Federal Laboratory Technology Transfer

Fiscal Year 2018

Summary Report to the President and the Congress

Prepared by:
National Institute of
Standards and Technology
U.S. Department of Commerce

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FOREWORD

The Department of Commerce (DOC) is pleased to submit this Fiscal Year 2018 Technology Transfer Summary Report to the President and the Congress. This report illustrates the continuing efforts of federal laboratories to ensure that the nation's investment in innovative research is transferred from our laboratories to the American people.

Federal laboratories, through their fundamental and mission-oriented research and development (R&D) investments, have historically been at the forefront of scientific discovery, invention, and technological innovation. Technology transfer facilitates the practical application of federal research directly through the transfer of laboratory results and by providing non-federal entities the opportunities to partner with federal laboratories on innovative research of mutual interest. Over the years, new products, services, and the formation of new companies have occurred through technology transfer initiatives.

The cross-agency focus on the lab-to-market efforts have emphasized the important role that innovation plays in accelerating the development of new industries, products, and services that lead to economic growth and job creation. Agencies have engaged in efforts to accelerate technology transfer activities, improved and expanded the collection of technology transfer metrics, and established performance goals and evaluation methods to enhance the efficiency and impact of their technology transfer activities.

This report fulfills the requirement contained in 15 U.S.C. § 3710(g)(2), for an annual report summarizing the use of technology transfer authorities by federal agencies. It highlights the achievements of federal technology transfer and includes data on the use of specific transfer authorities. Future editions of this report will be used to continue to keep the President and the Congress informed of the ongoing efforts of federal laboratories to expand our technology transfer efforts in partnership with U.S. industry, academic institutions, non-profit foundations, and state, local, and tribal governments. These efforts will continue to play a vital role in building the nation's economic strength.

Dr. Laurie E Locascio
Under Secretary of Commerce for Standards and Technology, &
Director, National Institute of Standards and Technology

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Chapter 1
Overview of Federal Technology Transfer

Many federal agencies conduct research and development (R&D) activities that result in the creation of new technologies. In most cases, these technologies are created to support specific needs of an agency's mission. In other cases, they are spontaneous creations of ongoing research. Regardless of how they are created, federal technologies can have significant value that goes beyond an agency's mission. It is the role of an agency's technology transfer office to identify this value and provide the most effective means to transfer it outside of the agency.

Federal legislation provides a variety of vehicles through which federal technologies can be transferred.[1] These vehicles facilitate the potential commercialization of inventions, enable the use of federal laboratory facilities by non-federal entities, and allow for the establishment of research partnerships between federal government laboratories and other entities. This includes the processing of patent applications and licenses as well as cooperative research and development agreements (CRADAs) and other mechanisms that convey knowledge, ownership rights, or establish formal research agreements.

Collaborative research is particularly important to the technology transfer process and in many ways, is fundamental to every agency's mission. By bringing together thousands of highly qualified researchers and world-class research facilities, collaborative research between federal and non-federal organizations greatly enhances researcher capabilities, core competencies, and creativity. This in turn leads to the flow of new ideas, new tools, more efficient techniques, new processes and products, and new businesses. Collaborative research also helps agencies attract and retain talented scientific personnel through rewards and royalty sharing opportunities.

Over the last decade agencies have responded to the need to improve technology transfer operations to better address the needs of business and especially small businesses that are vulnerable to a slow-moving bureaucratic system. The interagency coordination of efforts has led agencies to review their operations and propose new ways to improve the overall customer experience. These improvements include efforts to streamline operations to open doors to more efficient technology transfer opportunities. Other improvements target the way customers interact with the federal system.

This annual report summarizes the technology transfer activities and transfer vehicles used by 11 federal agencies that have significant federal laboratory operations:[2]

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[1] The primary legislation addressing federal technology transfer includes the Stevenson-Wydler Technology Innovation Act of 1980, 15 U.S.C. 3701 et seq., the Patent and Trademark Act Amendments of 1980 (Bayh-Dole Act), 35 U.S.C. 200 *et seq.*, the Small Business Innovation Development Act of 1982, 15 U.S.C. 638, and the Federal Technology Transfer Act of 1986, 15 U.S.C. § 3710a. Numerous other acts indirectly affect federal technology transfer activities.

[2] In this report, the term "Federal laboratory" refers to any laboratory, any federally funded research and development center, or any center established under 15 U.S.C. § 3705 or 15 U.S.C. § 3707 that is owned, leased, or otherwise used by a federal agency and funded by the federal government, whether operated by the Government or by a contractor.

Department of Agriculture (USDA)
Department of Commerce (DOC)
Department of Defense (DoD)
Department of Energy (DOE)
Department of Health and Human Services (HHS)
Department of Homeland Security (DHS)
Department of the Interior (DOI)
Department of Transportation (DOT)
Department of Veterans Affairs (VA)
Environmental Protection Agency (EPA)
National Aeronautics and Space Administration (NASA)

Each of these agencies has established programs for promoting the transfer and commercialization of technologies developed in its R&D laboratories and has provided the data contained in this report. The DOC's National Institute of Standards and Technology (NIST) prepared and organized this report. An electronic version of this report is available.

Federal R&D Spending

Spending on R&D by the federal government supports a wide variety of agency-specific missions, for instance, military objectives, health and human services issues, energy development, space exploration, and so forth. In FY 2018, the total federal budget for R&D was $129,425 million. Of this, $81,016 million (63%) was used to support R&D activities that occurred outside of the federal laboratories. This includes funding for grants, cooperative agreements, and similar instruments.[3] The remainder, $48,409 million (37%), supported R&D activities that occurred inside federal laboratories. This includes $35,953 million to support intramural activities and $12,456 million to support federally funded R&D centers (FFRDCs). The technology transfer activities described in this report support new technologies that arise from these federal laboratory R&D investments. As shown in the table below, the percent of an agency's budget that was available for federal laboratory R&D varied significantly among agencies.

Federal Obligations for R&D
By Agency FY2018 ($ million)[4]

	Total R&D	Intramural[(a)]	FFRDCs	Intramural and FFRDCs	Percent of Total R&D Budget
DoD	$52,973	$18,999	$1,683	$20,681	39%
HHS	$36,911	$8,315	$638	$8,953	24%
DOE	$12,832	$1,336	$7,502	$8,838	69%
NASA	$10,717	$1,484	$2,034	$3,518	33%
USDA	$2,479	$1,550	$0	$1,550	63%
VA	$1,349	$1,277	$73	$1,349	100%
DOC	$1,439	$1,027	$24	$1,051	73%
DOI	$766	$670	$1	$671	88%
DHS	$912	$365	$90	$455	50%
DOT	$1,046	$210	$80	$290	28%
EPA	$487	$255	$1	$256	52%
Other Agencies	$7,514	$466	$331	$797	11%
All Agencies	$129,425	$35,953	$12,456	$48,409	37%

(a) Intramural activities cover costs associated with the administration of intramural and extramural programs by federal personnel as well as actual intramural performance.

[3] A federal award is an instrument setting forth terms and conditions of an agreement between a federal agency and non-federal entity. Awards can include, among other things, grants and cooperative agreements. Grants and cooperative agreements are similar in that they transfer funds (or anything of value) to a non-federal entity but differ in that cooperative agreements involve substantial involvement by the federal awarding agency usually in terms of project oversight and management.

[4] National Science Foundation (NSF), National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development Fiscal Years 2018-19, Federal Obligations for Research and Development, by Agency and Performer, FY 18, Table 7.

In FY 2018, DoD spent the largest amount of funding for intramural activities and FFRDCs, $20,681 million (39% of its R&D budget). The HHS was second with $8,953 million (24% of its R&D budget) and DOE was third with $8,838 million (69% of its R&D budget).

Federal Technology Transfer Summary

Every federal agency that operates or directs one or more federal laboratories or that conducts research and development is required to prepare and submit an annual report of its technology transfer activities as described in 15 U.S.C § 3710(f). These reports contain details on each agency's technology transfer program as well as agency plans to use technology transfer to advance the agency's mission and to promote U.S. competitiveness.[5] The following tables summarize federal technology transfer activities for the five-year period from FY 2014 through FY 2018.[6]

[5] A list of agency technology transfer reports.

[6] Technology transfer data are routinely adjusted over time to account for new information resulting from changes in reporting procedures, patent decisions, programmatic changes, and other corrections. Throughout this report, data prior to FY 2018 have been adjusted where necessary to reflect the most accurate estimates for each year reported. The data in this report are accurate per the reporting agencies as of June 6, 2022. The data presented in this report may differ from individual agency reports submitted for FY 2018 if the agencies have updated those data after the agency report was submitted.

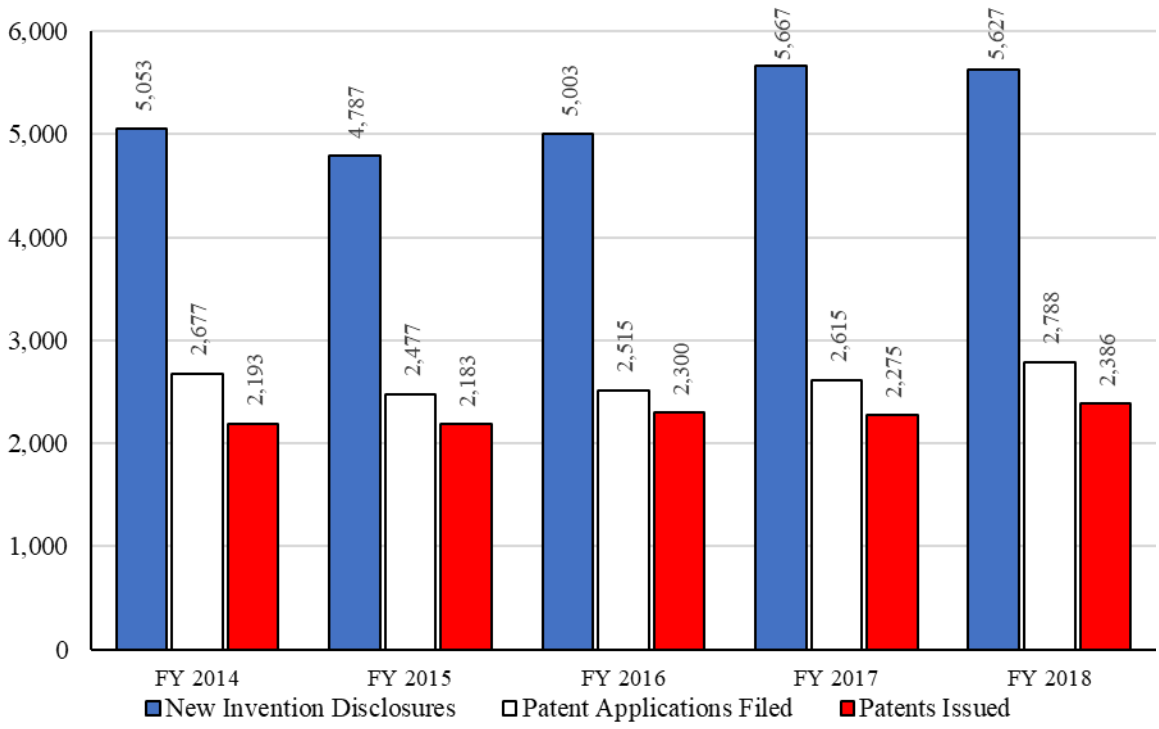
Federal Invention Disclosures and Patenting

The protection of intellectual property can be vital to attracting the additional investment and product development resources necessary for early-stage research products to be brought to their full commercial potential. Federal laboratory achievements in the areas of invention disclosures and patents issued are often cited as metrics of the active management of intellectual assets and technical know-how by federal agencies.

Between FY 2014 and FY 2018, invention disclosures reported by federal agencies increased by 11% to 5,627. Patent applications filed increased by 4% to 2,788, and patents issued increased by 9% to 2,386. NASA reported the largest number of invention disclosures with 1,775 in FY 2018, followed by DOE with 1,748 and DoD with 839. These three agencies accounted for 78% of all invention disclosures reported in this fiscal year.

In FY 2018, DoD reported the largest number of patent applications with 1,060, followed by DOE with 868, and VA with 255. These three agencies accounted for 79% of patent applications in FY 2018. DOE reported the largest number of patents issued in FY 2018 with 854, followed by HHS with 624, and DOD with 600. These three agencies accounted for 87% of reported patents issued in FY 2018.

Federal Invention Disclosures and Patenting

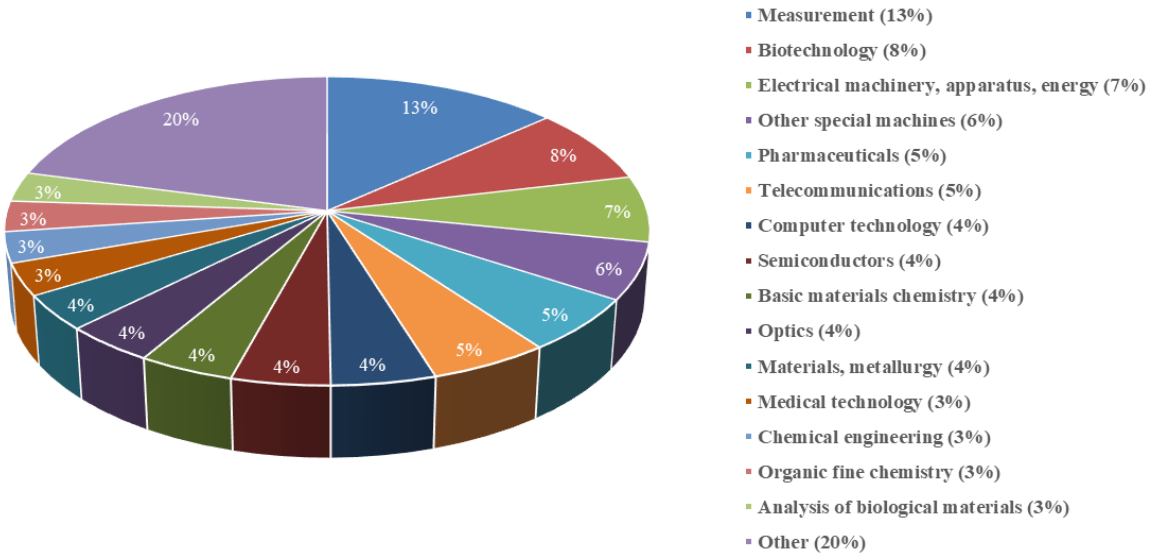


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	5,053	4,787	5,003	5,667	5,627
Patent Applications Filed	2,677	2,477	2,515	2,615	2,788
Patents Issued	2,193	2,183	2,300	2,275	2,386

Technical Area Summary of U.S. Federal Agency Patents

The chart below uses data from the U.S. Patent Office (USPTO) to illustrate the technical areas covered by patents issued to federal agencies in FY 2018. The chart shows the percentage of patents issued to federal agencies by technology area based on fractional count patents.[7] In FY 2018, the largest number of federal patents issued involved Measurement (13%), followed by Biotechnology (8%), Electrical Machinery, Apparatus, Energy (7%), Other Special Machines (6%), Pharmaceuticals (5%), Telecommunications (5%), Computer Technology (4%), Semiconductors (4%), Basic Materials Chemistry (4%), Optics (4%), Materials, Metallurgy (4%), Medical Technology (3%), Chemical Engineering (3%), Organic Fine Chemistry (3%), Analysis of Biological Materials (3%), and Other (20%).[8]

USPTO Patents Assigned to Selected U.S. Federal Agencies by Technology Area: FY 2018



[7] In this summary, patents are credited on a fractional-count basis (i.e., for patents with assignees from multiple federal agencies, other U.S. institutions, or foreign institutions, each federal agency receives fractional credit based on the proportion of its participating institution(s)). Furthermore, fractioning is used at the level of Internal Patent Classification (IPC) codes to ensure that the sum of patents across technology areas (WIPO technology classification) is equal to the total number of patents as each patent can be assigned to more than one technology area. Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in October 2018. Used with permission.

[8] Definitions for all technology areas addressed are included in Appendix B.

Federal Licenses

Licensing of federally developed technologies is an important technology transfer mechanism that creates incentives for industry to invest the resources necessary to develop and commercialize nascent leading-edge technologies. Successful development and commercialization of federal technologies create benefits to the economy and contribute to competitiveness and domestic economic growth. The ability to grant licenses to the nonfederal sector helps protect, utilize, or further develop and utilize federally developed innovations, which would not be further developed into commercial products or services otherwise. The terms and conditions under which federal intellectual property is licensed varies based upon many factors, including the extent of development of the technology, the financial resources needed to further develop the technology for consumer use, fields of use, projected market impact, and other factors.

Data for some agencies were not available for this report.[9] The values reported in this section are calculated using the data from agencies for which a complete set of data are available to more accurately reflect changes in these measures over time. Between FY 2014 and FY 2018, total active licenses reported by federal laboratories for which data were available increased by 6%, from 8,707 in FY 2014 to 8,226 in FY 2018.[10] New licenses reported by agencies for which data were available increased by 47%, from 904 in FY 2014 to 1,325 in FY 2018.[11] Invention licenses reported by agencies for which data were available decreased by 7%, from 3,486 in FY 2014 to 3,233 in FY 2018 while new invention licenses increased by 41% to 530.[12] Invention licenses refers to inventions that are patented or could be patented. Income-bearing licenses decreased by 5% to 5,644 and exclusive income-bearing licenses reported by agencies for which data were available increased by 72% to 885.[13]

In FY 2018, DOE reported the largest number of total active licenses with 4,742 licenses. The HHS was second with 1,867 licenses and NASA was third with 540 licenses. These three agencies accounted for 87% of all licenses reported in FY 2018.

In FY 2018, HHS reported the largest number of invention licenses with 1,411, followed by DOE 844, and NASA with 488. Together these three agencies accounted for 85% of invention licenses in FY 2018.

[9] Data for some agencies were not available for this report. Data for FY 2018 values for total active licenses, new licenses, invention licenses, and new invention licenses were not available for VA. Data for FY 2018 values for invention licenses, total active and new invention licenses, were not available for DoD. Data for FY 2014 and FY 2015 income bearing exclusive licenses were not available for DoD. Data for FY 2018 values for invention licenses, total active, new invention licenses, and income bearing exclusive licenses were not available for DOI.

[10] Total active licenses for all agencies, including those for which data were not available, decreased by 8% from 8,904 in FY 2014 to 8,226 in FY 2018.

[11] New licenses for all agencies, including those for which data were not available, increased by 46% from 907 in FY 2014 to 1,325 in FY 2018.

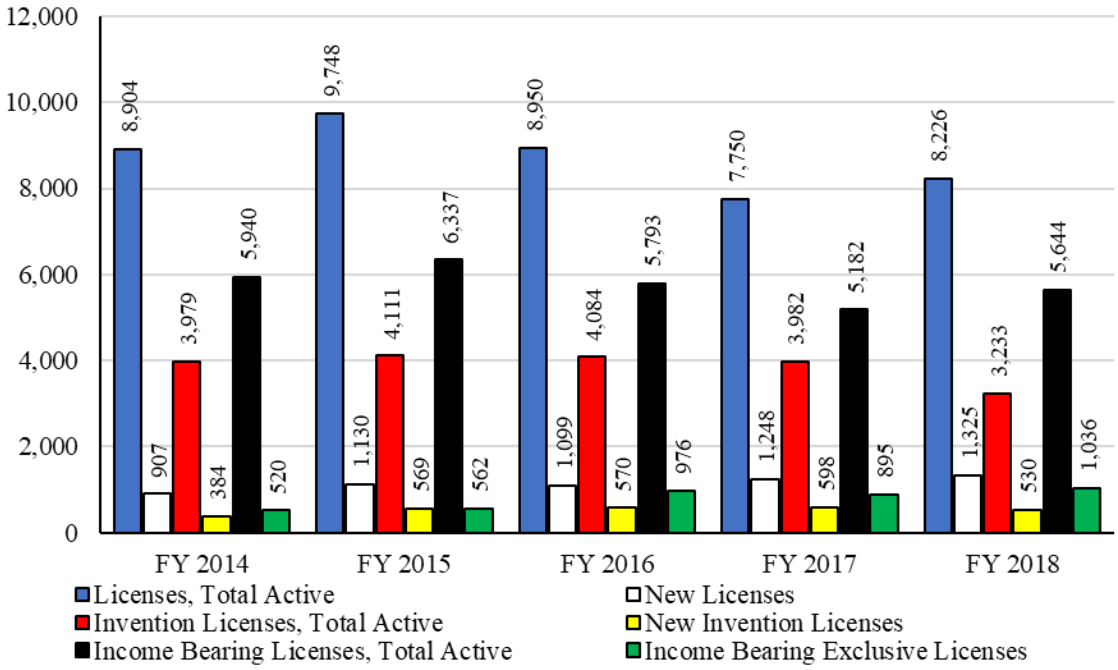
[12] Invention licenses for all agencies, including those for which data were not available, decreased by 19% to 3,233 while new invention licenses increased by 38% to 530.

[13] Exclusive income bearing licenses for all agencies, including those for which data were not available, increased by 99% to 1,036.

In FY 2018, DOE reported the largest number of income-bearing licenses, 3,323. The HHS was second with 978 followed by USDA with 472. Together these three agencies accounted for 85% of income-bearing licenses in FY 2018.

In FY 2018, USDA reported the largest number of income-bearing exclusive licenses with 324, followed by VA with 205, and DOE with 181. Together these three agencies accounted for 69% of income-bearing exclusive licenses in FY 2018.

Federal Licenses[14]



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	8,904	9,748	8,950	7,750	8,226
New Licenses	907	1,130	1,099	1,248	1,325
Invention Licenses, Total Active	3,979	4,111	4,084	3,982	3,233
New Invention Licenses	384	569	570	598	530
Income Bearing Licenses, Total Active	5,940	6,337	5,793	5,182	5,644
Income Bearing Exclusive Licenses	520	562	976	895	1,036

Federal Income from Licenses

Licensing income includes income received for earned royalties from partners, license issue fees, minimum annual royalties, paid-up license fees, and reimbursement for full-cost recovery of goods and services provided by the lab to the licensee, including patent costs. Data for some agencies were not available for these measures.[15] Between FY 2014 and FY 2018, income from all licensing reported by agencies for which data were available decreased by 23% to $139

[14] This figure shows data for all agencies, including those for which some data were not available.
[15] DoD was unable to provide values for licensing income for FY 2016, FY 2017, and FY 2018 and for invention licenses income for FY 2017 and FY 2018.

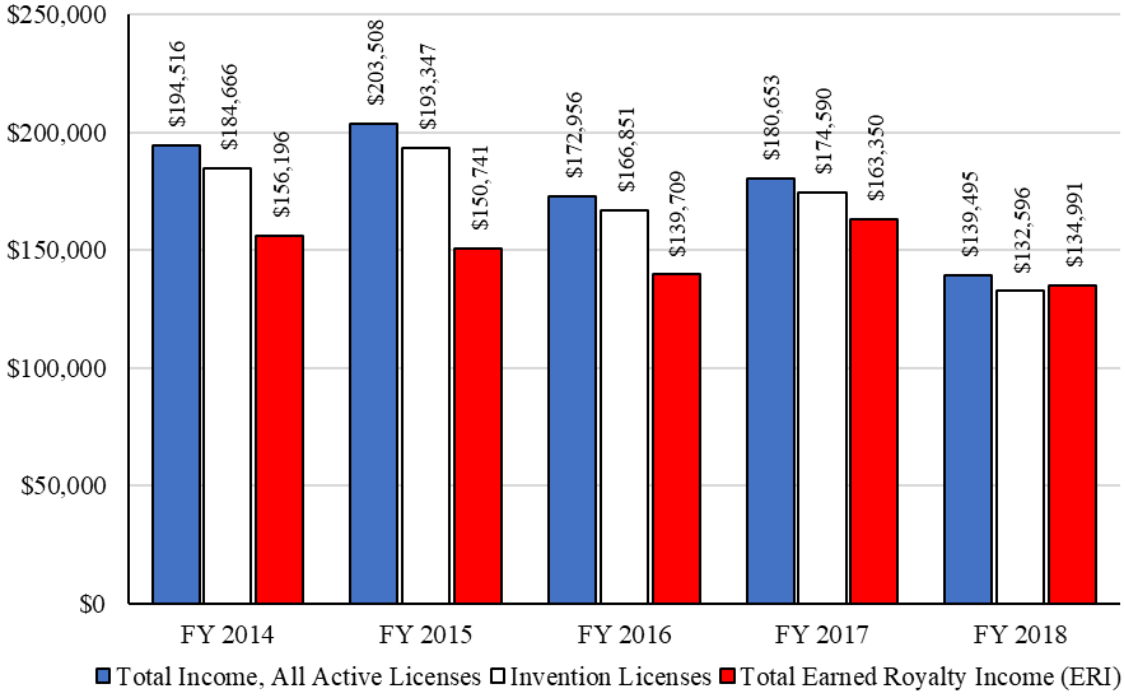
million.[16] Income from invention licenses reported by agencies for which data were available decreased by 23% to $132 million and total earned royalty income decreased by 14% to $135 million.[17]

The HHS accounted for the most licensing income with $111 million, followed by DOE with $21 million, and USDA with $4 million. Together these three agencies accounted for 97% of reported licensing income.

The HHS accounted for the most invention license income with $108 million, followed by DOE with $17 million, and USDA with $3 million. Together these three agencies accounted for 97% of Invention License Income.

The HHS accounted for the most Earned Royalty Income with $112 million, followed by DOE with $10 million, and DoD with $7 million. Together these three agencies accounted for 95% of Earned Royalty Income.

Federal Income from Licenses ($ thousands)[18]



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$194,516	$203,508	$172,956	$180,653	$139,495
Invention Licenses	$184,666	$193,347	$166,851	$174,590	$132,596
Total Earned Royalty Income, (ERI)	$156,196	$150,741	$139,709	$163,350	$134,991

[16] Income from all licenses for all agencies, including those for which data were not available, decreased by 28% to $139 million.
[17] Income from invention licenses for all agencies, including those for which some data were not available, decreased by 28% to $133 million
[18] This figure shows data for all agencies, including those for which some data were not available.

Federal Collaborative R&D Relationships

Collaborative R&D relationships between federal laboratories and non-federal collaborators are widely viewed as an effective and economical means of transferring technology through joint research. These relationships create a mutually advantageous leveraging of federal agency and collaborator resources and technical capabilities, as well as to provide avenues for both the collaborator and the federal laboratory to gain new competencies and develop new skills.

One frequently used mechanism for establishing joint research relationships is the cooperative research and development agreement (CRADA). The CRADA is a multifaceted mechanism that can be used to address several kinds of partnership needs. "Traditional CRADAs" refer to formal collaborative R&D agreements between a federal laboratory and nonfederal partners. Other special CRADA arrangements are used by federal agencies to address special purpose applications such as material transfer agreements or agreements that facilitate technical assistance activities.

