discoveries successfully transition into the private sector. The Pilot was modeled after the National Science Foundation's successful Innovation Corps (I-Corps) program, but tailored to the needs of DOE National Laboratories., The Pilot trains top laboratory researchers, through direct engagement with industry, entrepreneurs, and investors as well as in entrepreneurship, on how to move high-impact National Laboratory-invented clean energy technologies into the market.

In FY 2015, NREL worked with EERE to develop a training curriculum and syllabus, manage the program, select Lab-Corps faculty, provide support to other National Laboratories as needed, and write a lab call to solicit proposals from the other five participating National Laboratories (ANL, INL, LBNL, LLNL, and PNNL). Ultimately, 14 teams from technology areas across EERE were selected to participate in the first cohort. NREL also planned the opening session for the first cohort, which took place in October 2015.

4.2.3 Small Business Innovation Research/Small Business Technology Transfer

DOE directly engages the private sector through its Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, which together are important components of the DOE's transfer of knowledge and technology to the private sector.[13] DOE programs fund R&D at U.S. small businesses often in collaboration with U.S. National Laboratories and universities in technology areas that align with the DOE's mission.[14] FY 2015 and prior year SBIR and STTR allocations and awards are summarized in Table 3.

Table 3. DOE SBIR and STTR Allocations and Awards (FY 2009 to FY2015)

Fiscal Year	SBIR Allocation ($)	Number of SBIR awards	STTR Allocation ($)	Number of STTR Awards	Number of Awards with DOE Lab as Partnering Research Institution
2009	$137,869,000	529	$16,571,000	43	16
2010	$149,577,000	539	$17,950,000	77	13
2011	$145,567,000	312	$17,469,000	48	16
2012	$164,224,000	322	$22,333,000	45	16
2013	$162,437,000	380	$21,464,000	53	13
2014	$178,200,000	356	$23,800,000	53	13
2015	$191,696,000	401	$25,478,000	58	9

As shown in Table 3, in 2015 DOE made 401 SBIR awards totaling $191.7 million and 58 STTR awards totaling $25.5 million. For both types of awards there is often collaboration with

[13] S.493 – SBIR/STTR Reauthorization Act of 2011 congress.gov/bill/112th-congress/senate-bill/493

[14] General information on DOE's SBIR and STTR Programs, FY15 and prior year awards, and FY15 participating DOE labs can be found at science.energy.gov/sbir/awards/

universities and DOE National Laboratories. Typically 50 percent of SBIR awards include a sub-award to a consultant from a research institution. All STTR awards are required to have a partnership with a research institution and typically 25 percent of the partnerships involve DOE National Laboratories.

4.2.4 Other Opportunities for Partnerships and Commercialization

DOE supports commercialization activities to enhance technology transfer through partnerships and grant programs.. Three examples of these programs are the DOE Small Business Voucher Pilot, Technologist in Residence Pilot and Cyclotron Road. These programs support commercialization of technologies developed at DOE National Laboratories and U.S. colleges and universities.

Small Business Voucher (SBV) Pilot

The Small Business Voucher (SBV) Pilot, launched in FY 2015, aims to improve small businesses' awareness and affordable access to DOE National Laboratory intellectual and physical assets to advance DOE's mission. These partnerships between small businesses and DOE National Laboratories help promote economic development and innovation by pairing DOE's unparalleled laboratory resources and expertise with small business drive and creativity. In July of 2015, DOE obligated $20 million to five National Laboratories to launch the SBV Pilot: ORNL, PNNL, NREL, LBNL, and SNL.

The selected National Laboratories coordinated their efforts closely, to offer a uniform competitive process and standard terms and conditions to interested small business applicants. An IT platform, the Central Assistance Platform (CAP), available at: sbv.org, was developed by NREL to facilitate the small business communications and requests for vouchers. In September 2015, the first round of competition opened, and eligible small businesses were able to submit their requests for assistance via the CAP. The first round closed in October 2015.

Technologist in Residence (TIR) Program

In 2015, DOE launched the Technologist in Residence (TIR) Program to catalyze strong, long-term relationships between industry and DOE National Laboratories. The program is designed to help industrial partners leverage resources and expertise from across the National Laboratory enterprise; moving beyond the 'one company – one lab' model. TIR has established a Council of Technologists, a network of technologists from each of the National Laboratories, to help facilitate and optimize the program.

The TIR program is intended to streamline engagement and increase collaborative R&D between National Laboratories and private sector companies. TIR teams up senior laboratory technologists with industry professionals in "technologist pairs" for a period of up to two years. Each pair works together to identify the technical challenges of interest to the participating company and the resources and capabilities across the National Laboratories that may address them. The pair then proposes collaborative R&D projects to address the identified challenges in industry-relevant technologies.

Cyclotron Road

Cyclotron Road was launched by EERE in FY 2014 in collaboration with LBNL to serve as a home for top entrepreneurial researchers to advance technologies beyond the research laboratory. The goal behind this program is to support technology development by identifying the most suitable business models, partners, and financing mechanisms for long-term impact. Cyclotron Road selects the best technology innovators to receive salary and seed funding for up to two years, dedicated laboratory and office space at LBNL, and support obtaining additional funding for their projects.

In FY 2015, the highly competitive first cohort drew the interest of 150 applicants in just a three-week window, from which eight individuals were selected as Cyclotron Road innovators. With access to industry mentorship and commercial network support through LBNL, the program's first cohort had the opportunity to advance an array of energy materials and manufacturing technologies ranging from bio-based production of industrial plastics to ultra-high efficiency waste heat recovery systems. More than 20 LBNL scientists supported these cutting-edge projects, which drew over $1.5 million in follow-on funding in the first six months.

With the continued success of projects led by the Cohort 1 innovators, Cyclotron Road is poised to expand its impact in FY 2016 with the selection and funding of a second cohort.

5. User Facilities

DOE invests in a broad spectrum of research infrastructure – specialized facilities and instrumentation – to advance its mission goals. For example, DOE's SC User Facilities (Table 4) provide researchers with the most advanced tools of modern science including accelerators, colliders, supercomputers, light sources, neutron sources, and other facilities for studying phenomena from the nanoworlds to the atmosphere and beyond. In FY 2015 more than 32,000 researchers from academia, industry, and government laboratories, spanning all 50 states and the District of Columbia, utilized these unique User Facilities to perform new scientific research. A list of DOE's SC User Facilities can be found at the DOE SC User Facilities homepage.[15] In addition, over one thousand users of the SC User Facilities were from 297 companies of which 155 were identified as small businesses and 47 are listed on the Fortune Global 500.

A User Facility is a federally-sponsored research facility available for external use to advance scientific or technical knowledge under the following conditions:

- The facility is open to all interested potential users without regard to nationality or institutional affiliation.
- Allocation of facility resources is determined by merit review of the proposed work.
- User fees are not charged for non-proprietary work if the user intends to publish the research results in the open literature. Full cost recovery is required for proprietary work.
- The facility provides resources sufficient for users to conduct work safely and efficiently.
- The facility supports a formal user organization to represent the users and facilitate sharing of information, forming collaborations, and organizing research efforts among users.
- The facility capability does not compete with an available private sector capability.

DOE also supports a large collection of Shared R&D Facilities (Table 1Table 5) that are available at the election of the host institution on a full cost-recovery basis. These Shared R&D Facilities include a broad spectrum of DOE National Laboratory assets, such as technology benchmarking test beds (sometimes called "test facilities"), large-scale collaborative R&D centers, and specialized materials processing capabilities. Access to these facilities is made available to external users through SPP Agreements and CRADAs. The DOE energy technology offices support many unique, specialized facilities at the DOE National Laboratories.

Table 4. DOE User Facilities

User Facility	Location	Description	Program
Wireless National User Facility	Idaho National Laboratory	Wireless Communication RD&D	Multiple
Energy Systems Integration Facility	National Renewable Energy Laboratory	Energy Systems RD&D	EERE
Nuclear Scientific User Facilities	Idaho National Laboratory	Nuclear Energy R&D	NE
Linac Coherent Light Source	SLAC National Accelerator Laboratory	X-ray Free Electron Laser	SC/BES

[15] U.S. Department of Energy, Office of Science. User Facilities. science.energy.gov/user-facilities/

Stanford Synchrotron Radiation Light Source	SLAC National Accelerator Laboratory	X-ray Synchrotron Light Source	SC/BES
Advanced Light Source	Lawrence Berkeley National Laboratory	X-ray Synchrotron Light Source	SC/BES
Advanced Photon Source	Argonne National Laboratory	X-ray Synchrotron Light Source	SC/BES
National Synchrotron Light Source-II	Brookhaven National Laboratory	X-ray Synchrotron Light Source	SC/BES
Spallation Neutron Source	Oak Ridge National Laboratory	Pulsed Neutron Source	SC/BES
High Flux Isotope Reactor	Oak Ridge National Laboratory	Continuous Neutron Source	SC/BES
Center for Integrated Nanotechnologies	Los Alamos and Sandia National Laboratories	Nanoscale Science	SC/BES
Center for Nanophase Materials Sciences	Oak Ridge National Laboratory	Nanoscale Science	SC/BES
The Molecular Foundry	Lawrence Berkeley National Laboratory	Nanoscale Science	SC/BES
Center for Nanoscale Materials	Argonne National Laboratory	Nanoscale Science	SC/BES
Center for Functional Nanomaterials	Brookhaven National Laboratory	Nanoscale Science	SC/BES
Joint Genome Institute	Lawrence Berkeley National Laboratory	High-throughput DNA Sequencing and Analysis	SC/BER
Environmental Molecular Sciences Laboratory	Pacific Northwest National Laboratory	Experimental and Computational Molecular Science	SC/BER
Atmospheric Radiation Measurement Climate Research Facility	Multiple Sites	Climate Observation	SC/BER
National Energy Research Scientific Computing Center	Lawrence Berkeley National Laboratory	High Performance Computing	SC/ASCR
Oak Ridge Leadership Computing Facility	Oak Ridge National Laboratory	High Performance Computing	SC/ASCR
Argonne Leadership Computing Facility	Argonne National Laboratory	High Performance Computing	SC/ASCR
Energy Sciences Network	Lawrence Berkeley National Laboratory	High Performance Network for Scientific Research	SC/ASCR
Facility for Advanced Accelerator Experimental Tests	SLAC National Accelerator Laboratory	Linear-accelerator for beam-driven plasma wakefield R&D	SC/HEP
Fermilab Accelerator Complex	Fermi National Accelerator Laboratory	Particle accelerators for HEP research	SC/HEP
Accelerator Test Facility	Brookhaven National Laboratory	Laser and Electron Beams for Advanced Accelerator R&D	SC/HEP
Continuous Electron Beam Accelerator Facility	Thomas Jefferson National Accelerator Laboratory	Linear Accelerators for QCD research	SC/NP
Relativistic Heavy Ion Collider	Brookhaven National Laboratory	Circular collider for heavy ion research	SC/NP
Argonne Tandem Linac Accelerator System	Argonne National Laboratory	Superconducting Linear Accelerator for Nuclear Structure Research	SC/NP
DIII-D Tokamak	General Atomics	Fusion Energy R&D	SC/FES
National Spherical Torus Experiment (NSTX)	Princeton Plasma Physics Laboratory	Fusion Energy R&D	SC/FES
Alcator C-Mod[16]	Massachusetts Institute of Technology	Fusion Energy R&D	SC/FES

[16] In the FY2016 budget request, the Office of Science has proposed that this will be the final year of funding support for this facility.

Table 5. Subset of the 140 Shared R&D Facilities Operating at DOE National Laboratories

Shared R&D Facility	Laboratory
Materials Preparation Center	Ames National Laboratory
Materials Engineering Research Center	Argonne National Laboratory
Transportation Research and Analysis Computing Center	Argonne National Laboratory
Northeast Solar Energy Research Center	Brookhaven National Laboratory
Magnet Systems	Fermi National Accelerator Laboratory
Biomass Feedstock National User Facility	Idaho National Laboratory
CalCharge Battery Laboratory	Lawrence Berkeley National Laboratory
FLEXLAB	Lawrence Berkeley National Laboratory
Fuels Processing Laboratory	National Energy Technology Laboratory
Solar Energy Research Laboratory	National Renewable Energy Laboratory
Carbon Fiber Technology Facility	Oak Ridge National Laboratory
High Temperature Materials Laboratory	Oak Ridge National Laboratory
Applied Process Engineering Laboratory	Pacific Northwest National Laboratory
Combustion Research Facility	Sandia National Laboratories

5.1 High Performance Computing Facilities

The DOE's Office of Science (SC) has three Advanced Scientific Computing Research (ASCR) user facilities:

- National Energy Research Scientific Computing Center (NERSC);[17]
- Argonne Leadership Computing Facility (ALCF);[18] and
- Oak Ridge Leadership Computing Facility (OLCF).[19]

These facilities provide high end computing to SC and the Nation's researchers, including industry. ASCR's high-performance production class facility, the NERSC at LBNL provides high-performance computing (HPC) for basic scientific research and engineering sponsored by SC and supports over 6,000 users. ASCR's two Leadership Computing Facilities (LCFs) are world-leading HPC resources dedicated to breakthrough science and engineering by providing very large allocations of computing resources to the science community broadly, including users from industry, academia and other agencies. The LCFs each support approximately 100 projects and 1,000 users per year.

Together these facilities provide the computational science community with a world-leading capability dedicated to breakthrough science and engineering in a broad range of scientific disciplines. All of the SC facilities also provide a team of experts to assist and support facility users and their projects in order to achieve top performance of applications and to maximize benefits from the use of the HPC resources. These facilities are available on a peer-reviewed basis to all potential users including government, university, and industry.

[17] NERSC, nersc.gov/systems
[18] ALCF, alcf.anl.gov/computing-resources
[19] OLCF, olcf.ornl.gov/computing-resources/

SC has attracted companies to use NERSC and the LCFs to promote innovation and stimulate competitiveness through efforts including:

- The Innovative & Novel Computational Impact on Theory & Experiment (INCITE) Program;[20]
- The ASCR Leadership Computing Challenge (ALCC);[21]
- Director's Discretionary (DD) Programs;[22,23]
- The ORNL, ACCEL (Accelerating Competitiveness through Computational Excellence) Program;[24]

Currently, more than 100 NERSC users hail from U.S. companies. Through its new Private Sector Partnerships (PSP) effort, NERSC is expanding its communication and outreach to private-sector researchers. PSP leverages SBIR grants, Director's Reserve[25] allocations and co-sponsored HPC research agendas to grow the impact of scientific computing in U.S. industry. Additionally, many companies have benefited from a flexible user agreement at OLCF. This special industrial partnership user agreement allows an industrial firm to keep proprietary findings confidential as long as the firm can commit in advance to publish meaningful science results nonetheless. Section 5.1 of the "Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014" provides specific examples of private sector companies that use and benefit from the ASCR facilities.[26]

ASCR facilities are themselves the result of an industrial partnership. To keep the computing resources at the very high end, the ASCR computing facilities are regularly upgraded on a 3-5 year schedule. Because of the long-lead time in procuring a high-end system from commodity parts, these acquisitions include significant effort in non-recurring engineering research to ensure that the evolving technology will meet the needs of a scientific user facility.[27, 28] This partnership allows DOE to confidently purchase systems that do not yet exist and provides industry with a knowledgeable and demanding customer to help harden their technology, both hardware and software, into more user-friendly systems. For example, the partnership between IBM, LLNL and ANL to develop and deploy the Blue Gene computing line was recognized by then President Obama when they received the National Medal of Technology and Innovation for the resulting product.

[20] INCITE: Accessing ASCR Facilities. U.S. DOE, Office of Science, science.energy.gov/ascr/facilities/accessing-ascr-facilities/incite/

[21] ALCC: Accessing ASCR Facilities. U.S. DOE, Office of Science, science.energy.gov/ascr/facilities/accessing-ascr-facilities/alcc/

[22] Argonne Leadership Computing Facility, Director's Discretionary Program, alcf.anl.gov/dd-program

[23] OLCF Director's Discretionary Projects, olcf.ornl.gov/support/getting-started/olcf-director-discretion-project-application/

[24] ORNL ACCEL Program, olcf.ornl.gov/accel/about-accel/

[25] NERSC, For additional information on DOE Science Offices, Programs, and Allocation Managers, go to nersc.gov/users/accounts/allocations/doe-science-offices-programs-and-allocation-managers/

[26] Section 5.1. "Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014." U.S. Department of Energy. June 2016. energy.gov/sites/prod/files/2016/06/f33/Technology%20Transfer%20Report%20to%20Congress%20FY14.pdf

[27] The DOE High-End Computing Revitalization Act of 2004, Public Law 108-423 (PL 108-423) defines a High-end Computing System as a computing system with performance that substantially exceeds that of systems that are commonly available for advanced scientific and engineering applications.

[28] PL 108-423 further identifies a specific class of high-end computing systems as Leadership System that are among the most advanced in the world in terms of performance in solving scientific and engineering problems.

6. Scientific Research Programs with Significant Industrial Engagements

In recent years, DOE has implemented several new research and development activities designed to accelerate scientific and technological innovation through a highly collaborative multi-disciplinary research management model. The Department devised these activities to tackle particularly difficult research problems that require a team approach based on extensive strategic planning with the scientific and technical communities and on the Department's prior experience with other research programs.

Currently, there are four major funded activities using this approach: (1) Energy Innovation Hubs (Hubs), (2) Bioenergy Research Centers (BRC), (3) Energy Frontier Research Centers (EFRC), and (4) The Accelerator Stewardship Research and Development Program. The EFRCs focus on fundamental research, addressing one or more of the SC-Basic Energy Sciences (BES) basic research needs. The Hubs and BRCs are large, comprehensive, multidisciplinary research centers that bridge the gap between basic and applied research to address a single national energy challenge. Lastly, the Accelerator Stewardship R&D program is a novel approach to connecting potential industry partners to unique DOE research infrastructure. The overarching goal for all of these research entities is to enable innovative research to form the foundation for new technologies, thereby advancing the DOE mission in energy, environment, and national security. Each of these major activities has a unique structure and mode of operation designed to advance its specific research focus.

6.1 Energy Innovation Hubs

DOE's Energy Innovation Hubs combine basic and applied research with engineering to accelerate scientific discovery in critical energy issue areas. First established in 2010, the Hubs were founded on the premise that creative, highly-integrated research teams can accomplish more, faster, than researchers working separately. Hubs are built to accelerate the path from scientific discovery to real-world technology. They are also modeled after the strong scientific management characteristics of the Manhattan Project, Lincoln Lab at MIT that developed radar, AT&T Bell Laboratories that developed the transistor and, more recently, DOE's highly successful Bioenergy Research Centers established to advance fundamental science for advanced biofuels. In 2015, there were four Energy Innovation Hubs, listed in Table 6.

Table 6. DOE Energy Innovation Hubs

Topical Area	Hub Award	DOE Program Office
Nuclear Modeling and Simulation	Consortium for Advanced Simulation of Light Water Reactors (CASL)	Office of Nuclear Energy
Fuels from Sunlight	Joint Center for Artificial Photosynthesis (JCAP)	Office of Science, Basic Energy Sciences program
Batteries and Energy Storage	Joint Center for Energy Storage Research (JCESR)	Office of Science, Basic Energy Sciences program
Critical Materials	Critical Materials Institute (CMI)	Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office

Seeking solutions to strategic R&D challenges

Each Hub focuses on a single research topic area spanning from basic research, through engineering development, to facilitating commercialization by industry. The balance of these activities differs from one Hub to the next, depending on the needs of the individual research areas.

The Hub research areas were selected based on the following considerations:

- The focus area problem represents a significant grand challenge where major advances are likely to have a material impact on energy production, storage, or usage.
- A large-scale coordinated, multidisciplinary, systems-level approach is needed to accelerate the pace of discovery and innovation to realize efficiency, manufacturability, deployment, and utilization of new energy solutions.

An integrated, interactive multidisciplinary team

Each Hub is composed of a highly collaborative team of top talent across the full spectrum of R&D performers – including universities, private industry, non-profits, and government laboratories – integrating expertise in multiple scientific disciplines, engineering fields, and technology areas. They are expected to be world-leading R&D centers in their research areas.

6.1.1 Consortium for Advanced Simulation of Light Water Reactors

The Consortium for Advanced Simulation of Light Water Reactors (CASL) was established by DOE in 2010 as an Energy Innovation Hub to develop advanced modeling and simulation (M&S) tools that can be used to analyze the operation of US commercial light water reactors (LWRs). The program's focus during this initial period was on modeling and simulation of physical processes that affect operation of pressurized water reactor (PWR) cores. In 2015, the program was extended for an additional five years with the goal of finalizing development of the PWR analysis tools and extending the program's tools for use in analysis of boiling water reactor (BWR) and small modular reactor (SMR) operations.

The world-class scientists, engineers, computer scientists, students, and program managers from the 10 CASL founding partners and contributing partners, and led by ORNL and supported by the CASL Board of Directors, Industry and Science Councils, are responsible for the continued success of this modelling and simulation effort. Nearly 350 subject matter experts associated with CASL are developing and deploying its Virtual Environment for Reactor Applications (VERA), a "virtual reactor" designed to accurately simulate the coupled physical processes inside a reactor at unprecedented levels of detail. These reactor processes include neutron transport, thermal hydraulics, nuclear fuel performance, and corrosion and surface chemistry. VERA provides for a higher fidelity and resolution for modeling the reactor core and vessel systems of a nuclear reactor than is currently available in industry.

Key CASL accomplishments and initiatives in 2015 include a highly accurate modeling of the Watts Bar Nuclear Power Plant Unit 1 full 18 years of reactor operating history including fuel loading, depletion, shuffling, and discharge and Watts Bar Unit 2 reactor startup, implementation of a transient operation capability that supports further challenge problems progress, and improvements in the speed and efficiency of VERA analysis tools. The program remains on track to fulfill its end state vision within the second phase and it is making strong progress toward establishing VERA as a set of tools that are widely used by industry, academia, and the National Laboratories for analysis of LWR operations.

CASL by numbers:

- 181 journal articles
- 443 conference papers
- 311 technical reports
- 196 invited talks
- 675 milestone reports
- 275 programmatic reports

CASL is funded and managed by the Office of Nuclear Energy. For more information go to: casl.gov.

6.1.2 Joint Center for Artificial Photosynthesis

The Joint Center for Artificial Photosynthesis (JCAP) was originally selected to be the Fuels from Sunlight Energy Innovation Hub through a competitive solicitation in FY 2010. It was renewed in FY 2015 at $15 million per year for up to five additional years. It is led by the California Institute of Technology (Caltech) in primary partnership with LBNL.

The multi-disciplinary, multi-institutional team of scientists and engineers at JCAP aims to create transformative advances in the development of artificial photosynthetic systems for converting sunlight, water, and carbon dioxide into a range of commercially useful fuels. The benefits of such a solar energy-to-chemical fuel conversion system could be considerable, enabling fossil fuels to be replaced with fuels generated directly by sunlight. Basic research has provided considerable advances in the understanding of the complex photochemistry associated with natural photosynthesis in plants and in the use of inorganic photo-catalytic methods to split water or reduce carbon dioxide. However, science still lacks sufficient knowledge to design and develop solar fuel generation systems with the required efficiency, scalability, and sustainability for economic viability.

The mission of JCAP is to produce fundamental scientific discoveries and major technological breakthroughs to facilitate the transition from basic research to prototype development and potential industry interest. Its R&D ranges from discovery of new materials and concepts to science-based design and testing of prototypes for solar fuel generation. A unique aspect of this Hub is that, unlike other Hubs, there is no corresponding industry in solar fuels. However, JCAP actively seeks to interact with representatives from related industries. JCAP has established the Industrial Partnership Program to facilitate R&D collaborations. Member companies commit to making meaningful contributions, in both financial resources and intellectual capital towards mutually important research objectives. In return, the partner companies receive limited intellectual property rights and can locate their employees in residence at JCAP facilities to accelerate collaborative research. JCAP also engages industry on more focused topics of interest for specific R&D goals such as high throughput experimentation and prototyping.

JCAP by the numbers (as self-reported by JCAP through September 2016):

- 353 peer-review publications
- Students and staff entering the domestic and foreign workforce
    - 29 to industry
    - 25 to university faculty and staff positions
    - 4 to national Laboratory positions
- 69 total IP applications
- 6 industry representatives (former and current) on JCAP advisory boards. JCAP is funded and managed by the DOE Office of Science Basic Energy Sciences program. For more information visit science.energy.gov/bes/research/doe-energy-innovation-hubs/.

6.1.3 Joint Center for Energy Storage Research

The Joint Center for Energy Storage Research (JCESR, pronounced "Jay-CAEsar") was selected to be the Batteries and Energy Storage Energy Innovation Hub through a competitive solicitation; funding began December 14, 2012 at a level of approximately $25M/year for five years, subject to congressional appropriations. JCESR is focused on performing advanced scientific research to understand electrochemical materials and phenomena at the atomic and molecular scale, and to use this fundamental knowledge to discover and design next-generation energy storage technologies. JCESR's goal is to enable "beyond lithium ion" rechargeable batteries for transportation and for the grid that are five times more powerful and five times cheaper within five years (compared to 2011 benchmarks).

JCESR is led by ANL and has four other National Laboratory partners (LBNL, PNNL, SNL and SLAC), five University partners (University of Illinois Urbana-Champaign, University of Illinois Chicago, University of Chicago, University of Michigan, and Northwestern University), and five industry partners (United Technologies Research Corporation, Applied Materials, Johnson Controls, Clean Energy Trust and Dow Chemical). In addition, there are five funded collaborators (Notre Dame, University of Waterloo, Harvard University, Massachusetts Institute of Technology, and the University of Utah). JCESR also has 101 Affiliates in 25 states, consisting of industry, universities and non-profits. JCESR maintains regular contact with its affiliates through regional events. To date, JCESR has held ten regional events around the country and is in the process of planning further events for this year.

JCESR has several established mechanisms to promote the transfer of information and technology to the community. First, by publishing papers and filing invention disclosures; after nearly four years of operation JCESR has produced over 239 publications and filed 54 invention disclosures, and 27 patent applications. Second, the "Electrolyte Genome" has added over 16,000 organic molecules – each with various associated properties such as relaxed structure, vibrational analysis and ionization and electron affinity potentials, to the Materials Project database. Third, they have robust interactions with industry through industrial partners, advisory committees and councils (approximately 15 industrial representatives in addition to the four direct partners), links with industry through the Clean Energy Trust, and the Affiliates group, including the Affiliates Newsletter and meetings. These connections promote an ongoing dialogue with nascent and established industries to discuss results and potential new directions in the energy storage field. Additionally, the first piece of JCESR funded intellectual property was licensed in 2016. To this end, JCESR is aware of at least two start-ups that are looking to launch based on JCESR developed intellectual property. While licenses have not yet been completed for these start-ups, JCESR is excited by the outlook for the technology that it is developing. Finally, JCESR currently supports approximately 33 graduate students and 68 post-doctoral researchers whose training will enable longer-term careers in academia, the National Laboratories, or industry.

JCESR is funded and managed by the DOE Office of Science Basic Energy Sciences program. For more information visit science.energy.gov/bes/research/doe-energy-innovation-hubs/ and jcesr.org/.

6.1.4 Critical Materials Institute

The Critical Materials Institute (CMI), led by Ames Laboratory, is developing technologies that will enable U.S. manufacturers to make better use of the critical materials we have access to as well as eliminate the need for materials that are vulnerable to supply disruptions. CMI focuses on critical materials as identified by DOE's 2011 *Critical Materials Strategy*. These critical materials, which include five rare earth elements, are essential for U.S. competitiveness in clean energy industry and other strategic industries such as defense. Since beginning operations in June 2013, CMI has brought together scientists and engineers from four National Laboratories, seven universities and six companies to address challenges across the supply chain of critical materials, including mineral-related processing, manufacture, substitution, efficient use, and end-of-life recycling. The Hub will integrate scientific research, engineering innovation, and manufacturing and process improvements to provide a holistic solution to the materials challenges facing the nation.

CMI has more than 30 projects focused in the four areas shown in Figure 4. Critical Materials Institute Project Focus Areas. A complete project list with project titles sorted by project leader and location is available to the public at cmi.ameslab.gov/project-list.[29] CMI research is conducted at partner institutions, including National Laboratories, universities and industry locations.

CMI researchers have reported 20 invention disclosures. These range from improved extractive processes, recycling techniques, and substitute materials—technologies designed

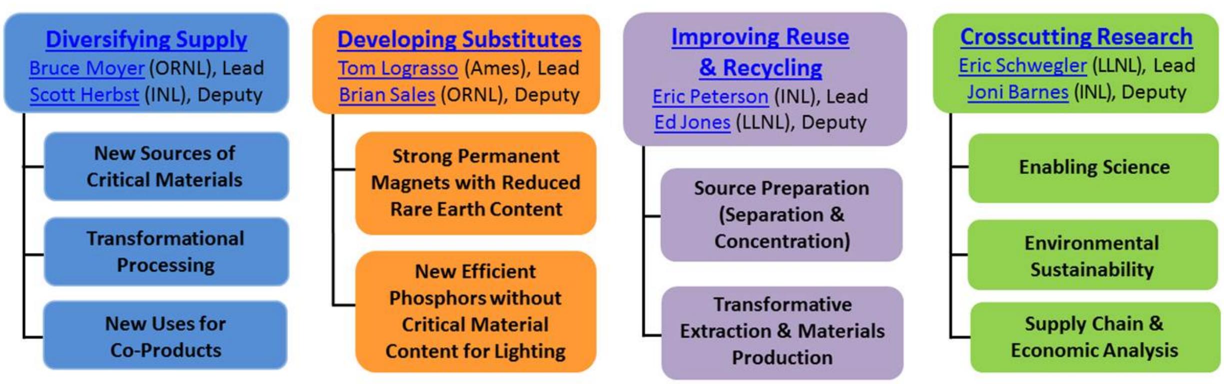


Figure 4. Critical Materials Institute Project Focus Areas

[29] CMI's complete project list is available at cmi.ameslab.gov/project-list.

to increase production and efficiency of, and reduce reliance on, the use of rare earths and other critical materials.

6.2 Bioenergy Research Centers

The ultimate goal for the three DOE Bioenergy Research Centers (BRCs) is to provide the fundamental science to underpin a cost-effective, advanced cellulosic biofuels industry. Using systems biology approaches, the BRCs are focusing on new strategies to reduce the impact of key cost-driving processes in the overall production of cellulosic biofuels from biomass. The three BRCs were established in 2007 through a competitive solicitation and are currently in the third year of a second five-year funding period. The three are the BioEnergy Science Center (BESC) at the ORNL, the Joint BioEnergy Institute (JBEI) at LBNL and the Great Lakes Bioenergy Research Center (GLBRC) at the University of Wisconsin in partnership with the Michigan State University. Each center is funded at $25 million per year, subject to congressional appropriations.

For cellulosic biofuels to be adopted on a large scale, they must represent environmentally sustainable and economically competitive alternatives to existing fuel systems. New strategies and findings emanating from the centers' fundamental research are addressing three grand challenges for cost-effective advanced biofuels production:

- Develop next-generation bioenergy crops by unraveling the biology of plant development
- Discover and design enzymes and microbes with novel biomass-degrading capabilities
- Develop transformational microbe-mediated strategies for advanced biofuels production

The science needed to solve these complex challenges requires multiple, coordinated, multidisciplinary teams approaching problems from varied perspectives to accelerate scientific progress.

As shown in Table 7, each of the three BRCs has industrial representation on their scientific advisory boards and board of directors; tracks invention disclosures, patent applications, options/licenses and issued patents; tracks subsequent employment of alumni; and tracks scientific publications. The BRCs span the country (Figure 5. Map of DOE Bioenergy Research Centers and Partners) and are funded and managed by the DOE Office of Science Biological and Environmental Research program.

Table 7. Bioenergy Research Center Metrics

Metric	BESC	JBEI	GLBRC	Total
Industrial Representatives on Advisory Committees and Boards	4	20	6	30
Tech Transfer Metrics				
Invention Disclosures and Patent Applications, FY15 (Total)	58 (172)	62 (336)	38 (254)	158 (762)
Options/Licenses, FY15 (Total)	- (1)	11 (69)	8 (42)	19 (112)
Awarded Patents (Total)	6	5	35	46
Employment Metrics*				
Employed in Academia	161	63	129	353
Employed in Industry	102	68	53	223
Unknown	18	16	19	53
Publication Metrics				
Publications FY15	104	82	126	312

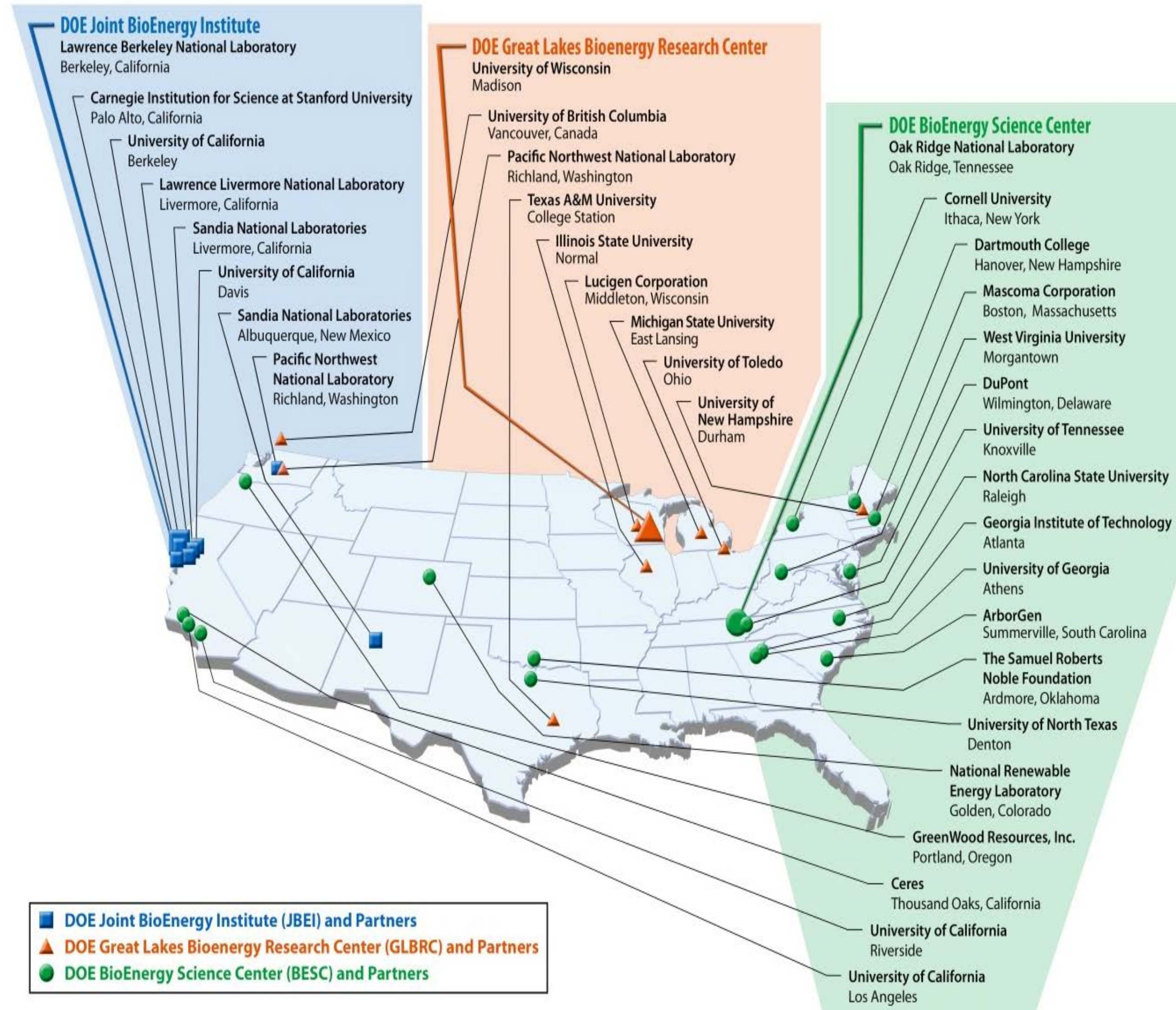


Figure 5. Map of DOE Bioenergy Research Centers and Partners

Total Publications	646	510	791	1947

* JBEI tracks an additional 14 alumni working for DOE National Laboratories and GLBRC tracks an additional 12 alumni working for non-profit entities

For more information on the BRCs visit science.energy.gov/ber/research/bssd/.

6.3 Energy Frontier Research Centers

DOE's Office of Science supports Energy Frontier Research Centers (EFRCs), major collaborative research efforts to accelerate high-risk, high-reward fundamental research that will provide a strong scientific basis for transformative energy technologies of the future.

The EFRCs represent a unique approach to energy research, bringing together the skills and talents of teams of investigators to perform energy-relevant, basic research with a scope and complexity beyond that possible in typical single-investigator or small group research projects. The EFRCs have world-class teams of researchers, often from multiple institutions, bringing together leading scientists from universities, National Laboratories, nonprofit organizations, and for-profit firms. These integrated, multi-investigator Centers are tackling some of the toughest scientific challenges hampering advances in energy technologies.

The EFRCs are addressing research challenges relevant to a wide range of energy technologies including solar energy utilization, electrical energy storage, carbon capture and sequestration, advanced nuclear systems, catalysis, bioscience, materials in extreme environments, hydrogen science, solid state lighting, and superconductivity. The EFRCs provide an important bridge between basic research and energy technologies, and complement other research activities funded by the DOE. EFRCs accelerate energy science by providing an environment that encourages high-risk, high-reward multidisciplinary research that would not be done otherwise; integrating synthesis, characterization, theory, and computation to accelerate the rate of scientific progress; developing new, innovative experimental and theoretical tools that illuminate fundamental processes in unprecedented detail; and training an enthusiastic, inter-disciplinary community of energy-focused scientists.

EFRCs by the Numbers

The EFRC program commenced in 2009; 46 Centers were selected by scientific peer review and funded at $2-5 million per year for a five-year initial award period. An open re-competition of the program in 2014 resulted in four-year awards to 32 centers, 22 of which are renewals of existing EFRCs and 10 of which are new EFRCs. The following statistics, collected in June 2015, refer to the first cohort of 46 EFRCs (2009 – 2014) and the first year of the second cohort of 32 EFRCs (2014-2015).

The Participants:

- The typical EFRC is funded at approximately $3.0M per year and involves between 15 and 20 senior investigators
- Most are multi-institutional centers led by universities and DOE National Laboratories, with some involvement by nonprofit organizations and industry
- Current EFRCs involve 530 senior investigators and, on a full- or part-time basis, an additional estimated 1250 researchers, including postdoctoral associates, graduate students, undergraduate students, and technical staff, at over 100 participating institutions, located in 33 states plus the District of Columbia

The Scientific and Workforce Impact:

- Over 6,500 peer-reviewed publications
- As reported by the EFRCs, students and staff are entering the workforce:
  - At least 550 to industrial positions
  - At least 425 to university faculty and staff positions
  - At least 225 to National Laboratories, government and not-for-profit positions

Technology Impact:

- ~340 U.S. patent applications and 210 foreign patent applications
- ~430 unpatented invention disclosures
- ~100 licensed disclosure or patents

- ~85 companies have benefited from EFRC research. The EFRC contributions span the energy landscape:
  - ~35% in Low-Carbon Power (non-nuclear)
  - ~15% in Energy Storage
  - ~10% in Energy Efficiency
  - ~40% in Chemical, Physical, Materials, Biological, and Geological Sciences Applications

The EFRCs program is funded and managed by the DOE Office of Science Basic Energy Sciences program. For more information visit science.energy.gov/bes/efrc/.

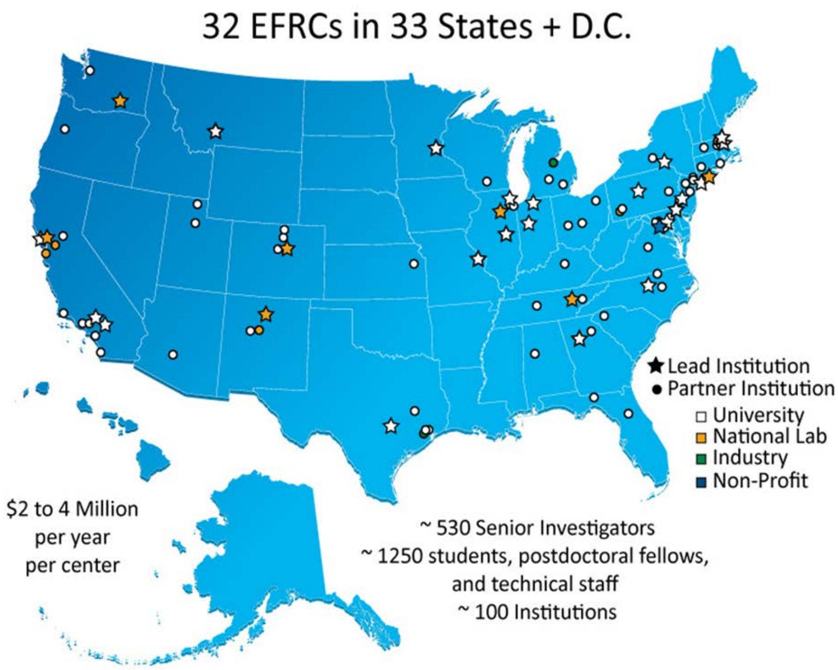


Figure 6. Map of Energy Frontier Research Centers

6.4 The Accelerator Stewardship Research and Development Program

Within DOE's Office of Science (SC), the High-Energy Physics (HEP) program has traditionally functioned as steward for long-term, fundamental accelerator R&D. This stewardship of "discovery science" accelerator R&D needs has served all of the SC programs. Accelerators are a key element of many SC programs, including Basic Energy Sciences (BES), Fusion Energy Sciences (FES), Nuclear Physics (NP), and, of course, HEP itself. Some of these programs have partnered with the Advanced Scientific Computing Research (ASCR) program to sponsor research in the computationally intensive aspects of accelerator science via the SciDAC (Scientific Discovery through Advanced Computing) program.