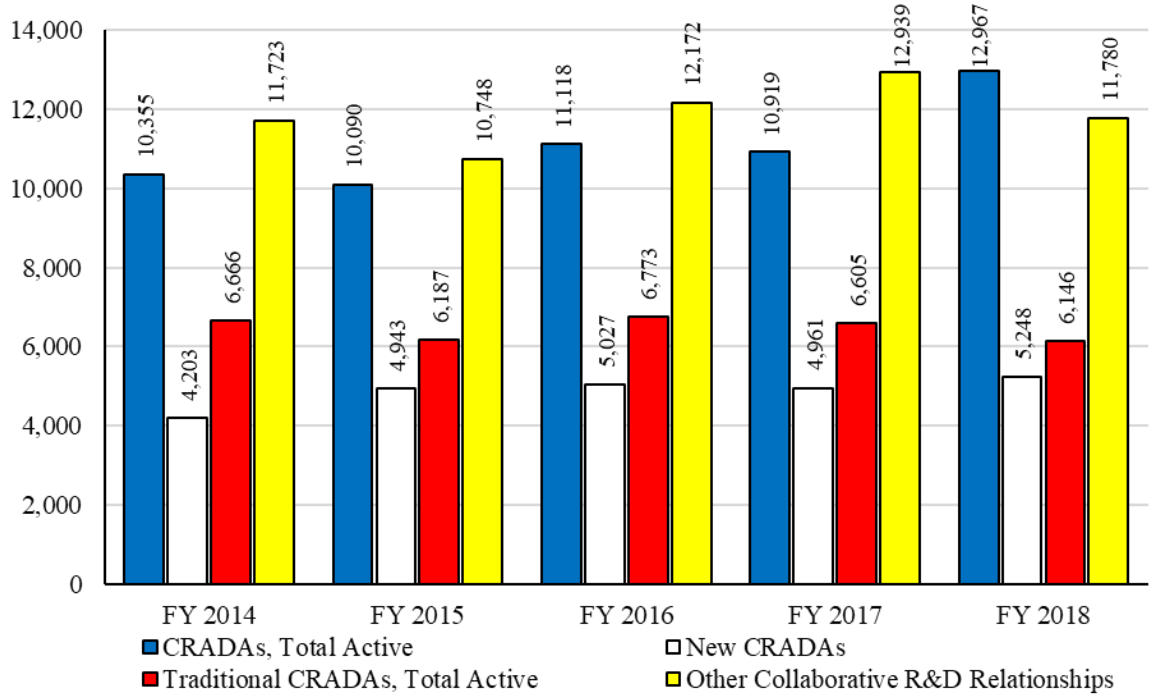
In addition to CRADAs, agencies have other specific authorities that also facilitate cooperative R&D relationships, such as Space Act Agreements (NASA) or other transaction authorities.

Data for some agencies were not available for these measures.[19] Between FY 2014 and FY 2018, active CRADAs increased by 25% to 12,967. New CRADA agreements increased by 25% to 5,248. Other collaborative R&D relationships increased by 0.5% to 11,780.

In FY 2018, DoD reported the largest number of CRADAs with 4,976, followed by DOC with 3,363, and VA with 1,688. The DOC reported the largest number of other collaborative R&D relationships with 3,497, USDA was second with 3,215, and NASA was second with 2,182 (Space Acts Agreements).

[19] DOE was unable to provide data on traditional CRADAs and other collaborative agreements for FY 2018.

Federal Collaborative R&D Relationships[20]



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	10,355	10,090	11,118	10,919	12,967
New CRADAs	4,203	4,943	5,027	4,961	5,248
Traditional CRADAs, Total Active	6,666	6,187	6,773	6,605	6,146
Other Collaborative R&D Relationships	11,723	10,748	12,172	12,939	11,780

Science and Engineering (S&E) Articles

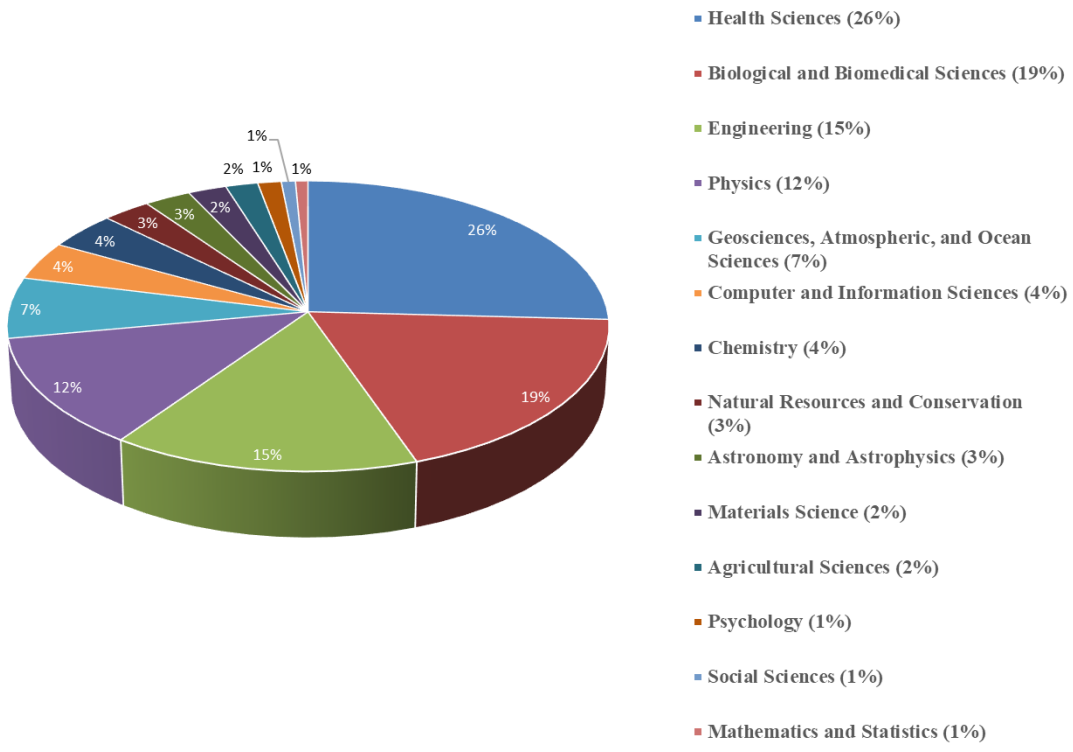
Although intellectual property has traditionally been tracked in terms of patents, licenses, and collaborative efforts, most federal research results are transferred through publication of S&E articles. Unfortunately, a uniform tracking system for S&E articles across all federal agencies does not exist; however, data from Thomson Reuters' Web of Science database can provide insight into the nature of S&E articles published by technology area even though not all articles published by federal agencies are included in the publications covered by this database. For example, in 2018, Thomson Reuters reports that federal researchers authored or coauthored 70,957 articles using a whole-count basis (where each agency gets full credit for each article even if the article has co-authors from different agencies).[21]

[20] This figure shows data for all agencies, including those for which some data were not available.

[21] Data prepared by Science-Metrix. Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) classified under Caspar fields using the CHI classification. Articles are classified by the year they entered the database, rather than the year of publication, and are assigned to a federal agency based on the institutional addresses listed in the article. Because the CHI classification classifies journals accounting for only about 60% of all publications indexed in the Web of Science, the classification was expanded to fully cover the database using a two-step approach. The first step was to classify all journals under the same fields as those determined for the preparation of the NSF SEI 2018 indicators. The remaining journals were then assigned to a unique field using citations to and from journals to determine their most relevant field. Used with permission.

The Thomson Reuters' database provide the additional benefit of identifying publications by federal researchers according to science and engineering categories. Using this data, the greatest percentage of articles addressed research in Health Sciences (26%), Biological and Biomedical Sciences (19%), Engineering (15%), Physics (12%), and Geosciences, Atmospheric, and Ocean Sciences (7%).[22]

S&E Articles Authored by Selected U.S. Federal Agencies, by S&E Fields: CY 2018



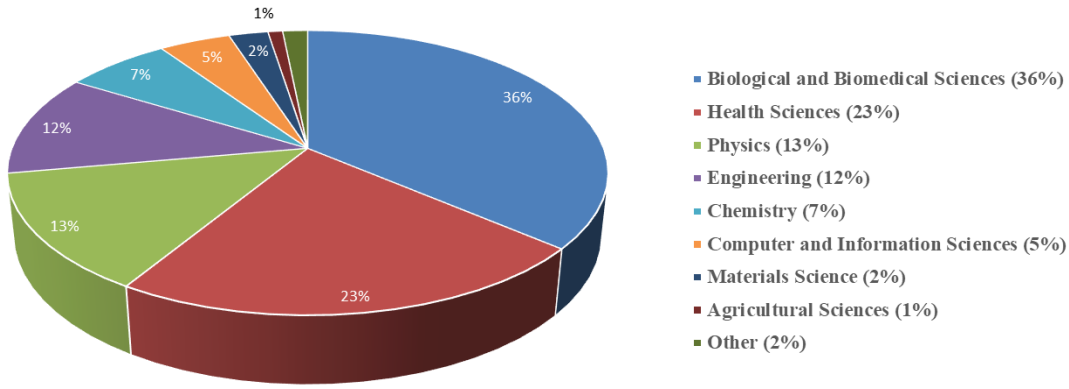
Citations within U.S. Patents

Thomson Reuters' data also provides insight into the commercial relevance of S&E articles authored by federal researchers through the number of articles cited in U.S. patents. In FY 2018, more than 18,897 articles authored or coauthored by federal researchers were cited in U.S. patents.[23] Of these, the greatest number of articles addressed research in Biological and

[22] Articles are credited on a fractional-count basis (i.e., each participating federal agency receives a share of the publication proportional to its share of addresses on the publication). Source: Prepared by Science-Metrix using the Web of Science database (Thomson Reuters) accessed in October 2018. All rights reserved. Used with permission.
[23] Data prepared by Science Metrix. Cited articles are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) classified under Caspar fields using the CHI classification. Cited articles are classified by the year of publication and are assigned to a federal agency based on the institutional addresses listed in the article. Because the CHI classification classifies journals accounting for only about 60% of all publications indexed in the Web of Science, the classification was expanded to fully cover the database using a two-step approach. The first step was to classify all journals under the same fields as those determined for the preparation of the NSF SEI 2018 indicators. The remaining journals were then assigned to a unique field using citations to and from journals to determine their most relevant field. Used with permission.

Biomedical Sciences (36%), Health Sciences (23%), Physics (13%), Engineering (12%), and Chemistry (7%).[24]

Citation of U.S. S&E Articles Authored by Selected U.S. Federal Agencies, in USPTO Patents, by S&E Field: FY 2017



Efforts to Enhance Technology Transfer Outcomes and Entrepreneurship

In addition to individual agency streamlining activities and developing new metrics to quantify technology transfer impact, federal agencies have also been involved in activities that have been designed to promote awareness and enhance the effectiveness of technology transfer activities.

The Innovation Corps Program

In 2011, the National Science Foundation (NSF) established the Innovation Corps (I-Corps™)[25] program to help scientists and engineers focus their attention upon critical business-related issues that are fundamental to the commercialization of new and emerging technologies. Originally designed to broaden the impact of NSF-funded basic research projects, other federal agencies have adopted the successful program to enhance the economic impact of their own technology transfer efforts.

DoD

The I-Corps DoD program is a partnership with the National Science Foundation to provide DoD-funded researchers with training from experienced entrepreneurs in how to commercialize their innovations. The DoD's Basic Research Office (BRO) is also looking to establish bridges that will allow teams who have completed the training to more seamlessly mature innovations into products that may enter DoD programs of record.

[24] Citations are classified on a fractional-count basis (i.e., for cited articles with collaborating institutions from federal agencies, other U.S. institutions, or foreign institutions, each federal agency receives fractional credit based on the proportion of its participating institution(s)). Source: Prepared by Science-Metrix using the Web of Science (Thomson Reuters) accessed in October 2018 and PatentsView accessed in October 2018. All rights reserved. Used with permission.

[25] See http://sbir.cancer.gov/resource/icorps/

NIH

The I-Corps at the National Institutes of Health (NIH) program is focused on educating researchers and technologists on how to translate technologies from the lab into the marketplace. The program provides three-member project teams with access to instruction and mentoring in order to accelerate the translation of technologies currently being developed with NIH and CDC Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) funding. It is anticipated that outcomes for the I-Corps teams participating in this program will include significantly refined commercialization plans and well-informed pivots in their overall commercialization strategies. Under this program, NIH and CDC foster the development of early-stage biomedical technologies, focus on teaching researchers how to gain a clearer understanding of the value of their inventions in the marketplace, and ultimately how to advance their technologies from the research lab into the commercial world. The program complements activities within the scope of the parent SBIR and STTR grant programs to help accelerate the commercialization of new products and services derived from NIH- and CDC-funded technical feasibility studies.

DOE

At DOE, the Energy I-Corps™ program, formerly known as Lab-Corps, pairs teams of researchers with industry mentors for an intensive two-month training where the researchers define technology value propositions, conduct customer discovery interviews, and develop viable market pathways for their technologies. Energy I-Corps is managed by DOE's National Renewable Energy Laboratory (NREL). The NREL leads curriculum development and execution, recruits program instructors and industry mentors, and assembles teams from the following national labs:

Argonne National Laboratory	Los Alamos National Laboratory
Fermi National Accelerator Laboratory	National Renewable Energy Laboratory
Idaho National Laboratory	Oak Ridge National Laboratory
Lawrence Berkeley National Laboratory	Pacific Northwest National Laboratory
Lawrence Livermore National Laboratory	Sandia National Laboratories

Other agencies have incorporated I-Corps™ into their programs. The DHS, DoD, and NASA partner with NSF to send their awardees through the NSF I-Corps™ programs. Other agencies develop their own programs that adapt the curriculum for their research communities: NSA's I-Corps™ for the Intelligence Community, I-Corps™ at ARPA-E, and the USDA I-Corps™ Agricultural Research Service pilot program.

Entrepreneur in Residence Programs

Several agencies have established Entrepreneur in Residence (EIR) programs that mentor technical researchers on the fundamentals of commercializing new technologies. While these programs vary across agencies, their common goal is to provide sound entrepreneurial advice from experienced business experts to accelerate technology transfer. Topics that are common to these programs include methods of establishing market values, managing intellectual property rights, performing due diligence, fund raising, and requirements for starting a new business.

The DOE's EIR initiative was started in 2007 by the Office of Energy Efficiency & Renewable Energy to address long-standing concerns that national laboratory inventions were not being sufficiently transferred into the marketplace. By placing venture capital-sponsored entrepreneurs at key national laboratories, DOE aims to accelerate laboratory technology transfer; start-up entrepreneurs are able to work directly with the laboratories and bridge the gap between leading scientific and business talent. Technology assessments and proposing business structures to commercialize promising technologies can be conducted on site. Entrepreneurs are permitted to work directly with laboratory staff for a hands-on look at various inventions and potentially viable technologies.

The NIH Office of Technology Transfer began its first EIR program in 2012. The EIRs are charged with three key activities: 1) review NIH technologies to assess commercial relevance; 2) work with the private sector to facilitate commercialization of the NIH technologies into marketable products; and 3) educate scientists on life science product development and commercialization.

The USDA's Agricultural Research Service (ARS) has seven Technology Transfer Coordinators (TTCs) stationed in different geographical areas around the country. Each TTC acts as a type of EIR. The TTCs are engaged in numerous activities including planning, administrating, coordinating, and evaluating technology transfer activities of their assigned geographic region's research programs to affect the optimum transfer of research for development and commercialization. They work closely with ARS researchers to select the most beneficial and expeditious mechanism(s) for technology transfer on a case-by-case basis. They participate in the planning of research programs and preparing material that illustrates ARS research results and accomplishments.

The NIST has also initiated an EIR program in cooperation with the Maryland Technology Development Corporation. Through this initiative experienced EIRs and NIST researchers come together to identify commercial opportunities for technologies emerging from NIST's laboratories. The NIST EIRs are not full-time paid positions; rather, they are guest researchers who undertake a variety of tasks to identify the commercial value of NIST technologies and mentor and educate NIST researchers on career opportunities in technological entrepreneurship.

Chapter 2
Agency Performance in FY 2018

Each federal agency prepares and submits an annual report covering data on technology transfer as described in 15 U.S.C. § 3710(f). These reports include details on each agency's technology transfer program and efforts to use technology transfer to advance the agency's mission and promote U.S. competitiveness.

This chapter provides a comparable summary of the content of these 11 federal agency reports. For each agency, this report considers three main topic areas:

- Statistical data on the agency's technology transfer activity levels for a number of measures (e.g., cooperative R&D relationships, invention disclosure and patenting, and intellectual property licensing) for the most recently closed fiscal year (FY 2018) and several prior years (FY 2014-2018);
- Streamlining activities at each agency to lower administrative burden and make technology transfer more accessible; and
- Reported examples of successful downstream outcomes arising from the agency's technology transfer activities, such as new products or improved industrial processes available in the marketplace that arise from the transfer and commercialization of federal lab inventions.

Department of Agriculture (USDA)

President Abraham Lincoln coined the phrase "the People's Department" acknowledging the role of the U.S. Department of Agriculture in solving problems that benefits all people every day. Thus, well before the coining of the modern-day phrase of "technology transfer," it was the culture of USDA to deliver solutions to the people of the United States. Today, USDA broadly defines technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. Although a seemingly simple statement, the process of adoption is complicated, requiring integration of many assets from disparate sources in the successful delivery of solutions. "Public benefit" is achieved through many mechanisms including public release of information, tools, and solutions (e.g., germplasm, plants, and other materials); adoption and enhancement of research outcomes by partners through collaborative research; formal CRADAs authorized by the Federal Technology Transfer Act (FTTA); direct federal, state, or local technical assistance; or through licensing of biological materials or protected intellectual property directly to not-for-profit entities and for-profit private sector firms. Additionally, successful adoption of USDA knowledge and research outcomes typically require complementary assets and services provided by multiple agencies in USDA, including agencies that are not primarily engaged in direct research in the physical and life science arenas.

Private-sector involvement in technology transfer adds the benefit of creating new or expanded businesses, jobs, and economic prosperity. Science-based innovations from USDA intramural research – often developed through public-private partnerships (PPPs) – create new or improved technologies, processes, products, and services that benefit the Nation by increasing productivity, increasing efficiency (keeping costs low), and enhancing global competitiveness for the U.S. agriculture sector. Thus, technology transfer functions are critical to accelerating the utility of public research and development (R&D) investments, creating economic activity, job creation, and sustainable economic development.

The Agriculture Research Service (ARS) has been delegated authority by the Secretary of Agriculture to administer the patent program for ARS, review CRADAs, and administer technology licensing programs for all intramural research conducted by USDA. These activities are housed in the Office of Technology Transfer.

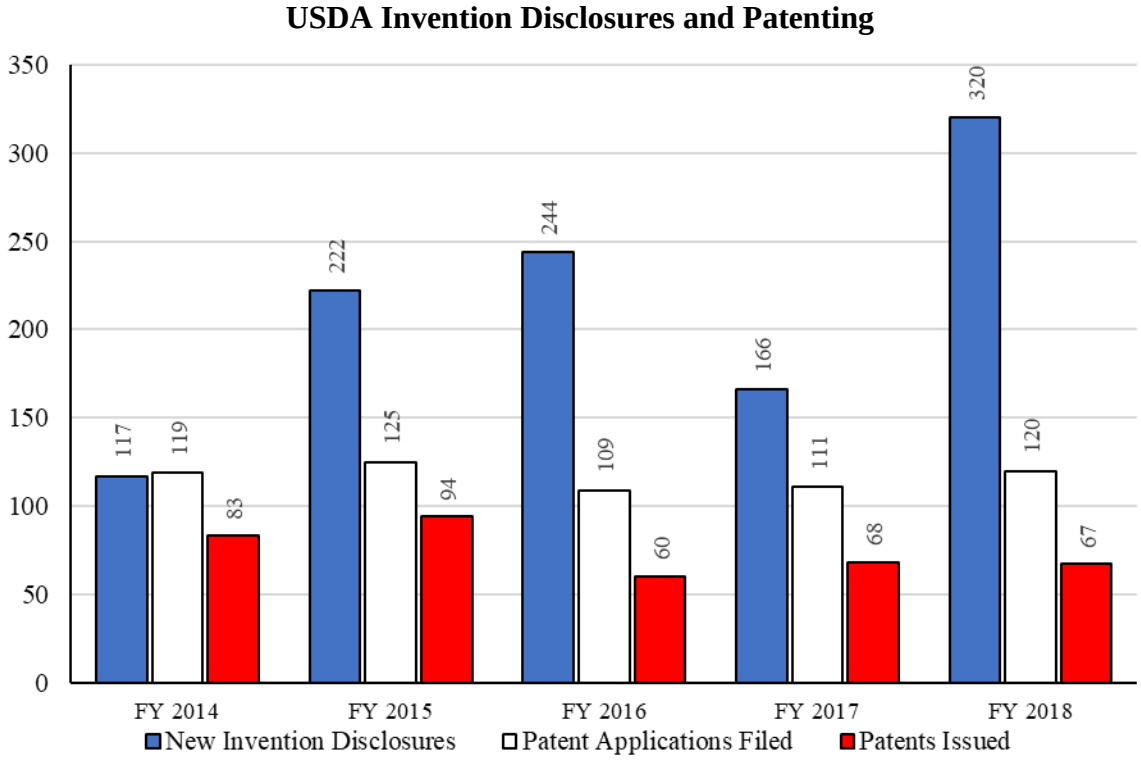
The USDA's annual technology transfer report is available online.

More information about USDA's technology transfer activities is available on the following websites:

Agricultural Research Service (ARS)
Animal and Plant Health Inspection Service (APHIS)
Forest Service (FS)

USDA Invention Disclosures and Patenting

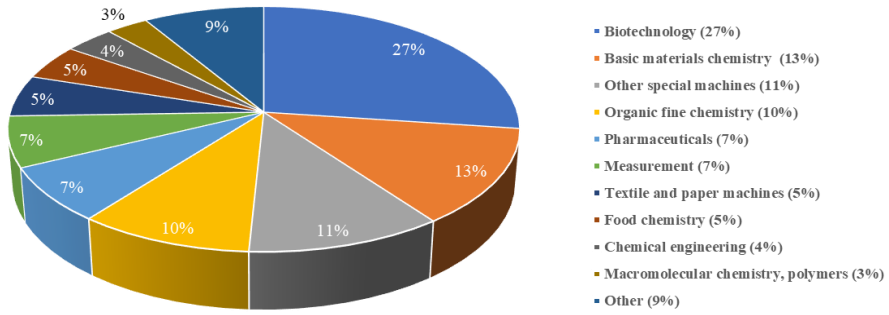
Between FY 2014 and FY 2018, invention disclosures received increased by 174%, from 117 in FY 2014 to 320 in FY 2018. Patent applications filed increased 1%, from 119 in FY 2014 to 120 in FY 2018. Patents issued decreased by 19%, from 83 in FY 2014 to 67 in FY 2018.



Patents issued to USDA in FY 2018 covered many technology areas including Biotechnology (27%), Basic Materials Chemistry (13%), Other special machines (11%), Organic fine chemistry (10%), and Pharmaceuticals (7%).[26]

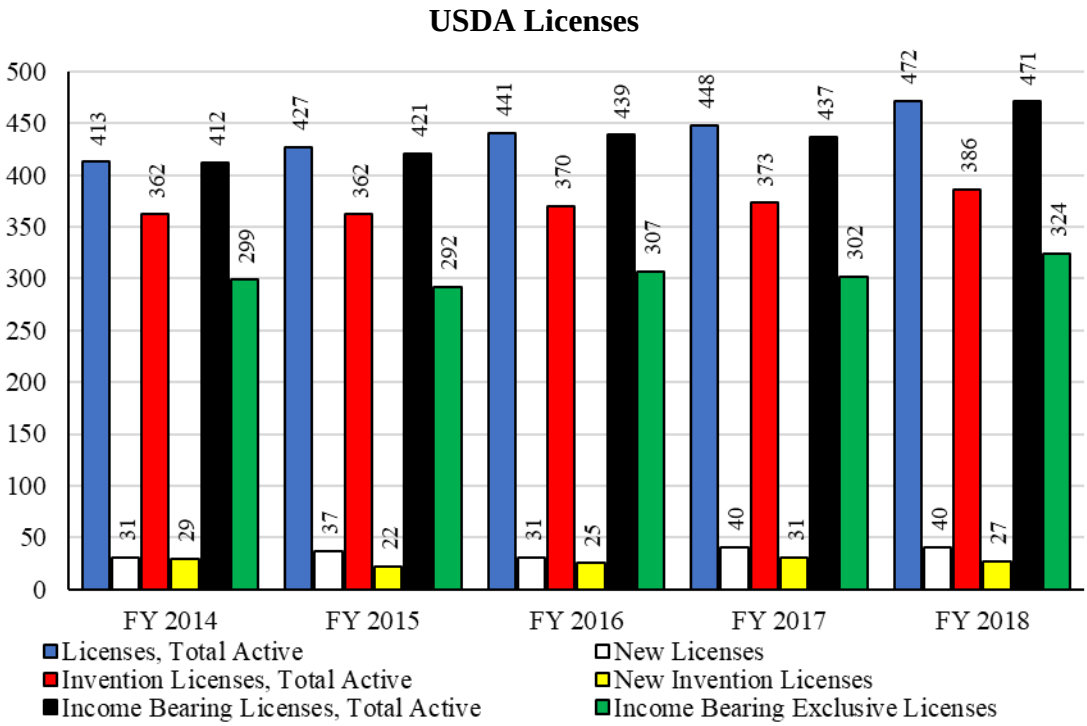
[26] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

USPTO Patents Assigned to USDA by Technology Area: FY 2018



USDA Licenses

Between FY 2014 and FY 2018, total active licenses increased by 14% to 472 licenses in FY 2018. Total active invention licenses increased by 7% to 386 licenses. Total active income bearing licenses increased 14%, from 412 in FY 2014 to 471 in FY 2018, while income-bearing exclusive licenses increased by 8% to 324.

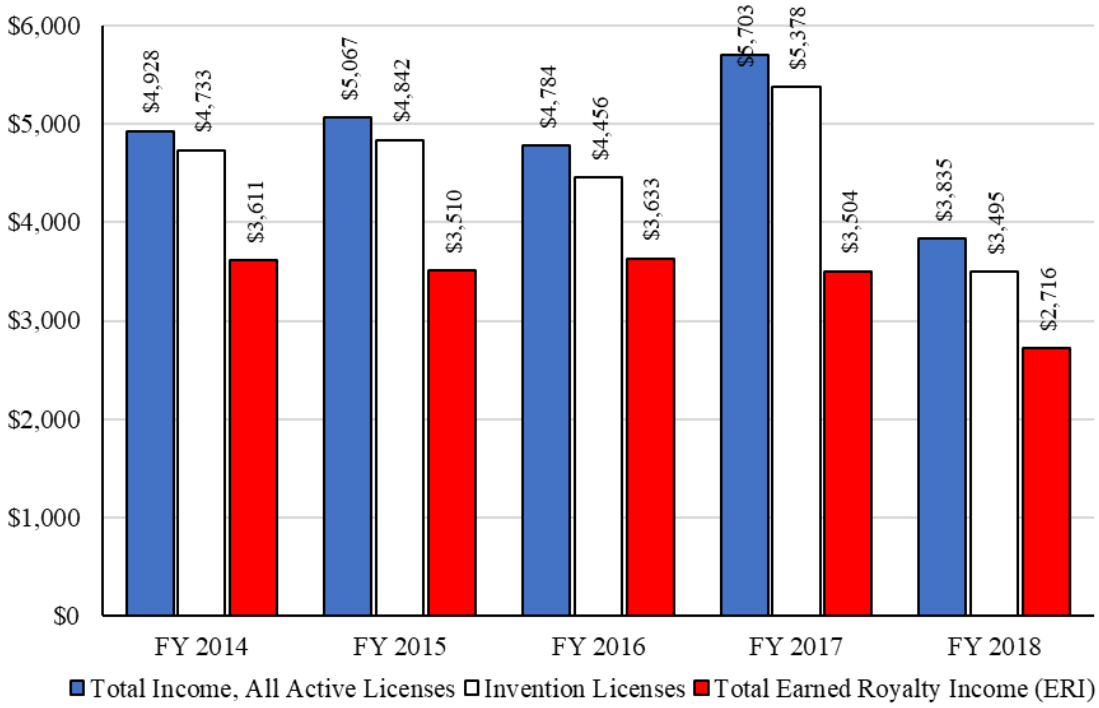


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	413	427	441	448	472
New Licenses	31	37	31	40	40
Invention Licenses, Total Active	362	362	370	373	386
New Invention Licenses	29	22	25	31	27
Income Bearing Licenses, Total Active	412	421	439	437	471
Income Bearing Exclusive Licenses	299	292	307	302	324

USDA Income from Licensing

Between FY 2014 and FY 2018, total income from all active licenses decreased by 22% to $3.8 million in FY 2018. The income from invention licenses decreased by 26% to $3.5 million. Total earned royalty income decreased by 25% from $3.6 million in FY 2014 to $2.7 million in FY 2018.

USDA Income from Licensing ($ thousands)

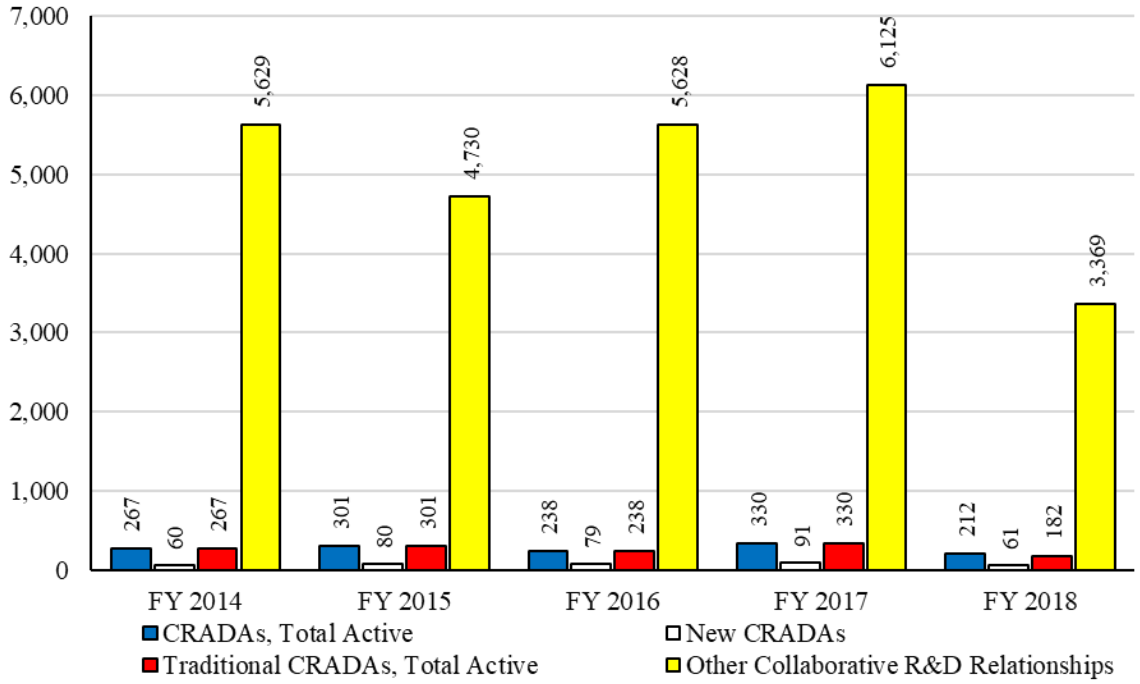


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$4,928	$5,067	$4,784	$5,703	$3,835
Invention Licenses	$4,733	$4,842	$4,456	$5,378	$3,495
Total Earned Royalty Income, (ERI)	$3,611	$3,510	$3,633	$3,504	$2,716

USDA Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs decreased by 21% to 212 agreements while new CRADAs increased by 2% to 61. Traditional CRADAs decreased by 32% to 182. Other collaborative R&D relationships decreased by 40% to 3,369 in FY 2018.[27]

USDA Collaborative R&D Relationships



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	267	301	238	330	212
New CRADAs	60	80	79	91	61
Traditional CRADAs, Total Active	267	301	238	330	182
Other Collaborative R&D Relationships	5,629	4,730	5,628	6,125	3,369

[27] In prior reports, USDA reported all agreements that were not CRADAs as "Other collaborative R&D agreements". Beginning in with their FY 2017 agency report, USDA is reporting only agreements that are similar to CRADAs" as "Other collaborative R&D agreements". For USDA, "Other collaborative R&D agreements" includes Trust Fund Cooperative Agreements, Reimbursable Agreements, Material Transfer Research Agreements, Specific Cooperative Agreements and Non-Funded Cooperative Agreements, Challenge Cost-Share Agreements, Collections Agreements, Cooperative Agreements, Inter-agency & Intra-agency Agreements, Joint Venture Agreements, Participating Agreements, Research Cost-Reimbursable Agreements, Research Joint Venture Agreements.

USDA Efforts to Streamline Technology Transfer Operations

- The ERS continues to enhance and update its website. Following a recent upgrade, the site is faster and features more intuitive navigation for customers to enhance information delivery. The ERS has added features to enhance functionality for mobile users.
- The National Institute of Food and Agriculture (NIFA) administers the USDA Small Business Innovation Research (SBIR) program. In FY 2018, NIFA promoted SBIR funding opportunities to USDA intramural research Cooperative Research and Development Agreement (CRADA) partners through a partnership between NIFA's SBIR program and the Agricultural Research Service (ARS) Office of Technology Transfer (OTT).
- The RD continues to enhance its Web presence to make information and programs more accessible to the public as well as to concentrate outreach efforts to ensure that businesses and communities in greatest need have access to the necessary resources to be competitive.

USDA Downstream Success Stories

Agricultural Research Service (ARS): Overcoming antibiotic resistance using a novel antibiotic

Beta-lactam antibiotics are a class of broad-spectrum (i.e., effective against a large variety of organisms) antimicrobials that include penicillin derivatives and cephalosporins. The use of these important drugs has been limited over the years with the development of antibiotic-resistant bacterial strains. Tunicamycin is a powerful antibiotic that can be combined with beta-lactam antibiotics to overcome this resistance. Scientists have known about this antibiotic for decades, but toxicity in human and animal cells prevented it from being used for therapeutic application. Recently, ARS researchers in Peoria, Illinois, have chemically modified tunicamycin into less harmful derivatives. The modified tunicamycins did not show any toxicity to human and hamster cells but were still capable of increasing the efficacy of clinical penicillin-based drugs by 32 to 64 times. This significant discovery now allows older-type antibiotics to once again be effective and is an important step toward combating drug resistance. It is currently being evaluated by a U.S. drug company.

ARS: An effective method to dry and decontaminate wet whole almonds

California produces 80 percent of the world's almonds with a value of more than $5.33 billion. Contamination of almonds with Salmonella has caused several large and expensive recalls by the industry and outbreaks of human illness. The occurrence of rain during the harvest season may result in the complete loss of an almond crop due to increased risk of microbial contamination and lack of adequate drying technology. The ARS scientists in Albany, California, developed an effective and energy-saving new technology based on sequential infrared heat and hot air to simultaneously dry and decontaminate wet whole almonds. The results were provided to industry and contributed to ARS receiving the 2018 Research and Development Award by the Institute of Food Technologists.

ARS: Efficient nitrate recycling and re-use

Nitrate contamination of surface and ground waters is a serious problem in many agricultural regions. It is a human health risk and contributes to eutrophication of fresh water and the Gulf of Mexico. Most mitigation efforts focus on denitrification through a process of encouraging

microbes to convert nitrate to nitrogen gas. This is inherently wasteful because much energy is required for the initial manufacture of nitrogen fertilizer. A more efficient solution would be to develop methods to recycle nitrate for re-use. The ARS scientists in St. Paul, Minnesota, have developed a system that can remove nitrate from contaminated water and concentrate it for re-use as fertilizer. The system runs on electricity from solar panels, so it is suitable for remote locations. A feasibility test was successfully conducted on a contaminated trout stream that has a nitrate concentration of more than 20 ppm (twice the United States Environmental Protection Agency safety standard of 10 ppm). The system was able to remove an average of 42 percent of the nitrate from water passing through it, concentrating it in a tank that ultimately reached a concentration exceeding 500 ppm, which was subsequently used elsewhere as fertilizer. This approach could be used to recover nitrate from streams and contaminated wells, ponds, and lakes.

National Institute of Food and Agriculture (NIFA): Experiential Training in Use of Unmanned Aerial Systems (UAS) Technology for Agriculture Applications

The primary purpose of this four-year interdisciplinary multi-institution project is to increase the number of south Texas students graduating from 2-yr Associate-granting institutions transitioning to 4-yr Bachelor of Science and Master's degrees (TAMUCC, TAMUK, UTRGV) in fields related to the agricultural, plant, and biological sciences. Faculty and staff at partner institutions will provide undergraduate and graduate training and education in the use of Unmanned Aerial System (UAS) technology for precision farming in agriculture. Targeted coursework will be created to include two permanent on-line introductory courses in UA Vehicles technology and ethics, and one blended (on-line/hands-on) course in UAS applications. Training will include internships and assistance in research projects aligned with UAS as a tool for crop/soil management, plant, and natural resource sciences. The project will produce 28 Bachelor of Science and 11 Master's of Science graduates working in food, agriculture, and natural resources-related fields. This project will also affect 48 students from two-year academic institutions. Educational needs areas addressed by this project include: curricula design in terms of development of new courses of study and student experiential learning. The major project outcome will be production of approximately 40 Hispanic Americans equipped with additional experience and education in food, agricultural, and natural sciences and who will be better prepared to engage in careers with the USDA or other federal agencies as well as the private sector.

Forest Service (FS): The new normal: empirical estimates of future fire environments in the Pacific Northwest

A set of time series maps provides empirical estimates of how climate change might affect the geographic distribution of large wildfires and fire rotations in the Pacific Northwest. This information can help forest resource managers and policymakers plan strategically for changing conditions. Large wildfires in the Pacific Northwest are increasingly frequent compared to the last three decades of the 20th century. These wildfires are the result of their environment. As droughts become more common in much of the western United States and temperatures warm, forest environments appear to be coming more suitable for large wildfires

Scientists with the PNW Research Station and collaborators extrapolated and contrasted what is consider today's ‘‘normal" fire environment to what might be considered normal by the end of

this century as a result of forecasted changes in climate. Their findings indicate more forest area in all ecoregions of the Pacific Northwest will be suitable for the occurrence of wildfire larger than 100 acres over the next century. The largest increases are projected to occur on federal lands, while private and state lands showed less. By the end of the century, the models predict shorter fire-rotation periods; cooler, moister forests are projected to experience larger magnitudes of change than warmer, drier forests.

This project yielded a set of time series maps that provide forest resource managers, fire protection agencies, and policymakers with empirical estimates of how much and where climate change might affect the geographic distribution of large wildfires and effect fire rotations. Areas where the fire environment is not likely to change much might serve as focal areas for fire refugia and reserves designed to maintain or restore older, denser, closed canopy forests. Forests that are currently classified as moderately suitable for large wildfires or are predicted to transition into it may be places to focus active management to improve resilience to future wildfires. Management to ameliorate fire risk may be needed where forests have or are predicted to transition into higher wildfire suitability classes and, due to their location, also pose threats to infrastructure or valued forest resources, and where fire has not been as common.

NIFA: Adapt-N

A project out of Cornell University entitled, New Tools and Incentives for Carbon, Nitrogen, and Greenhouse Gas Accounting and Management in Corn Cropping Systems, now in its fourth year, seeks to provide small- to large-scale corn growers with low-cost soil C assessment and greenhouse (GHG) accounting tools, and provide policymakers with an evaluation of the current and long-term costs and benefits of various policy incentives for this sector of the agricultural economy (see http://www.adapt-n.com/).

- Milestones achieved: The Adapt-N tool will be available online to corn growers in 26 states and includes new output data on greenhouse gas emissions including N2O. Interest in Adapt-N includes both agricultural industry and environmental protection groups.
- Workforce development: The project involves three graduate students and four undergraduates.
- Outcomes: The Climate Team developed the capacity to produce downscaled climate projections from a set of GCMs driven by the IPCC's four Representative Concentration Pathways (RCPs). These are being used to drive DayCent and PNM crop-soil biogeochemical models, the outputs of which are being linked to economic performance and mitigation policy efficacy at nationally integrated scales. Collectively, soil C assessment results indicate that tillage has a greater impact on soil organic C in the top 30 cm than crop rotation or residue removal.
- Potential Impacts: Increased carbon sequestration would decrease greenhouse gases mitigating climate change.

NIFA: Soy-based resin that can replace traditional anti-fouling boat paint without containing copper

The ePaint Company is located in East Falmouth, MA and has received support from the SBIR program. Biofouling in the marine environment is where marine organisms attach to hard surfaces and is a major problem for marine aquaculture. The most common approach to this problem is to use paint that contains copper because it will inhibit attachment to hard surfaces.

The problem is that copper can accumulate in sediments and the water column, and this poses environmental problems. This company has developed a soy-based resin that contains a photosensitizer that in the presence of blue light causes the formation of peroxides. The peroxides are short-lived but they are effective in deterring attachment by marine tunicates, sponges, and other organisms to hard surfaces. The company is working with shellfish farmers in New England and salmon farmers in Canada, Norway, and Chile and is in the process of commercializing their anti-fouling paint.

Department of Commerce (DOC)

Technology transfer plays an important role in DOC's mission to promote job creation, economic growth, sustainable development, and improved standards of living for all Americans. The DOC works in partnership with businesses, universities, state, tribal and local governments, and communities to promote innovation and improve the nation's overall competitiveness in the global economy. The DOC pursues these objectives through policies and programs directed at strengthening the nation's economic infrastructure, facilitating the development of cutting-edge science and technology, providing critical scientific information and data, and managing national resources.

DOC conducts research and development (R&D) in areas of science and technology at the laboratory facilities of NIST, NOAA, and NTIA's Institute for Telecommunication Sciences (ITS). Technology transfer, which is a key part of the programmatic activities in these laboratories, connects technological advances of DOC's science and engineering programs to the U.S. economy.

In addition to the technology transfer efforts of DOC laboratories, DOC is responsible for coordinating technology transfer activities across federal agencies. The DOC coordinates the Interagency Working Group for Technology Transfer (IAWGTT) through the facilitation by NIST of interagency discussion on policy, new approaches to technology transfer, and lessons learned from agency transfer programs.[28] The NIST also serves as the host agency for the Laboratory Consortium for Technology Transfer (FLC), which provides a forum for federal labs to develop strategies and opportunities for linking technologies and expertise with the marketplace, as well as serving as the Executive Secretariat for the National Science and Technology Council's Lab-to-Market subcommittee.

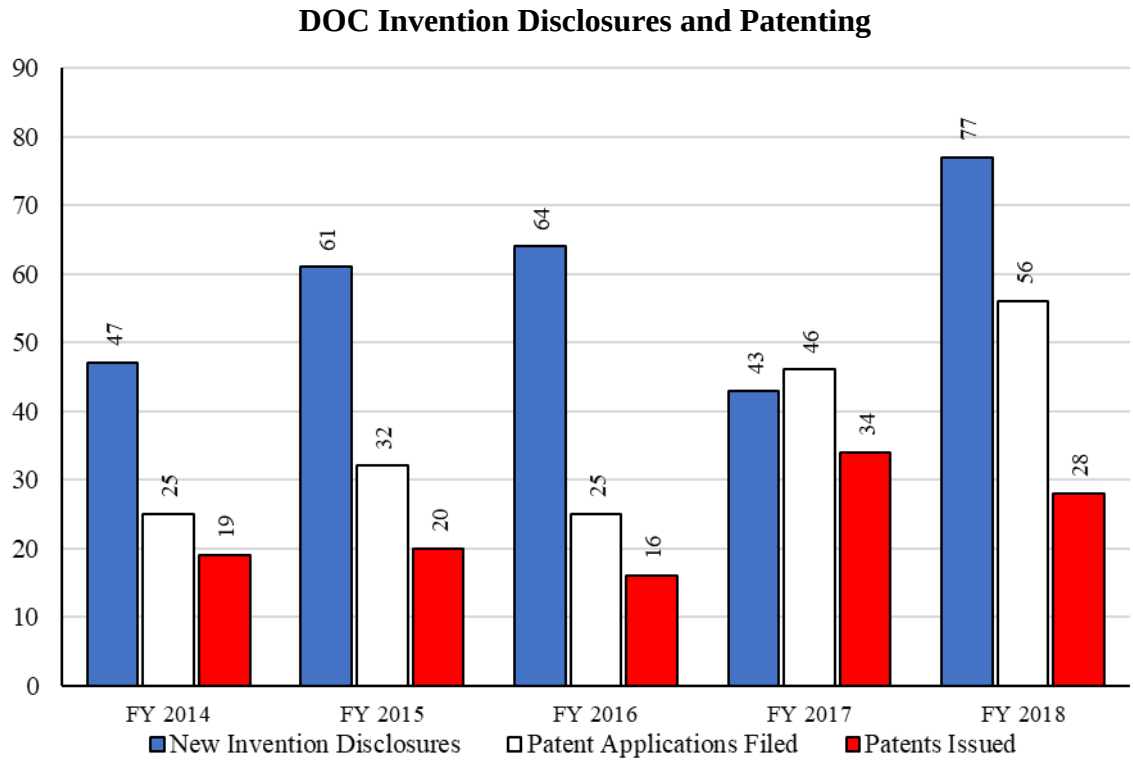
More information about DOC technology transfer is available on the following websites.

NIST | NOAA | ITS

[28] Agencies participating in the IAWGTT, established pursuant to Executive Order 12591 of April 10, 1987, include the Department of Agriculture, Department of Commerce, Department of Defense, Department of Energy, Department of Health and Human Services, Department of Homeland Security, Department of the Interior, Department of Transportation, Department of Veterans Affairs, Environmental Protection Agency, and National Aeronautics and Space Administration.

DOC Invention Disclosures and Patenting

Between FY 2014 and FY 2018, new inventions disclosed increased by 64% to 77 disclosures in FY 2018. Patent applications filed increased by 124% to 56, and patents issued increased by 47% to 28.

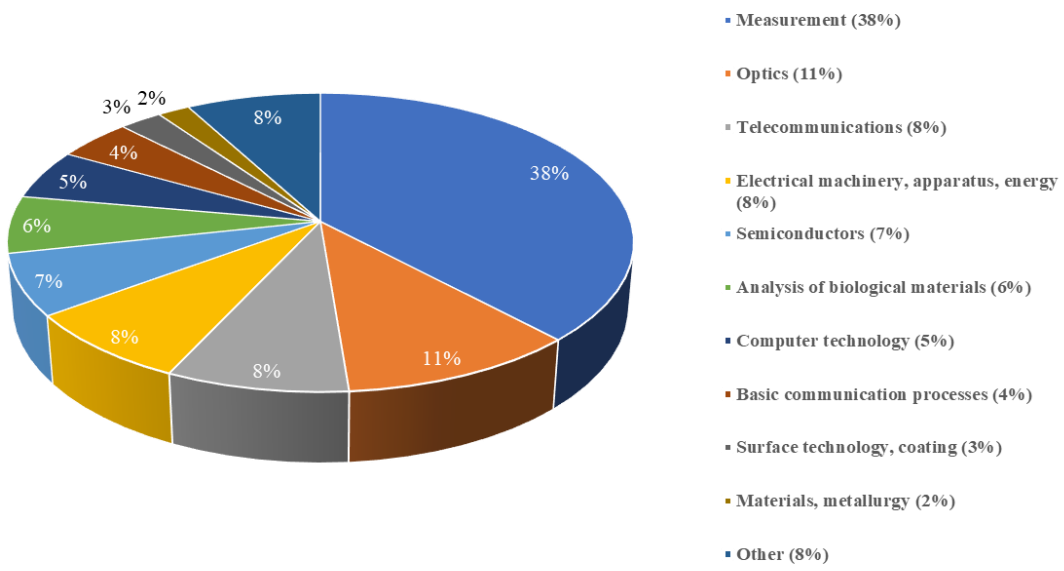


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	47	61	64	43	77
Patent Applications Filed	25	32	25	46	56
Patents Issued	19	20	16	34	28

Patents issued to DOC in FY 2018 covered many technology areas including Measurement (38%), Optics (11%), Telecommunications (8%), Electrical machinery, apparatus, energy (8%), and Semiconductors (7%).[29]

[29] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in October 2018. Used with permission.

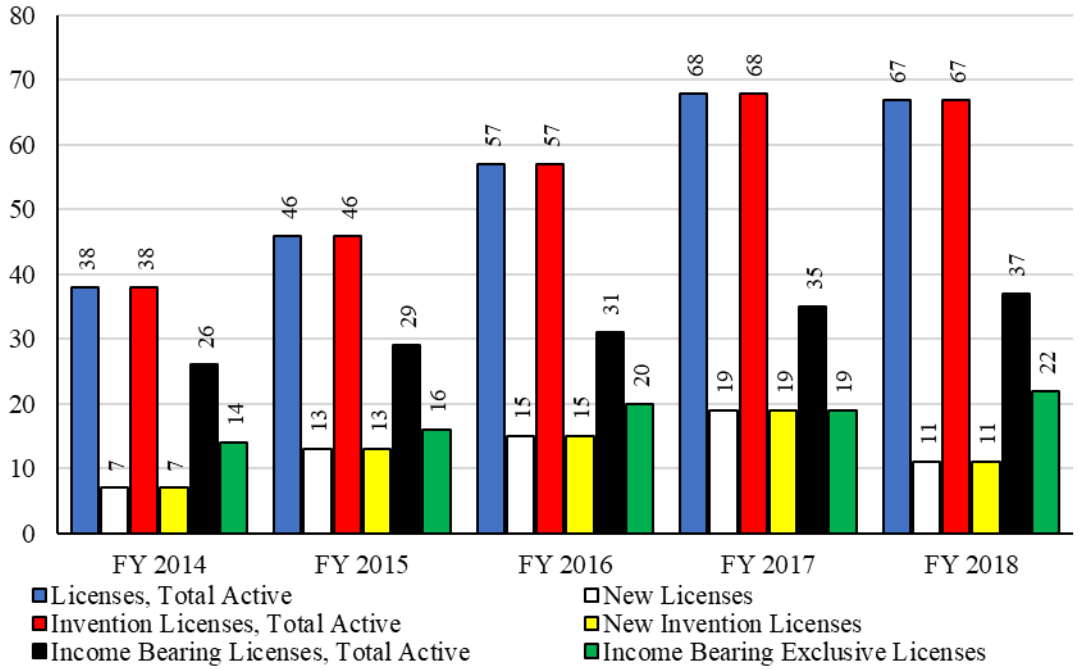
USPTO Patents Assigned to DOC by Technology Area: FY 2018



DOC Licenses

Total active licenses increased by 76% from 38 in FY 2014 to 67 in FY 2018. New licenses increased by 57% to 11. All licenses were invention licenses. Total active income bearing licenses increased by 42% to 37, while income bearing exclusive licenses increased by 57% to 22.

DOC Licenses

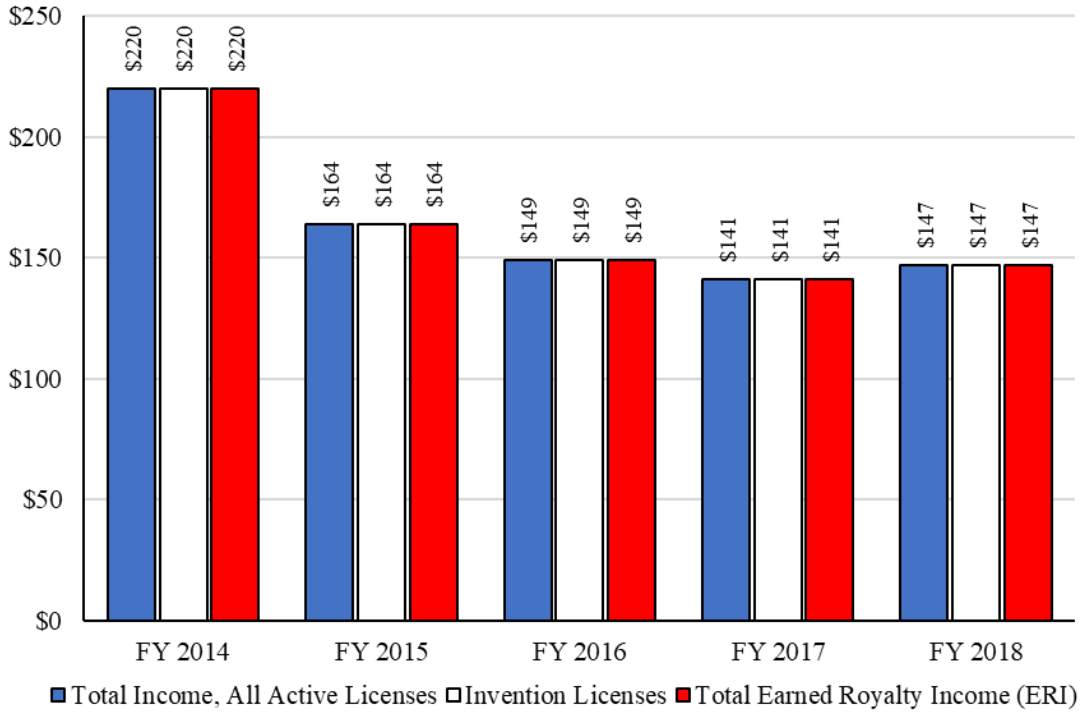


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	38	46	57	68	67
New Licenses	7	13	15	19	11
Invention Licenses, Total Active	38	46	57	68	67
New Invention Licenses	7	13	15	19	11
Income Bearing Licenses, Total Active	26	29	31	35	37
Income Bearing Exclusive Licenses	14	16	20	19	22

DOC Income from Licensing

DOC reported that all income from licensing comes from invention licenses. During the five-year period, from FY 2014 to FY 2018, there was a 33% decrease in total income from all active licenses, from $220 thousand in FY 2014 to $147 thousand in FY 2018.