In recent years, it has become apparent that accelerator R&D stewardship should be carried out in a broader context than simply discovery science. Accelerators are critical to many areas beyond their traditional role in discovery science, and they influence our everyday lives in myriad—though typically unrecognized—ways. Because of our traditional involvement in this area, HEP was designated by the Office of Science to oversee long-term accelerator stewardship activities within SC, in close consultation with other SC programs.

The Accelerator Stewardship program spans three principal activities: improving access to SC accelerator R&D infrastructure for industrial and other users; near-term translational R&D to adapt accelerator technology for medical, industrial, security, defense, energy and environmental applications; and long-term R&D for the science and technology needed to build future generations of accelerators. HEP manages this program in close consultation with other Office of Science programs, including Nuclear Physics and Basic Energy Sciences, and in consultation with other federal stakeholders of accelerator technology, most notably DOD, NSF, DNDO, and NIH.

Accelerator Stewardship pursues targeted R&D to develop new uses of accelerator technology with broad applicability. Initial workshops and requests for information identified three target application areas with broad impact: accelerator technologies for ion beam therapy of cancer, laser technologies for accelerators, and energy and environmental applications of accelerators. Awards were made to teams of researchers to increase the performance and reduce the size of cancer therapy machines (by 10x), increase the speed of scientific lasers (by more than 1000x), and develop efficient accelerator power sources that can save LCLS more than $1 M per year in energy costs.

The Accelerator R&D Stewardship subprogram also supports facility operations through two mechanisms: a dedicated Accelerator Stewardship facility (the Brookhaven Accelerator Test Facility (ATF)) and the Accelerator Stewardship Test Facility Pilot Program. The Brookhaven ATF is a low-power electron and laser test facility dedicated to accelerator studies. Beam time at the ATF is awarded based on a merit-based peer review process. The ATF currently supports more than twenty user experiments with more than one third being conducted by the private sector.

The Accelerator Stewardship Test Facility Pilot Program launched in FY 2015, and provides seed funding and/or operations support to engage a broader user community, including industry users, at seven Office of Science National Laboratories (ANL, BNL, Fermilab, LBNL, ORNL, SLAC, and TJNAF). Unlike the SC user facilities, this class of SC assets is frequently unseen and underexploited by the broader community. A public portal has been created, and public events were held to make the broad community aware of these facilities, reaching over 450 members of the public at six DOE Labs. More than thirty proposals to use facilities and expertise were made, and seven were seed-funded through a competitive peer-reviewed process. The experience gained from the pilot program will be used to formulate a long-term mechanism for making SC's unique accelerator test facilities more available.

To publicize our accelerator R&D stewardship activities, the Accelerators for America's Future website serves as a source of information on the uses of accelerators for science and society at large, the activities and meetings of relevance to both accelerator providers and users, reports of key workshops, and other accelerator-related resources of interest to these communities. Most importantly, the site maintains links to the accelerator-related capabilities of the DOE National Laboratories to facilitate making contact with these institutions in support of DOE's accelerator R&D stewardship activities.

The Accelerator Stewardship program was authorized by Congress in 2014, and the program is in its third year of execution.

7. Applied Energy Research and Development Partnerships and Initiatives

The DOE brings some of the nation's best scientific minds and capabilities to address our energy challenges and implement the President's strategy for growing our economy and ensuring our national security. DOE's mission is to advance the energy, environmental, and nuclear security of the United States and to promote scientific and technological innovation in support of that mission. The following programs support our nation's continued leadership in RDD&D of energy technologies, U.S. job creation, long-term economic growth and national security.

7.1 Advanced Research Projects Agency-Energy

The Advanced Research Projects Agency – Energy (ARPA-E) was established by the America COMPETES Act of 2007 following a recommendation by the National Academies in the *Rising Above the Gathering Storm* report[30]. ARPA-E is tasked with funding energy projects that identify and promote revolutionary advances in fundamental and applied sciences, translating scientific discoveries and cutting-edge inventions into technological innovations; and accelerating transformational technological advances in areas that industry by itself is not likely to undertake due to technical and financial uncertainty.

Projects supported by ARPA-E must address at least one of ARPA-E's goals:

1. Enhance the economic and energy security of the United States through the development of energy technologies that result in:
    a. reductions of imports of energy from foreign sources;
    b. reductions of energy-related emissions, including greenhouse gases; and
    c. improvement in the energy efficiency of all economic sectors.
2. Ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

During execution of the projects, ARPA-E Program Directors provide awardees with technical guidance that combines scientific expertise and industry experience, while ARPA-E technology-to-market advisors supply awardees with critical business insight and strategies to move technologies toward market realization. The technology-to-market program also provides awardees with practical training and critical business information to equip projects with an understanding of market needs to guide technical development and help projects succeed.

A key component of the ARPA-E model is hands-on engagement with awardees. ARPA-E works with awardees to rectify issues that may arise during the life of their projects (which

[30] National Academies in the Rising Above the Gathering Storm. 2007. nap.edu/catalog.php?record_id=11463

typically run for three years), and in cases where issues cannot be resolved ARPA-E discontinues those projects.

In the relatively short time since its official launch in 2009, the Advanced Research Projects Agency (ARPA-E) has implemented a unique model for the support and management of high-risk energy research. ARPA-E uses assessments by subject matter experts as well as metrics of activity and progress to guide its project management and planning (Table 8). ARPA-E's project management includes a strong emphasis on moving prototype technology from the laboratory to the marketplace, so key metrics include new company formation, follow-on funding from the private sector, support for technology demonstration, and/or product development from other Government sources.

Table 8. ARPA-E Metrics (FY 2010-2015)

	2010	2011	2012	2013	2014	2015	Total
Programs	6	5	3	6	3	8	31
New projects	96	20	68	98	87	72	441
New projects led by DOE Lab	4	1	9	6	6	6	32
New projects with DOE Labs as collaborators	2	0	15	26	13	6	62
Projects led by small company (<500 employees)	33	6	18	30	32	18	137
Journal Publications	n/a	n/a	134	262	217	235	848
New company start-ups*	n/a	n/a	12	12	6	6	36
Projects with follow-on funding from the private sector*	6	5	6	5	12	11	45
Follow-on funding from private sector*	>$100 million	>$100 million	>$250 million	>$175 million	>$225 million	>$400 million	>$1.25 billion
Projects with follow-on funding from other government sources*	n/a	n/a	10	6	21	23	60

ARPA-E provides annual reports to Congress which can be found on the ARPA-E website at arpae.energy.gov/?q=about/documentation/annual-reports.

* Values are estimates derived from publicly available information and voluntary reporting by project alumni and, therefore, are conservative in nature. The values are compiled through February of the following year (e.g., for 2013, the values given were compiled through February of 2014).

Additional Table Notes:

(1) Several metrics were tracked as of later years, as indicated by the "n/a" entries.

(2) From the Agency's official launch in 2009 through the end of Fiscal Year 2015, ARPA-E projects (including both active and closed projects) have produced 1,062 subject matter inventions and 370 patent applications, for which 101 patents have been issued."

Outside of ARPA-E's cooperative agreements, ARPA-E makes SBIR awards in three phases through two types of combined awards: (1) Phase I/Phase II awards funded up to $1,725,000 with a period of performance up to 36 months; and (2) Phase I/Phase II/sequential Phase II awards funded up to $3,225,000 with a potential period of performance of up to 48 months.

As of February 2016, ARPA-E has funded approximately $1.3 billion over more than 475 projects through 30 focused programs and three open funding solicitations. While success of these programs and projects will ultimately be measured by impact in the marketplace, ARPA-E looks at various metrics to measure progress towards eventual market adoption including several types of "hand-offs" for the next stage of the project. As of February 2016, ARPA-E has successfully facilitated numerous hand-offs including:

- At least 36 ARPA-E project teams have formed new companies to advance their technologies;
- Several ARPA-E awardees have announced strategic partnerships with established industry participants, ranging from jointly developing a demonstration site to being acquired by the larger company; and
- Over 60 ARPA-E projects have partnered with other government agencies for further development.

In addition, 45 ARPA-E projects have attracted more than $1.25 billion in private-sector follow-on funding after ARPA-E's investment. ARPA-E provides annual reports to Congress which can be found at arpae.energy.gov/?q=about/documentation/annual-reports.

7.2 Cybersecurity for Energy Delivery Systems

The DOE Office of Electricity Delivery and Energy Reliability (OE) Cybersecurity for Energy Delivery Systems (CEDS) program partners with the energy sector to research and develop cybersecurity protections tailored to the needs of energy delivery systems, aligned with the Roadmap[31]. The goal of CEDS is to enhance the reliability and resiliency of the nation's energy infrastructure by reducing the risk that energy delivery could be disrupted by cyber-attacks. Examples of CEDS R&D efforts that transitioned to practice are shown in Table 9.

Table 9. Examples of Tech Transitions from CEDS R&D Efforts

Organization	Description
R&K Cyber Solutions LLC	• In January 2015, the Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL) licensed Hyperion software technology to R&K Cyber Solutions LLC. • Hyperion is software that can quickly recognize malicious software even if the specific program has not been previously identified as a threat. • By computing and analyzing program behaviors associated with harmful intent, the software can look inside an executable program to determine the software's behavior without using its source code or running the program, thereby detecting vulnerabilities and uncovering malicious content before it has a chance to execute.
Applied Communication Sciences (Vencore Labs)	• Applied Communication Sciences (now Vencore Labs) developed innovative technology to provide anomaly and intrusion detection for Advanced metering infrastructure (AMI) and distribution automation (DA) wireless mesh networks. • As of June 2015, this technology is operational at the Sacramento Municipal Utility District (SMUD), Hawaiian Electric, Commonwealth Edison (ComEd), and Baltimore Gas & Electric (BGE). • SMUD has entered into an ongoing service agreement to use the SecureSmart service as "their eyes on network", relying upon ACS to monitor both their AMI and DA systems.
SEL	• SEL's Exe-Guard technology helps prevent unexpected cyber-activity, provides malware protection while maintaining high reliability, and is specifically developed for energy delivery control systems. • In December 2015, the project team transferred the research result of the Exe-Guard project to the Open Source community. • Exe-Guard is fully commercialized in six products from SEL and there are plans for more products to be released with the technology integrated in the near future.

[31] *Roadmap to Achieve Energy Delivery Systems Cybersecurity*: energy.gov/sites/prod/files/Energy%20Delivery%20Systems%20Cybersecurity%20Roadmap_finalweb.pdf

7.3 Regional Carbon Sequestration Partnerships

In 2003, the U.S. Department of Energy's Office of Fossil Energy awarded cooperative agreements to seven Regional Carbon Sequestration Partnerships (RCSPs). These public-private partnerships are comprised of more than 400 organizations covering 43 states and four Canadian provinces, including representatives from state and local agencies, regional universities, National Laboratories, non-government organizations, foreign government agencies, engineering and research firms, electric utilities, oil and gas companies, and other industrial partners (Figure 7. Regional Carbon Sequestration Partnerships Map). The RCSPs are

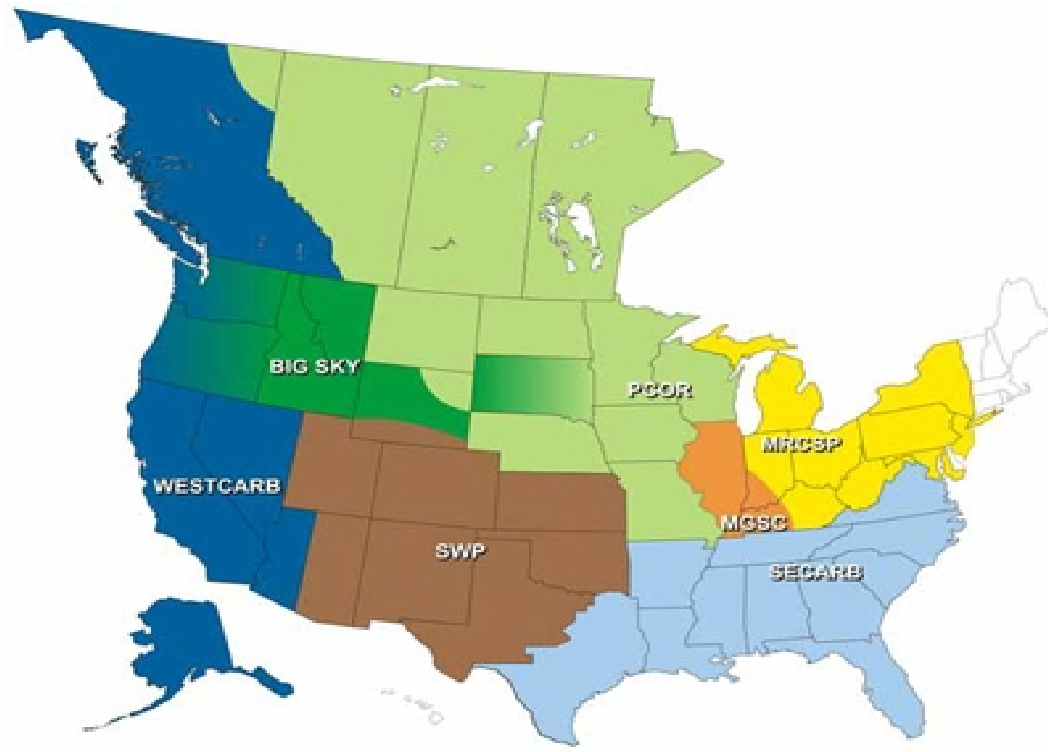


Figure 7. Regional Carbon Sequestration Partnerships Map

helping to develop the technology and infrastructure needed for implementing large-scale CO_2 in their respective regions and geologic formations, and to inform on policy issues and regulatory framework development.

The RCSPs have taken a phased approach to addressing technology development and safe geologic storage practices necessary to progress toward commercialization of the technology. A description of these phases and their respective objectives were outlined in the Report on Technology Transfer for Fiscal Year 2014[32].

In Fiscal Year 2015 the Regional Partnerships, in collaboration with multiple national laboratories and other research institutions, continued working to implement their respective large-scale field tests involving at least 1 million metric tons of CO_2 per project. The field tests

[32] Section 7.3. Regional Carbon Sequestration Partnerships. "Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014." U.S. Department of Energy. June 2016. energy.gov/sites/prod/files/2016/06/f33/Technology%20Transfer%20Report%20to%20Congress%20FY14.pdf

are demonstrating the long-term, effective, and safe storage and utilization of CO_2 in the major geologic formations throughout the United States and portions of Canada. Since 2009 the Regional Partnerships stored 6 million metric tons of CO_2 to validate formation capacity and demonstrate safe and permanent storage. The lessons learned to date have been compiled and are now being incorporated into the next round of Best Practice Manuals shown in Table 10, which will be released in Fiscal Year 2016.

Table 10. Carbon Sequestration Schedule of Manuals

Best Practices Manual	Version 1 (Phase II)	Version 2 (Phase III)	Final Guidelines (Post Injection)
Monitoring, Verification and Accounting (MVA) for Geologic Storage Projects	2009/2012	2016	2020
Public Outreach and Education for Geologic Storage Projects	2009	2016	2020
Site Screening, Selection, and Characterization for Geologic Storage Projects	2013	2016	2020
Risk Analysis and Simulation for Geologic Storage of CO_2	2010	2016	2020
Operations for Geologic Storage Projects	-	2016	2020

7.4 Carbon Capture, Utilization and Storage Technologies (CCUS)

DOE's Carbon Capture Program, administered by the Office of Fossil Energy and the National Energy Technology Laboratory, is conducting R&D activities on Second Generation and Transformational carbon capture and utilization technologies that have the potential to provide step-change reductions in both cost and energy penalty as compared to currently available first generation technologies. The primary goal of the carbon storage research is to understand the behavior of Carbon dioxide (CO_2) when stored in geologic formations. This information is important to ensure that carbon storage will not affect the structural integrity of an underground formation, and that CO_2 storage is secure and environmentally acceptable. CO_2 utilization efforts focus on pathways and novel approaches for reducing CO_2 emissions by developing beneficial uses for the CO_2 that will mitigate CO_2 emissions in areas where geologic storage may not be an optimal solution. CO_2 can be used in applications that could generate significant benefits. It is possible to develop alternatives that can use captured CO_2 or convert it to useful, revenue generating, products such chemicals, cements, or plastics.

Processes or concepts must take into account the life cycle of the process to ensure that additional CO_2 is not produced beyond what is already being removed from or going into the atmosphere. Furthermore, while the utilization of CO_2 has some potential to reduce greenhouse gas emissions to the atmosphere, CO_2 has certain disadvantages as a chemical reactant. Carbon dioxide is rather inert and non-reactive. This inertness is the reason why CO_2 has broad industrial and technical applications.

Section 7.4 of the Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014 provides details of major CCUS demonstration projects.[33] These projects are summarized briefly in Table 11.

[33] Section 7.4. Carbon Capture, Utilization, and Storage. "Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014." U.S. Department of Energy. June 2016. energy.gov/sites/prod/files/2016/06/f33/Technology%20Transfer%20Report%20to%20Congress%20FY14.pdf

Table 11. Carbon Capture, Utilization, and Storage Technologies: Major Demonstration Projects

Project	Description	DOE Cost Share	Key Technology
Southern Company IGCC, Plant Ratcliffe in Kemper County, Mississippi	• Pre-combustion technology • 582 MW (net) generation • 67% CO_2 capture for EOR	• \$270 million (CCPI-2) • \$136.7 million (Section 313, FY16 Consolidated Appropriations Act)	Operational experience with the new scaled-up Transport Integrated Gasifier (TRIG™) using local Lignite coal and utilizing Selexol® CO_2 separation technology applicable to newly-built commercial power plants.
Peta Nova (NRG W.A. Parish Project) in Thompsons, Texas	• Post-combustion retrofit of existing coal unit with new CCS technology • 240 MW (net) generation • 90% CO_2 capture for EOR	• \$167 million (CCPI-3) • \$23.3 million (Section 313, FY16 Consolidated Appropriations Act)	Operational experience with retrofit of existing coal plant to capture and treat the gas stream for CO_2 removal using the KM CDR process. Potentially applicable to the nearly 40% of existing U.S. power generation fleet that uses coal.
Air Products and Chemicals Inc. at Valero Refinery in Port Arthur, Texas	• Post-combustion ICCS at Hydrogen production facility • +90% CO_2 capture for EOR	• \$284 million	Operational experience with industrial CO_2 capture at oil refinery hydrogen production facility using Vacuum Swing Adsorption (VSA) CO_2 capture technology. Project is in use and is a showcase for industrial CCUS technology.
Archer Daniels Midland (Biofuel Plant) with Geologic Storage in Decatur, Illinois	• Post-combustion ICCS at corn to ethanol production facility • +99% CO2 capture for geologic storage	• \$141 million	Operational experience with industrial CO_2 capture and geologic storage in the Mt. Simone Sandstone formation saline reservoir. Project has a negative carbon footprint since the CO_2 that would normally be released into the atmosphere will be captured and sequestered. National Sequestration Educational Center (NSEC) created as part of the public outreach effort of this project.

7.5 Crosscutting Technology Research Program Extreme Environment Materials: Advanced Ultra-Supercritical (AUSC) Consortium

The Office of Fossil Energy supports the Extreme Environment Materials Program, which focuses on materials R&D that will lower the cost and improve the performance of fossil-based power-generation systems. New materials are essential for advanced power generation systems with carbon capture and storage capability to achieve performance, efficiency, and cost goals. Materials of interest are those that enable components and equipment to perform in the harsh environments of an advanced power system. A significant focus for this program has been development of materials that enable improvement in the efficiency of fossil power generation.

The National Energy Technology Laboratory is working with industry, National Labs and non-profit organizations to develop the new materials needed to meet these goals. The Advanced-Ultra-Supercritical (AUSC) Consortium, was formed as part of the Extreme Environments Materials Program to achieve a step increase in the operating efficiency of coal fired Rankin cycle power plants by the use of advanced structural materials. Figure 8 shows how increasing steam temperature & pressure increases thermal efficiency and decreases emissions for power generation from coal.