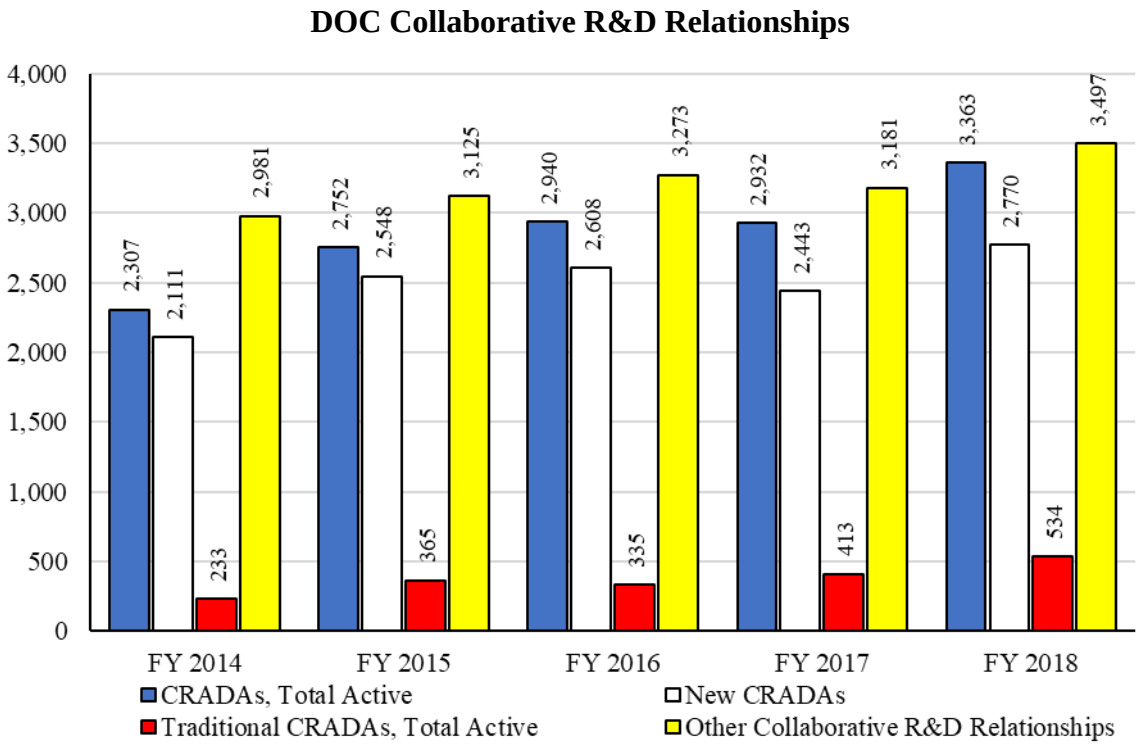
DOC Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$220	$164	$149	$141	$147
Invention Licenses	$220	$164	$149	$141	$147
Total Earned Royalty Income, (ERI)	$220	$164	$149	$141	$147

DOC Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs increased by 46% to 3,363 agreements while new CRADAs increased by 31% to 2,770. Traditional CRADAs increased 129%, from 233 in FY 2014 to 534 in FY 2018. Other collaborative R&D relationships increased by 17%, from 2,981 in FY 2014 to 3,497 in FY 2018.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	2,307	2,752	2,940	2,932	3,363
New CRADAs	2,111	2,548	2,608	2,443	2,770
Traditional CRADAs, Total Active	233	365	335	413	534
Other Collaborative R&D Relationships	2,981	3,125	3,273	3,181	3,497

Efforts to Streamline Technology Transfer Operations

The NIST has undertaken several efforts to streamline and simplify the technology transfer process. It revised its standard CRADA to expedite review of these documents and reduce the overall size of these documents by approximately one third. The NIST also implemented several new licensing programs to encourage small businesses to participate. These programs lay out terms in advance to ease concerns of small businesses about overall costs. It is conducting detailed analysis of the flow of documents to understand where significant delays occur within the system. In many cases, these delays are with the partner and NIST does not have direct control; however, by continued efforts to identify and understand issues experienced by partners, NIST expects to identify new ways to simplify and streamline technology transfer practices. In FY 2018, the average number of days between the receipt date of an invention disclosure and the filing date of the first non-provisional patent application was 337 days and the average CRADA approval time was 91 days.

DOC Downstream Success Stories

NIST: New Cell Lines Produce NIST Monoclonal Antibody for Improved Manufacturing of Biologic Drugs

When NIST issued the world's first standardized monoclonal antibody (mAb) in July 2016, the exhaustively analyzed protein known as NISTmAb (NIST Reference Material 8671) was intended as a valuable tool for biopharmaceutical companies. Its purpose is to help ensure the quality of measurement techniques used in the development and manufacture of biologic drug therapies for a wide range of health conditions, including cancers, autoimmune disorders, and infectious diseases. Although the molecule has been precisely characterized, the current proprietary method for its production has not.

In a new paper in the journal mAbs, researchers at the Institute for Bioscience and Biotechnology Research (IBBR), a joint institute of NIST and the University of Maryland, described how they took the first step to solve this dilemma: engineering three mouse cell lines to produce nonproprietary versions of NISTmAb that closely resemble the characteristics of the original reference material.

"By creating the means to produce our already well-characterized monoclonal antibody, the NISTmAb, we can now make the measurements that will define the production process as well as the product," states NIST research biologist Zvi Kelman, who coauthored the mAbs paper. "From that, we can develop a standardized model for monoclonal antibody biomanufacturing that will give researchers and manufacturers a second valuable reference tool."

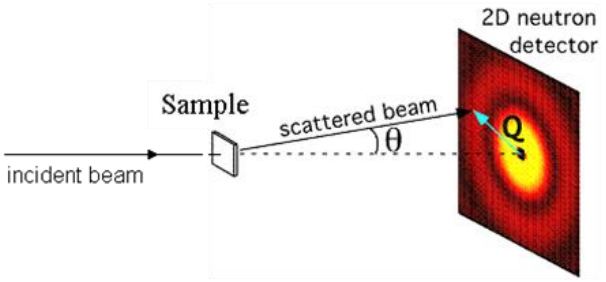
Monoclonal antibodies are proteins manufactured in the laboratory that can target specific disease cells, viruses, and other antigens (agents that trigger an immune response) for removal from the body or can be used to deliver therapeutic chemicals or radiation to select sites. Since the first commercial mAb was approved in 1986, their impact on medicine has been astounding. Today, five of the 10 top-selling drugs are mAbs with annual sales currently at $100 billion and expected to rise to $150 billion within three years.

NIST: Industry Now Has Access to a Rare Resource

NIST's nSoft consortium helps product developers solve difficult problems by giving them access to a powerful tool, unlike anything in an industry R&D lab, for seeing the structure of materials.

The NIST's Material Measurement Lab developed a new model for outreach to increase industry access to federally funded scientific instruments. These tools are often under-utilized by private-sector researchers, because they don't have the expertise to use them. nSoft and the NIST Center for Neutron Research (NCNR) train scientists from industry members to measure materials nondestructively. Members of nSoft develop expertise in neutron science by planning and executing their own experiments at NCNR with guidance from NIST scientists.

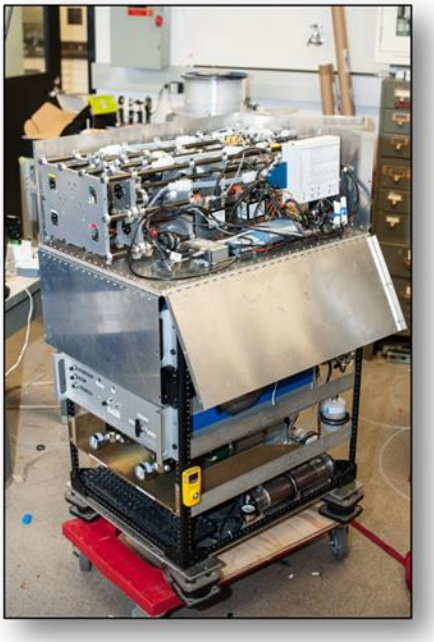
nSoft works at the pace of business, and once trained, industry members can get timely access to the instrument, helping them meet product development milestones. The outcomes from experiments are shared publicly so that all U.S. industry sectors may benefit. While the results of experiments are often published in scholarly journals, helping industry scientists conduct their own experiments is an accelerated form of technical transfer from federal research facilities to the people who benefit.



Beams of neutrons can pass through soft materials--cancer drugs, vaccines, high performance plastics and composites, agricultural products, and even batteries--without damaging their structure, yet still "see" the molecules from which they are made. With few research reactors like NIST's around, there are few experts who know how to conduct experiments and analyze data from neutron studies. In response, NIST launched the nSoft consortium in 2012.
Credit: Boualem Hammouda

To date, nSoft has helped companies develop therapeutics with a longer shelf-life and higher strength materials and provided key insight into how plants can stay hydrated in arid and harsh environments.

NOAA: High Precision Devices Receives Phase II Small Business Innovation Research (SBIR) Award to Commercialize NOAA NOy Cavity Ringdown Instrument
High Precision Devices, a small company located in Boulder, Colorado, successfully completed Phase I of its commercialization plan under NOAA's SBIR-Technology Transfer activity, and has been granted a Phase II award to complete the commercial development of NOAA's patented NOy-Cavity Ring-Down Spectrometer.



The NOy-Cavity Ring-Down Spectrometer, a patented technology developed at NOAA's Earth System Research Laboratory, is a sensitive, compact detector that measures total reactive nitrogen (NOy), as well as NO2, NO, and O3 using cavity ring-down spectroscopy (CRDS). This product is unique in that the optical cage system holds four optical cavities (with associated sample cells) and a laser together, allowing a measurement of all four trace gases simultaneously with a robust calibration in a small package. The NOAA CRDS is compact and has lower power, size, weight, and vacuum requirements than chemiluminescence-based instruments on the market, while approaching equivalent sensitivity, precision, and time response.

The goal for Phase II with High Precision Devices is to develop an even more compact, transportable, and powerful instrument that will attract commercial sale.

NOAA: Scientists and Industry Professionals Join Forces to Develop Best Practices for Finfish Aquaculture

Aquaculture has been identified as a priority area for NOAA Fisheries. Fish in the genus Seriola are highly desirable fish that enter the food supply through recreational and commercial fishing and now through aquaculture. They can be found on seafood restaurant menus, commonly sold under the names of yellowtail and amberjack. They are also a mainstay of sushi restaurants where the same species have Japanese names such as Hiramasa, Hamachi, or Kampachi. Seriola species are important aquaculture species in Japan, Mexico, Chile, Australia, and in the European Union. In the United States, Seriola are commercially cultured in Hawaii, and large-scale offshore fish farming of these species is anticipated in Southern California and the Gulf of Mexico.

To advance the culture of these species, NOAA scientists and collaborators sequenced the Seriola genome and used genomic and physiological approaches to improve aquaculture procedures. California Sea Grant and NOAA Fisheries hosted the 2nd Seriola Workshop that brought together the research and culture community to discuss research progress, identify routes of collaboration, and coordinate synergistic projects for breeding, rearing, and feeding of yellowtail, amberjacks, and related Seriola species in culture. This workshop formed several new domestic and international collaborations that will better address these research priorities and more rapidly benefit commercial Seriola culture in the United States and globally.

NTIA ITS: Table Mountain Research

The Table Mountain Field Site and Radio Quiet Zone supports fundamental research in the nature, interaction, and evaluation of telecommunication devices, systems, and services. Each year, private companies, universities, and other organizations conduct research at Table Mountain under CRADAs.

- In FY 2018, capabilities were added to the Table Mountain test facilities in support of NOAA's Radio Frequency Interference Monitoring System (RFIMS) program. The ITS helped NOAA develop the technical specifications for a Request for Proposals to develop, produce, install, and maintain a radio frequency interference monitoring system to mitigate the risk of potential interference by commercial wireless carriers that are slated to begin sharing the spectrum with NOAA satellite operations in 2020. A 2.4-meter Earth Station satellite dish capable of capturing Polar Operational Environmental Satellite (POES) satellite imagery was used to test the degree of interference that could be tolerated, and a robust command and control system was built to command, verify, and log interference transmitted to RFIMS candidate solutions under test. A 6.5 m Geostationary Operational Environmental Satellite (GOES) receiver dish is being procured to support future Meteorological Satellite Testbed activities. The ITS built a Spectrum Survey System (SSS) to prototype near-real time monitoring, data collecting, and reporting methods that might be used by RFIMS. This system can also be used to analyze potential sharing concerns in other frequency bands.
- In FY 2018, several companies used the Table Mountain site under a CRADA to safely test and demonstrate LADAR technologies under development in atmospheric conditions and at distances relevant to potential applications, to fully test the functionality of new antenna designs during product development, and to safely and accurately test an Adaptive Tactical Laser System (ATLAS) compensated beacon adaptive optics (CBAO) system under development. Applications for these technologies include detection and tracking of wind shear and wake vortices, remote wind measurements for the offshore wind energy industry, mission-critical communications, electronic warfare, direction finding/geolocation, and sensing of hazardous liquids and gases.
- For the past 11 years, the University of Colorado's Research and Engineering Center for Unmanned Vehicles safely and accurately tested collective and autonomous sensing and communication technologies for small-unmanned aircraft used for atmospheric science applications such as the study of tornadogenesis.

Department of Defense (DoD)

The Defense Laboratory Office (DLO) provides overall policy guidance for and oversight of Department-wide technology transfer efforts. The DLO ensures, to the maximum extent practicable, that DoD developed technologies demonstrating commercial viability are integrated into the private sector; that technologies developed outside of the DoD that demonstrate national security utility are transferred into the DoD acquisition process; and that those technologies demonstrating both commercial and national security applications are made available to the DoD as well as industry and academia.

The DoD is unique in applying the principles, practices, and tools of technology transfer in the execution of its mission. The DoD funds and develops mission-focused technology, and technology transfer statutory authorities enable it to promote and facilitate the commercialization of that technology for both military and civilian purposes. Concurrently, DoD is a technology buyer as it strives to purchase new technology embodied in products and systems to meet the challenges faced by our warfighters. In many instances, technology transfer and technology transition are becoming a seamless path to fielding new technology critical to responding to the new and dynamic threats of asymmetric warfare, the global war on terrorism, and the ever-expanding role of civil assistance and disaster recovery worldwide. In the 1980's, when much of the technology transfer legislation was enacted, the federal government, including DoD, was the principle-funding source for R&D. Consequently, technology transfer was viewed as a "spin out" to the marketplace, a stimulus to the domestic economy, and a return on investment for taxpayer funded R&D. Today, the majority of U.S. R&D is industry funded. This shift in funding has led to a greater emphasis on technology transfer as a collaborative effort between DoD labs and their partners in industry, academia, and state and local government.

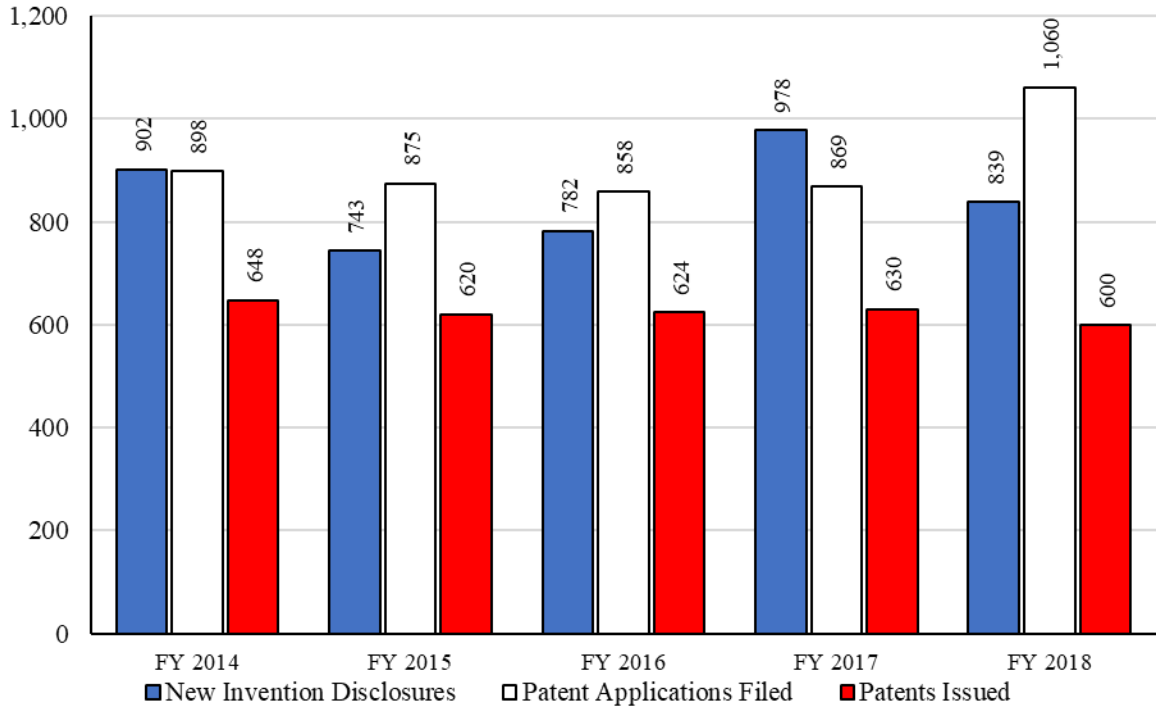
Each of the Military Services, DoD Agencies, and Office of the Secretary of Defense (OSD) maintain technology transfer websites to inform the public and make available general information.

DoD Research & Engineering Enterprise
U.S. Army Research Laboratory
Office of Naval Research

DoD Invention Disclosures and Patenting

Between FY 2014 and FY 2018, new inventions disclosed decreased by 7%, from 902 disclosures in 2014 to 839 disclosures in FY 2018. Patent applications filed increased by 18% from 898 in FY 2014 to 1,060 in FY 2018. Patents issued decreased by 7%, from 648 in FY 2014 to 600 patents in FY 2018.

DoD Invention Disclosures and Patenting

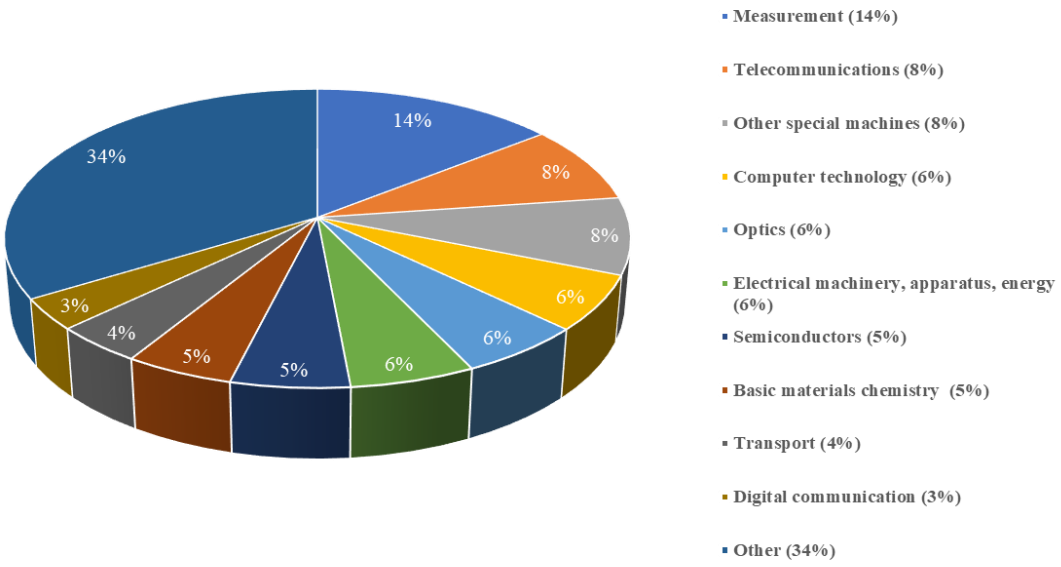


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	902	743	782	978	839
Patent Applications Filed	898	875	858	869	1,060
Patents Issued	648	620	624	630	600

Patents issued to DoD in FY 2018 covered many technology areas including the top categories of Measurement (14%), Telecommunications (8%), Other Special Machines (8%), Computer Technology (6%), and Optics (6%).[30]

[30] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

USPTO Patents Assigned to DoD by Technology Area: FY 2018

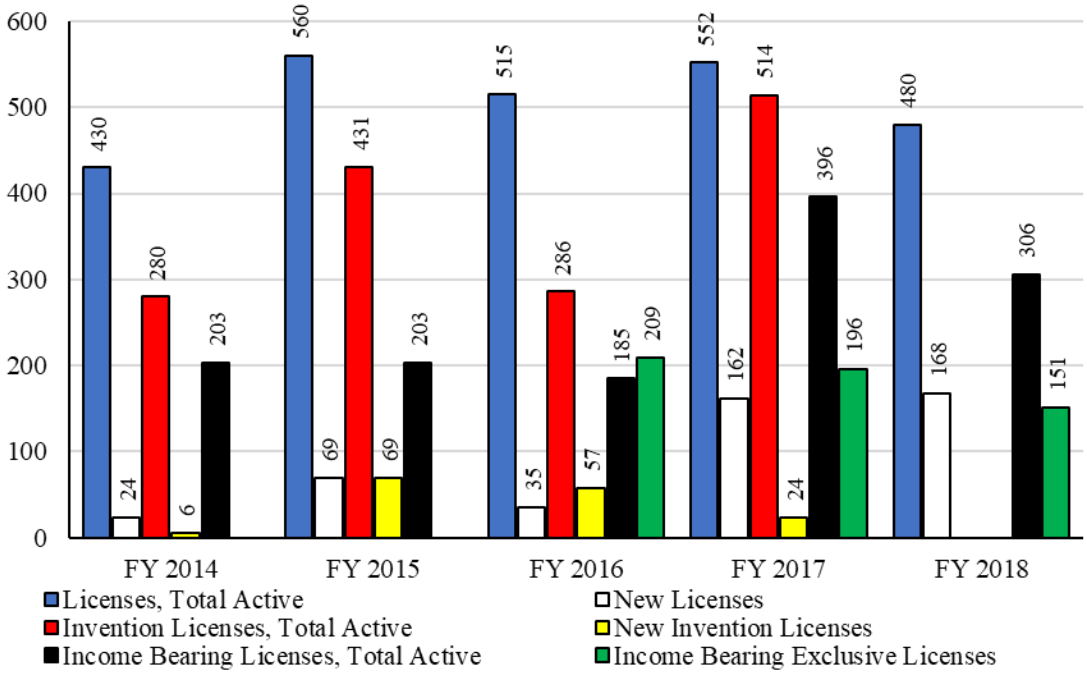


DoD Licenses[31]

Total active licenses increased by 12%, from 430 licenses in FY 2014 to 480 licenses in FY 2018, while new licenses increased by 600% to 168. From FY 2014 to FY 2017, total active invention licenses increased by 83% to 514 and new invention licenses increased by 300% to 24. From FY 2014 to FY 2018, total active income bearing licenses increased by 50% to 306.

[31] DoD was unable to report data on Income Bearing Exclusive Licenses for FY 2014 and FY 2015, for Invention Licenses, Total Active for FY 2018, and for New Invention Licenses for FY 2018.

DoD Licenses



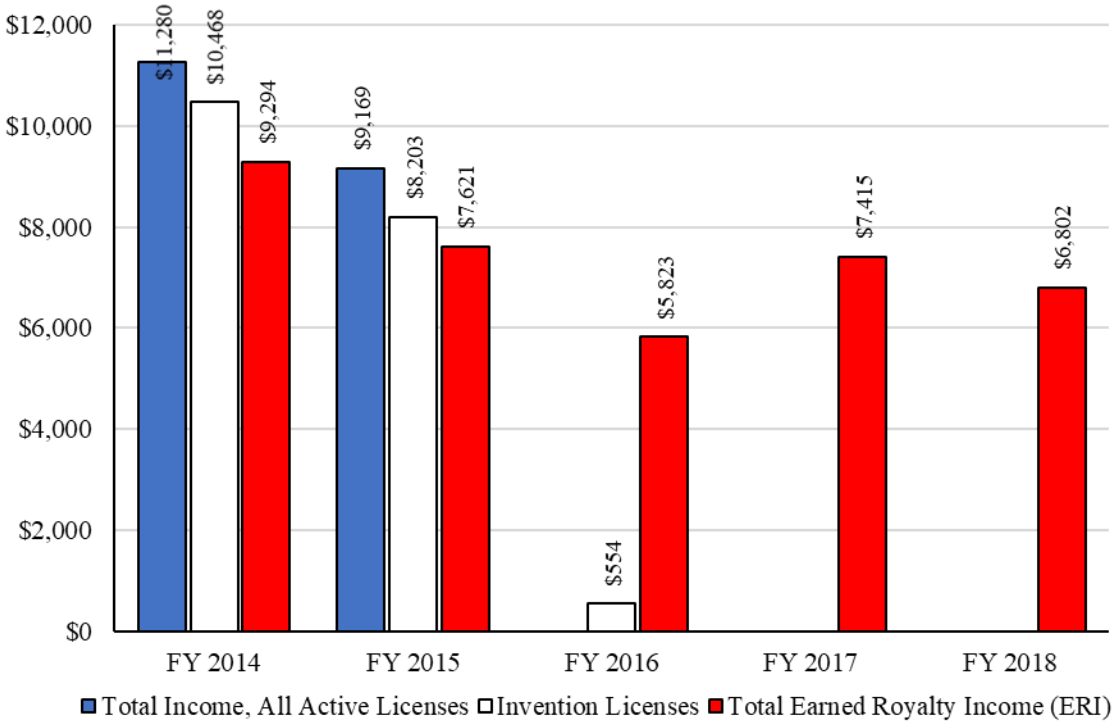
	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	430	560	515	552	480
New Licenses	24	69	35	162	168
Invention Licenses, Total Active	280	431	286	514	n.a.
New Invention Licenses	6	69	57	24	n.a.
Income Bearing Licenses, Total Active	203	203	185	396	306
Income Bearing Exclusive Licenses	n.a.	n.a.	209	196	151

DoD Income from Licensing[32]

From FY 2014 to FY 2018, total earned royalty income decreased by 27% to $6.8 million.

[32] DoD was unable to report total income for FY 2016 through FY 2018 or invention license income for FY 2017 and FY 2018.

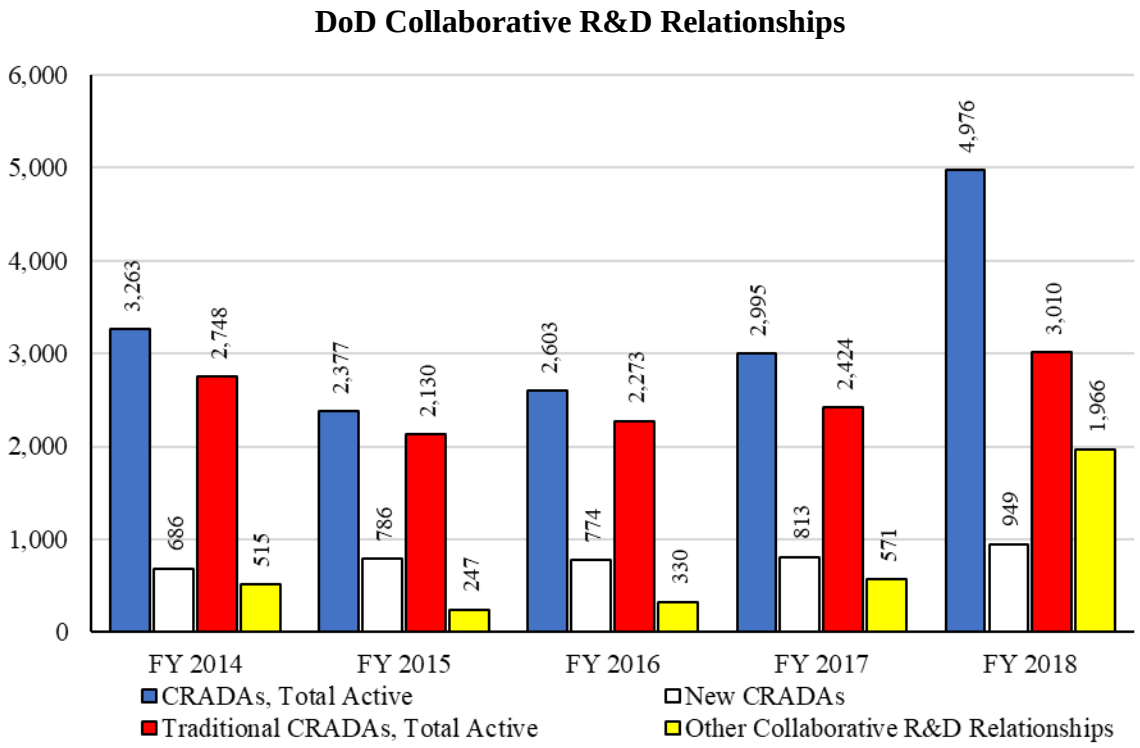
DoD Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$11,280	$9,169	n.a.	n.a.	n.a.
Invention Licenses	$10,468	$8,203	$554	n.a.	n.a.
Total Earned Royalty Income, (ERI)	$9,294	$7,621	$5,823	$7,415	$6,802

DoD Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs increased by 52%, from 3,263 in FY 2014 to 4,976 agreements in FY 2018, while new CRADAs increased by 38%, from 686 in FY 2014 to 949 in FY 2018. Traditional CRADAs increased by 10%, from 2,748 in FY 2014 to 3,010 in FY 2018. Other collaborative relationships increased by 282% from 515 in FY 2014 to 1,966 in FY 2018.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	3,263	2,377	2,603	2,995	4,976
New CRADAs	686	786	774	813	949
Traditional CRADAs, Total Active	2,748	2,130	2,273	2,424	3,010
Other Collaborative R&D Relationships	515	247	330	571	1,966

DoD Downstream Success Stories

Walter Reed Army Institute of Research (WRAIR): Antimalarial Drug Tafenoquine
With no vaccine yet available, malaria persists as one of the top infectious disease threats to U.S. military service members and support staff stationed overseas. A serious and sometimes fatal disease, malaria is transmitted by Anopheles mosquitoes infected with one of several species of the causative agent, the protozoan Plasmodium. Although only about 1,700 U.S. cases are diagnosed each year, the vast majority are found in travelers returning from endemic areas that include sub-Saharan Africa, the Middle East, and South Asia. Malaria occurs in more than 100 countries and territories globally and threatens almost half of the world's population. The World Health Organization (WHO) estimates that 216 million clinical cases of malaria occur annually, causing 445,000 deaths. The disease has long wreaked havoc globally on both public health systems and local/national economies, and WHO's strategies are now targeting the reduction of global incidence by at least 90 percent by 2030.

Tafenoquine recently became the first new prophylactic drug against this global health threat approved by the U.S. Food and Drug Administration (FDA) in more than 18 years. An 8-aminoquinoline chemical derived from primaquine, the drug was first synthesized in 1978 by scientists at Walter Reed Army Institute of Research (WRAIR). Following extensive WRAIR research on the candidate drug, a technology transfer effort by the U.S. Army Medical Materiel Development Activity (USAMMDA) now adds an important weapon to the U.S. military's antimalarial repertoire, protecting troops during overseas deployments.

In 2013, USAMMDA accelerated Army efforts to transition the WRAIR tafenoquine technology as a prophylactic drug seeking FDA approval. The tafenoquine team compiled a list of requisite criteria for successful tech transfer of tafenoquine and contacted several pharma companies, focusing on each company's interest in and capabilities to achieve the additional tafenoquine research and development needed to take the drug to FDA review and subsequent marketing.

The tafenoquine team at USAMMDA subsequently selected 60° Pharmaceuticals as the best fit to commercialize tafenoquine and best protect deployed Department of Defense (DoD) personnel. A notable factor in the company's selection was the expertise of former WRAIR/USAMMDA scientist Geoffrey Dow, the company's co-founder and current CEO, who has more than 20 years' experience in tropical diseases, including antimalarial drug development.

In December 2017, 60° Pharmaceuticals submitted technical documents on tafenoquine to the FDA for U.S. licensing. The company had to ensure that its tafenoquine tablets are in full compliance with FDA regulations regarding quality, bioavailability, and other factors. The company also submitted a market licensing application to the Therapeutic Goods Administration in Australia (approved September 2018). It has committed to provide the drug commercially, with anticipated launches in U.S. and Australian markets this year.

Army: SHRAIL™ (the Sirkin-Hiles Rail)
Despite dramatic advancements in combat medicine, medical litters or stretchers have changed little over the conflicts of the past century, and surgeons in far-forward situations often are

unable to use standard surgical tools in the absence of an operating room table equipped with a retractor, arm boards, intravenous poles, lights, and other instruments.

Conceived by two U.S. Army combat surgeons, the SHRAIL™ (Sirkin-Hiles Rail) medical device is a lightweight rail system that allows medical personnel to attach a small surgical rail to the side of a standard litter that, in turn, serves as a standard attachment point for any needed medical equipment. Consisting of four anodized aluminum rails with color-coded locking nuts, the SHRAIL weighs 15 pounds and can be collapsed and carried in a backpack, making it available in a broad range of battlefield scenarios.

Despite the seeming simplicity of the solution, previous efforts to create a portable, lightweight support system for surgical tools on standard litters had failed. What Army Col. Jason Hiles and Maj. Max Sirkin did was to envision an elegant, easy-to-assemble solution that met the size, weight, and time constraints of medical personnel operating in austere combat and far-forward scenarios.

In December 2017, Morzine Medical, LLC, entered into a patent licensing agreement with the U.S. Army Medical Materiel Development Activity (USAMMDA) in conjunction with the U.S. Army Medical Research and Materiel Command's Medical Technology Transfer office. Morzine Medical, which manufactures other austere surgical products including a stationary operating table, developed a commercially available SHRAIL™ and is preparing to market it as a commercial off-the-shelf product. The company proved to be an ideal partner to commercialize the USAMMDA technology, having already successfully penetrated the field medicine market through U.S. military sales of its Doak M4 Portable Surgical Table. The SHRAIL™ medical device was a perfect fit to expand the company's product line and provide a resource for purchase of the product for the military.

Along with helping to save lives in combat situations, the technology has commercial applications, including remote search-and-rescue operations, humanitarian efforts, and the ability to create overflow critical care capacity in civilian hospitals in the event of a mass casualty event. For the U.S. Army, commercial transfer is a necessary component of ensuring that the SHRAIL meets its potential of saving the lives of seriously injured warfighters in combat settings or remote locations. Licensing the patented technology to a commercial developer exploring these potential markets makes it far more likely that the lifesaving device will be manufactured at scale and made available to the military to assist austere medical operations in combat and far-forward situations.

Navy: Laser Analysis and Sorting Instrument (LASI)
The Laser Analysis and Sorting Instrument (LASI) is a Navy-patented device and method of using lasers to separate and characterize particles in fluids. Developed at the U.S. Naval Research Laboratory (NRL), the technology uses a combination of advanced optics and microfluidics. A fluid flow pushes samples containing particulates through a network of flowing channels, where laser light interacts with streaming particles to create optical forces unique to those particles. Different particles, such as red blood cells or bacteria, react differently based on factors like size, surface morphology, shape, refractive index, and internal structures. By measuring cell responses, the instrument can identify and sort single cells based on their

physical, biochemical, and biological characteristics. The NRL team—Dr. Sean Hart, Dr. Rita Manak, Alex Terray, and Amanda Horansky McKinney—were principally responsible for the successful LASI technology transfer to LumaCyte, LLC, a research, instrumentation, and analytics company based in Charlottesville, Virginia. Formal transfer of the NRL-developed technology to LumaCyte occurred under a Cooperative Research and Development Agreement (CRADA) signed in March 2014, followed by a Patent License Agreement (PLA) executed in the same month.

The technology transfer effort built upon professional relationships among the team members that began years earlier at NRL, where co-inventors Dr. Hart and Terray worked together for more than a decade developing LASI technology. These relationships underlie the unique aspect of this transfer: the uncommon technology transfer process of an NRL inventor (Dr. Hart) leaving the lab to create a company (LumaCyte) specifically to transition his invention, while his co-inventor (Terray) remained at NRL, running the LASI program and serving as the Navy lab's lead during the technology transfer. Under the CRADA and PLA agreements negotiated by NRL's technology transfer experts (Dr. Manak and Horansky McKinney), the two LASI researchers sustained a constant, symbiotic exchange of information that yielded a much-improved commercial product.

This effort led directly to LumaCyte's LASI-based Radiance™ instrument now on the market, which offers a more rapid, highly sensitive automated analysis and sorting of cell mixtures. By depending on the cell's intrinsic properties, LASI has the noteworthy feature of not requiring the addition of antibody or genetic labels typically used to tag cells pre-assay. This is a significant advance over similar instrument technologies. There is a constant need for more powerful laboratory tools across the myriad fields within biological research, development, and technology. Anticipated beneficiaries of the Navy technology include R&D programs in vaccine manufacturing, cell therapy, infectious disease, drug discovery, and cancer diagnostics and treatment.

Department of Energy (DOE)

DOE is one of the largest supporters of technology transfers within the federal government. The Department plays a key role in moving new technologies developed in research labs across the country into the commercial marketplace, fueling the innovation engine that powers the U.S. economy. Bridging the gap between research and development (R&D) and commercial deployment is crucial to DOE's mission to enhance U.S. security and economic growth through transformative science and market solutions. By creating globally competitive industries in the United States, the DOE enables significant cost-savings for industries and consumers and creates jobs for Americans.

The DOE's National Laboratories address 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. Among the many things that the National Laboratories do, some include the following:

- Conduct research of the highest caliber in physical, chemical, biological, 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.

DOE laboratories and facilities that are actively engaged in technology transfer include the following:

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)

National Nuclear Security Administration:
- Lawrence Livermore National Laboratory (LLNL)
- Los Alamos National Laboratory (LANL)
- Sandia National Laboratories (SNL)
- Savannah River Site
- Kansas City 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 Energy Efficiency and Renewable Energy:
- National Renewable Energy Laboratory (NREL)

Office of Nuclear Energy:
- Idaho National Laboratory (INL)

Office of Fossil Energy:
- National Energy Technology Laboratory (NETL)

Office of Environmental Management:
- Savannah River National Laboratory (SRNL)

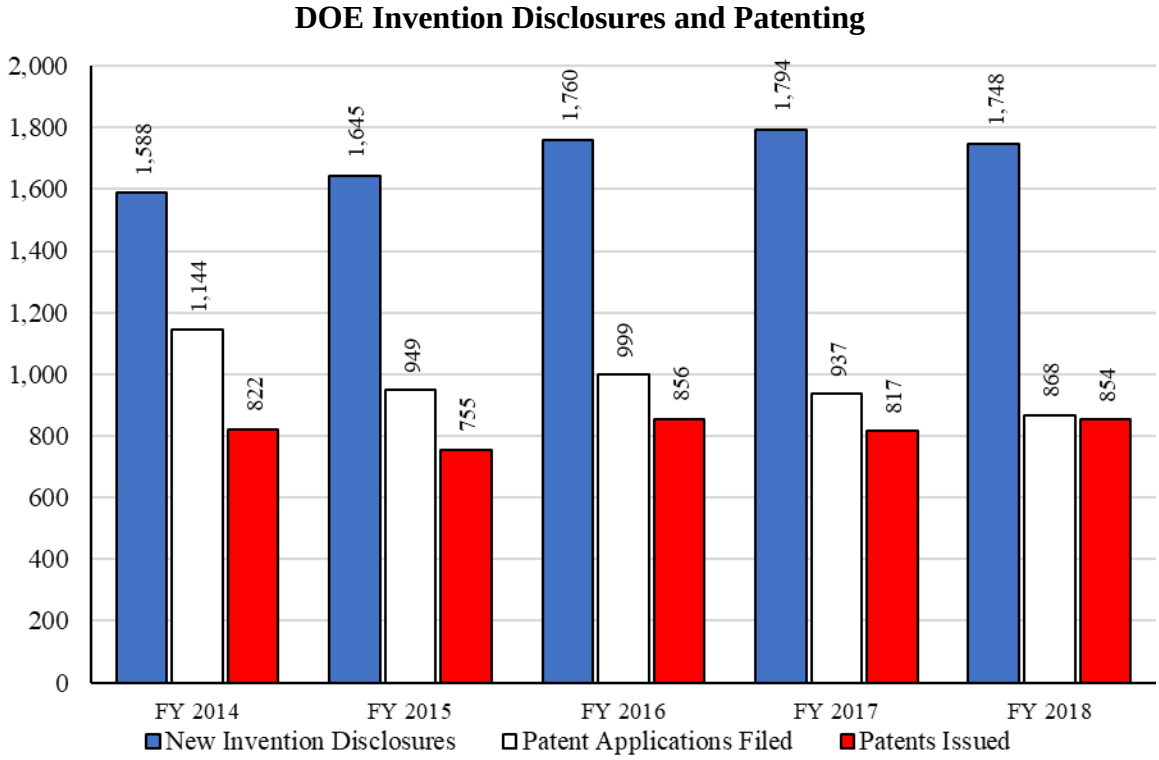
Science and engineering are not linear. The DOE's system of National Labs, user facilities, research centers, and shared research facilities, makes the pursuit of discovery—and the many solutions that result—both a collaborative enterprise and a shared national resource. Collaboration with industry, academia, and other federal and state agencies is essential to develop, demonstrate, deploy, and commercialize the output from DOE's broad R&D investments.

The Office of Technology Transitions (OTT) mission is to expand the commercial impact of the DOE's research and development portfolio to advance the economic, energy, and national security interests of the Nation. OTT develops DOE's policy and vision for expanding the commercial impact of its research investments and streamlines information and access to DOE's national labs and sites to foster partnerships that will bring innovations from the labs into the marketplace. OTT works alongside the Office of Energy Efficiency and Renewable Energy, the Office of Environmental Management, the Office of Fossil Energy, the Office of Nuclear Energy, NNSA's Office of Strategic Partnership Programs, and the Office of Science to advance the Department's technology transfer and commercialization goals and objectives for the Department's laboratories, plants, and sites.

More information about DOE's technology transfer activities is available online with the Office of Technology Transitions and NNSA's website.

DOE Invention Disclosures and Patenting[33]

Between FY 2014 and FY 2018, new inventions disclosed increased by 10%, from 1,588 in FY 2014 to 1,748 disclosures in FY 2018. Patent applications filed declined by 24%, from 1,144 in FY 2014 to 868 FY 2018, while patents issued increased by 4%, from 822 in FY 2014 to 854 patents in FY 2018.



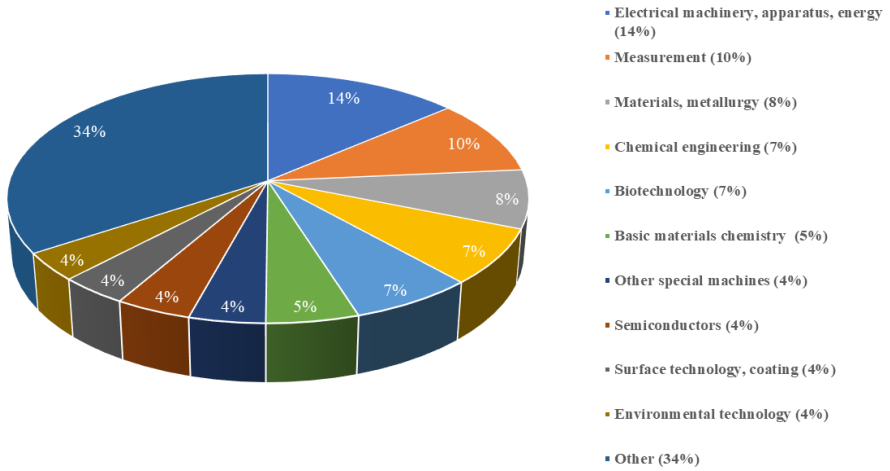
	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	1,588	1,645	1,760	1,794	1,748
Patent Applications Filed	1,144	949	999	937	868
Patents Issued	822	755	856	817	854

Patents issued to DOE in FY 2018 covered many technology areas including Electrical Machinery, apparatus, energy (14%), Measurement (10%), Materials, metallurgy (8%), Chemical Engineering (7%), and Biotechnology (7%).[34]

[33] The data in this section arises from all DOE National Laboratories—the majority of intellectual property arising from federal funding at the DOE National Laboratories is owned, assigned to and licensed by the Laboratory Management and Operating Contractors, and not the Department of Energy.

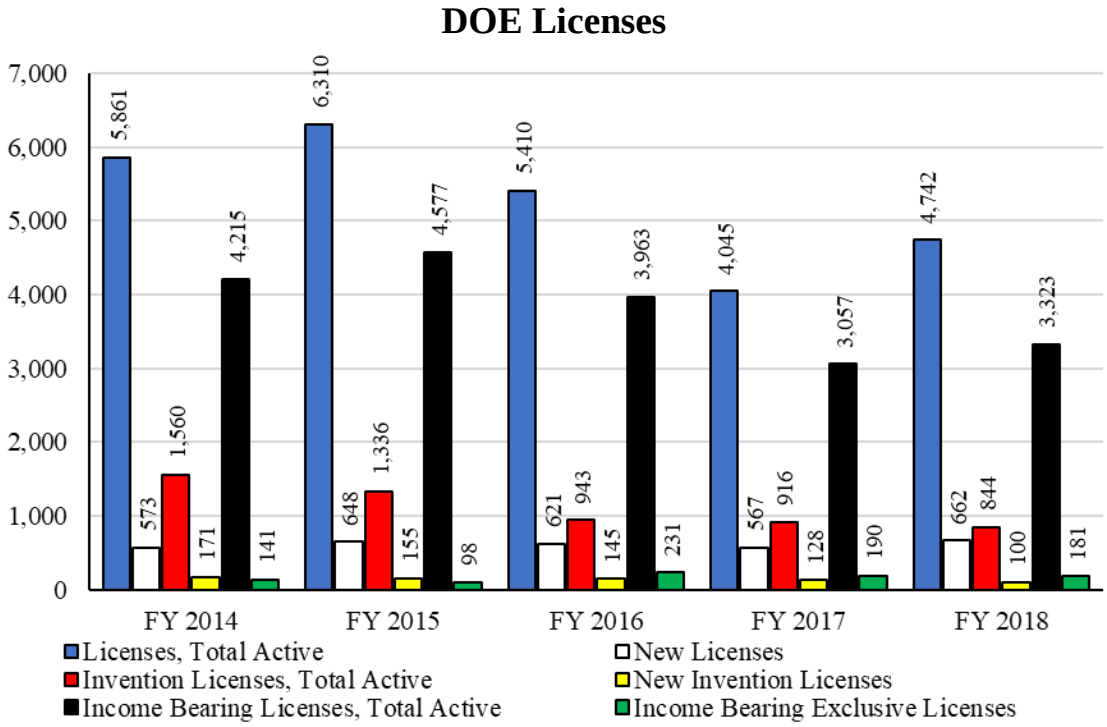
[34] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

USPTO Patents Assigned to DOE by Technology Area: FY 2018



DOE Licenses

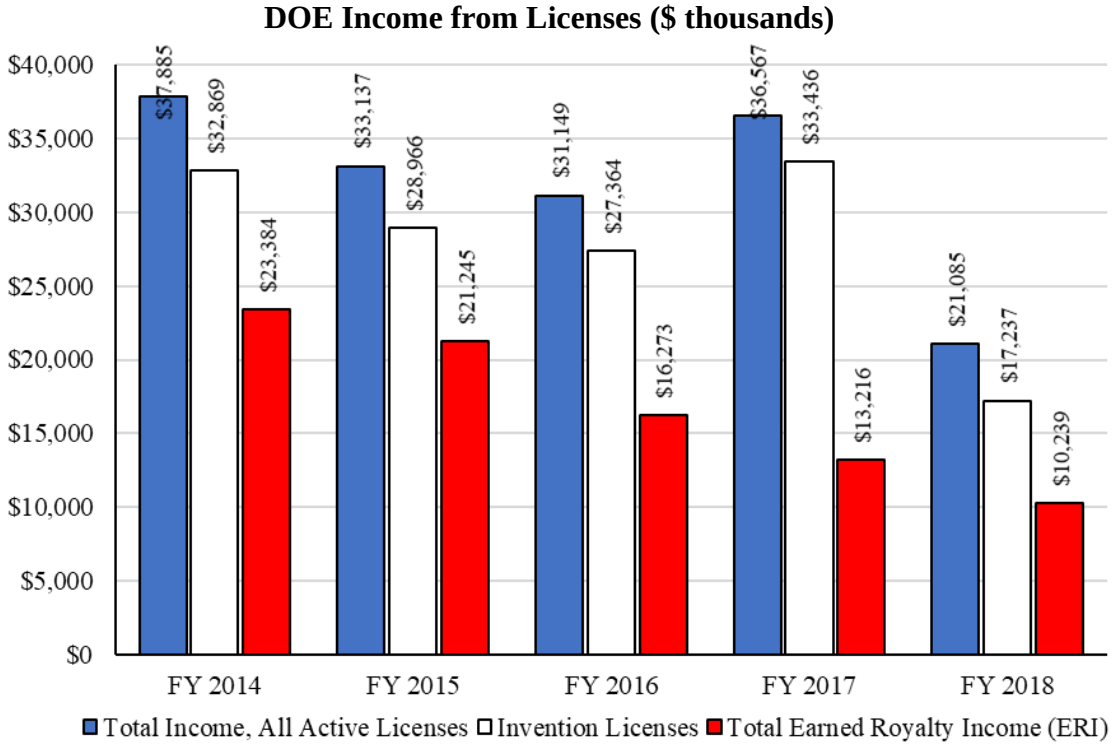
Total active licenses decreased by 19%, from 5,861 in FY 2014 to 4,742 in FY 2018. New licenses increased by 16%, from 573 in FY 2014 to 662 in FY 2018. Total active invention licenses decreased by 46%, from 1,560 in FY 2014 to 844 in FY 2018. New invention licenses decreased by 42%, from 171 in FY 2014 to 100 in FY 2018. Income bearing licenses decreased by 21%, from 4,215 in FY 2014 to 3,323 in FY 2018, and income bearing exclusive licenses increased by 28%, from 141 in FY 2014 to 181 in FY 2018.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	5,861	6,310	5,410	4,045	4,742
New Licenses	573	648	621	567	662
Invention Licenses, Total Active	1,560	1,336	943	916	844
New Invention Licenses	171	155	145	128	100
Income Bearing Licenses, Total Active	4,215	4,577	3,963	3,057	3,323
Income Bearing Exclusive Licenses	141	98	231	190	181

DOE Income from Licensing

Total income from all active licenses decreased by 44%, from $37.9 million to $21.1 million. License income from invention licenses decreased by 48%, from $32.9 million in FY 2014 to $17.2 million in FY 2018. Total earned royalty income decreased 56%, from $23.4 million in FY 2014 to $10.2 million in FY 2018.