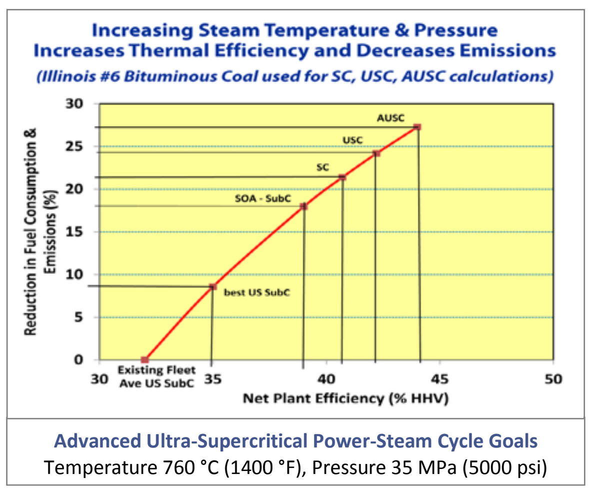


Figure 8. Steam Temperature & Pressure Effects on Thermal Efficiency and Emissions

The AUSC program is focused on performance testing of existing nickel super-alloys that are capable of operating in the harsh environments (e.g. high temperature 760°C and pressure 4000 psi) associated with AUSC operating conditions. Most of these nickel super-alloys were developed for use in gas turbines or jet engines. Testing of these materials was needed in the different and harsh environment of a coal fired boiler. The Consortium is investigating the viability of these alloys for boiler and steam turbine applications at AUSC temperatures and pressures.

Figure 9. Corrosion Test Loop: World's First Steam Loop Operating at 760°C

After a review of existing data on mechanical properties and resistance to oxidation at AUSC temperatures, laboratory scale tests were performed on the most promising alloys to determine relevant mechanical properties, resistance to steam-side oxidation and resistance to fire-side corrosion. The alloys were also tested for their fabricability, weldability, and castability in the forms needed for Rankine cycle power plants and potential application in future Brayton cycle power plants. A key milestone of the boiler materials evaluation work was recently completed in a long term combined fireside/steam corrosion test loop installed at Southern Company's Plant Barry (Figure 9).

Analyses of the exposed alloys indicate very good resistance to fireside corrosion during the test period with the type of coal used in the plant's boiler.

The AUSC program also conducted research on materials for an AUSC steam turbine. A steam turbine capable of operating at the same temperature as the high-temperature steam delivers from an AUSC boiler is also needed. The steam turbine materials project focused on a few selected nickel super alloys for casting or forging into components. Work focused on developing the specific methods for casting these materials and determining the weldability, mechanical properties and reparability of the candidate alloys for turbine rotors, casings and valves. Studies were performed to establish a design basis for commercial scale components. Two significant accomplishments of this project were the first triple melt Haynes 282 forging ingot and the world's largest Haynes 282 valve body casting.

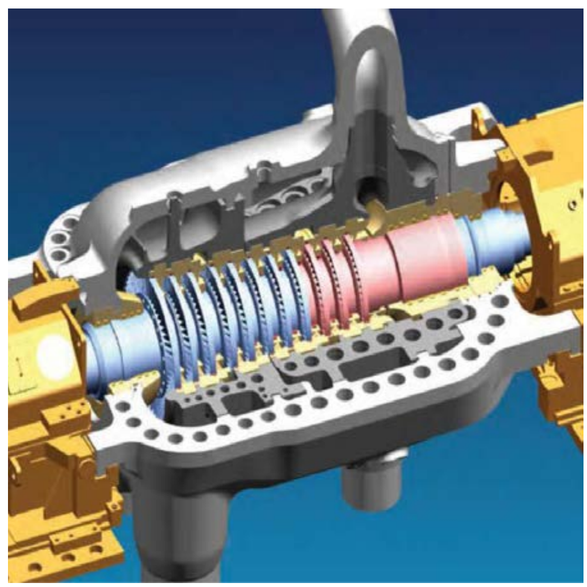


Figure 10. An impulse design High Pressure section for an Advanced Ultra Supercritical Steam Turbine

The goal of the AUSC Program is to reduce the identified risk barriers to full-scale demonstration and ultimately commercial deployment of a coal fired power plant operating at ASUC temperatures and pressures. The AUSC Consortium has completed the Pre-FEED for a

Component Test Facility ("ComTest") that will define the performance requirements of key components of an AUSC power plant: design; tests for suitably sized components; and finally design, fabricate and test these components at AUSC conditions at this facility where operation of scalable components can be tested for sufficient amount of hours to gather data needed for the design of an a commercial scale AUSC demonstration power plant. Figure 10 shows an impulse design for the steam turbine.

7.6 National Risk Assessment Partnership

The National Risk Assessment Partnership (NRAP) is an initiative within DOE's Office of Fossil Energy and led by the National Energy Technology Laboratory that applies DOE's core competency in science-based prediction for engineered–natural systems to the long-term storage of CO_2. The science-based prediction of engineered–natural systems is a core competency that cross cuts many of today's energy challenges. Over decades, DOE has built a unique set of resources for predicting how these complex and heterogeneous systems behave under extreme conditions and over large ranges in time.

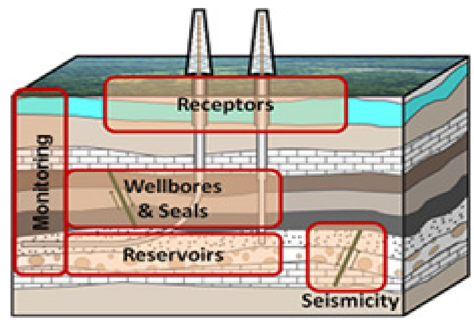


Figure 11. Carbon Capture and Storage

Carbon capture and storage (CSS) can be an effective way to reduce CO_2 emissions, and its technological feasibility is quickly becoming a reality, but business and regulatory concerns still block the way to its rapid commercial deployment. Industry investors worry about the uncertainties and potential liabilities inherent in owning an operation that must remain secure and intact for hundreds, if not thousands, of years. Regulators also need broad technical information to address CO_2 storage. One way to aid these decision makers is to reduce uncertainty by predicting and quantifying the long-term risks of CCS. The National Risk Assessment Partnership (NRAP) is developing a science-based methodology to do just that.

NRAP leverages the broad technical capabilities of its National Laboratory complex to break down the barriers to commercial deployment of CO_2 storage. NRAP's basic goals are to: (1) Build a suite of science-based tools to predict the performance of CO_2 storage sites; (2) Use those tools to elucidate key storage-security relationships across a range of potential scenario; and (3) Develop monitoring and mitigation protocols to reduce risk and uncertainty.

Site operators can rely on the tools, methodologies, and key findings generated by NRAP to develop risk management strategies, such as cost-effective monitoring and mitigation plans, tailored to specific sites. Regulators can rely on the tools, methodologies, and key findings to inform decisions related to CCS. Armed with the ability to quantify risk and to estimate the cost of long-term liability, industry will gain the confidence to invest in CCS projects and regulators will gain the confidence in predictions of CCS site performance.

NRAP Successes

- Generated the first publicly available quantitative risk calculation for a complete CO_2 storage system.

- Created the first comprehensive risk model for induced seismicity.
- Quantified the leakage potential for a range of CO_2 storage cases over a 1,000-year period.
- Developed several reduced-order models for every component of the storage system.
- Conducted experiments to validate phenomena important to risk assessment.
- Demonstrated the use of electrical resistivity tomography to remotely detect CO_2-saturated groundwater.
- Identified no-impact thresholds for groundwater quality.
- Combined early detection methods in a novel strategy to quantify the occurrence and magnitude of leakage event

Appendix A – Technology Transfer Offices at DOE National Labs and Facilities

Table 12. Technology Transfer Offices at DOE National Labs and Facilities

Technology Transfer Offices at DOE National Labs and Facilities			
Ames Office of Sponsored Research Administration	Stacey Joiner	joiner@ameslab.gov	515.294.5932 ameslab.gov/techtransfer
Argonne Office of Technology Development and Commercialization (TDC)	Suresh Sunderrajan	Ssunderrajan@anl.gov	630.252.8111 anl.gov/technology
Brookhaven Office of Technology Development and Commercialization (TDC)	Lee Cheatham	lcheatham@bnl.gov	631.344.8941 bnl.gov/techtransfer/
Fermi Lab Office of Partnerships and Technology Transfer	Cherri Schmidt	cherri@fnal.gov	630.840.5178 N/A
Idaho National Laboratory Technology Deployment Office	Mark Kaczor	mark.kaczor@inl.gov	208.526.0360 inl.gov/inl-initiatives/technology-deployment/
LBNL Innovation and Partnerships Office (IPO)	Elsie Quaite-Randall	equaiterandall@lbl.gov	515.486.7234 lbl.gov/tt/
LLNL Industrial Partnerships Office (IPO)	Richard Rankin	rankin8@llnl.gov	925.423.9353 ipo.llnl.gov
LANL Office of Market Transition within the Richard Feynman Center for Innovation	David Pesiri	pesiri@lanl.gov	505.665.7279 lanl.gov/projects/feynman-center/
NETL Office of Technology Transfer	Jessica Sosenko	jessica.sosenko@netl.doe.gov	412.386.7417 netl.doe.gov/business/tech-transfer/
NREL Office of Technology Transfer within the Office of Innovation Partnering and Outreach	Kristin Gray	kristin.gray@nrel.gov	303.275.3050 nrel.gov/technologytransfer/
National Security Campus	Angie Ladwig	aladwig@kcp.com	816.488.5676 N/A
Nevada National Security Site	Monica Sanchez	Monica.Sanchez@nnsa.doe.gov	702.295.2309 N/A
ORNL Office of Technology Transfer within the Office of Science and Technology Partnerships	Jennifer Caldwell	caldwelljt@ornl.gov	865.574.4180 ornl.gov/partnerships
PNNL Office of Technology Commercialization (OTC)	Peter Christensen	peter.christensen@pnnl.gov	509.375.6159 pnnl.gov/business/tech_transfer.aspx
Pantex Technology Transfer	Perry Kent	pkent@pantex.com	806.477.5422 N/A
PPPL Office of Technology Transfer, Patents and Publications	Laurie Bagley	lbagley@pppl.gov	609.243.2425 pppl.gov/organization/technology-transfer
Sandia Industry Partnerships Office	Peter Atherton	prather@sandia.gov	505.284.3768 sandia.gov/working_with_sandia/technology_partnerships/index.htm
Savannah River Office of Research and Technology Partnerships	Chuck Meyers	Chuck.Meyers@srs.gov	803.725.3020 srs.gov/general/srnl/tech_transfer/tech_transfer.htm
SLAC Office of Intellectual Property and Research Partnerships	Jan Tulk	jtulk@slac.stanford.edu	650.926.5701 N/A
Jefferson Lab Technology Transfer and Invention Review Committee	Joseph L. Scarcello	scarcell@jlab.org	757.269.7027 jlab.org/exp_prog/techtransfer/
Y-12 Office of Commercialization and Partnerships	Jeremy Benton	jeremy.benton@cns.doe.gov	865.574.5981 N/A

Appendix B – Technology Transfer Data for Fiscal Years 2010-2015

The Technology Transfer Commercialization Act of 2000 (P.L. 106-404) requires each federal agency that operates or directs federal Laboratories or that engages in patenting or licensing of federally owned inventions to provide the Office of Management and Budget (OMB) with an annual report on its technology transfer plans and recent achievements. A copy is also provided to the Department of Commerce's National Institute of Standards and Technology (NIST), where that Secretary prepares an overall federal assessment of technology transfer activities for the President and Congress based on the program information in these agency reports such as DOE's. Specific data requirements to be reported each year are established by NIST.

In accordance with OMB's reporting guidelines, DOE's technology transfer data for fiscal years 2010-2015 are in Section 3 with additional information shown in the tables below. Section 3 also includes two figures illustrating historical trends. A glossary of terms is provided at the end of this section.

The tables below for FY 2010 through FY 2015 quantify additional issues regarding DOE's technology transfer metrics. Shown in Table 13, non-federal SPPs is a much larger component of industrial interactions than CRADAs, with more than 2,300 SPP agreements active per year vs 700 CRADA agreements. Both non-federal SPP and CRADA numbers have been relatively stable over the last five years.

Table 13. CRADAs and Non-federal SPP

	FY10	FY11	FY12	FY13	FY14	FY15
CRADAs, total active* in the FY	697	720	742	742	704	734
Number with small businesses	264	264	265	237	245	257
New, executed in the FY	176	208	184	142	180	184
CRADA funds in (thousands)	$62,332	$68,178	$64,221	$61,818	$70,080	$ 64,848
Non-Fed SPP**, total active in the FY	2,222	2,273	2,519	2,733	2,021	2,395
Number with small businesses	382	409	429	439	390	420
New, executed in the FY	668	688	747	992	800	775
Non-federal SPP funds in (thousands)	$287,370	$264,343	$285,113	$283,462	$239,765	$249,024

* Active means legally in force at any time during the FY

** SPP – Strategic Partnership Projects (see Appendix C - Glossary for definition)

nr – not recorded

As shown in Table 14, DOE's success rate in patents issued has decreased slightly during the last year from 822 to 755. Patent applications issued has remained relatively stable.

Table 14. Invention Disclosure, Patenting and Commercialized Technologies

	FY10	FY11	FY12	FY13	FY14	FY15
New inventions disclosed in the FY*	1,616	1,820	1,661	1,796	1,588	1,645
U.S. patent applications filed	965	868	780	845	962	856
Foreign patent applications filed	86	192	153	99	182	93
U.S. patents issued	480	460	483	554	693	632
Foreign patents issued	177	143	193	159	129	123
Commercialized Technologies	nr	858	310	338	482	577

* Inventions arising at the DOE Laboratories and Facilities

Table 15 shows a more detailed breakdown of the types of licensing activities. Patent licensing decreased in FY 2015 to 1,336, down from 1,560 in FY 2014. The rate of copyright licenses is much higher than other license types at 4,687. In addition, Table 16 shows that the majority of licensing income (more than 85%) is received from patent licenses.

Table 15. Profile of Active Licenses

	FY10	FY11	FY12	FY13	FY14	FY15
All licenses, total active* in the FY	6,224	5,310	5,328	5,217	5,861	6,310
New, executed in the FY	822	665	757	568	573	648
Patent licenses, total active in the FY	1,453	1,432	1,428	1,353	1,560	1,336
New, executed in the FY	166	169	192	153	171	155
Copyright licenses, total active in the FY	3,338	3,291	3,323	3,610	3,980	4,687
New, executed in the FY	339	362	423	358	330	440
Other** licenses, total active in the FY	1,433	587	577	254	321	287
New, executed in the FY	317	134	142	57	72	53

* Active means legally in force at any time during the FY

** Bailment or trademark

Table 16. Licensing Income

(thousands of $)	FY10	FY11	FY12	FY13	FY14	FY15
Total Licensing Income Received	$40,642	$44,728	$40,849	$39,573	$37,885	$33,137
Patent Licenses	$37,066	$40,600	$36,103	$36,068	$32,869	$28,966
Copyright Licenses	$2,762	$3,983	$4,075	$3,315	$3,663	$3,939
Other Licenses	$814	$145	$671	$190	$1,353	$232
Total Royalty Income Earned	$25,220	$27,107	$28,735	$27,669	$23,384	$21,245

Appendix C – Glossary

Technology partnering encompasses several activities, and the most appropriate partnering mechanism depends on the objective of each partner. The most commonly used technology transfer mechanisms are described below.

- **Cooperative Research and Development Agreements (CRADAs).**[34] A legal agreement between government laboratories and nonfederal parties in which both participants agree to collaborate, by providing personnel, services, facilities, or equipment and pool the results from a particular research and development program. The nonfederal parties must provide funds or in kind contributions (no direct funding is provided by the laboratory). Rights to inventions and other intellectual property are negotiated between the laboratory and participant, and certain data that are generated may be protected for up to five years. DOE guidance is provided through DOE Order 483.1 and DOE manual 483.1-1.
- **Strategic Partnership Projects (SPPs).** Performing work for non-DOE sponsors under DOE Order 481.1. SPP agreements permit reimbursable R&D to be carried out at DOE National Laboratories and Facilities. This work is categorized into work for federal agencies and non- federal entities (NFE). It is the NFE work that is included as technology partnering in this report. For proprietary R&D conducted for NFEs, the federal laboratory or facility is reimbursed by the NFE sponsor for the full cost of the activity. Intellectual property rights generally vest in the NFE but may be negotiated.
- **Licensing.** Licensing is the negotiating and entering into license agreements and bailments that provide rights in intellectual property (IP) made, created, or acquired at or by a DOE facility and which is controlled or owned by the contractor for that facility. A license transfers *less* than ownership rights to intellectual property, such as a patent or software copyright, to permit its use by the licensee. Licenses may be exclusive, or limited to a specific field of use, or limited to a specific geographical area. A potential licensee must present plans for commercialization. Royalties and income are often associated with the licensing.
- **Personnel Exchanges.** These arrangements allow facility staff to work in a partner's technical facilities, or the partner's staff to work in the government Laboratory, in order to enhance technical capabilities and/or support research in certain areas. Costs are typically borne by the sponsoring organization. IP arrangements may be negotiated as part of these exchanges. (Personnel Exchange activities are not included in this report.)
- **Technical Assistance**. Technical consulting usually takes the form of technical assistance to small businesses, undertaken in response to an inquiry or request for such assistance from an individual or organization seeking knowledge, understanding or solutions to a problem, or means to improve a process or product. For example, Sandia and Los Alamos lead the New Mexico Small Business Assistance (NMSBA) program with partner universities. In 2013, the program provided targeted technical support to 354 small businesses. The extent of such consulting is limited to a relatively low level of overall effort, but the relative impact to a small business may be large (Technical assistance activities have not been included in this report.).

[34] CRADA, energy.gov/gc/laboratory-partnering

Appendix D – DOE R&D 100 Awards (FY 2015)

U.S. Department of Energy (DOE) researchers have won 33 of the 100 awards given out this year by R&D Magazine for the most outstanding technology developments with promising commercial potential. The R&D 100 awards, sometimes called the "Oscars of Innovation," are given annually in recognition of exceptional new products or processes that were developed and introduced into the marketplace during the previous year.

To be eligible for an award, the technology or process has to be in working and marketable condition—no proof of concept prototypes are allowed—and had to be first available for purchase or licensing during 2014.

Since 1962, when the annual competition began, the Energy Department's National Laboratories have received more than 800 R&D 100 awards. The awards are selected by an independent panel of judges based on the technical significance, uniqueness and usefulness of projects and technologies from across industry, government and academia.

The list of corresponding technologies and National Labs follows below. Please note that many of these were developed in collaboration with private companies or academic institutions.

ARGONNE NATIONAL LABORATORY

- The Binary Pseudo-Random Calibration Tool, developed by researchers at Argonne, Brookhaven and Lawrence Berkeley national Laboratories with collaborators at Abeam Technologies Inc., provides the highest resolution ever achieved, 1.5 nanometers, and is used to characterize all advanced imaging systems from interferometers to electron microscopes. This new technology can calibrate a broad range of optical instruments, including those used for extreme ultraviolet lithography and high-precision visible light optics. Metrology techniques are used in practically all branches of modern industry, including interferometric microscopes, scanning and transmission electron microscopes, X-ray microscopes, and atomic force microscopes.
- Versatile Hard Carbon Microspheres Made from Plastic Waste: This technology, developed by researchers at Argonne and Purdue University, allows the inexpensive 2- to 5-micrometer hard carbon microspheres made from unsorted plastic waste to be turned into a wide range of high-value applications. The carbon microsphere manufacturing process completely destroys unwanted plastic waste in an environmentally responsible manner. The one-step, low-energy, solventless process produces carbon microspheres that can serve important tribological and advanced battery applications, in addition to having many other uses including inks, printer toners, and high-performance composites, ceramics, and polymers.

Read more about these projects at: [anl.gov/](anl.gov/)

BROOKHAVEN NATIONAL LABORATORY

- aFCL is a novel superconducting fault current limiter that can transmit a large amount of electrical energy during the "on" state without any added conduction losses. The device can rapidly (within 1/8 of the cycle) interrupt the flow of energy when an emergency occurs ("off" state), such as a short circuit. The devices can be connected in parallel units and programmed to operate at a specified current level.