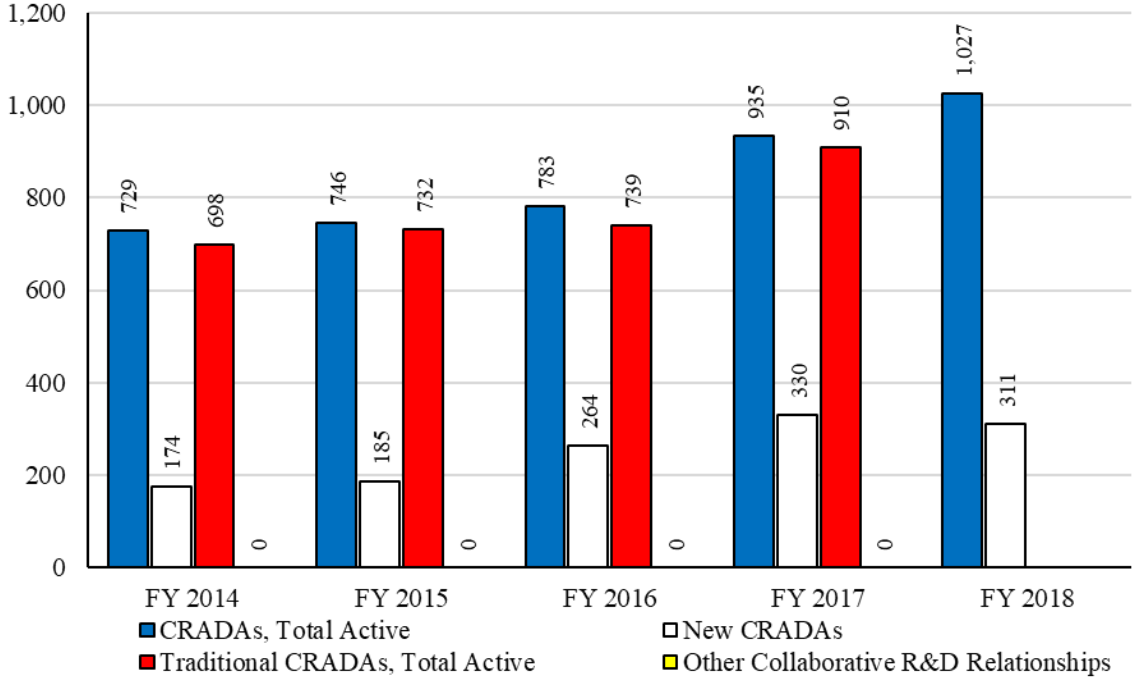
	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$37,885	$33,137	$31,149	$36,567	$21,085
Invention Licenses	$32,869	$28,966	$27,364	$33,436	$17,237
Total Earned Royalty Income, (ERI)	$23,384	$21,245	$16,273	$13,216	$10,239

DOE Collaborative R&D Relationships[35]

Between FY 2014 and FY 2018, total active CRADAs increased by 41%, from 729 in FY 2014 to 1,027 in FY 2018. New CRADAs increased by 79%, from 174 in FY 2014 to 311 in FY 2018.

[35] DOE was unable to report Traditional CRADAs, Total Active and Other Collaborative R&D Relationships for FY 2018.

DOE Collaborative R&D Relationships



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	729	746	783	935	1,027
New CRADAs	174	185	264	330	311
Traditional CRADAs, Total Active	698	732	739	910	n.a.
Other Collaborative R&D Relationships	0	0	0	0	n.a.

DOE Downstream Success Stories

"Innovation Powered by DOE" is a new public-facing dashboard that allows one to search and filter by title, popular topic, industry sector and subsector, DOE National Laboratory or Site, state or province of over 450 DOE technology transfer and commercialization success stories of public and private partnerships driven by DOE's National Laboratories and Site with partners all over the globe. Recent successes include:

Ames Laboratory: Acid-free rare-earth magnet recycling
One invention with two dramatic outcomes is the result of a new acid-free rare-earth magnet recycling process invented by scientists at the Critical Materials Institute (CMI) and Ames Laboratory. During the recycling process, magnets are dissolved in water-based solutions, allowing scientists to recover more than 99 percent purity rare-earth elements. In addition, cobalt is recovered from cobalt-containing magnet wastes. The rare-earth materials recovered are used in making new magnets while the recovered cobalt shows promise for use in making battery cathodes.

The technology resulted from analyzing industrially generated wastes from three U.S. magnet manufacturing and processing companies. A U.S. hard disk drive shredding company supplied shredded HDDs. In addition, the Ames Laboratory Materials Preparation Center reduced magnets from the research into metal ingots, and collaboration is ongoing with a commercial partner, Infinium Metals, to produce metal ingots at larger scale.

Ames Laboratory and CMI scientists Ikenna Nlebedim and Denis Prodius, and Anja-Verena Mudring, formerly of Ames Laboratory and currently of Stockholm University, developed the innovative recycling process. Nlebedim, lead investigator, says, "The unique strength of this technology is that it eliminates operational hazards and negative environmental impacts associated with acid-based dissolution process without sacrificing purity, efficiency, and potential economic impact." Patents for the process have been filed, and the recycling process has earned a prestigious 2018 Notable Technology Development Award from the Federal Laboratory Consortium (FLC).

Sandia National Laboratories: Sandia Launches a Bus into Space
Sandia National Laboratories recently launched a bus into space. Not the kind with wheels that go round and round, but the kind of device that links electronic devices (a USB cable, short for "universal serial bus," is one common example).

The bus was among 16 total experiments aboard two sounding rockets that were launched as part of the National Nuclear Security Administration's HOT SHOT program, which conducts scientific experiments and tests developing technologies on nonweaponized rockets. The respective flights took place in April 2018 at the Kauai Test Facility in Hawaii.

The pair of flights marked an increase in the program's tempo.

"Sandia's team was able to develop, fabricate, and launch two distinct payloads in less than 11 months," said Nick Leathe, who oversaw the payload development. The last HOT SHOT flight—a single rocket launched in May 2018—took 16 months to develop.

The sounding rockets are designed to achieve an altitude of about 1.2 million feet and to fly about 220 nautical miles down range into the Pacific Ocean. Sandia uses refurbished, surplus rocket engines, making these test flights more economical than conventional flight tests common at the end of a technology's development.

The HOT SHOT program enables accelerated cycles of learning for engineers and experimentalists. "Our goal is to take a 10-year process and truncate it to three years without losing quality in the resulting technologies. HOT SHOT is the first step in that direction," said Todd Hughes, NNSA's HOT SHOT Federal Program Manager.

Lawrence Livermore National Laboratory (LLNL): LLNL Licenses Breakthrough Laser Technology for Industrial and Therapeutic Applications

Lumitron Technologies, Inc. has acquired the key licenses from the Lawrence Livermore National Laboratory that will bring to market a new generation of advanced x-ray and gamma-ray systems.

Lumitron's game-changing HyperVIEW x-ray platform is set to revolutionize many fields of human endeavor including key aspects of the medical and security industries. Unlike existing commercial endeavors which have produced x-rays in essentially the same manner for more than 120 years, Lumitron's proprietary x-ray technology represents a generational leap in scientific innovation, according to UCI's Prof. Chris Barty, Lumitron's Chief Technical Officer and former CTO of LLNL's National Ignition Facility and Photon Science Directorate, home of the world's largest laser system, the National Ignition Facility, and America's largest nuclear fusion project.

"Lumitron brings the precision and unique capabilities of billion-dollar-scale, particle-accelerator-based synchrotron x-ray light sources to the point of need in a form factor similar in size to a modern CT machine," says Prof. Barty, a world-renowned leader in the fields of laser science, x-ray and gamma-ray source development and novel photonics applications further explained. "Just as the laser has revolutionized the production and use of visible light in much of modern technology, the HyperVIEW has the potential to provide a transformational view into the human body and beyond."

"Existing clinical x-ray systems are generally limited to a resolution of just under 1mm. By contrast, the Lumitron HyperVIEW technology is capable of imaging objects up to 1000x smaller and of detection and analysis of the elemental and isotopic composition of the object. The HyperVIEW technology can also capture motion at the picosecond time-scale, that is 1000th of a billionth of a second."

According to Prof. Barty, the HyperVIEW technology presents the potential to create the first true Theranostics machine capable of both remarkable imaging detail and cellular level treatment, simultaneously. The implications for medical applications in particular are astounding.

Pacific Northwest National Laboratory (PNNL): Micro Aerosol Disinfecting System Aides in Battle Against Coronavirus

Salt water is converted into a powerful micro-aerosol disinfectant that kills 99.999 of bacteria viruses and spores including the COVID-19 virus. This disinfectant is now in use by the Florida State Firefighters Association (FSFA).

being used by the Florida State Firefighters Association to disinfect emergency vehicles, fire stations, and more.
Source: Department of Energy.

First responders are on the frontline in the battle against COVID-19, often exposing themselves, equipment, and vehicles to the deadly virus. FSFA has added a new disinfection technology developed at PNNL in their effort to control and mitigate the ongoing spread of the virus. The technology, known as Paerosol, was licensed to a South Carolina company called NanoPure in 2018.

Recent testing conducted by Mako Medical Laboratories in North Carolina has provided preliminary results demonstrating Paerosol's effectiveness at eliminating the COVID-19 viral particles.

The PNNL initially developed a prototype of the Paerosol technology through a now-concluded Department of Energy program. The technology was further developed with internal PNNL funding and support from the Defense Threat Reduction Agency. It was licensed to Watertech, now called NanoPure, in 2015. The company has sold hundreds of units and is seeking approval from the Environmental Protection Agency to sell and ship the salt solution directly to customers.

The FSFA has deployed multiple response units in the state of Florida and has disinfected dozens of fire stations, restaurants, businesses, hospitals, schools, and first response vehicles. According to the FSFA, Paerosol is simple to use, cost effective, and requires no technical training, no site preparation, and no clean up.

The FSFA has reached out to other fire department agencies across various states to expand the services model nationwide. The FSFA also plans to begin disinfecting personal protective equipment, such as masks, as well as food processing facilities and transportation systems, such as subways, buses, and airplanes.

Department of Health and Human Services (HHS)

Research at HHS is conducted by the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the National Institutes of Health (NIH).

The mission of Technology Transfer at HHS is to facilitate partnerships with a wide array of stakeholders and effectively manage the inventions conceived by scientists working at the NIH, FDA, and CDC. In doing so, HHS Technology Transfer supports the larger HHS mission to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce illness and disability.

Working on behalf of NIH, FDA, and CDC, Technology Transfer offices across HHS apply responsive, and sometimes creative approaches to meet the needs of all parties involved, operating with a goal of moving scientific research and discovery forward for the benefit of public health. Technology Transfer at HHS does the following:

- Protects U.S. intellectual property and the discoveries conceived by NIH, FDA, and CDC intramural researchers. This includes working with researchers to determine if an invention warrants patent protection, overseeing the filing of Employee Invention Reports (EIRs), and coordinating the patenting, filing, and prosecution process.
- Serves as a bridge through marketing and communications, connecting the inventive discoveries made by scientists in the NIH, FDA, and CDC research programs to commercial partners with the capability of developing these technologies into products and services to benefit public health. Without technology transfer, the full potential of these inventions would not be realized, and the public would not receive the full benefit of these biomedical discoveries.
- Facilitates partnerships with outside parties to allow for joint collaboration.
- Negotiates licenses and collaborative agreements such as CRADAs to ensure the timely development of federal technologies, which contribute to society by driving economic growth and productivity; these collaborations leverage the strengths of each institution to advance basic and clinical research objectives.
- Monitors the development of these technologies to ensure commercialization milestones are reached, products are brought to the market, and royalty fees are paid.
- Facilitates the transfer of thousands of research materials and data into and out of HHS.

The NIH's annual technology transfer report is available online.

More information about HHS technology transfer activities is available on the following websites:

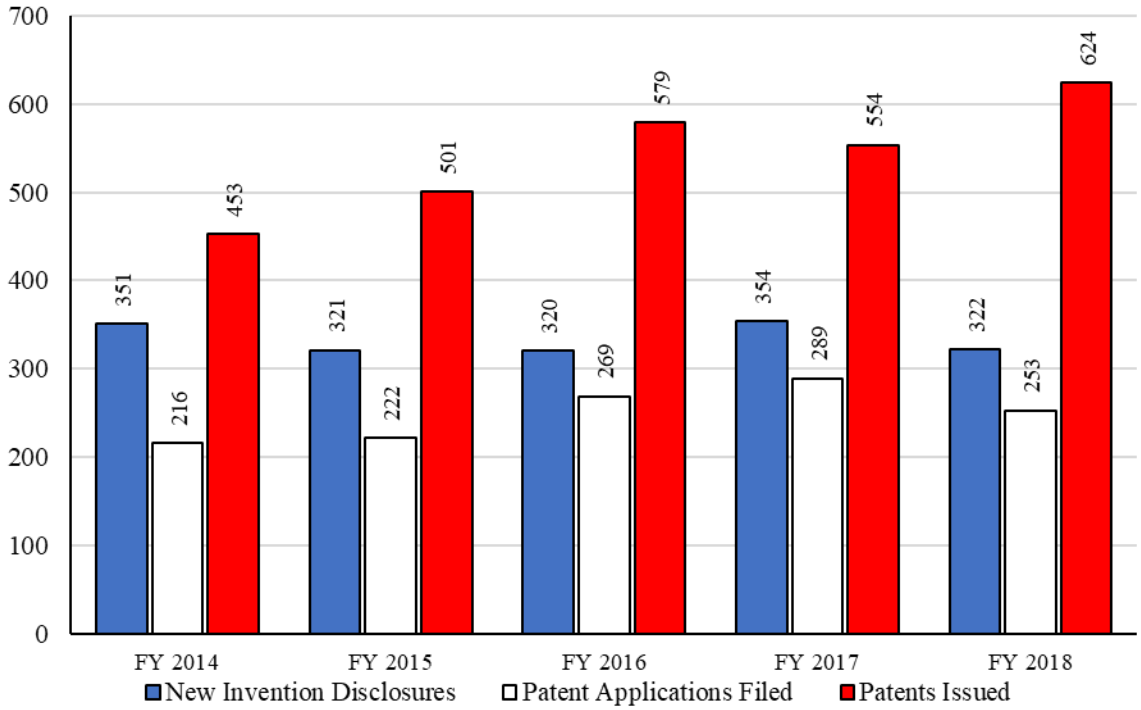
CDC | NIH | FDA

HHS Invention Disclosures and Patenting

Between FY 2014 and FY 2018, new invention disclosures decreased by 8%, from 351 in FY 2014 to 322 disclosures in FY 2018. Patent applications filed increased by 17%, from 216 in FY

2014 to 253 in FY 2018, while patents issued increased by 38%, from 453 in FY 2014 to 624 patents in FY 2018.

HHS Invention Disclosures and Patenting

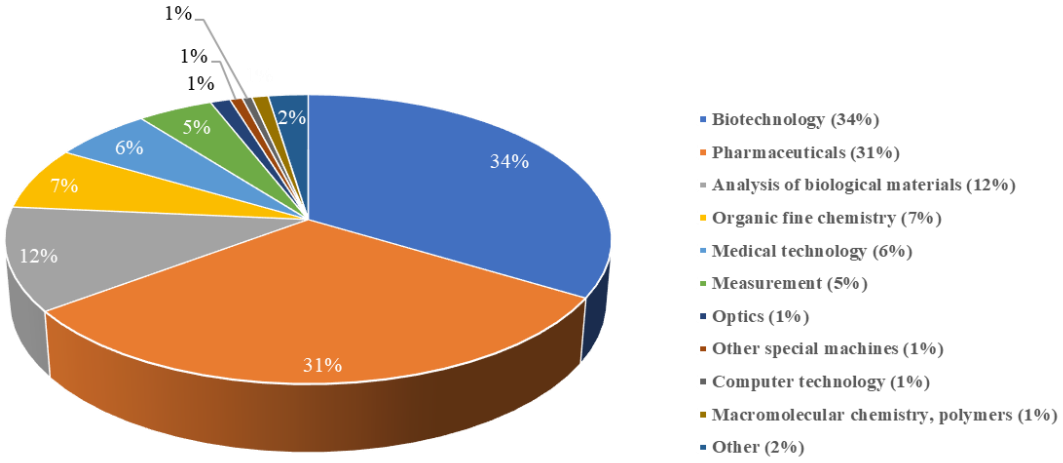


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	351	321	320	354	322
Patent Applications Filed	216	222	269	289	253
Patents Issued	453	501	579	554	624

Patents issued to HHS in FY 2018 covered many technology areas including Biotechnology (34%), Pharmaceuticals (31%), Analysis of biological materials (12%), Organic fine chemistry (7%), and Medical technology (6%).[36]

[36] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

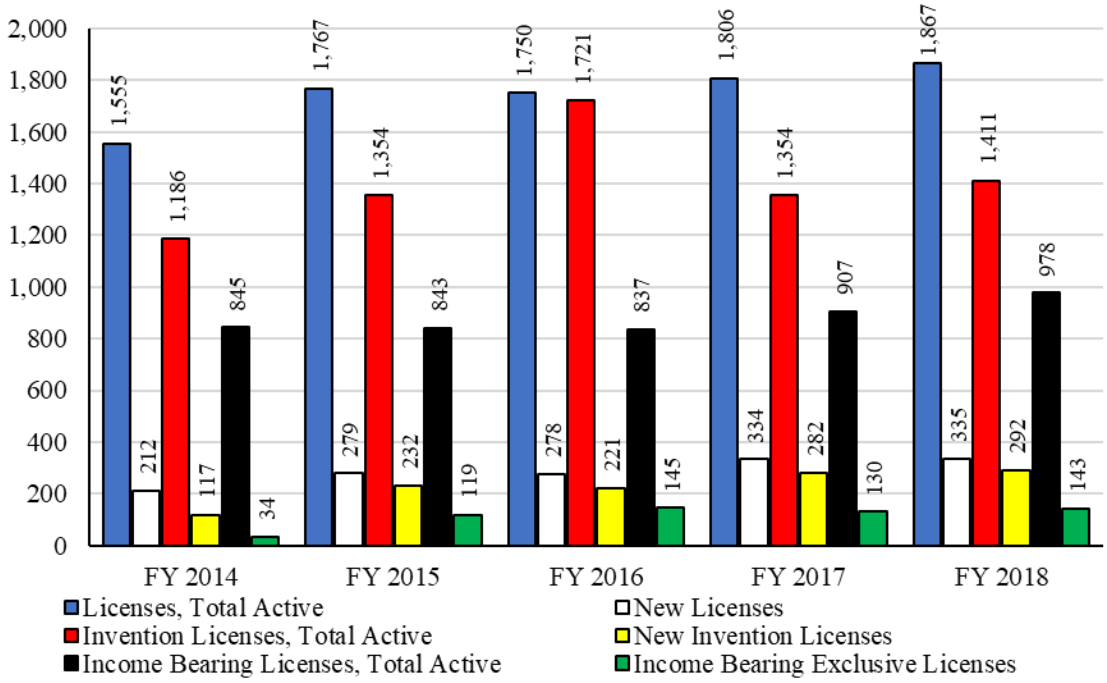
USPTO Patents Assigned to HHS by Technology Area: FY 2018



HHS Licenses

Between FY 2014 and FY 2018, total active licenses increased by 20%, from 1,555 in FY 2014 to 1,867 licenses in FY 2018. New licenses increased by 58%, from 212 in FY 2014 to 335 in FY 2018; total active invention licenses increased by 19%, from 1,186 in FY 2014 to 1,411 in FY 2018; and new invention licenses increased by 150%, from 117 in FY 2014 to 292 in FY 2018. Total active income bearing licenses increased by 16%, from 845 in FY 2014 to 978 in FY 2018, while income bearing exclusive licenses increased by 321%, from 34 in FY 2014 to 143 licenses in FY 2018.

HHS Licenses

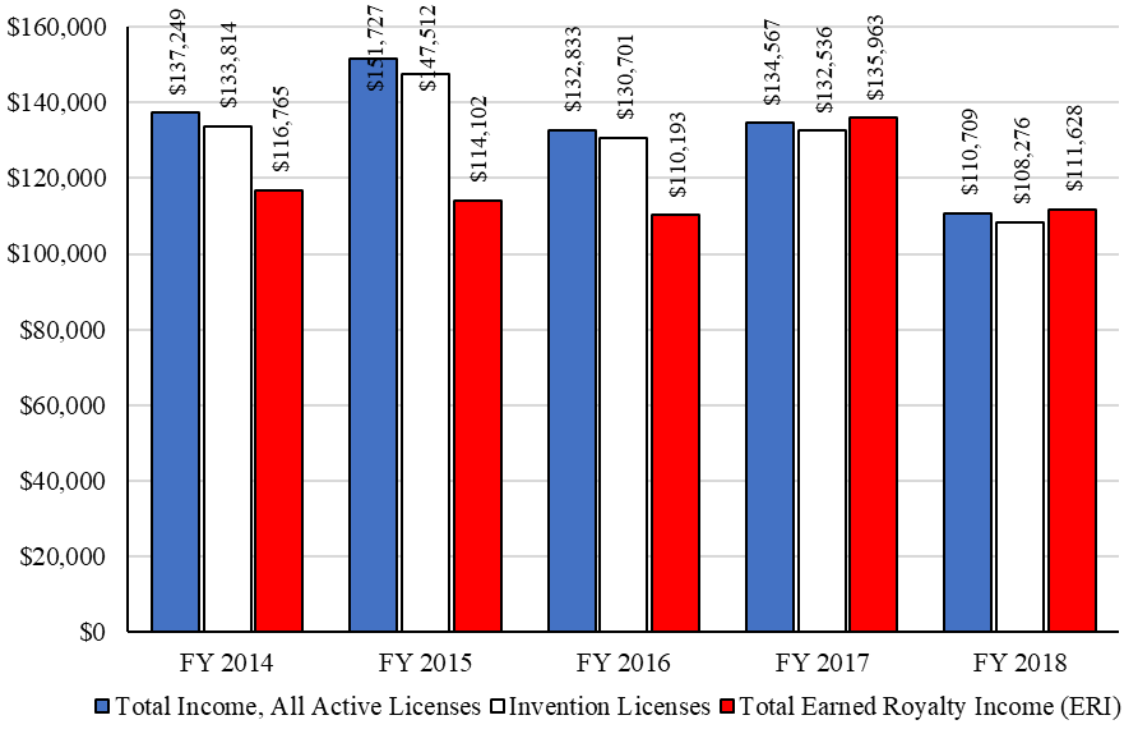


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	1,555	1,767	1,750	1,806	1,867
New Licenses	212	279	278	334	335
Invention Licenses, Total Active	1,186	1,354	1,721	1,354	1,411
New Invention Licenses	117	232	221	282	292
Income Bearing Licenses, Total Active	845	843	837	907	978
Income Bearing Exclusive Licenses	34	119	145	130	143

HHS Income from Licensing

Between FY 2014 and FY 2018, total income from all active licenses decreased by 19%, from $137.2 million in FY 2014 to $110.7 million in FY 2018. The income from invention licenses decreased by 19%, from $133.8 million in FY 2014 to $108.2 million in FY 2018, while total earned royalty income decreased by 4%, from $116.8 million in FY 2014 to $111.6 million in FY 2018.

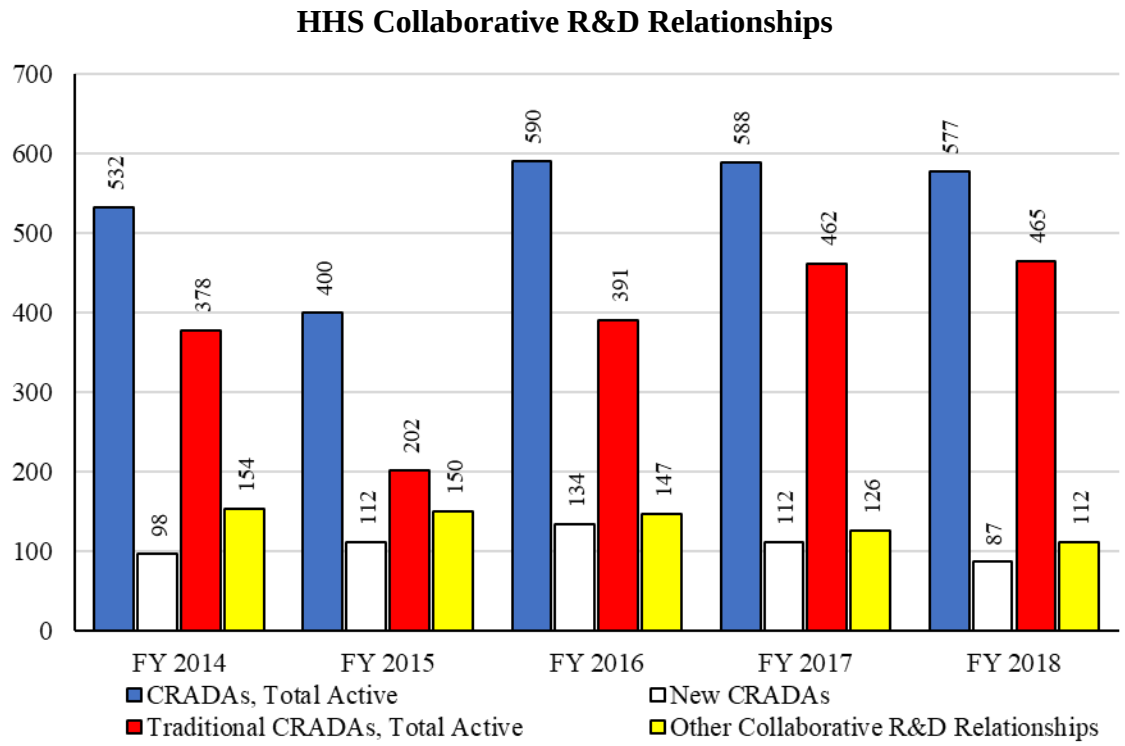
HHS Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$137,249	$151,727	$132,833	$134,567	$110,709
Invention Licenses	$133,814	$147,512	$130,701	$132,536	$108,276
Total Earned Royalty Income, (ERI)	$116,765	$114,102	$110,193	$135,963	$111,628

HHS Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs increased by 8%, from 532 in FY 2014 to 577 in FY 2018, while new CRADA agreements decreased by 11%, from 98 in FY 2014 to 87 in FY 2018. Traditional CRADAs increased by 23%, from 376 to 465. Other collaborative R&D relationships decreased by 27%, from 154 to 112.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	532	400	590	588	577
New CRADAs	98	112	134	112	87
Traditional CRADAs, Total Active	378	202	391	462	465
Other Collaborative R&D Relationships	154	150	147	126	112

HHS Downstream Success Stories

National Center for Advancing Translational Sciences (NCATS): 3D Tissue Platforms for Drug Discovery

With the assistance and expertise of the Office of Strategic Alliances (OSA), NCATS has executed agreements with Rockefeller University and Columbia University in New York City to develop 3-D printed skin tissues that can be used to investigate possible therapies for diseases such as cancer and psoriasis. Traditional drug development involves analyzing the effects of potential drugs in 2-D laboratory-grown cells or in laboratory animal models, both of which have limitations. Through these collaborations, NCATS intramural researchers and their collaborators are using the techniques of 3-D bioprinting to combine living cells with scaffolding materials, to create testing platforms of laboratory grown human tissues that closely mimic natural tissues in human organs. Such 3-D tissue models will more closely mimic the complexity of tissues in the human body in a reproducible, automated, and scalable manner and can be used for compound testing and could accelerate drug development.