Read more about this project at: bnl.gov/world/

LAWRENCE BERKELEY NATIONAL LABORATORY

- OpenMSI is a Cloud-based platform that allows users to view, analyze and manipulate cutting-edge mass spectrometry imaging (MSI) data directly in a Web browser. Scientists use MSI to study tissues, cell cultures and bacterial colonies in great detail, but as resolution of those images increases, so does the size of their data sets. Most MSI data sets now range from tens of gigabytes to several terabytes in size, which makes even basic tasks challenging. However, with OpenMSI, scientists can view, analyze and manipulate MSI data wherever they have an Internet connection. They can also share data and analyses with collaborators by sending them a URL.
- The Continuous Active-Source Seismic Monitoring (CASSM) system offers scientists a continuous imaging of the subsurface – almost to a "movie" of the subsurface – opening a multitude of possibilities for understanding Earth processes. That's important, since scientists exploring Earth's subsurface constantly need to know what is there and what is happening. In emerging fields like geologic carbon sequestration, enhanced oil recovery and earthquake prediction, such knowledge is critical. However, monitoring the subsurface has been hampered by limitations in current monitoring technologies which produce "snapshots" of the subsurface.
- SIREN addresses a key market gap in the gas sensor, detector and analyzer industry. It provides a sensitive, selective, cost-effective, non-toxic and easy-to-use sensor platform for applications ranging from environmental protection, security and health. This technology employs bionanofilms with tunable functionality to create portable devices for detecting small molecules of interest. This is achieved by leveraging genetic engineering and molecular recognition concepts. The biomimetic manufacturing of these films is inspired by nature; turkey skin-like collagen-bundled nanostructures that change color as they are exposed to certain molecules. This invention is also a breakthrough in the concept of nanomanufacturing, as it exploits the unique and natural ability of the bacteriophage to synthesize materials in a self-replicating manner and produce responsive structural color films through a self-assembly process.
- V2G-Sim quantifies second-by-second energy use for any number of different plug-in electric vehicles (PEVs) while driving under varying driving conditions, or while charging. V2G-Sim couples unique sub- models of vehicle powertrain dynamics, vehicle charging and discharging and automated methods to rapidly initialize and execute large numbers of individual vehicle models. Users can also activate built-in models for automated trip-specific drive cycle generation and electrochemical models to predict the internal dynamics and degradation of a vehicle battery. That's importance, since the field of vehicle-grid integration (VGI) has the potential to transform two major energy sectors in the U.S.: transportation and the electricity grid. For this to happen, however, grid operators, the electric power industry and the automobile industry need a tool to accurately predict exactly where and when electricity demands from plug-in electric vehicles (PEVs) will take

place, and whether individual PEVs will have the flexibility to provide grid services while still meeting the mobility needs of each driver.

- Extended Pressure Inductive Coupled Plasma-synthesized Boron Nitride Nanotubes (EPIC BNNTs) address a constraint that has severely limited the scientific study and industrial application of boron nitride nanotubes (BNNTs) – the lack of availability of the synthesized materials. The EPIC BNNTs technology represents a new high-throughput, scalable synthesis method, EPIC, which enables continuous production of BNNTs. EPIC BNNTs are the lightest, strongest material ever made. In addition, EPIC BNNTs have chemical and thermal stability greater than that of carbon fiber, which enables their use in metal and ceramic matrix composites for ultra-high toughness and fracture-resistance alloys and high-performance ceramics.
- A high-capacity anode has been moved from technology to product thanks to a team at Berkeley Lab and Zeptor Corp. – incorporating the technology into a high-capacity rechargeable battery that can double the lifespan of a state-of-the-art lithium-ion battery and increases capacity by 40%. This technology uniquely enables the practical, economical and commercial use of silicon in an anode – ushering in the long-awaited shift from low-capacity graphite anodes to high-capacity silicon ones. At pilot scale, the technology is being tested with initial results showing higher capacity, longer lifespan, significantly improved safety, and lower costs than state-of-the-art battery technologies.

Read more about these projects at: lbl.gov/

LAWRENCE LIVERMORE NATIONAL LABORATORY

- The Large Area Projection Micro Stereolithography (LAPμSL) technology is a 3-D printing device; an image projection micro-stereolithography system that rapidly produces very small features over large areas, by using optical techniques to write images in parallel, as opposed to conventional techniques, which either require mechanical stages move or the rastering of beams to expose pixels in series. That makes LAPμSL distinct from other state-of-the-art 3-D printers, which sacrifice overall part size in exchange for small feature size. Parts produced with LAPμSL can be used as master patterns for injection molding, thermoforming, blow molding and various metal-casting processes. Other commercial applications envisioned for the LAPμSL system include medical devices, dentistry and microfluidics.
- Zero-order Reaction Kinetics (Zero-RK) is a computer code that has significantly advanced predictive computer science for designing next-generation car and truck engines. The code provides an innovative computational method that speeds up simulations of realistic fuels a thousand-fold over methods traditionally used for internal combustion engine research.
- The High-power Intelligent Laser Diode System (HILADS) is a new laser pumping system that employs advances in laser diodes and electrical drivers to achieve two-to-three-fold improvements in peak output power and intensity over existing technology, in a 10 times more compact form that can scale to even larger arrays and power levels. Developed by a team of LLNL scientists and engineers, in partnership with Tucson, Arizona-based Lasertel, HILADS improves upon other laser technologies by providing significantly more optical power at significantly higher intensity in a system with a substantially smaller footprint and

a higher degree of integration. These developments enable the creation of more energetic laser systems that exhibit higher wall plug efficiency.

Read more about these projects at: llnl.gov/

LOS ALAMOS NATIONAL LABORATORY

- SHMTools (Structure Health Monitoring Tools) is a software suite that serves as a modular framework to quickly develop, modify and evaluate custom-designed analysis processes for SHM applications. SHM is quickly becoming an essential tool for improving the safety – and efficient maintenance – of critical structures, such as aircraft, pipelines, bridges, buildings, power plants and wind turbines. Developed by engineers at Los Alamos National Laboratory, SHMTools provides more than 100 advanced and fully documented algorithms, all of which include references to SHM literature. The algorithms cover the complete analysis workflow from data acquisition through data processing and statistical modeling to decision making. SHMTools, including its standardized data sets and examples, is publicly available as open source for use and expansion by both SHM researchers and practitioners.

Read more about this project at: lanl.gov/

NATIONAL ENERGY TECHNOLOGY LABORATORY (NETL)

- EYESIM v2.3 Immersive Real-Time Virtual Reality Software for Improving Energy Plant Operations and Safety, developed by the NETL, Schneider Electric and West Virginia Univ., is a comprehensive software solution that provides a continuous, realistic view of commercial-scale energy plant operations by combining a high-performance, immersive 3-D virtual reality engine with a high-fidelity, real-time, dynamic plant simulator. EYESIM recreates the look-and-feel and sounds of an actual operating plant. By enabling hands-on interaction with process equipment, EYESIM enables industry users to optimize plant operations, control and maintenance, as well as safety procedures for process malfunctions and abnormal situations. To provide better process understanding, the EYESIM product also offers augmented virtual reality that enables users to open and view the internals of plant equipment during operation.

Read more about this project at: netl.doe.gov/

NATIONAL RENEWABLE ENERGY LABORATORY (NREL)

- A method to make bioethylene using genetically modified cyanobacteria, rather than the traditionally used petroleum, was developed by NREL scientist Jianping Yu. That traditional method of producing ethylene produces as much as three tons of CO_2 for every ton of ethylene. Yu's method redirected the cyanobacteria to use a portion of the CO_2 to produce ethylene, not only a valuable product, but a gas capable of migrating out of the cell walls and enabling continuous production. That could lead to a greener future where ethylene production could actually help mitigate CO_2 from the environment.

Read more about this project at: nrel.gov/

OAK RIDGE NATIONAL LABORATORY (ORNL)

- BAAM-CI, or Big Area Additive Manufacturing-CI is a large-scale manufacturing platform developed by ORNL researchers and Cincinnati Inc. BAAM-CI allows arbitrary geometric components to be 3-D printed on a scale 10 times larger than any other commercial system and to deposit material 200 times faster than existing processes, while being more efficient than traditional manufacturing methods like stamping and blow molding. BAAM-CI is also the first manufacturing project capable of depositing carbon fiber reinforced plastic into printed materials, endowing objects with greater strength and four to seven times the material's original stiffness.
- Collective Offloads Resource Engine Direct Technology (CORE-Direct) is an application acceleration and scaling technology that improves efficiency by offloading complex data-exchanging patterns to the network hardware. Developed by a team of ORNL researchers and Mellanox Technologies, CORE-Direct is based on an open architecture and supports a wide variety of data exchanging patterns. Applications using it have demonstrated a 51 percent improvement in completion time.
- Hyperion, or Automated Behavior Computation for Compiled Software, assesses and computes software or malicious behavior with precise mathematics to prevent inappropriate or illegal access to computer systems. Hyperion can also capture, share and reuse malware analyst intelligence to detect and eliminate malicious behavior in future scenarios.
- The Multifunctional Superhydrophobic Transparent Glass Coating, which was developed by researchers at ORNL and United Protective Technologies, can be customized to be superhydrophobic, fog-resistant and antireflective. That makes it ideal for solar panels, lenses, detectors, windows, weapons systems and many other products. The coating can be fabricated through industry standard techniques, which makes it easy and inexpensive to scale up and apply to a wide variety of glass platforms.
- The Porous Graphene Desalination Membrane was created to desalinate and purify water for human consumption. The membrane contains a single layer of graphene, and its permeability is engineered to reduce energy consumption found in traditional techniques. A smaller surface area adds to the technology's cost effective appeal and potential to replace standard desalination techniques, minimizing capital cost and a desalination facility's footprint in large-scale operations.
- GENOA software is 3-D printing simulation platform developed by ORNL researchers in collaboration with Alpha STAR Corp. That software accurately predicts the printability of products with the focus on deflection, residual stress, damage initiation and crack growth formation.
- The Infrared Nondestructive Weld Examination System developed at ORNL received a silver special recognition award in the Market Disruptor Services category. The highly reliable welding quality inspection and monitoring system can evaluate vehicle parts during and after welding, sending continuous feedback to production lines to correct any internal issues.

Read more about these projects at: ornl.gov/

PACIFIC NORTHWEST NATIONAL LABORATORY (PNNL)

- CHAMPION (Columnar Hierarchical Auto-associative Memory Processing in Ontological Networks), an analytical software developed at PNNL allows users to sort through massive amounts of data from digital networks and hone in on true threats. PNNL licensed the software to Champion Technology Company Inc. to pursue applications in cybersecurity, financial services and healthcare.
- SPIN, or Subambient Pressure Ionization with Nanoelectrospray is a technology developed at PNNL to improve the accuracy and sensitivity of mass spectroscopy. SPIN increases the size of the samples that can be captured by the detectors in mass spectrometers by nearly 50 percent, which could lead to a range of improvements, from increasing the sensitivity of assessing the runoff of chemicals in soils to catching the signs of cancer in blood earlier than thought possible.
- Hydrothermal Processing (HTP) to Convert Wet Biomass into Biofuels is a new chemical processing system developed by PNNL researchers that turns biological materials into biofuels in much more energy-efficient fashion than previous methods. PNNL has licensed the technology to Genifuel Corp. for further development and is also working with the Water Environment Research Foundation to demonstrate the process's effectiveness with municipal wastewater.
- The Pressurized Magic Angle Spinning Technology for Nuclear Magnetic Resonance (NMR) Spectroscopy is a technique that allows scientists to watch molecular interactions as they occur in conditions that mimic their real surroundings. The technology has already applied the technology to studying carbon sequestration, recreating the ultra-high pressures of fracking, and tracking the complex chemical reactions that occur in the making of biofuels.
- The Power Model Integrator is a new forecasting tool that delivers up to a 50-percent increase in the accuracy of energy use forecasts. By simultaneously analyzing multiple models and determining how to combine them in a more accurate forecast of future energy needs, the technology has the potential to reduce blackouts and save millions of dollars in wasted energy costs.

Read more about these projects at: pnnl.gov/

SANDIA NATIONAL LABORATORIES

- LED Pulser is a low-cost, high-brightness, fast- pulsed, multi-color light-emitting diode (LED) driver. The technology uses custom electronic circuitry to drive high-power LEDs to generate light pulses with shorter duration, higher repetition frequency and higher brightness than commercial off-the-shelf systems. A single device can emit up to four different colors, each with independent pulse timing. These capabilities have enabled various science, engineering and R&D applications that are otherwise possible only with far more expensive light sources and optics.
- IC ID is a technology that addresses the crucial and increasingly visible problem of maintaining the integrity of the integrated circuit (IC) supply chain, both for consumer electronics and national security and military systems. On the consumer side, counterfeit ICs sold as authentic diminish market share, introduce product safety and quality shortcomings and damage suppliers' reputations. The Semiconductor Industry Association estimates that counterfeiting of ICs costs the U.S.-based semiconductor industry more than

$7.5 billion per year. In response, IC ID uses physical unclonable functions to allow cryptographic authentication of ICs without requiring the storage of any secret values. IC ID can be used to detect counterfeited or modified ICs, and it can be integrated into smart cards, credit cards and other authentication tokens to improve their security.

- The Lightweight Distributed Metric Service (LDMS) is a monitoring software that provides the continuous system-wide platform awareness and snapshots of system status across an entire HPC platform that system administrators, application developers and users need to understand and troubleshoot application resource contention, network congestion, I/O bottlenecks and associated causes of compute delays. These snapshots offer insights into how platform resources are being utilized, stressed or depleted due to the aggregate workload.
- CO2 Memzyme addresses the grand challenge of efficient carbon capture. Designed by Sandia National Laboratories and the Univ. of New Mexico, it represents an advance in gas separation technology. The memzyme captures carbon dioxide from a gas mixture at high rates (2,600 GPU) and with high selectivity (>500 CO2/N2), surpassing a fundamental barrier in polymeric membrane technology and realizing the first technology that meets/exceeds DOE targets for cost-effective carbon capture (< $30/ton). The memzyme simultaneously produces nearly pure carbon dioxide (99%) for industrial re-use. In addition to being a 2015 R&D winner, this technology was also recognized with a Gold Special Recognition Award in Green Tech.
- The 6.5kV Enhancement-Mode Silicon Carbide JFET Switch addresses the fact that rising global energy usage has placed unprecedented demands on an aging electrical grid, which must be revolutionized to not only become more efficient, but become more reliable through the integration of renewables and energy storage systems. The key to enabling next-generation power-conversion technology lies in not only using high-voltage SiC devices and reducing current throughout a system, but in greatly reducing the switching losses. United Silicon Carbide Inc. and Sandia National Laboratories' 6.5-kV SiC device and power module represents a high-voltage module based on reliable, normally off SiC JFETs. It reduces switching losses over that of Si-IGBTs by a factor of 20, and exhibits the fastest turn-on and turn-off of any 6.5-kV-rated power module.

Read more about these projects at: sandia.gov/

Y-12 NATIONAL SECURITY PROJECT

- ChIMES (Chemical Identification by Magneto-Elastic Sensing) is a new passive, low-cost chemical sensing technology. ChIMES sensors are based on a set of target response materials (TRMs) that expand when they are in the presence of a target. The expanding volume is used to impose mechanical stress on a magneto-elastic alloy, changing its magnetic properties in ways that can be detected wirelessly. The response takes less than 1 min. The sensing element is tiny – 12.7 mm in length and 3.8 mm in diameter—and multiple elements can be ganged for detection of multiple and variable targets. In addition, the separation of the sensing element and the detection system means there's exceptional latitude in miniaturizing the sensor and tailoring its shape, size and appearance to suit a specific application.

Read more about this project at: [y12.doe.gov/](y12.doe.gov/)

Appendix E – National Laboratory Success Stories

There are many examples of technology transfer and industry partnering activities that reflect successful programs at DOE's National Laboratories and Facilities. The following are brief descriptions of successes in FY 2015. These examples illustrate the nature and range of technology transfer activities across the complex.

Table 17. U.S. National Laboratory and Facility Success Stories

U.S. National Laboratory or Facility	Project
Ames Laboratory	The Critical Materials Institute – new castable cerium-modified high temperature aluminum alloys
Argonne National Laboratory	Collaboration between Argonne and BASF Corp. in Energy Storage Space
Brookhaven National Laboratory	Sensing 3-D Interaction Positions in Semiconductor Radiation Detectors
Fermi National Accelerator Laboratory	Carbon Nanotube Cathode
Idaho National Laboratory	NanoSteel's Super-strong Steel Materials
Kansas City National Security Campus	Metal Additive Manufacturing
Lawrence Berkeley National Laboratory	CinderBio – Better Industrial Enzymes from Nature
Lawrence Livermore National Laboratory	Laser Peening
Los Alamos National Laboratory	Entropy Engine
National Energy Technology Laboratory	Safer, Cleaner Coatings to Protect Metals from Corrosion
National Renewable Energy Laboratory	NREL + SolarCity and the Hawaiian Electric Companies
Nevada National Security Site	Medical Patients to Benefit from New Isotope Production Agreement
Oak Ridge National Laboratory	Big Area Additive Manufacturing
Pacific Northwest National Laboratory	Sound Waves Screen for Threats and Contraband
Sandia National Laboratory	Modeling and Simulation for Material Manufacturing
Savannah River National Laboratory	Thermal Cycling Adsorption Process (TCAP)
SLAC National Accelerator Laboratory	The Large Synoptic Survey Telescope
Thomas Jefferson National Accelerator Facility	New Process for Producing Boron-Nitride Nanotubes
Y-12 National Security Complex	ChIMES (Chemical Identification by Magneto-Elastic Sensing)

Highlights from the Department of Energy's Technology Transfer Activities

DOE plays a key role in moving innovative technologies developed in National Laboratories and Facilities across the country into the commercial marketplace, fueling the innovation engine that powers the U.S. economy. Bridging the gap between R&D and commercial deployment is crucial to DOE's mission, because it creates globally competitive industries in the United States, enables significant cost-savings for industries and consumers, and creates good jobs for Americans.

The DOE's National Laboratories tackle the critical scientific challenges of our time -- from combating climate change to discovering the origins of our universe -- and possess unique instruments and facilities, many of which are found nowhere else in the world. They address large scale, complex R&D challenges with a multidisciplinary approach that places an emphasis on translating basic science to innovation. Specifically, the National Laboratories:

- Conduct research of the highest caliber in physical, chemical, biological, and computational and information sciences that advances our understanding of the world around us;
- Advance U.S. energy independence and leadership in energy technologies to ensure the ready availability of clean, reliable, and affordable energy;
- Enhance global, national, and homeland security by ensuring the safety and reliability of the U.S. nuclear deterrent, helping to prevent the proliferation of weapons of mass destruction, and securing the nation's borders; and
- Design, build, and operate distinctive scientific instrumentation and facilities, and make these resources available to the research community.

DOE oversees the construction and operation of some of the Nation's most advanced R&D facilities, located at National Laboratories and universities. These state-of-the-art facilities are shared with the science community worldwide and offer some technologies and instrumentation that are available nowhere else. In FY 2015, these Facilities were used by over 32,000 researchers from universities, National Laboratories, private industry, and other federal science agencies.[35]

Science and engineering are not linear, nor are they uniform, but the DOE's system of National Laboratories, user facilities, research centers and shared research facilities, makes the pursuit of discovery -- and the many solutions that result -- both a collaborative enterprise and a shared national resource. Collaboration with industry and academia is essential to develop, demonstrate, deploy and commercialize the output from DOE's broad R&D investments.

In February of 2015, DOE's OTT was established to expand the commercial impact of DOE's portfolio of research, development, demonstration and deployment (RDD&D) activities over the short, medium and long term. The OTT works closely with the National Laboratories and engages with the public and private sectors to promote scientific and technological innovation to advance the economic, energy, and national security interests of U.S. In doing so, OTT

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[35] Department of Energy, Office of Science. *User Facilities.* science.energy.gov/user-facilities/

coordinates and encourages more effective technology transitions across the RDD&D spectrum from its National Laboratories.

Technology Pull through Engagement at Every Level: The Critical Materials Institute

(Ames National Laboratory)

Led by the Ames Laboratory, several technologies have resulted from the strong National Lab/University/Industry collaborative effort of the Critical Materials Institute (CMI), a DOE Energy Innovation Hub. CMI Team Members include four DOE National Laboratories (Ames, INL, LBNL, ORNL), six universities (Brown, Colorado School of Mines, Iowa State University, Purdue, Rutgers, UC Davis), and seven Industry partners (Advanced Recovery, Cytec, Eck Industries, General Electric, OLI Systems, Simbol Materials, United Technologies Research Center) and one research institute (Florida Industrial and Phosphate Research Institute).

Cast of new Al Ce alloy engine block made at ORNL.

The CMI's emphasis on collaboration at every stage of R&D has produced over 40 invention disclosures since its inception in 2013, resulting in numerous patent applications and one license to date. Funding for the CMI comes from DOE's Office of Energy and Renewable Energy, Advanced Manufacturing Office, and is coupled with costshare from its Team Members.

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 being developed.

One successful CMI project involves several National Lab Team Members and Eck Industries. This project produced castable cerium-modified aluminum 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 wide-spread 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 them 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.

In addition to its Team Members, the CMI engages other companies, universities, non-profits, and federal agencies through the establishment of an Affiliate program. CMI Affiliates are entities interested in being informed about CMI research outcomes and providing valuable insight on materials trends to CMI on a continuing basis. Currently, there are 19 Affiliates consisting of one Federal agency, six large businesses, three small businesses, seven start-ups, one university, and one non-profit.