National Cancer Institute (NCI): CRADA Makes Possible Clinical Trial to Evaluate Therapy for Rare Brain Cancer

A CRADA allows NCI and Celgene to collaborate to conduct a Phase II clinical trial to evaluate Celgene's proprietary agent, Marizomib, in patients with recurrent, low-grade ependymomas. Ependymomas—a rare brain cancer that begins in the cells lining the spinal cord canal, ventricles, or choroid plexus—have a high rate of recurrence. The clinical outcome for patients with advanced ependymomas is generally poor, due to a lack of standard therapy options. Through this collaboration, NCI and Celgene will evaluate targeting of the constitutively activated NF-κB signaling pathway via Marizomib in patients with recurrent ependymomas. Marizomib has the potential to quickly receive marketing approval because it was already granted orphan designation by the FDA for the treatment of malignant gliomas. Overall, this collaboration aims to provide better health care management and increased progression-free survival in patients with recurrent ependymomas.

NCI: CRADA Enables Three-Way Collaboration for Preclinical Research into Ovarian Cancer Prevention

A Materials CRADA between NCI's extramural Division of Cancer Prevention (DCP), the NCI CCR Center for Advanced Preclinical Research (CAPR), and Amgen, Inc., enables a three-way collaboration to conduct preclinical studies that will evaluate ovarian cancer prevention.

Specifically, in preclinical studies proposed and funded by DCP, the partners will utilize and evaluate Amgen's proprietary agent, mu-RANK-Fc recombinant fusion protein, in CAPR's proprietary genetically engineered mouse models to study the effects of pharmacological inhibition of the RANK/RANKL signaling pathway on the development of ovarian cancer. Potentially, the study results should provide data on the effects of RANKL inhibition on ovarian cancer development and progression. Under the terms of the Materials-Cooperative Research and Development Agreement (M-CRADA), the preclinical studies will utilize CAPR's GEM models to also study the impact of inhibition of the RANK/RANKL signaling pathways on the cellular proliferation of breast, ovary, and fallopian tubes. Furthermore, it is hoped that these studies will complement a pre-surgical trial currently being developed by NCI DCP's Cancer Prevention

Clinical Trials Consortia to investigate the effect of denosumab treatment on tubal/ovarian proliferation in BRCA1/2 mutation carriers.

The NCI's Technology Transfer Center (TTC) recommended an approach that streamlined the TT process by consolidating the agreements needed to support the study into one CRADA. To accomplish this, rather than establishing a separate agreement with CAPR, the CAPR investigator was named as a co-PI on the study because CAPR will be performing the research studies with funding provided by DCP.

NCI: Agreements Aid in Development of Algorithms to Detect Cervical Precancers
The TTC executed 14 Data Transfer Agreements (DTAs) with institutions worldwide for the development of algorithms for detection of cervical precancers based on cervical images. In its "Cervix Image Sharing Protocol (CISP)" study, the Clinical Genetics Branch of NCI's Division of Cancer Epidemiology and Genetics (DCEG) aims to develop better screening and diagnostic tools for cervical cancer, using machine learning algorithms to better guide treatment in low resource settings. Under the DTA developed by TTC, NCI provides institutions with digital cervical images and accompanying clinical data from large epidemiological studies on HPV and cervical cancer screening. These training sets are used to develop algorithms to detect cervical precancers. This effort supports DCEG's goal to foster development of cervical cancer prevention solutions for all kinds of settings—including low resource settings that rely on robust, low-cost screening, and triage tools.

National Institute of Allergy and Infectious Disease (NIAID): Rapid Diagnostic Kits for Onchocerciasis and Lymphatic Filariasis
Onchocerciasis, commonly known as river blindness, is caused by the parasitic worm Onchocerca volvulus (Ov) and is transmitted to humans through the bite of the blackfly. It causes itching, skin disfiguration, and, with chronic exposure, permanent blindness. Worldwide, 169 million people are at risk of infection. Lymphatic filariasis (LF), commonly known as elephantiasis, is a painful and profoundly disfiguring disease, transmitted by mosquitos carrying parasitic worms. Of the three species known to cause LF, Wuchereria bancrofti (Wb) accounts for 90 percent of cases, including all cases on the African continent. Nearly 900 million people worldwide are at risk of infection.

The World Health Organization (WHO) has targeted LF for global elimination and onchocerciasis for elimination in select countries in Africa by 2020. Accurate surveillance data are required to inform program decisions around stopping treatment and detecting signs of reinfection.

Dr. Thomas Nutman and his colleagues at NIAID discovered Ov16, a recombinant antigen derived from Ov that can be used to detect Onchocerciasis before it is clinically apparent, and Wb123, an antigen specific to Wb with no cross reactivity against other closely related filariae. These two innovations were licensed to PATH in 2013 and 2014 respectively. By April 2016, three rapid diagnostic kits became commercially available. They are as follows: SD BIOLINE Onchocerciasis IgG4 rapid test, the Ov16 monoplex test for Oncoerciasis; SD BIOLINE Lymphatic Filariasis IgG4 rapid test, the Wb123 monoplex test for LF; and SD BIOLINE

Onchocerciasis and Lymphatic Filariasis IgG4 rapid test, the Ov16/Wb123 biplex test for combined surveillance. As of mid-2018, more than half a million of these diagnostic tests have been used in 18 countries worldwide.

Centers for Disease Control and Prevention (CDC): Mosquito Trap for Control and Surveillance of Mosquitoes Including Carriers of Zika and Other Viruses

An autocidal gravid ovitrap (AGO trap) was developed by researchers within the Division of Vector-Borne Diseases at the Centers for Disease Control and Prevention (CDC) as a low-cost, pesticide-free method for controlling mosquito populations. The AGO trap requires no power and is economical to manufacture. It has shown efficacy for at least two months without replacement of its inexpensive consumable components, in marked contrast to weekly application of pesticides that can be unsafe for use around children, pets, and livestock.

In August 2018, the U.S. Patent and Trademark Office recognized the CDC with a "Patents for Humanity Honorable Mention" for this low-cost, simple-to-assemble, and easy-to-maintain mosquito trap to reduce the spread of disease in resource limited settings.

Food and Drug Administration (FDA): New CRADA with Apple and FDA Allows Assessment of Patient Symptomology Using Mobile Sensor Technologies

The wearable medical device market is forecasted to more than double in the next five years, according to ReportsNReports.com. A new collaboration between NCI, Apple, and the FDA exemplifies the research taking place to explore the potential patient benefits of mobile health technologies. The objective is a feasibility study in clinical trials utilizing Apple's proprietary mobile sensor technologies to assess behavioral and physiological symptomology of patients enrolled in NCI intramural protocols. A growing number of mobile health solutions are enabling the tracking, diagnosis, and management of various physiological processes and disease conditions. Many common devices such as smartphones (e.g., iPhone) have integrated robust sensors to collect and track data. This collaboration focuses on using a stream of sensor data that can augment clinical, imaging, and laboratory-based evaluations to provide a more accurate, detailed and quantitative picture of the patients' symptomology, functional status, response to therapy, and quality of life.

Current methods for evaluating cancer patients include clinical, laboratory, and imaging examinations in the physician's office–and primarily involve physical examinations and patient interviews. These evaluation methods are intermittent, providing a snapshot of the patient's status at the time of assessment. They are also largely subjective, relying on physician judgement and the patient's ability to recall events and describe their symptoms and experience. Given these limitations, the use of remote sensor technologies could provide an objective, frequent, and near-real time stream of data in a machine-readable format. Data would be free of human bias, potentially enhancing the ability of both clinicians and patients to manage the complexities of cancer care. For example, continuous biometric data could provide actionable insights into fluctuations for patient activity level, as well as cognitive function and mood throughout treatment. It is theorized that biometric data could also empower patients to become active participants in their own care, by providing them with quantitative feedback on daily activities and status. The TTC worked with FDA's Technology Transfer Office to negotiate the agreement.

Department of Homeland Security (DHS)

As the designated DHS Office of Research and Technology Applications (ORTA; 15 USC §3710(b)), the Technology Transfer and Commercialization Program (T2C) manages technology transfer and commercialization activities for the Department, including DHS Components and the DHS laboratory network. T2C works directly with the DHS Office of General Counsel Technology Programs Law Division (OGC-TPLD) to protect, manage and license DHS intellectual property. T2C also has delegated responsibility for establishing research collaborations and partnerships through Cooperative Research and Development Agreements (CRADAs) and providing additional resources or support to develop and move technologies from lab to market.

More information about DHS technology transfer activities is available on the following website:

http://www.dhs.gov/technology-transfer-program.

Revitalization

Throughout fiscal year (FY) 2018, S&T was in the midst of developing a new organizational structure to improve its ability to more rapidly transfer technology capabilities to DHS Components and Homeland Security Enterprise (HSE) end users, enable quick response to emerging threats, and improve research and development (R&D) business practices to make it easier for industry, including the start-up community, to work with S&T.

The new structure went into effect at the beginning of FY19, and enables the agency to be more agile and responsive: ready to move quickly to respond to changes in the threat environment and to make use of existing technologies that can be adapted and leveraged to expedite the development of vital capabilities. Another critical element is the ability to more rapidly transfer capabilities to where they are most needed, working closely with S&T's DHS Component partners and industry to deliver effective solutions.

The core of the revitalization is the three-pronged operating model blueprint that:

1) focuses first on understanding customers' needs through strategic and transparent engagement, leveraging S&T's expertise in operational analysis and systems engineering to help customers refine their needs;
2) applies a deliberate, team-based approach that leverages S&T's full range of capabilities, beginning with seeking out ready-made or easily adaptable solutions that can be delivered quickly and cost-effectively; and
3) efficient, transparent, and accountable execution when a solution must be adapted or developed.

To accomplish this, S&T has reorganized into four primary offices that work collaboratively.

- The **Office of Mission and Capability Support** will conduct the majority of program management in support of borders, immigration, maritime, first responders, detection capabilities, and physical and cybersecurity.
- The **Office of Science and Engineering** will include operations and requirements analysis, systems engineering, standards, technology scouting, test and evaluation, and transition.

- The **Office of Innovation and Collaboration** will focus on industry and international partnerships through the Office of Industry Partnerships' individual program offices including the Technology Transfer and Commercialization Branch, the Silicon Valley Innovation Program, and the Small Business Innovation Research Program in collaboration with International Partnerships, Federally Funded Research and Development Centers (FFRDCs), the Office University Programs, and the Office of National Laboratories operates five laboratory campuses, dedicated to conducting Research, Development, Test and Evaluation (RDT&E) in HSE related mission areas as well as maintaining coordination with DOE National laboratories to deliver networked laboratory capabilities to the HSE.
- The **Office of Enterprise Services** will include all S&T support functions such as administration, communications, finance and budget, and the chief information office.

Streamlined CRADA Process

As part of the revitalization effort, T2C evaluated its internal policies and procedures and moved forward to streamline the CRADA process. CRADAs assist DHS by facilitating collaborations with non-federal entities to leverage the expertise and resources of both parties. DHS relies heavily on CRADAs to test and evaluate technologies in operational environments. This allows DHS R&D program managers (PMs) to support the development and delivery of technology solutions to homeland security end users. The CRADA Program works with PMs and OGC-TPLD to refine CRADA statements of work and negotiate terms and conditions with CRADA partners.

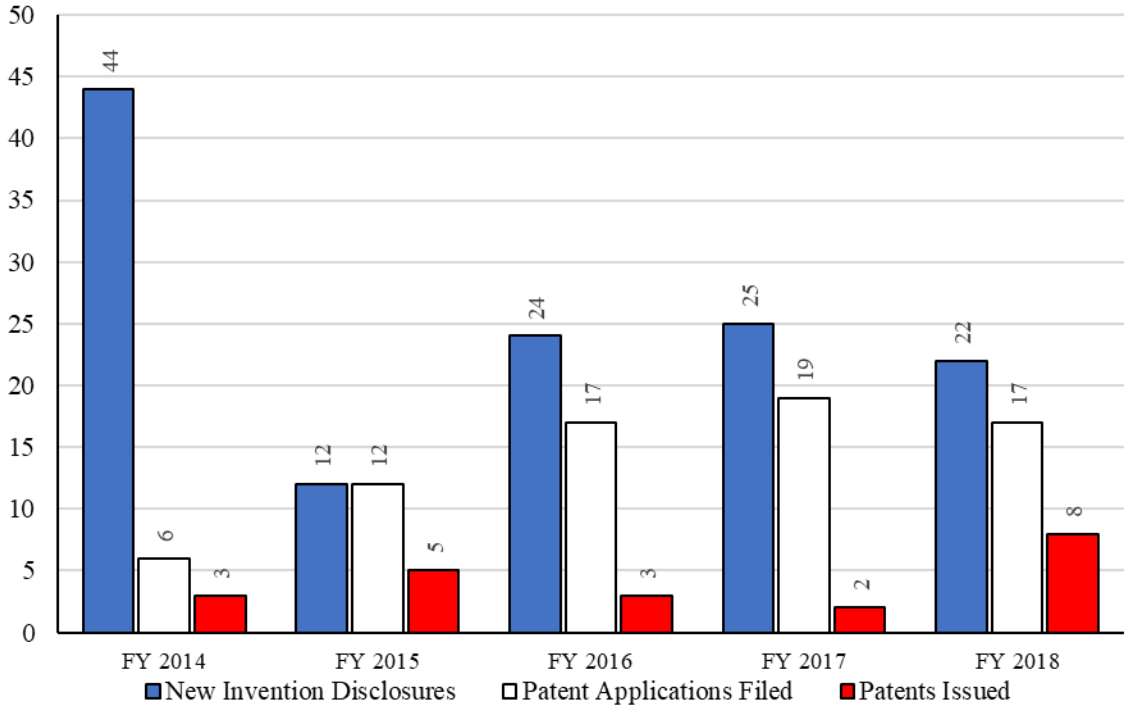
In FY18, T2C worked with the DHS OGC-TPLD to develop and implement a new standard template for DHS CRADAs. This streamlined template is much shorter and easier for our partners to understand and populate, containing only the basic language required for a CRADA and moving activity-specific information into the statement of work. The new template reduced the overall time required to develop, review, and execute a CRADA by an average of 45 days, resulting in most CRADAs taking an average of 75 days to move through the process.

T2C works across the revitalized S&T matrixed organizational structure and uses its tools and mechanisms to promote the delivery of technology solutions supported through DHS S&T funding. This model allows S&T to leverage its science, engineering, and business engagement capabilities more rapidly to innovate and field solutions.

DHS Invention Disclosures and Patenting

In FY 2018, DHS reported 22 new inventions disclosures. From FY 2014 to FY 2018, DHS reported an 183% increase in patent applications filed, with 6 in FY 2014 to 17 in 2018, and a 167% increase in patents issued, with 3 in FY 2014 to 8 issued FY 2018.

DHS Invention Disclosures and Patenting

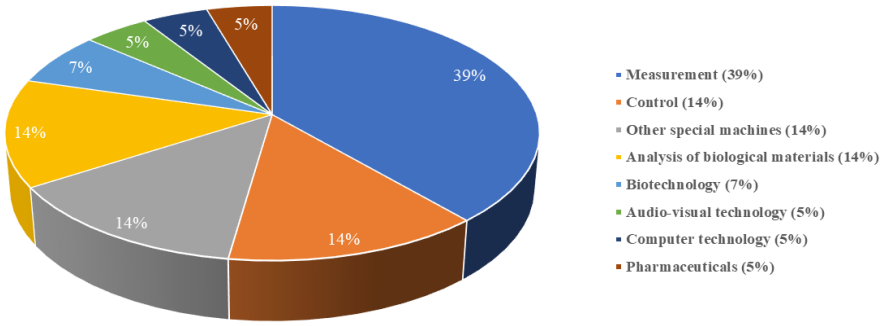


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	44	12	24	25	22
Patent Applications Filed	6	12	17	19	17
Patents Issued	3	5	3	2	8

Patents issued to DHS in FY 2018 covered multiple technology areas including Measurement (39%), Control (14%), Other special machines (14%), Analysis of biological materials (14%), and Biotechnology (7%).[37]

[37] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

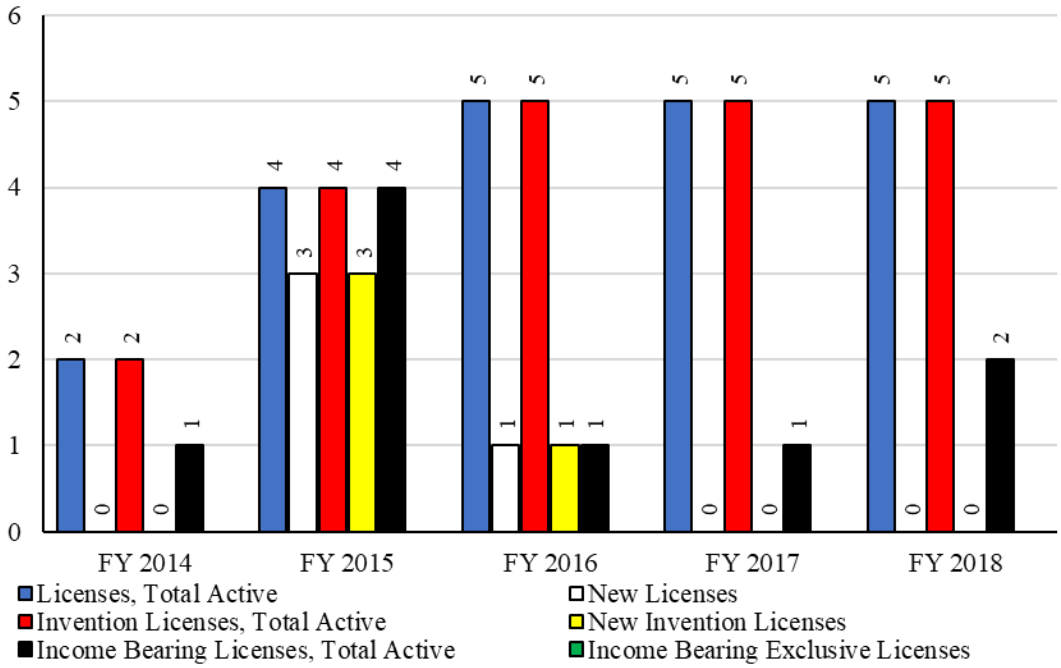
USPTO Patents Assigned to DHS by Technology Area: FY 2018



DHS Licenses

In FY 2018, DHS managed 5 active license agreements. Out of the 5 active agreements, two were income bearing.

DHS Licenses

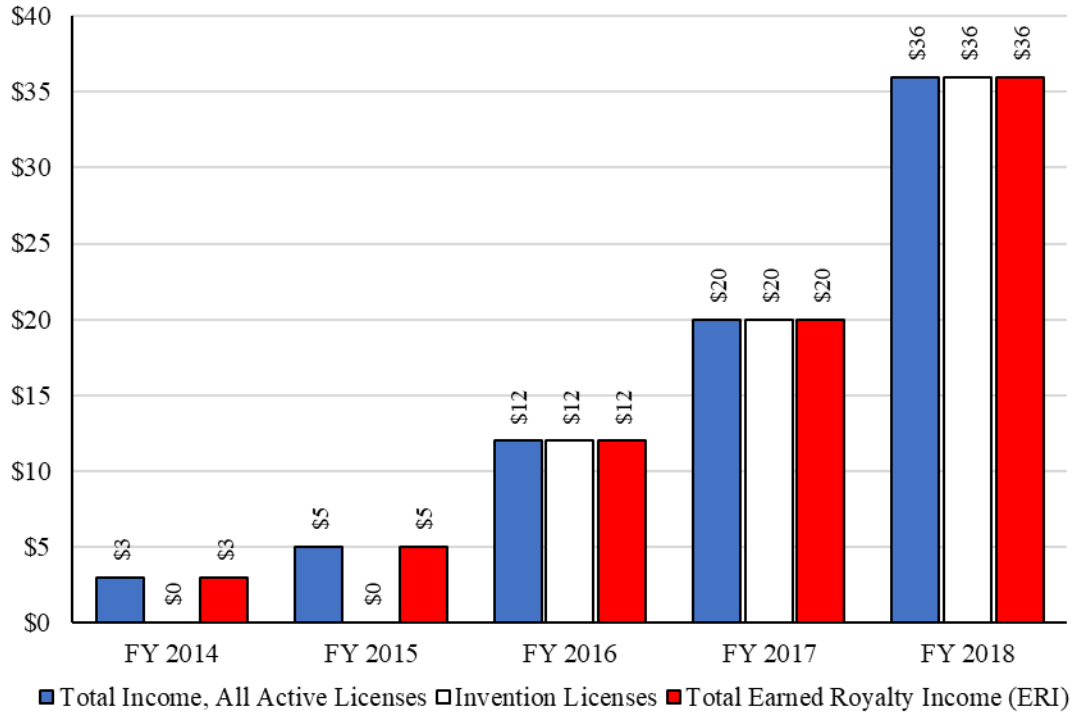


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	2	4	5	5	5
New Licenses	0	3	1	0	0
Invention Licenses, Total Active	2	4	5	5	5
New Invention Licenses	0	3	1	0	0
Income Bearing Licenses, Total Active	1	4	1	1	2
Income Bearing Exclusive Licenses	0	0	0	0	0

DHS Income from Licensing

From FY 2014 to FY 2018, DHS reported a 1100% increase in Total Earned Royalty Income from $3 thousand in FY 2014 to $36 thousand in FY 2018.

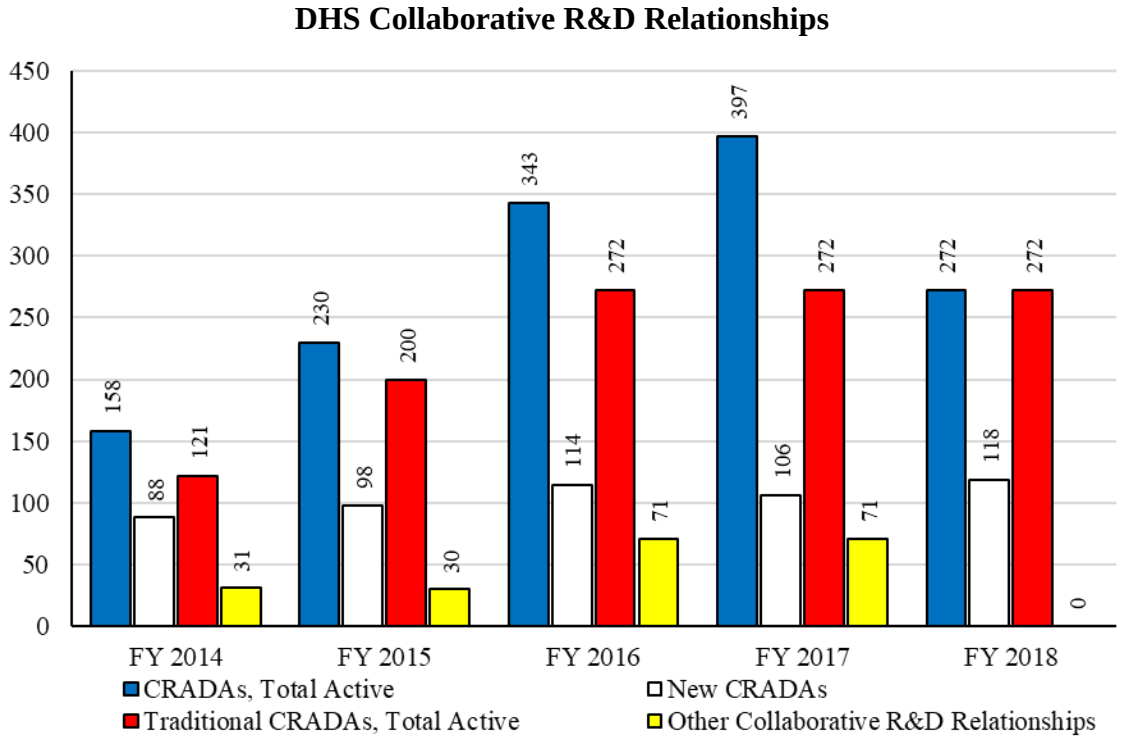
DHS Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$3	$5	$12	$20	$36
Invention Licenses	$0	$0	$12	$20	$36
Total Earned Royalty Income, (ERI)	$3	$5	$12	$20	$36

DHS Collaborative R&D Relationships[38]

Total active CRADAs increased by 72%, from 158 in FY 2014 to 272 agreements in FY 2018. New CRADAs increased by 34%, from 88 in FY 2014 to 118 new agreements in FY 2018.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	158	230	343	397	272
New CRADAs	88	98	114	106	118
Traditional CRADAs, Total Active	121	200	272	272	272
Other Collaborative R&D Relationships	31	30	71	71	0

[38] DHS was unable to report Non-Traditional CRADAs, Small Business related and Other Collaborative R&D Agreements for FY 2018.

Department of the Interior (DOI)

Technology transfer for the DOI includes a range of activities designed to disseminate scientific and technical information and knowledge between the DOI, other federal agencies, and non-federal entities. It includes, but is not limited to, publications, exchange of scientific and technical information, protecting and licensing intellectual property rights, and sharing, (or otherwise making available) for scientific or technical purposes, the expertise and specialized scientific material and resources which the DOI manages. In general, technology transfer activities within the DOI are consistent with its mission to protect and manage the Nation's natural resources and cultural heritage; provide scientific and other information about those resources; and honor trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

This section describes the actions that the DOI took in FY 2018 to advance technology transfer. These range from developing new technologies that would help identify various substances in water to improved methods to measure water quality in high biofouling environments. These activities demonstrate the innovation, expertise, and dedication of the Department's employees, including its many scientists and engineers, to help reduce risks to public health, safety, and the environment from natural and man-made hazards.

The DOI's bureaus have varying levels of involvement with scientific and technical research, innovation, and technology transfer. In FY 2018, as in previous years, the majority of technology transfer activities reported by the Department under the Federal Technology Transfer Act of 1986 (FTTA) were undertaken by the U.S. Geological Survey (USGS), which is the largest research and development (R&D) organization in the Department, both in terms of funding and personnel. Typically, USGS accounts for roughly two thirds of the Department's R&D funding.

The DOI's scientists, engineers, and other technical personnel advance the state of knowledge related to the resources it manages and ensure that this information is accessible to resource managers, private industry, and the general public. The vast majority of the Department's technology transfer activities use traditional technology transfer mechanisms, such as publications of peer reviewed papers and reports, webpage postings, fact sheets, and presentations at meetings and conferences. In 2018, DOI personnel authored or co-authored over 12,300 reports, books, fact sheets, and other publications, including almost 4,500 scientific publications.

Bureaus also use other conventional approaches to share scientific and technical resources and expertise with each other, universities, and other entities to address resource management issues. For example, seven DOI bureaus are active participants in the network of 17 Cooperative Ecosystem Studies Units (CESUs), a collaboration among 15 Federal agencies and more than 400 non-federal partners (including universities, Tribes and tribal organizations, state agencies, museums, aquariums, arboretums, and conservation organizations). Each CESU is hosted by a university.