Collaboration between Argonne and BASF Corp. in Energy Storage Space

(Argonne National Laboratory)

BASF's NCM battery materials plant in Elyria, Ohio

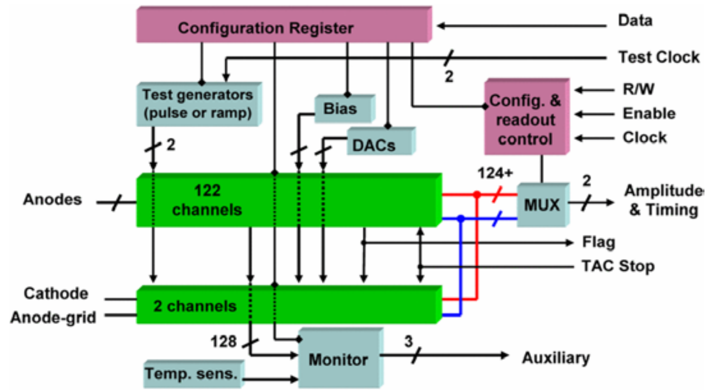
Reliable, cost-effective energy storage is essential if we are to reduce American reliance on fossil fuels, decrease greenhouse gas emissions, and create jobs through the development of a growing industry. Argonne National Laboratory and industry collaborator BASF Corporation (Florham Park, N.J.) have delivered a major breakthrough in this pursuit with the Nickel-Cobalt Manganese (NCM) cathode technology, which improves lithium-ion battery energy while reducing manufacturing cost and environmental impact. A long-term investment by the U.S. Department of Energy (DOE) in Argonne's advanced battery research has paid off, as NCM has become a dominant focus for cathode material development in the market, with applications ranging from power tools to hybrid electric vehicles. Additionally, NCM promises to be a key technology for enabling large-scale energy grid storage.

The development of NCM represents an advancement in lithium-ion battery technology from earlier cathode chemistries. Nickel and manganese are considerably cheaper than cobalt, and batteries with NCM cathodes have higher performance than the alternative chemistries. 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 NCM cathode technology and has invested in further R&D as well as facilities to produce NCM-based products. Most notable is a 70,000-square-foot plant BASF opened in Elyria, Ohio, in 2012 specifically to produce NCM materials. BASF invested $50 million in the construction, which was also supported under the American Recovery and Reinvestment Act by a $24.6 million grant from DOE.

Argonne and BASF received a "Deals of Distinction™" Award in 2010 from the Licensing Executives Society, Inc., which noted the agreement's significant potential to improve the environment and provide economic growth. "NCM has been a game-changer in the industry," said Mike Fetcenko, Director of Battery Materials for BASF. "People are using this Argonne technology without even knowing it, and we fully expect they will be using it more and more."

Sensing 3-D Interaction Positions in Semiconductor Radiation Detectors

(Brookhaven National Laboratory)



Block diagram of the ASIC.

Cadmium Zinc Telluride (CZT) detectors are currently being used in room temperature gamma-ray spectrometry for security, medical, industrial and space applications. More recently, mercuric iodide (HgI) has been suggested as another potential candidate for room temperature imaging applications. However, both CZT and HgI's spectral resolution is strongly limited by several deficiencies like poor mobility of holes, electron trapping, and non-uniformities.

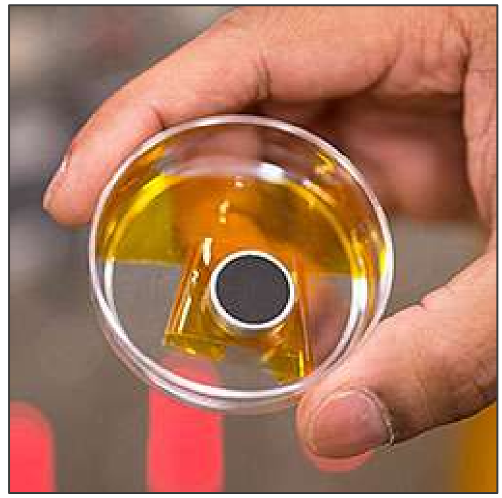
To address these deficiencies, scientists at University of Michigan developed a 3-D Position Sensitive Detector (3D-PSD). Engineers at Brookhaven National Laboratory in collaboration with University of Michigan have developed an application specific integrated circuit (ASIC) for the 3D-PSD that combines the pixilation of the anode electrode with the measurement of the amplitude and timing. This ASIC is composed of 130 input channels, each providing charge amplification, stabilized filtering, peak and timing detection with associated analog memories, and multiplexing.

The ASIC operates in three modes: configuration, acquisition, and readout. In *configuration mode,* the ASIC allows independent access to the channel register or global configuration register. In *acquisition mode* the ASIC provides the charge amplification, discrimination, and processing (peak and timing) of the events in the anodes and cathodes, and it releases a low voltage differential signal flag in correspondence of a successful acquisition. In *readout mode,* the ASIC provides either normal or sparsified channel readout of the peak and timing information associated with the last acquisition.

The ASIC is covered by three issued patents and was funded by Office of Science of the Department of Energy and Domestic Nuclear Detection Office (DNDO) of the US Department of Homeland Security. The ASIC developed has been licensed by two companies who plan to use these ASICs for medical and security imaging applications.

Carbon Nanotube Cathode

(Fermi National Accelerator Laboratory)



Carbon Nanotube Cathode

Scientists are a step closer to building an intense electron beam source without a laser. Using Fermilab's High-Brightness Electron Source Lab (HBESL), a team led by RadiaBeam Technologies is testing a carbon nanotube cathode—about the size of a nickel—that completely eliminates the need for a room-sized laser system. Tests with the nanotube cathode have produced beam currents a thousand to a million times greater than the one generated with a large, pricey laser system. Fermilab was sought out to test the experimental cathode because of its capability and expertise for handling intense electron beams, one of relatively few labs that can support this project. A U.S. Department of Energy Small Business Innovation Research grant funds the collaboration between California-based RadiaBeam, Fermilab, and Northern Illinois University.

The new cathode appears at first glance like a smooth black button, but at the nanoscale it it is made of millions of nanotubes that function like tiny lightning rods. When a strong electric field is applied, it pulls streams of electrons off the surface of the cathode, creating the electron beam. The exceptional strength of carbon nanotubes prevents the cathode from being destroyed. Traditionally, accelerator scientists use lasers to strike cathodes in order to eject electrons through photoemission. The electric and magnetic fields of the particle accelerator then organize the electrons into a beam. The tested nanotube cathode requires no laser: it only needs the electric field already generated by an accelerator to siphon the electrons off, a process dubbed field emission.

This new technology has extensive applications in medical equipment and national security, since an electron beam is a critical component in generating X-rays. While carbon nanotube cathodes have been studied extensively in academia, Fermilab is the first facility to test the technology within a full-scale setting. This remarkable result means that electron beam equipment used in industry may become not only less expensive and more compact, but also more efficient. A laser like the one in HBESL runs close to half a million dollars, about one hundred times more expensive than RadiaBeam's cathode.

The team continues to study ways to optimize the design of the cathode to prevent any smaller, adverse effects that may take place within the beam assembly. Future research also may focus on redesigning an accelerator that natively incorporates the carbon nanotube cathode to avoid any compatibility issues. The work represents the kind of research that will be further enabled at the Illinois Accelerator Research Center — a facility that brings together Fermilab expertise with that of industry and academia, for the benefit of the U.S. economy.

NanoSteel's Super-strong Steel Materials

(Idaho National Laboratory)

The ever-changing demands of modern technologies drive a need for metal alloys with specific novel properties. In 1996, Dr. Daniel Branagan, a National Laboratory researcher, discovered a new class of nanostructured steel material, which became the basis for a new class of steel. This material has been used widely to provide solutions addressing needs in a wide range of industries. After demonstrating the technology at the lab scale, funding from the U.S. Defense Advanced Research Projects Agency (DARPA) helped scale up the process. The technology was developed in Idaho Falls, Idaho.

Numerous industries — including those supporting automobiles, oil and gas, mining, and steel production — are creating products that require performance capabilities beyond the known boundaries of existing materials.

In 2002, NanoSteel formed as a successful startup company. It is focused on engineering compelling nanomaterial solutions for industry's most difficult problems. Based on the foundation of its original surface coatings technology, NanoSteel created progressive generations of iron-based alloys, including foils, powder metals, and sheet steel. Surface technology has been used in extreme-wear and corrosion environments including power generation, mining and aggregates, concrete and cement, and oil and gas. NanoSteel is a leader in nanostructured steel materials design. The company's most recent milestone is production of a third-generation Advanced High Strength Steel (AHSS) sheet design breakthrough for the automotive industry.

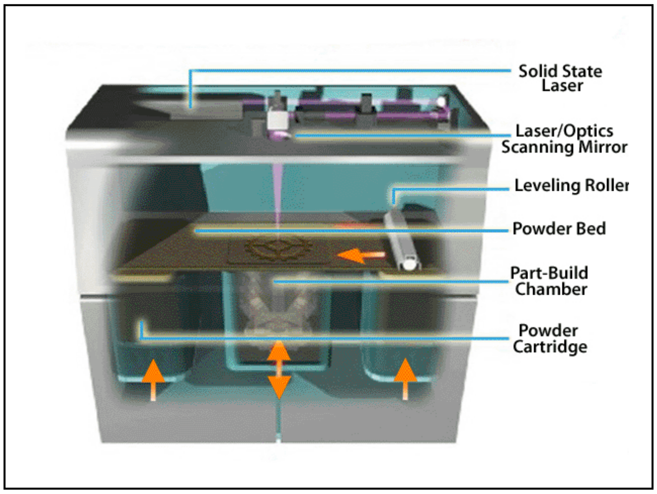
Through the development of new nanoscale formation mechanisms, NanoSteel created a new class of steel that will allow automotive engineers and designers to reduce weight through the use of thinner, higher-strength gauges while maintaining the structural integrity needed for safety.

NanoSteel has won five R&D 100 Awards, and generated more than 200 licenses, patents and patents pending. In 2011, a General Motors subsidiary invested in the company.

Metal Additive Manufacturing

(Kansas City National Security Campus)

Selective laser melting (SLM) is an emerging powder-bed based additive manufacturing (AM) technology enabling the fabrication of complex geometries rapidly. The products are high quality/low quantity with designs that are highly customized, much like products made at the Kansas City National Security Campus (KC NSC). The AM process allows for more creativity in designs that could result in revolutionary designs instead of evolutionary designs but they introduce challenges when it comes to qualifying them for use in nuclear weapons. To meet this challenge, the KC NSC has partnered with Missouri University of Science and Technology (MS&T).



A selective laser melting machine.

MS&T's expertise in material science will enable the research required to meet the AM qualification challenges. The research objectives are to improve the properties of the built parts, to control microstructures for achieving desired properties, to maximize powder reuse, and to increase process sustainability. The research topics include powder characterization, material property characterization methods, temperature effects on material properties, controlling microstructure and mechanical properties, and chemistry specifically for the additive manufacturing process.

KC NSC purchased an AM machine (see figure above) for MS&T to conduct their research. The collaboration with MS&T started in FY 2015 and will continue for 5 years with a total of nearly $5 million dollars of NNSA funding. This research enhances MS&T's material expertise and provides KC NSC with the data needed to qualify the process for nuclear weapon parts.

CinderBio – Better Industrial Enzymes from Nature

(Lawrence Berkeley National Laboratory)

The scientific concept that microbes living in extreme temperatures or toxic conditions could yield more effective industrial enzymes has moved several steps closer to reality. Researchers at Lawrence Berkeley National Laboratory (LBNL) have produced enzymes from these microbes, called extremophiles, that can replace chemicals used in biofuel production, paper pulping and operations in the textile and food processing industries, among others.

LBNL researchers have harnessed enzymes to reduce chemical and water use in industrial applications from microbes found in naturally hot, volcanic waters

LBNL researchers, funded by the DOE Office of Science, first sought to understand how microbes from hot acidic pools in Yellowstone National Park could thrive. Their work led to a technology that harnessed biodegradable, stable, acid- and heat-resistant enzymes from the microbes. Seeing the potential across a range of industrial applications, researchers Jill Fuss and Steve Yannone founded a startup – Cinder Biological, or CinderBio – and licensed the LBNL technology. Along the path to commercializing their technology, the CinderBio team earned a semi-finalist spot in the UC Berkeley b-plan competition and placed third in the FLoW DOE National Clean Energy Business Plan competition.

In 2015, supported by a Phase 1 SBIR grant, the team conducted field trials cleaning dairy processing equipment, using the enzymes in place of industry-standard chemicals. As a result, water use was reduced by almost 30%, and biofilms from food processing operations were removed quickly and effectively. CinderBio continues to develop the technology in an incubator lab space in Berkeley with an eye to refining food processing industry applications to reduce chemical waste and yield reclaimable wastewater in place of the chemical wastewater typically hauled offsite. In the future, the enzymes may be applied to biofuel production and the paper pulping and textile industries.

Laser Peening

(Lawrence Livermore National Laboratory)

Laser peened panels for DOD fighter jet wings. *(Images courtesy of MIC)*

The continual demand for greater material strength, durability, and longevity in structural applications makes metal a constant focus and challenge for material scientists and engineers. One of the best ways to modify the mechanical and structural properties of metal is through peening, a process that uses surface impaction to produce permanent, and compressive residual stress layers within a metal's surface; once the external impact stress dissipates, the peened material retains its harder, more durable quality.

Contemporary peening processes used round metallic or ceramic balls to compress a material and harden its surface. Though this process works, shot peening has less-than-exact control due to the nature of ballistic balls, the limited or sub-surface impaction depths, and the prevalence of pitting throughout the target surface material. To combat these limitations, Metal Improvement Company (MIC)—a subsidiary of Curtiss-Wright Surface Technologies—and LLNL partnered to develop the commercial production of a more efficient method to strengthen metal: laser peening.

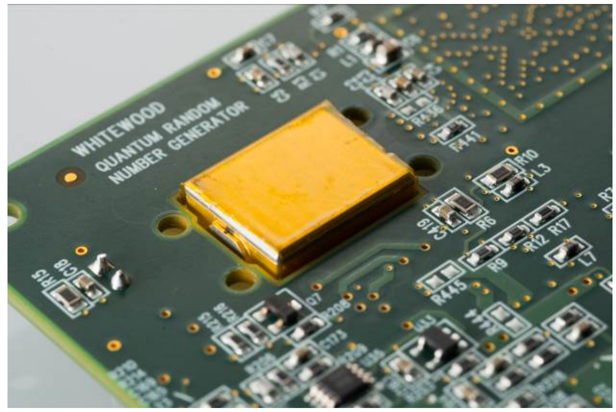
Although laser peening technology existed in the 1960s, its irregularity undermined the technology's commercial viability. That is, until LLNL began applying its high-energy, high-repetition-rate, short-pulse laser to peening applications in the 1990s. Since laser-based peening allows for precision control and compaction depths of 5–10 times deeper than shot peening, a perfected laser-peeing process would expand potential applications from gears, coils, and crankshafts to more structurally demanding items such as steam turbine blades, aircraft structures, and high-performance engine components. Leveraging Livermore's robotic mounts for fast, customized, computer-controlled peening angles, laser peening soon acquired the characteristics of speed, efficiency, and consistent coverage to warrant commercial development. Shot-peening industry leader MIC funded additional research at LLNL to hone the short-pulse laser technology for laser peening and subsequently licensed the patent portfolio covering the LLNL laser system. MIC opened its first laser peening facility in 2002 and now has three peening facilities in the US, one in the UK, and mobile peening systems with the capability to go on-site anywhere in the world.

The commercial laser peening process developed by LLNL and MIC extends the service lifetime of aircraft engines, power turbines, and other critical components of military and civilian systems by a factor of 10. The impacts of this technology are particularly evident in the aerospace industry, where laser peening has improved more than 10,000 jet engine turbine blades and extended the lifespan for components of aircraft for customers ranging from Boeing, Rolls Royce, Siemens, and the Department of Defense. Using LLNL's technology, MIC now treats blades for steam and gas turbines for all major electric power equipment manufacturers in the U.S.

MIC integrated LLNL-developed laser technology and peening capability into a viable commercial process that continues having a major global impact. Laser peening improves performance, increases service life, and reduces costs for various industry structures and propulsion, yielding billions of dollars in savings for jet engine fan blades, fuselages, wings, and other components of civil and military aircraft structures, electricity generation steam turbines, and high-performance racing vehicles.

Entropy Engine

(Los Alamos National Laboratory)



Example of Whitewood's Entropy Engine.

In September of 2014, Whitewood Encryption Systems, Inc. licensed one of the largest technology portfolios from Los Alamos National Laboratory to bring the potential for truly secure data encryption to the marketplace after nearly 20 years of development. The technology at the heart of the agreement is a compact random-number-generation technology that enables cryptographic keys to be created based on the truly random polarization state of light particles known as photons. Because the randomness of photon polarization is based on quantum mechanics, an adversary cannot predict the outcome of this random number generator.

This represents a vast improvement over currently marketed "random-number" generators that are actually not random but are based on mathematical formulas that can be broken by a computer with sufficient speed and power. The new technology can be directly applied to benefit all current cryptographic applications including encryption and because of its high data rate output the product can supply the needs of large scale systems and datacenters. The project was initially funded at Los Alamos through Laboratory Directed Research and Development (LDRD) funding. Later the Department of Homeland Security's Transition to Practice program within DOE's Science and Technology directorate helped bring the technology to market.

The quantum random number generation technology has communication and security protocols that can be used by groups of devices to communicate securely with each other using quantum cryptography. These protocols, and the devices that implement them, have the potential to make quantum technology less expensive and more readily available in the future.

Entropy Engine ™, launched by Whitewood in August 2015, is the first product that utilizes the quantum random number generation technology. The product has subsequently expanded to represent a complete entropy distribution system called netRandom™ in March 2016. The Entropy Engine is a computer card that fits most network servers and creates truly random numbers at a rate of up to 200 million bits each second and the netRandom software solution enables random numbers to be delivered on-demand over a network to existing encryption applications and devices performing cryptographic operations across datacenters, cloud computing systems, mobile phones and the Internet of Things.

The Entropy Engine is more than ten times higher performing than other quantum devices currently on the market and is one of the world's most cost-effective, quantum-powered random number generators. The newly formed partnership between Los Alamos National Laboratory and Whitewood Encryption Systems represents a major step forward for the field.

This alliance brings together leading researchers in networked quantum communications with top executives in cloud computing and enterprise IT and security systems in order to leverage decades of cutting-edge research to develop and deploy next-generation solutions for data security.

Los Alamos scientists Richard Hughes, Jane Nordholt, Raymond Newell and Glen Peterson and others were the inventors of patents issued both before the transfer and subsequently in 2015 and 2016.

Safer, Cleaner Coatings to Protect Metals from Corrosion

(National Energy Technology Laboratory)

Corrosion-related issues cost the U.S. economy $276 billion a year. The Energy Department's National Energy Technology Laboratory (NETL) teamed up with Carnegie Mellon University (CMU), both located in Pittsburgh, PA, to create a revolutionary and cost-effective technology to reduce that impact. The work resulted in the creation of a new CMU/NETL spin-off called LumiShield, which signed a licensing agreement with the Laboratory in June 2015.

The "Ionic Liquid Solvent for Aluminum Electroplating Process" electrodeposits aluminum, replacing coatings based on heavy metals that are expensive, heavily regulated, and environmentally harmful.

The new process, which electrodeposits aluminum using standard equipment available in most electroplating shops, is set to make its mark on the industry by replacing coatings based on heavy metals, such as cadmium and chromium, which are expensive and toxic. Electroplating is the process of depositing a metal coating onto an object by putting a negative charge on it and immersing it in a solution. The technology holds great potential for reducing the costs of protecting products from corrosion while eliminating some difficult environmental hazards.

Aluminum is less toxic than most of the materials used in anti-corrosion coatings, but it cannot be plated in the presence of water, making it much more difficult to apply. In addition, existing technology for aluminum coatings requires an inert atmosphere and uses a toxic chemical called toluene at elevated temperatures as a solvent, requiring it to be performed in sealed vessels. That is a much more expensive coating approach.

The new electroplating technology licensed from NETL by LumiShield uses a plating solution containing ionic liquids (salts in liquid state) in open vessels without creating toxic vapors. The result is a more cost-efficient, environmentally responsible process. In addition, the process can be altered to produce a variety of properties and finishes to meet specifications for a range of applications.

LumiShield, which has created three jobs to date, was created based on the new technology and specializes in corrosion-resistant metal products that are less expensive and less environmentally harmful than existing approaches. Corrosion-resistant coatings like the LumiShield electroplating technology are in demand as a way of reducing costs. The new technology could have a significant positive impact in the fight against corrosion on a wide range of products, resulting in decreased costs and reduced impacts to the environment.

NREL + SolarCity and the Hawaiian Electric Companies

(National Renewable Energy Laboratory)

SolarCity's work with NREL at the ESIF to optimize PV inverter technology will ultimately enable greater deployment of solar PV on homes and buildings across the country.

NREL is collaborating with solar energy company SolarCity at the Energy Systems Integration Facility (ESIF) to address the safety, reliability, and stability challenges of interconnecting high penetrations of distributed photovoltaics (PV) with the electric power system. The work includes collaboration with the Hawaiian Electric Companies to analyze high-penetration solar scenarios using advanced modeling and inverter testing at the ESIF.

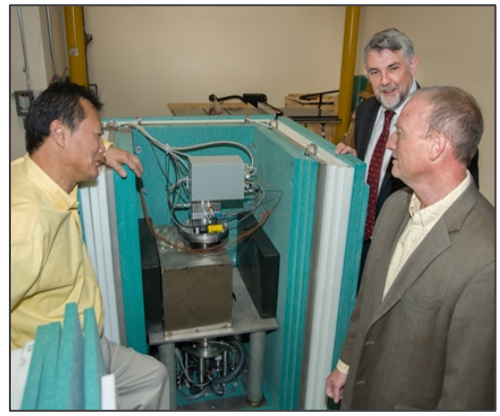
The ESIF's unique megawatt-scale power hardware-in-the-loop capability allows researchers to analyze the behavior of distributed electricity generation and distribution devices while connected to a testing system that dynamically emulates the characteristics of a power system. Testing with SolarCity and Hawaiian Electric at the ESIF is covering dynamics between inverter-based assets on the electric grid, such as transient overvoltage from PV inverters, multi-inverter unintentional islanding, and voltage regulation. NREL will also evaluate SolarCity's PV generation curtailment hardware and software based on the potential need for PV power curtailment, or the use of less solar power than is available at a specific time, through a remote signal. Hawaiian Electric is partnering with NREL and SolarCity throughout the process, providing technical input on testing and setup, as well feedback on results.

SolarCity ultimately aims to increase the penetration of renewable energy technologies on the electric grid by addressing the system-level challenges of interconnecting high-penetration distributed PV. For Hawaiian Electric, this testing will allow the company to approve PV deployments for customers who have been waiting for interconnection on these high-penetration solar circuits.

Medical Patients to Benefit from New Isotope Production Agreement

(Nevada National Security Site)

Global Medical Isotope Systems, LLC (GMIS), and the Nevada National Security Site (NNSS) are collaborating under a CRADA to develop a new process to produce molybdenum-99 (99Mo) to meet the demands of the medical community. Moving from the huge infrastructure required for reactor-based production to this new system will provide patients and doctors a needed U.S. based secure, reliable, and convenient source of isotopes.



Imaging is Everything! (from left to right) Dr. Francis Tsang of Global Medical Isotope Systems (GMIS), Dr. Chris Deeney representing the NNSS, and Zane Wilson, Chief Executive Officer of GMIS, observe the electrically powered neutron source that generates isotopes for medical imaging in GMIS's southern Nevada facility.

The NNSS partnership with GMIS will take advantage of NNSS's expertise and experience garnered from its long-held national security missions in radiation detection, measurement, and simulation. The technology will introduce a safe, decentralized, on-demand production system, answering the critical supply needs of the industry while complying with the nuclear nonproliferation objectives of the U.S.

This patented technology uses a D-D high-yield neutron generator, producing >109 neutrons per second to induce fission in a depleted uranium blanket that yields 99Mo as a fission product. The 99Mo can then be chemically extracted and sold to radiopharmaceutical companies to produce 99mTc using Technetium generators.

The system technology is scalable, allowing for custom deployments and the ability to respond to customers' unplanned needs. 99Mo, the parent isotope of technetium-99m (99mTc), is used in approximately 40,000 diagnostic medical procedures every day in the U.S. GMIS intends to operate facilities that supply nuclear pharmacies and to license the technology to other operators on a regional basis. As an added benefit, this agreement will promote economic development in the Las Vegas area, where GMIS is headquartered, and throughout the nation.

GMIS is developing a stand-alone system to produce the critical isotope on demand in the Las Vegas area and ultimately nationwide. GMIS anticipates employing more than 50 people in high-paying technical jobs locally within two years.

Big Area Additive Manufacturing

(Oak Ridge National Laboratory)

Big Area Additive Manufacture (BAAM) is basically large-scale additive manufacturing, or large scale 3-D printing. ORNL has developed improvements that decrease the cost and increase the efficiency of BAAM systems, with an emphasis on materials, processes and controls that enable the manufacture of parts one to two orders of magnitude greater size and two orders of magnitude greater deposition rate than the state of the art.

Oak Ridge National Lab 3D printed Shelby Cobra which was showcased at the 2015 North American Auto Show (NAIAS) in Detroit Jan 12-15th.

A replica Shelby Cobra "plug-n-play laboratory on wheels" was printed at the Manufacturing Demonstration Facility at ORNL using a BAAM system developed using gantries supplied by Cincinnati Incorporated (Cincinnati, OH) and ORNL automation and robotic expertise. The car was built with a team of six people in just six weeks and was 3D printed with advanced composites that cut its weight in half while improving performance and safety. Techmer (Clinton, TN) produced the composite materials and Tru-Design (Knoxville, TN) developed the surface finishing techniques. The ORNL-developed drive train is an electric motor powered by wide-bandgap power electronics and can be charged wirelessly.

The speed of next-generation additive manufacturing offers new opportunities for the automotive industry, as well as aerospace and other industries, especially in prototyping. ORNL is identifying the critical equipment and materials advancements required to establish additive manufacturing as a mainstream manufacturing process in the following areas:

- Expanding current build volumes;
- Optimizing build parameters to increase deposition rates;
- Integrating smarter in situ process controls for rapid certification and quality control;
- Developing new materials and technologies for improved material properties;
- Investigating alternate low-cost feedstock materials;
- Increasing performance enhancements for materials, materials combinations, and functionality of components.

Large scale additive manufacturing removes the traditional limits on part geometry, and highly-complex components can also be fabricated faster while consuming less material and energy. Additive manufacturing also eliminates the need for expensive part tooling and detailed drawing packages, causing a paradigm shift for the design-to-manufacturing process.

Sound Waves Screen for Threats and Contraband

(Pacific Northwest National Laboratory)

The Product Acoustic Signature System (PASS) is a non-invasive tool that quickly and accurately evaluates the contents of sealed liquid-filled containers and large, homogeneous bulk solid commodities. It can determine characteristics of a liquid or solid and detect foreign objects, hidden compartments, contraband, and explosives hidden inside containers. Used at border checkpoints, airports, harbors, and entry points at industrial facilities, PASS is the safest and most accurate screening alternative to physically opening every container that crosses borders. Pacific Northwest National Laboratory (PNNL) originally developed the technology in Richland, Wash. with funding from the U.S. Army to inspect chemical weapons stockpiles in Iraq after the first Gulf war. Spearhead Innovations Technology Group, of Annapolis, MD, a subsidiary of Mehl Griffin & Bartok Ltd., licensed the technology in 2002. Spearhead anticipates hiring up to 20 more employees across Maryland, Pennsylvania, and Arizona, depending on sales orders.

The PASS device uses sound waves to quickly screen and detect anomalies inside sealed containers.

PASS works by sending ultrasonic pulses into a container, analyzing any resultant echoes, and comparing the measurements with values in a database to categorize the material. The hand-held device is sensitive enough to detect very fine differences between fluids, such as different grades of fuel. The ability to interrogate closed containers greatly reduces the safety risks to Customs and Border Patrol agents and others using the device, and it saves valuable time and money in cargo throughput.

Current applications of PASS include cargo inspection, screening and sorting, fuel compliance and security, fill-level detection, and quality control of chemical compound mixtures in industrial processing tanks. Spearhead also recently modified PASS's database to include chemical weapons agent acoustic signatures provided by PNNL. PASS has been used domestically and internationally by at least 13 government or military organizations. The devices have been used to identify and interdict the attempted smuggling of cocaine hidden within 55-gal drums of hydraulic oil, as well as precursor chemicals for illicit drug manufacturing. A U.S. pharmaceutical company reduced its screening time from hours to minutes by using PASS to check chemical feedstock shipments from overseas manufacturers.

Modeling and Simulation for Material Manufacturing

(Sandia National Laboratory)

3M combines a myriad of technologies to create innovative products for customers around the world. The company's products cover a wide range, from adhesives such as industrial and consumer tapes and repositionable notes, to nanotechnology films, including display films to enhance the color and energy efficiency of LCDs and light management coatings for LED lighting. In order to keep commercializing innovative products, precise predictive modeling and simulation tools, along with specialized knowledge, are essential to ensure ideas can be manufactured cost-effectively and quickly. Sandia and 3M have been working together to achieve this goal since the mid-'90s, first as part of the Coating and Related Manufacturing Processes Consortium and later through the Nanoparticle Flow Processing Consortium.

Lori Holmes, 3M Engineering Specialist, and Eric Vandre, 3M Senior Research Engineer, working together to check a composition measurement of a multilayer adhesive sample.

3M leverages Sandia production modeling expertise and Sandia benefits from 3M's unique understanding of material-process relationships and know-how in physical modeling requirements. Functional knowledge, from 3M's historical experience and current scientific endeavors, is combined with fast-evolving modeling knowledge from Sandia. Frequent extended working visits between 3M and Sandia strengthen the collaboration.

Sandia-developed open-source modeling platforms Goma 6.0 and LAMMPS are being used by 3M to improve manufacturing process and product design. Goma 6.0 is an R&D 100 award-winning software for simulating manufacturing processes. LAMMPS is a widely used computer code that models material behavior. These two tools guide 3M's quest to reduce costs and facilitate process improvements.

The partnership between Sandia and 3M continues under a one-on-one Umbrella CRADA focused on Multilayer, Structured Film Processing. The collaboration has had a sizable impact in accelerating the production of 3M adhesive tapes and abrasive materials, helping to produce them faster and more uniformly.

Thermal Cycling Adsorption Process (TCAP)

(Savannah River National Laboratory)

When it was determined that SRNL could provide SHINE Medical Technologies, Inc., with specific technology and expertise in radio-isotope separation to assist in the creation of a domestic supply of moly-99 without the use of highly enriched uranium, NNSA's Global Threat Reduction Initiative (GRTI) linked SHINE and SRNL. From the outset, U.S. Patent No. 8,470,073, relating to SRNL's thermal cycling adsorption process (TCAP) for separation of hydrogen isotopes, was identified for transfer to SHINE. Initial discussions began in 2011. Since that time, SRNL has fabricated a TCAP unit for proof of concept purposes through a Work for Others Agreement and provided SHINE with additional assistance through NNSA work authorizations.

Savannah River National Lab's thermal cycling absorption process (TCAP) is the best hydrogen isotope separation process in the world.

TCAP is the best hydrogen isotope separation process in the world, which can be used in the production of the medical isotope technetium-99m (^{99m}Tc). (^{99m}Tc) is used in tens of millions of medical diagnostic procedures annually. TCAP has gradually replaced all other separation processes for hydrogen isotope production and is currently the sole process of purifying tritium at the Savannah River Site (SRS).

The use of TCAP provides the high-purity inputs needed for SHINE's patented technology, which enables the production of large quantities of medical isotopes, including Mo-99, from which technetium-99m is easily extracted. The GTRI mission (to reduce and protect vulnerable nuclear and radiological material located at civilian sites worldwide) and goals (convert, remove, protect) led to a mandate for them to help establish a reliable U.S. domestic supply of Mo-99, produced without the use of Highly Enriched Uranium (HEU).

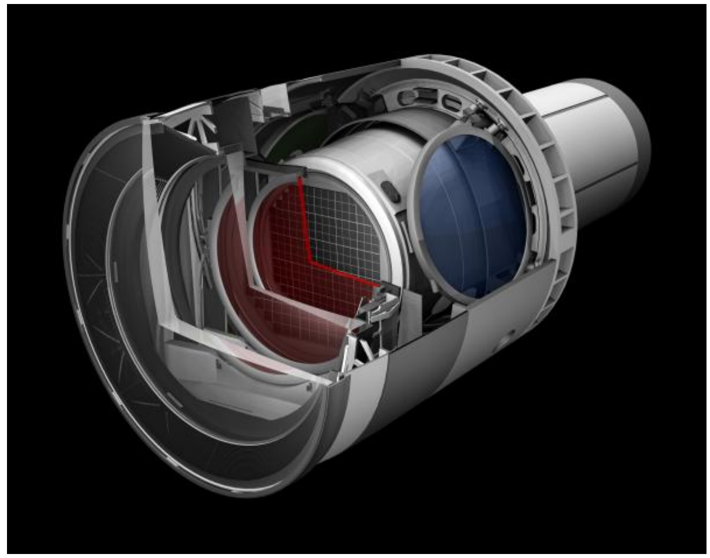
So this technology transfer is beneficial two-fold. Internationally it assists global Mo-99 production facilities in converting to the use of Low Enriched Uranium LEU targets and on the domestic front this means assisting with acceleration of establishing commercial non-HEU based Mo-99 production domestically. Despite constituting approximately half of the world's demand for Mo-99, the US does not produce any moly-99 domestically and currently imports its entire supply from foreign nuclear reactors. Many of these reactors are beyond their original design life and scheduled to be shut down in the coming years. SHINE will build its first medical isotope manufacturing facility in Janesville, Wisconsin. It will be able to produce enough Mo-99 every year to supply two-thirds of the US patient population.

As an end result, SRNL granted Shine an exclusive license on SRNL's patented technology hydrogen isotope separation process for use in medical isotope production. Shine will build its first medical isotope manufacturing facility in Janesville, Wisconsin. It will be able to produce enough moly-99 every year to supply more than two-thirds of the US patient population.

The Large Synoptic Survey Telescope

(SLAC National Accelerator Laboratory)

The Large Synoptic Survey Telescope (LSST) will survey the entire visible southern sky every few days for an entire decade – the widest, fastest and deepest view of the night sky ever observed. This will create a vast public archive of astronomical data that will dramatically advance research in dark energy, dark matter and galaxy formation. SLAC National Accelerator Laboratory is leading the construction of the LSST camera, which will be the largest digital camera ever built. The LSST project is a public/private, interagency project with funds provided by the Department of Energy, the National Science Foundation, and various private and foreign donors.



SLAC is constructing LSST's 3.2-gigapixel camera

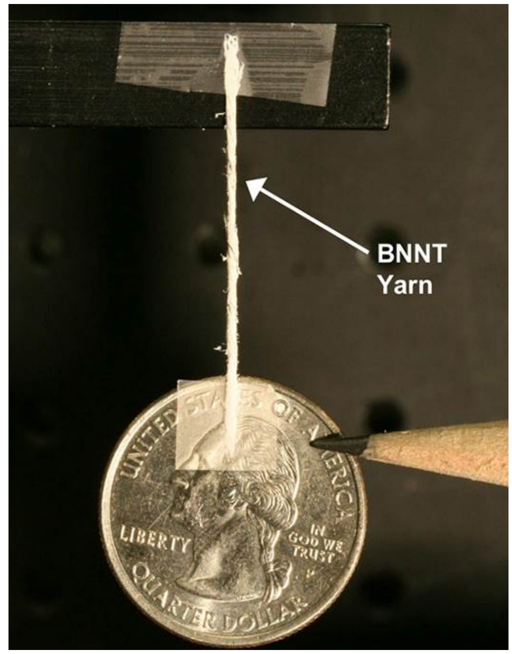
The LSST camera is a 3.2-gigapixel camera which is the size of a small car and weighs over 3 tons. The assembly and testing of the camera is taking place in a new 2,000 square foot, 2-story-tall clean room at SLAC, and will take approximately 5 years to construct. Management of the image data will drive advances in big-data science and computing, as the LSST is expected to catalog more galaxies than there are people on Earth. This will create an estimated 6 million gigabytes of data per year that must be indexed and analyzed by sophisticated hardware and computational methods. This data will not only be available to scientists but also to the general public, which will broaden public participation in science and advancement of STEM-based education.

The LSST will open a new window on the universe and will enable precision studies on many astronomical topics. The LSST project was ranked as the highest-priority ground-based large initiative by the National Academy of Science in the category of astronomy and astrophysics. This project brings together U.S. and foreign partners and will engage with researchers from around the world and will be operated by a multinational group of scientists on site at its installation location in Chile.

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

(Thomas Jefferson National Accelerator Facility)

In 2009, researchers at Jefferson Lab in Newport News, Virginia, developed a now-patented process to synthesize high-quality BNNTs. BNNTs have the potential to revolutionize 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, vibration damping products and rugged aerospace components. The extraordinary 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.



A yarn spun of boron-nitride nanotubes suspends a quarter. ***Image courtesy of Jefferson Lab.***

This new synthesis technology allows for the large-scale production of high-quality BNNTs that are free of catalysts and are much more crystalline than those grown by the most closely related method. The research that enabled the new technology was sponsored by the DOE, the Office of Naval Research, the Commonwealth of Virginia, and in collaboration with NASA and the National Institute of Aerospace.

The goal of the research was to create novel materials that could benefit nuclear physics as well as aerospace and other applications of advanced materials. The process was developed using a unique particle accelerator built with superconducting radiofrequency technology. CEBAF is the first large-scale implementation of superconducting radiofrequency accelerator technology, and it was proposed, designed, and built to enable nuclear physics research. Jefferson Lab scientists then leveraged their expertise in this technology to build a first-of-its-kind sister accelerator to power a free-electron laser. This laser allowed researchers to develop the patented synthesis technique for high-quality BNNTs and subsequently learn how to transfer the process to commercial lasers.

The BNNTs are very narrow and long; are as strong as carbon nanotubes; have few walls; are highly resistant to heat, most chemicals, high voltage, and neutron radiation; are thermally conductive and are made of pure boron nitride (which suggests they are likely not harmful to living cells). Recent research has shown that BNNTs bond more strongly to epoxies and certain plastics than do carbon nanotubes. BNNTs are anticipated to impact the energy efficiency of high-power electronics by providing thermally conductive electrically insulating layers.

BNNTs were first produced at Berkeley Lab in 1995, but it took almost 15 years to discover a process that could be scaled to commercial levels. Patents regarding the material developed at

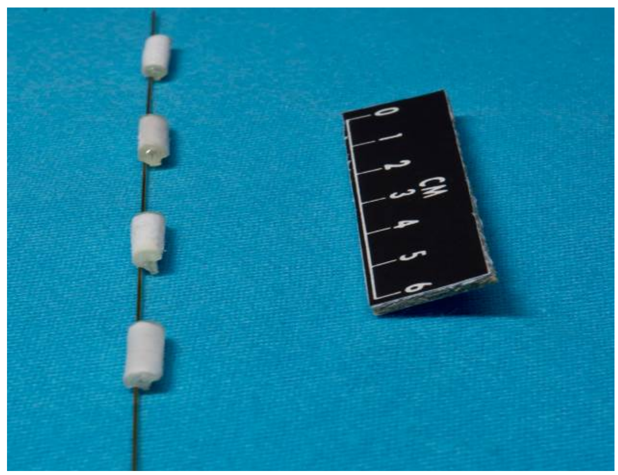
Jefferson Lab have been licensed to a small start-up company, BNNT, LLC. The company manufactures BNNTs for scientific investigations, application R&D and commercial products. As of January 2016, the company has provided BNNTs to more than 450 researchers in 28 countries.

ChIMES (Chemical Identification by Magneto-Elastic Sensing)

(Y-12 National Security Complex)

In collaboration with the University of Tennessee, Y-12 developed a new, low-cost sensor technology known as ChIMES (Chemical Identification by Magneto‑Elastic Sensing), which uses target response materials (TRMs) as actuators in magneto-elastic sensors. The TRMs can come from numerous classes of chemical and biochemical compounds, with many degrees of selectivity. Using strategically selected TRMs, the sensors can be built to detect chemical and biological agents, toxic industrial chemicals, waterborne and airborne pollutants, illegal drugs, food pathogens, and exhaled gases that indicate diseases—just to name a few possibilities.

While the ChIMES sensor can detect a broad range of targets, its most compelling attribute is that the sensor does not require direct contact with the readout electronics. Most sensors in today's market require a hardwired connection to the electronics, which means inserting a lead or probe through a hole in the suspect material, container, or structure, which exposes the analyst to a risk of contamination.



An array of three ChIMES sensors.

The ChIMES sensor has the very rare capability of wireless communication through a metallic or nonmetallic barrier. This feature alone enables many applications in which penetrations into the sampled environment are unwanted or infeasible because of health, safety, or environmental concerns. Another important feature is the size of the sensing element. The sensing element is tiny (with the current version being 12.7 mm in length and 3.8 mm in diameter), and several elements can be ganged for detection of multiple and variable targets. In addition, the separation of the sensing element and the detection system means there is exceptional latitude to miniaturize the sensor and tailor its shape, size, and appearance to suit a specific application. A single detection system can be used with an unlimited number of sensing elements. Configurations can be built for real-time or persistent readout, and, with relatively small modifications, a variation sensitive to radiation can be designed.

ChIMES received a 2015 R&D 100 Award, making it one of the 100 most technologically significant products introduced into the marketplace last year. A key piece of the success of this technology was the continuous stream of innovations created through the collaboration and partnership with the University of Tennessee. Y-12 continues work to miniaturize the electronic equipment that interprets sensor data while pursuing other opportunities to further the development to produce ChIMES units for the mainstream market.

Appendix F – Other New Technology Transfer Activities and Partnerships

Ames National Laboratory

Critical Materials Institute's Affiliates Program

The Critical Materials Institute (CMI) revised its Affiliates program in November of 2015. An Affiliate is an entity interested in being informed about CMI research outcomes and providing input to CMI on a continuing basis. The CMI Affiliates are an integral part in keeping the CMI's research relevant to the needs of the rare-earth community and the world. The CMI gains valuable input from its Affiliates and the Affiliates, in turn, develop new relationships, connect with unique talent, and stay abreast of cutting-edge research in the field.

Benefits that accrue to the Affiliates are as follows:

- CMI Annual Meetings and Topical Workshops
- Opportunities to interact with (and potentially recruit) CMI students, postdocs
- Networking with other CMI Affiliates, TEAM Members, and researchers
- CMI bi-weekly newsletters and CMI monthly webinars
- Priority notification of inventions available for licensing, to the extent allowed by Fairness of Opportunity requirements
- Partnering for new funding opportunities
- Opportunities to expand engagement under appropriate contractual terms
- Participation on the CMI Industry Council

Currently, there are 19 CMI Affiliates consisting of one federal agency, six large businesses, three small businesses, seven start-ups, one university, and one non-profit.

Powder-to-Parts Facility

The Ames Laboratory is investing some of its Contractor royalty funds into the start-up of a Powder-to-Parts (P2P) facility. The P2P facility is planned to be a state-of-the-art facility that bridges advanced powder making technology, additive manufacturing (AM), other net- shape parts fabrication, and non-destructive evaluation with professional development. This unique research and prototyping facility will offer custom powder-based parts fabrication and qualification under one roof, catalyzing rapid manufacturing implementation.

The Powder-to-Parts facility is being formulated and developed to take advantage of Ames Laboratory's world-leading synthesis and processing research accomplishments in gas atomization over the last 25 years. The Lab is seeing an increase in industry funded projects and anticipates that DOD supported work in this area will also increase as powder making and additive manufacturing gain prominence within both the public and private sector communities. Currently, the Lab has a 100% funds in CRADA in this area with a major U.S. company, an SPP with a small business that has SBIR funding, and is in negotiations for a SPP with another large U.S. company.

Brookhaven National Laboratory

Technology Maturation.

Supporting the Laboratory's strategic theme of "discovery to deployment", BNL has made investments in technology maturation projects by using royalty funds. These include R&D on inventions that enhance or extend the scope of patent claims, technology maturation experiments to improve market viability, demonstration, and/or support other activities (including support for BNL participation in partnerships activities such as CRADAs, Energy Efficiency and Renewable Energy (EERE), Advanced Research Projects Agency – Energy (ARPA-E), Department of Defense (DoD) proposals, etc.) that enhance the commercial viability of technologies, as well as licensing potential of new ideas or discoveries.

Proof of Concept/Feasibility program.

As part of the technology maturation efforts, BNL will also pilot for FY 2016 a Feasibility/Proof of Concept program fund aimed at promoting, fostering and stimulating new and innovative ideas among BNL researchers. It is intended to provide an opportunity for the researchers to test their ideas/research that could potentially enhance BNL's core scientific and technical disciplines and also address unmet market needs within the DOE's mission space.

The funds are designed to:

- Provide an opportunity for researchers to test a new idea so that they may qualify for future research funds
- Support new projects including testing the feasibility of new ideas/applications in the commercial world
- Support IP development

Industry network development.

BNL leadership in industry organizations continues to bear fruit in expanding licensing and partnership opportunities for the Laboratory. BNL has a consistent presence with local, regional, state, national and international groups, including Accelerate Long Island, Licensing Executives Society, Small Business Development Center at Stony Brook University and other local groups. These activities have opened doors to new user facility and Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) sub-award opportunities.

Build the innovation ecosystem.

BNL continues to expand its programs of entrepreneurial engagement and economic development. Through funding from Accelerate Long Island, two new start-up company(s) received $100K each in funding with potential add on funding. BNL continues to look for opportunities. BNL is active with investor and entrepreneur groups around the country, including the Long Island Capital Alliance, Topspin Partners, Norquest Capital, and Long Island Angels giving BNL a forum in which to showcase technologies to the investment community thus assisting in the transition and commercialization of nascent technologies.

Outreach to industry and research staff at BNL.

OTCP continues to provide educational opportunities to scientific researchers and the post doc community on diverse areas, such as how to work with industry; how to build companies and provide entrepreneurial training through and with SBU (CEBIP, Center of Excellence in Wireless and Information Technology [CEWIT], Center for Biotechnology); understanding the SBIR/STTR programs, Intellectual Property training and departmental sessions on IP.

Specific University Programs.

BNL supports technology through its investment in patents. In addition to patenting, BNL is also part of the economic ecosystem in the region working closely with Universities such as Stony Brook University, Cold Spring Harbor Laboratory and others through the LI Bio Center Cluster and the recently awarded NIH REACH project.

Lawrence Berkeley National Laboratory

LBNL Innovation and Partnerships Office

The Innovation and Partnerships Office (IPO) instituted the Berkeley Lab Innovation Corps (BLIC) in FY 2015. BLIC is dedicated solely to advancing lab-to-market efforts for Berkeley Lab technologies and to providing entrepreneurial and commercialization training and resources for lab researchers. IPO coordinates a monthly BLIC event open to all LBNL employees. Past events have included guest expert speakers on topics such as the current venture capital landscape, Bay Area startup resources (Breakout Labs, QB3), and legal considerations for startup companies. Presentations have included lessons learned from Berkeley Lab teams participating in DOE's Lab-Corps. IPO also maintains an online calendar of workshops and events of interest to BLIC's entrepreneurial researchers.

IPO has developed and instituted a pre-training curriculum in customer discovery and the business model canvas for Berkeley Lab's DOE Lab-Corps teams. To date, two Lab-Corps teams have completed the pre-training in advance of their Lab-Corps participation, enabling them to focus immediately on their technology commercialization plans during the intense six-week Lab-Corps session. In addition, three Berkeley Lab teams participating in Bay Area Regional NSF I-Corps training completed the pre-training before their six-week I-Corps programs.

IPO developed a secure, online Innovation Portal in FY 2015, enabling researchers and division support staff to view the status of their inventions, intellectual property, and licensing agreements online. The portal facilitates online Nondisclosure Agreements and Material Transfer Agreements to speed potential industry partnerships and offer full transparency for LBNL researchers requesting agreements.

IPO, in coordination with the Bay Area's Wareham Development, identified an opportunity for shared lab space open to companies working to commercialize technologies owned or managed by LBNL. Four startups have been selected to occupy the space, called Momentum, later in 2016.

IPO leads LBNL's participation in Cleantech-to-Market (C2M), a U. C. Berkeley Haas School of Business program bringing together teams of business, engineering, and science graduate students to evaluate commercialization pathways for early stage LBNL inventions. LBNL's technology transfer staff helped found C2M with the business school staff nearly 10 years ago.

National Renewable Energy Laboratory

Energy License

With an eye toward increasing shareholder value, a growing number of fortune 500 companies have adopted voluntary targets for the reduction of greenhouse gas emissions. With these goals in mind, the National Renewable Energy Laboratory is uniquely positioned to offer technology solutions that can catalyze the adoption of energy efficiency & renewable energy (EERE) technologies while reducing GHG emissions.

The NREL Eco License is designed to incentivize large-scale deployment of EERE technologies by allowing licensees to deduct a portion of their carbon dioxide (CO_2) emission offsets against a portion of the royalty obligation owed to NREL. NREL will not engage in carbon credit arbitrage and no credits will be assigned to NREL, but rather NREL will place an economic value on 1 kilogram of CO_2 emission offsets. CO_2 emission coefficient standards are provided as license exhibit D. Licensees can apply the calculated offset against their royalty obligation. As defined by the Small Business Administration, domestic large entities qualify for a 10% deduction while domestic small to medium sized entities can take a 20% deduction. In doing so, NREL is able to promulgate the spirit of the Bayh-Dole Act; promote the adoption of EERE technologies, promote U.S. competitiveness, give preference to U.S. small businesses and promote the utilization of federally funded innovations to benefit the public.

Industry Participation in NREL Tech Transfer Awards

Innovation and Technology Transfer Awards recognize employees for exceptional initiative in promoting the transfer of NREL-developed technologies into the private sector. In 2015, for the first time, industry companies and collaborating partners were invited to the event to celebrate technology successes with the Laboratory.

Strategy for IP Management Plans

NREL has adopted a novel approach to intellectual property management plans. The agreements are structured to offer tiered option rights that allow private entities to access intellectual property at a level congruent with their funds-in/cost share contributions.

IP Mapping

NREL has been very active in mapping the intellectual property landscape for BETO-funded R&D areas to proactively identify areas of applied interest between labs and industry.

Oak Ridge National Laboratory

The State of Tennessee, in partnership with the University of Tennessee and Oak Ridge National Laboratory (ORNL), have created a new $2.5 million manufacturing innovation program called RevV! The purpose of this pilot program is to assist Tennessee manufacturers by providing access to the world-class researchers and facilities available at ORNL through an industry voucher program. ORNL works with manufacturers across the state to tackle their toughest challenges in product development and in process innovation to help Tennessee manufacturers maintain a competitive advantage in the global marketplace.

Unique capabilities and expertise that can be engaged at ORNL include:

- Materials science and technology including advanced materials processing, characterization, and fabrication
- Measurement, sensor and control systems
- Computational science, data analytics, and modeling and simulation
- Energy and environmental related technologies

In its first year, RevV! funded fourteen manufacturing projects at ORNL supporting companies across the state.

Pacific Northwest National Laboratory

PNNL Launches Exploratory License

Pacific Northwest National Laboratory developed a new type of license in FY 2016 that is providing a quick and easy pathway to PNNL intellectual property for licensees unfamiliar with PNNL or other national Laboratories. The new "exploratory" license is a combination six-month, non-exclusive option and research license. It gives companies an easy, inexpensive way to explore whether a PNNL technology is a fit for their products or business, while also providing a pathway to a full, long-term relationship.

The exploratory license consists of a simple two-page form and simplified terms: $1,000 fixed price, U.S.-only, and one patent per agreement, so PNNL can turn these around in less than five business days. PNNL patents that are eligible for the exploratory license are shown in an easily searchable online database. Three months after putting the exploratory license in place, PNNL had already executed three of them with commercial companies.

PNNL Works with Innovative Collaborators for Investment and Commercialization

PNNL is constantly seeking new ways to collaborate with other organizations to support the commercialization and deployment process. For example, PNNL is working with a number of investment firms that specialize in early "patient capital," investing incrementally in nascent technologies on a stage-gate basis, in exchange for enhanced equity ownership/returns when the technology is eventually transformed into a business. One such firm is the private investor group FedIMPACT and its partner IP Group, which, to date, has committed to fund two PNNL technologies related to data storage and advanced analytical instrumentation.

In another example of an innovative collaboration, PNNL connected a cybersecurity startup that was based on PNNL technology with the EarlyX Foundation, Pepperdine University's nonprofit education foundation. A team of 26 MBA students and alumni at EarlyX identified an impressive 68 vertical market opportunities. With the help of PNNL researchers and commercialization managers, the EarlyX team conducted feasibility analyses and created market entry plans for 13 of the most promising markets. The involvement of EarlyX helped the startup, Champion Technology Company Inc., carry the technology over the proverbial “valley of death,” into commercial-stage development and marketing. The business then raised $1.54 million in seed funding and launched its beta-version cybersecurity product in 2016, while also winning a 2016 Federal Laboratory Consortium Award for Excellence in Technology Transfer with PNNL.

Sandia National Laboratory

Academic Alliance

Sandia formed the Academic Alliance to bring together the Labs’ status as a Federally Funded Research and Development Center and the know-how of major national research universities. The goal of the Academic Alliance is to advance science and engineering to enhance our national prosperity and security by providing opportunities for students and faculty to experience research work at a National Laboratory; engaging in joint recruiting of top graduate students, postdoctoral fellows and faculty; increasing transfer of technology from Sandia and universities to the private and federal sectors; and collaborating to address nationally significant problems.

The MOU was signed by Sandia President and Laboratories Director Paul Hommert, left, and Purdue President Mitch Daniels, right, at Sandia’s office in Washington, D.C. Also pictured are Marcey Hoover, deputy director of Sandia’s Energy & Climate Program Management Unit, and Suresh Garimella, Purdue executive vice president for Research and Partnerships. (Photo by Robert Severi)

Academic Alliance universities are working closely with Sandia on opportunities to explore more jointly held intellectual property, and more opportunities for technology transfer for the public good. Significant progress has been made with Purdue by the recent establishment of a commercialization agreement between the two institutions.

The universities currently taking part in the Academic Alliance are Georgia Tech, Purdue University, University of Illinois Urbana-Champaign, University of New Mexico, and University of Texas at Austin.

Center for Collaboration and Commercialization (C3)

Rob Leland, Sandia Vice President and Chief Technology Officer (fifth from the left), discussed his vision for Sandia entrepreneurs at a July Roundtable.

C3 will be an inspiring and energizing place that will serve as a public face for Sandia National Laboratories, providing access to the Labs, and building linkages with the community. It will be a place where Sandians and their industrial, academic, and government partners can interact easily and freely, outside the gates. Located in the Sandia Science & Technology Park (SS&TP), the new multi-tenant facility will be dedicated to increasing Sandia's collaboration and commercialization activities.C3 will offer spaces for lease along with programs and services for tenants and partners, all designed to facilitate successful partnerships.[36]

Entrepreneur Exploration: A Part of Region's Startup Ecosystem

Monthly programs at the Sandia Science & Technology Park (SS&TP) inspired businesspeople and would-be entrepreneurs as the Entrepreneur Exploration program was launched in 2015. One-on-one advice, presentations, and training sessions helped participants refine their business goals and learn how to commercialize technology.

In 2015 over 400 Sandians, SS&TP leaders, New Mexico Small Business Assistance (NMSBA) Program participants, and community leaders participated in Entrepreneur Exploration programs. Events included Office Hours, Roundtables, and Bootcamps.

- During Office Hours, business experts and serial entrepreneurs offered personalized assistance, answered challenging startup questions, and helped businesses outline their action plans and define critical milestones.
- At Roundtables, industry leaders provided overviews of specific startup topics and then answered questions from the audience.
- In Bootcamps, mentors taught the fundamentals of Lean Startup methodology and worked with entrepreneurs to outline their business model in an interactive format.

Entrepreneur Exploration is the first new program for the Center for Collaboration and Commercialization (C3) initiative, which will include a facility planned for the SS&TP. Currently, Entrepreneur Exploration programs are being held at the National Museum of Nuclear Science & History, also located in the SS&TP. The permanent C3 multi-tenant building will serve as a public face for Sandia, dedicated to increasing Sandia's collaboration and commercialization

[36] Visit sstp.org/C3 to find out more the Center for Collaboration and Commercialization and the Entrepreneurship Exploration Program

activities and building linkages with the community. It will be a place where Sandians and their partners can interact easily and freely, outside the gates.[36]

New Mexico Small Business Assistance (NMSBA) Program Results

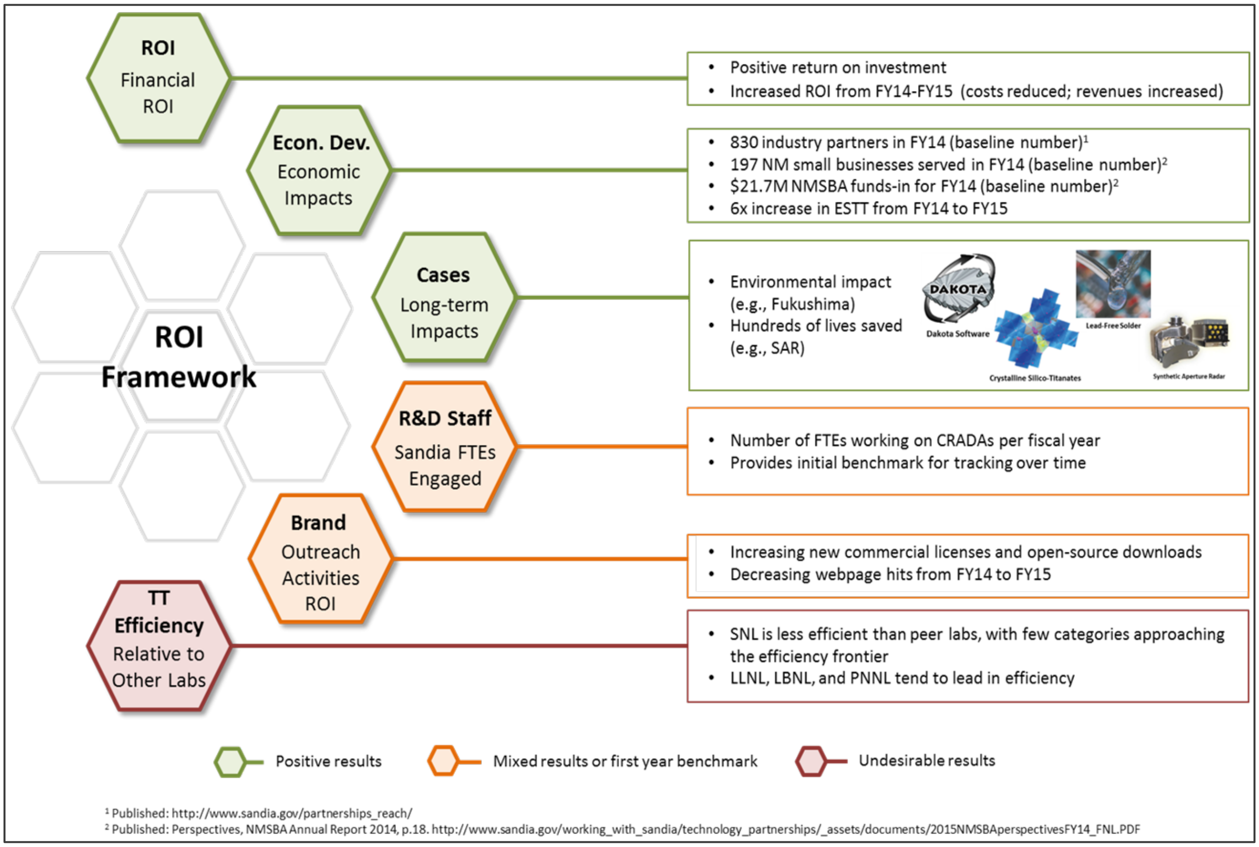
The New Mexico Small Business Assistance (NMSBA) Program, a joint program between Sandia National Laboratories and Los Alamos National Laboratory, was created by the state of New Mexico to bring the technology and expertise of the National Laboratories to local small businesses to promote economic development in the state, with an emphasis on rural areas. In exchange for assistance to these businesses, the two Labs get credit against their gross receipts taxes. In calendar year 2015, Sandia received $2.4 million in tax credits (the maximum allowed by law) from the state. In addition to the benefit of the tax credit, Sandia scientists and engineers have been able to apply their unique expertise in real world scenarios, supporting 205 small businesses in 18 counties resulting in jobs created and retained for New Mexicans. There were 81 Sandia Principal Investigators across 63 departments that supported NMSBA.

Since its start in 2000, NMSBA has assisted 2,495 small businesses for a total of $48.5M. The program has had a significant economic impact to New Mexico with 4,863 jobs created and retained. To find out more the New Mexico Small Business Assistance Program, visit nmsbaprogram.org.

Sandia Tech Transfer ROI Framework

In FY 2015, a corporate milestone was created with the intention of developing a consistent measure for return on investment (ROI) of technology transfer. In response, the Sandia Technology Transfer group developed a comprehensive return on investment (ROI) framework based upon a review of relevant literature. Shown on the next page, the framework consists of six different components including a traditional financial ROI calculation, an economic development impact assessment, case studies that measure long-term outcomes and impacts, a measure of impact on R&D staff, a costs/benefits analysis for branding (i.e. outreach activities ROI), and an econometric model of Sandia's tech transfer efficiency.

Sandia Technology Transfer ROI Framework Summary Results



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Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities

Fiscal Year 2015

Report to Congress
July 2018

U.S. DEPARTMENT OF ENERGY