In addition, some bureaus and/or offices have offered prizes to help develop new or improve existing technologies. The bulk of the prize competition activities at DOI are undertaken by the Bureau of Reclamation's Water Prize Competition Center (WPCC). In FYs 2017-2018, the WPCC completed, had underway, or launched 15 prize competitions which included 14 from the WPCC, and one jointly offered by the National Invasive Species Council, DOI's Office of Hawaiian Affairs, and other DOI bureaus. Reclamation plans to launch 17 more competitions over the next few years.

Bureaus that are active in research and development, or have research capabilities that complement U.S. commercial interests, may also utilize technology transfer agreements authorized by the FTTA to join forces with non-federal partners. Such agreements allow the Department's bureaus and private sector industries to pool their expertise and resources to jointly create and advance technologies that could help fulfill agency missions while helping U.S. industries innovate and commercialize technologies, which can strengthen our national economy and create jobs.

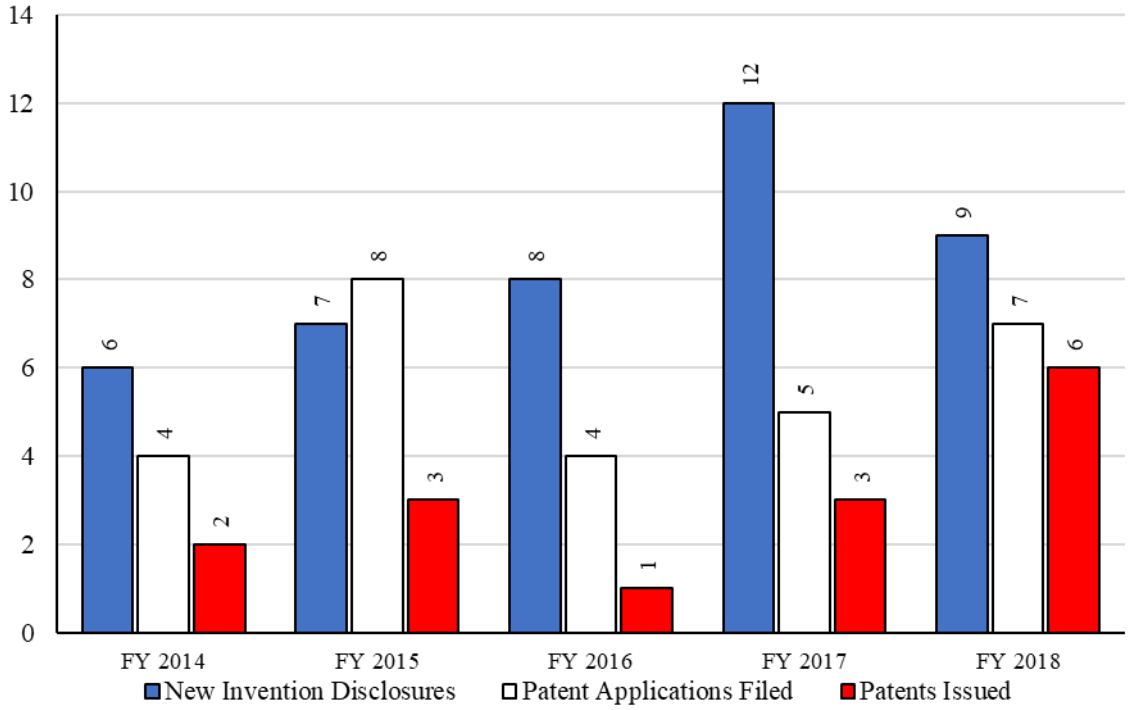
DOI's annual technology transfer report is available online.

More information about DOI technology transfer activities is available online.

DOI Invention Disclosures and Patenting

From FY 2014 to FY 2018, new inventions disclosed increased by 50%, from 6 in FY 2014 to 9 disclosures in FY 2018. Patent applications filed increased by 75%, from 4 in FY 2014 to 7 in FY 2018. Patents issued increased by 200%, from 2 in FY 2014 to 6 in FY 2018.

DOI Invention Disclosures and Patenting

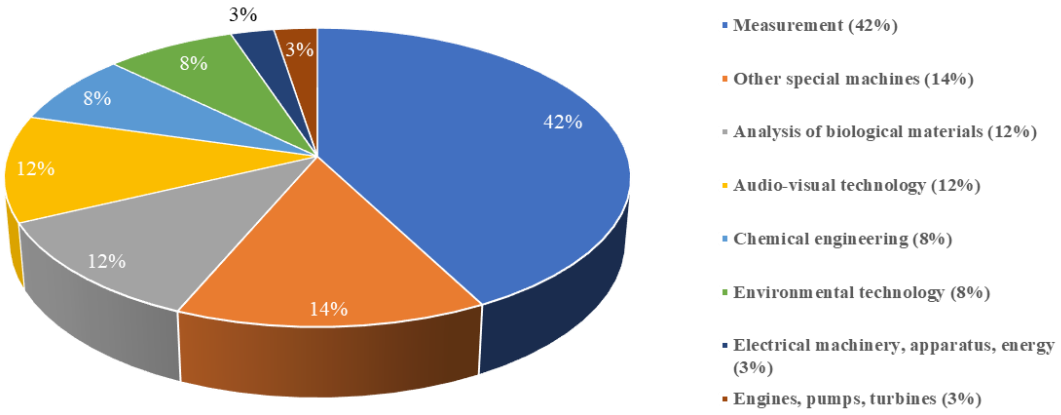


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	6	7	8	12	9
Patent Applications Filed	4	8	4	5	7
Patents Issued	2	3	1	3	6

The patents issued to DOI in FY 2018 covered multiple technology areas including the following: Measurement (42%), Other special machines (14%), Analysis of biological materials (12%), Audio-visual technology (12%), and Chemical engineering (8%).[39]

[39] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

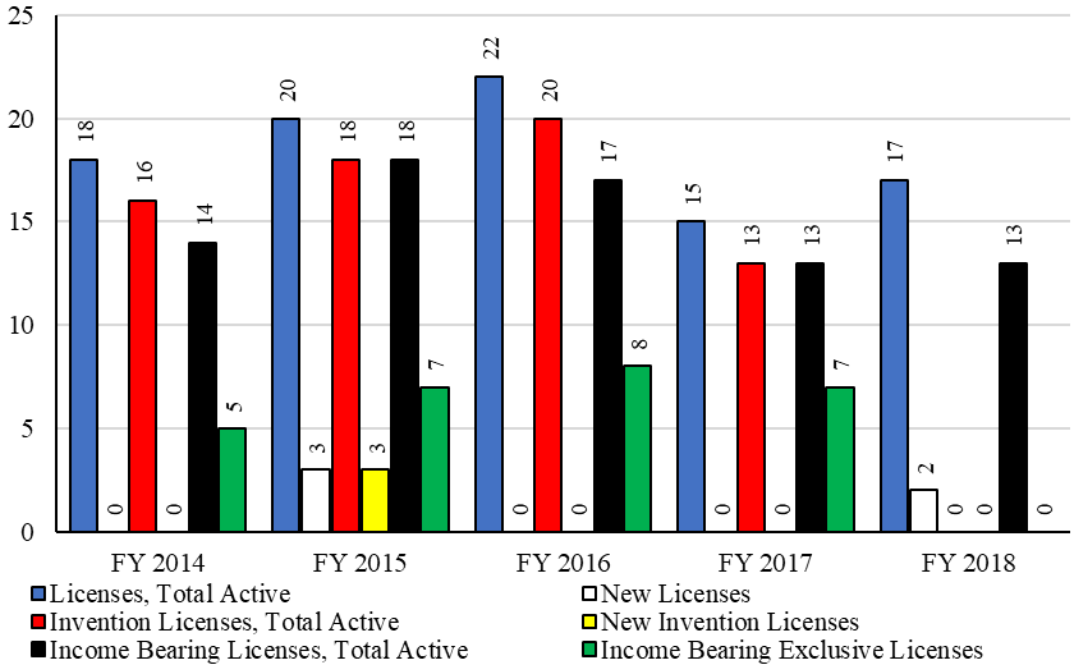
USPTO Patents Assigned to DOI by Technology Area: FY 2018



DOI Licenses

From FY 2014 to FY 2018, total active licenses decreased by 6%, from 18 in FY 2014 to 17 licenses in FY 2018. New invention licenses increased from 0 in FY 2014 to 2 in FY 2018. DOI reported no total active invention licenses or new invention licenses in FY 2018. From FY 2014 to FY 2018, DOI reported a 7% decrease in total active income bearing licenses, from 14 in FY 2014 to 13 in FY 2018.

DOI Licenses

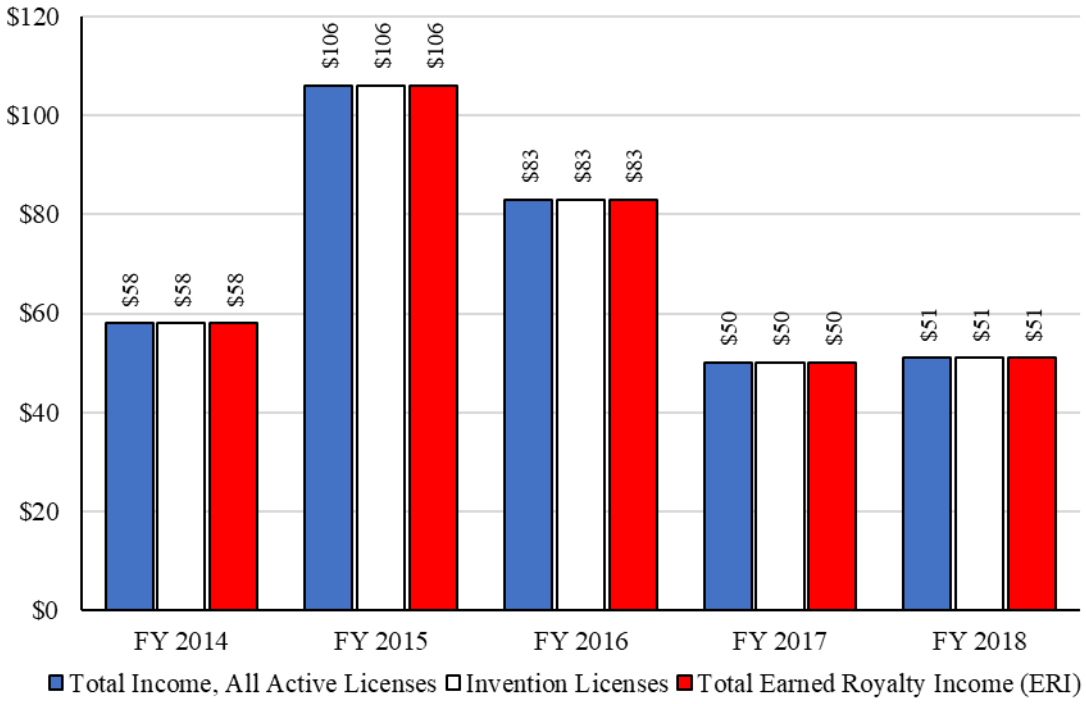


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	18	20	22	15	17
New Licenses	0	3	0	0	2
Invention Licenses, Total Active	16	18	20	13	0
New Invention Licenses	0	3	0	0	0
Income Bearing Licenses, Total Active	14	18	17	13	13
Income Bearing Exclusive Licenses	5	7	8	7	0

DOI Income from Licensing

Between FY 2014 and FY 2018, total income from all active licenses decreased by 12%, from $58 thousand in FY 2014 to $51 thousand in FY 2018. The income from invention licenses decreased by the same amount, as all income received came from invention licenses. Total earned royalty income also decreased by 12%, from $58 thousand in FY 2014 to $51 thousand in FY 2018.

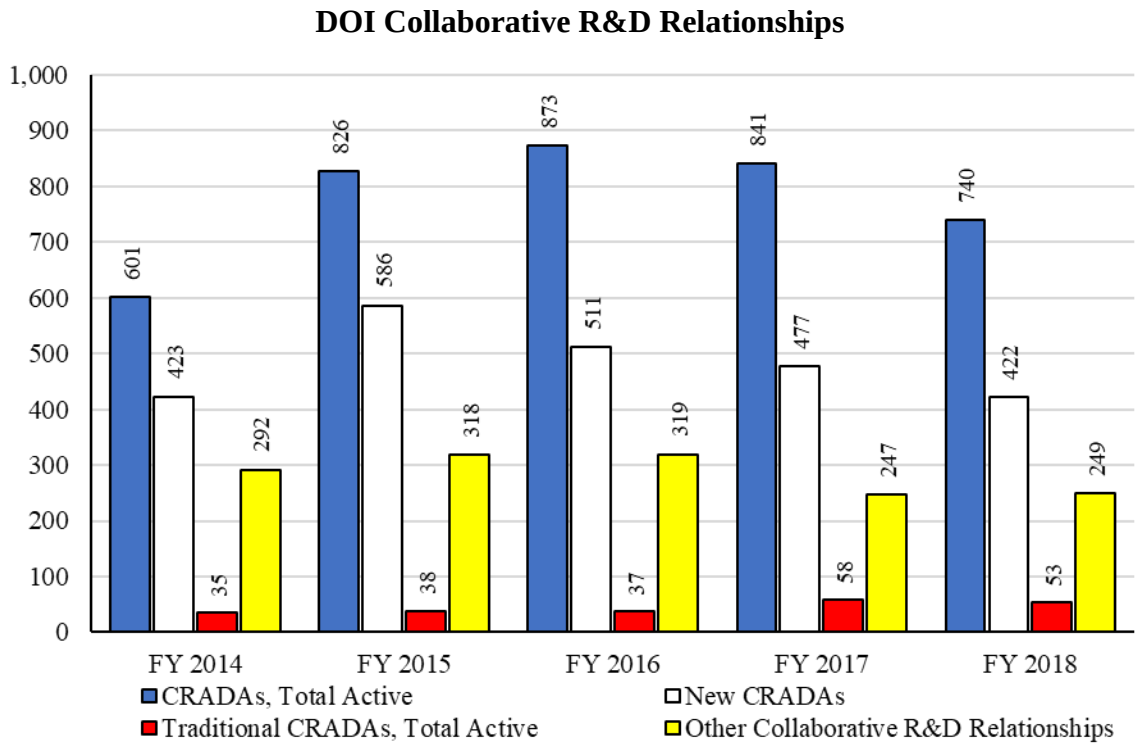
DOI Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$58	$106	$83	$50	$51
Invention Licenses	$58	$106	$83	$50	$51
Total Earned Royalty Income, (ERI)	$58	$106	$83	$50	$51

DOI Collaborative R&D Relationships

From FY 2014 to FY 2018, total active CRADAs increased by 23% from 601 to 740 agreements. The number of new CRADAs decreased by 0.2% from 423 in FY 2014 to 422 in FY 2018. Traditional CRADAs increased by 51%, from 35 in FY 2014 to 53 agreements in FY 2018. Other collaborative R&D relationships decreased by 15%, from 292 in FY 2014 to 249 in FY 2018.

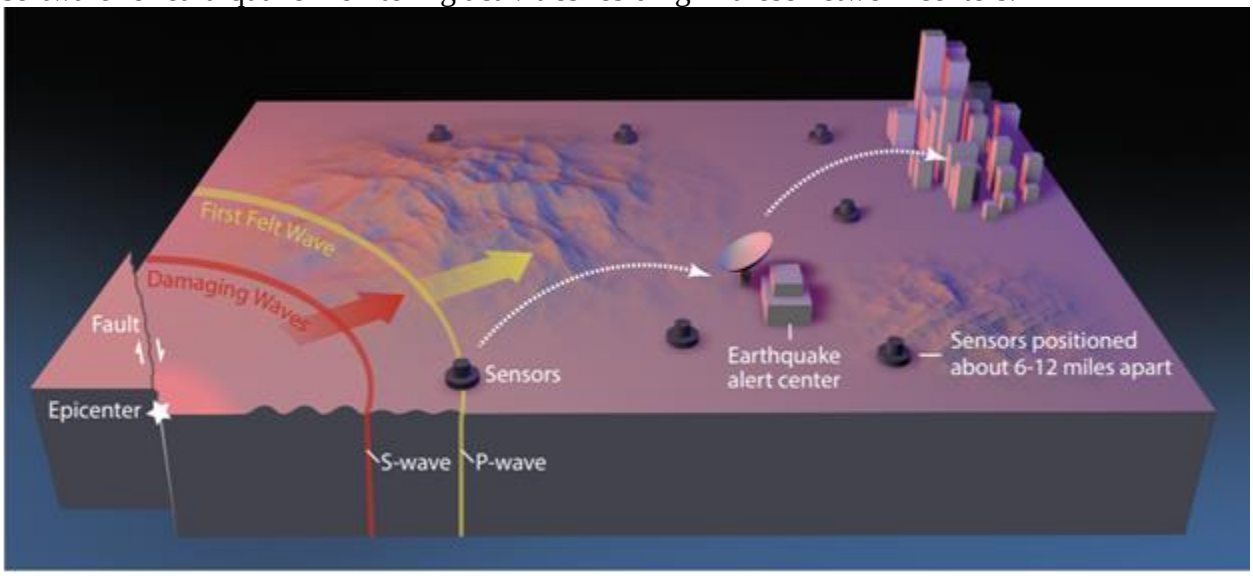


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	601	826	873	841	740
New CRADAs	423	586	511	477	422
Traditional CRADAs, Total Active	35	38	37	58	53
Other Collaborative R&D Relationships	292	318	319	247	249

DOI Downstream Success Stories

United States Geological Survey: ShakeAlert – An Earthquake Early Warning System
The U.S. Geological Survey (USGS) has formed partnerships with both public and private entities to develop an earthquake early warning (EEW) alert system called ShakeAlert. The system has the potential to have a significant impact because earthquakes pose a national challenge, with more than 75 million Americans living in areas of significant seismic risk. The Federal Emergency Management Agency (FEMA) has estimated that the average annual loss from earthquakes is $5.3 billion.

The USGS, through its CRADA authority, collaborated with several organizations—including the California Geological Survey, Caltech Seismological Laboratory, Berkeley Seismological Laboratory, USGS Menlo Park, USGS Pasadena, and the California Governor's Office of Emergency Services—to form the California Integrated Seismic Network (CISN) to monitor earthquakes and collect data to support improvements to earthquake resilience. The CISN also collaborated with other seismic networks, such as the Advanced National Seismic System (ANSS), to detect earthquakes' first wave (p-wave) and the more damaging subsequent transverse and surface waves. This collaboration enables USGS and ANSS to leverage their substantial investment in sensor networks, data telemetry systems, data processing centers, and software for earthquake monitoring activities residing in these network centers.



USGS image created by Erin Burkett (USGS) and Jeff Goertzen (Orange County Register).

Earthquake early warning systems like ShakeAlert work because the warning message can be transmitted almost instantaneously while shaking waves from the earthquake travel through the Earth at speeds of a few miles per second. When an earthquake occurs, seismic waves—including compressional (P) waves, transverse (S) waves, and surface waves—radiate outward from the epicenter. The faster but weaker P waves trip nearby sensors, causing alert signals to be sent out, giving people and automated electronic systems some time (seconds to minutes) to take protective actions before the arrival of the slower but stronger S waves and surface waves. Computers and mobile phones receiving the alert message can calculate the expected arrival time and intensity of shaking at your location.

USGS: Academy of Natural Sciences of Drexel University CRADA – "Quantifying Floodplain Ecological Processes and Ecosystem Services."
Floodplain and wetland areas lie at the intersection of terrestrial and aquatic systems, serving as biogeochemical "hotspots" for material transformations and nutrient processing within a watershed. During flood events, when the bulk of downstream discharge and pollutant loading occurs, floodplain topographic features and vegetation slow the water velocity. This allows for settling and deposition of sediments and increases the opportunity for nutrient uptake and processing. The capacity of the floodplain ecosystem to retain sediment, nutrients, and floodwaters provides critical ecosystem services to local and downstream communities in the Delaware River Watershed (DRW). Ecosystem services are defined as the benefits to people provided by or via the natural environment. For example, nutrient retention within a floodplain supports high water quality, which is important for fish and other wildlife. As a result, recreational activities (such as fishing, boating, wildlife watching), would (or should) increase, as would the value of those services. However, the ability of floodplains to provide functions and services vary depending on human land use and management decisions, as well as natural hydrogeomorphic variation. To make informed decisions about location-specific tradeoffs between land use planning and conservation, stakeholders need a better understanding of the services provided by floodplains in their specific areas.

Quantifying ecosystem services by linking ecosystem function to values, offers a framework to assess the value provided by floodplains and the tradeoffs associated with land management decisions.

Currently, there is a lack of knowledge specific to the Delaware River Watershed on how floodplain ecosystem functions translate into ecosystem services and values. The intention of this CRADA with the Academy of Natural Sciences of Drexel University is to fill this knowledge gap by leveraging and building upon floodplain function and ecosystem service methods developed for the Chesapeake Bay watershed. This will be accomplished through a combination of fieldwork, mapping, and modeling for the DRW. This assessment of floodplain condition and associated ecosystem services will help identify areas for targeted management in order to maintain areas with high ecosystem service values, and to restore areas that could provide the most ecosystem service benefits.

The goals of this project are to 1) inform Delaware River Watershed Initiative (DRWI) to conserve and restore water quality and overall ecological health, and 2) facilitate strategic targeting of conservation and restoration actions within the floodplain of the DRW.

United States Fish and Wildlife Service (FWS): National Conservation Training Center
The FWS Conservation Library at the National Conservation Training Center (NCTC) in Shepherdstown, West Virginia, provides a searchable collection of selected documents, images, historical artifacts, audio clips, publications, and video, most of which are in the public domain. FWS also makes internal publications, reports, and other information available to the public through the FWS website. Collections of current and legacy publications (including biological and technical publications) are available online from the NCTC library catalog and websites. NCTC also maintains links to biological and technical publications, as well as additional publications regarding birds, wetlands, fish hatcheries, and National Wildlife Refuges.

NCTC also hosts publicly-accessible webinars dealing with a variety of scientific and technical issues that affect the nation's fish and wildlife resources. During FY 2018, NCTC hosted 60 online science, technology, and educational webinars; 70 e-courses; and 33 podcasts related to managing the nation's fish, wildlife, and plant resources. These are an important component of FWS's traditional technology transfer activities.

FWS: Aquatic Invasive Species

The FWS Aquatic Invasive Species program works to prevent the transfer and introduction of exotic, introduced, non-native, and other potentially harmful species and to develop early detection and rapid response capabilities. For example, the program worked with numerous partners to develop methods for detecting miniscule amounts of free-floating DNA (environmental DNA or eDNA) in water samples to confirm the presence (or absence) of species at levels undetectable by traditional sampling methods. This innovative technology is now being applied widely in monitoring programs and, as it continues to be further developed and refined, will significantly benefit both FWS programs and partners by allowing earlier detections of invasive species.

The FAC program is also applying rapid screening tools it has developed to help determine a species' risk for invasion. Knowledge of both low- and high-risk species will help industry, states, and consumers make more responsible choices about which species to acquire and use. In addition, these tools will help state agencies make decisions on potentially invasive species and work with industry to manage risky species in their jurisdictions. For example, Michigan's Public Act 537, established new protections to minimize the risk of invasive species that require, among other things, the use of FWS's risk assessment protocol.

Office of Surface Mining Reclamation and Enforcement (OSMRE): National Technical Training Program (NTTP)

Established in 1985, NTTP is an ongoing training program designed to aid the bureau's mission by increasing the technical competence and professionalism of State, Tribal and OSMRE regulatory and reclamation staff. The NTTP provides comprehensive training in the skills needed to carry out the mandates of SMCRA. The entire program, from identification of training needs through course development and presentation, is a cooperative effort between State, Tribal, and OSMRE offices. The NTTP utilized 160 subject matter expert instructors (mostly volunteers) from State, Tribal, and DOI offices in FY 2018, to teach classes. The instructors are experts in mining regulatory and reclamation practices who keep abreast of changing technologies, evolving methodologies, and policies to ensure the training reflects the best protection and land restoration practices.

In FY 2018, NTTP trained 873 students from State, Tribal and OSMRE programs. It offered 39 training sessions covering technical, legal, and programmatic subjects ranging from best practices and technologies to protect society and the environment from the adverse effects of surface and underground mining, to methods to restore land use capabilities. The course subjects are, where possible, tailored to conditions and characteristics specific to each mining region, and offered in or near those regions. Course subjects include a wide variety of technical areas for a variety of practical applications including the design of abandoned mine land restoration, proper

inspection tools and techniques, soils and revegetation, identification and handling of acid/toxic forming materials, water quality assessment, legal aspects of enforcement procedures, and preparation of evidence and testimony. In FY 2018, the program achieved an overall effectiveness rating of 90 percent, based on student and supervisor responses regarding the value of the training in their current positions.

National Park Service (NPS): Benefits-Sharing Agreement
Yellowstone National Park executed a non-traditional CRADA with a small business that plans to commercialize research results from a study of microbial mats collected from thermal areas in the park. The company is providing non-monetary benefits related to a genetic monitoring program for the purpose of conserving genetic diversity within the park. The company will provide monetary benefits upon successful commercialization of its discoveries.

Doublet Pool, Yellowstone National Park. Research on microorganisms found in extreme environments, such as this thermal feature, has led to some significant discoveries and practical applications. Credit: NPS/Yellowstone National Park

Bureau of Reclamation (Reclamation): Test New Mussels Resistant Coatings for Reclamation Infrastructure.
Reclamation conducts research across a broad portfolio of technologies for corrosion protection and methods to reduce fouling of infrastructure by mussels. This includes research into durable, "foul-release" coatings that would negate mussels' ability to attach to the infrastructure. Reclamation's Materials and Corrosion Laboratory (MCL) entered into a material transfer agreement to test new protective coatings that contain super hydrophobic additives for corrosion protection capabilities in coatings applications.

Reclamation's MCL conducted a side-by-side laboratory comparison with and without a superhydrophobic additive in different coating systems to determine if there is any benefit in corrosion protection. The results showed improvement in corrosion protection for cyclic exposure while some mechanical and appearance properties decreased compared to the parent

system. The only logical use for this new superhydrophobic additives would be for atmospheric exposure but would have some obstacles to overcome.

The testing results were shared with the company who provided their protected super hydrophobic additives while gaining a better understanding of possible new market applications for their technology. Testing this new additive allowed Reclamation to continue to gain knowledge and develop new and better coatings for its water infrastructure.

Department of Transportation (DOT)

The U.S. Department of Transportation (DOT) is the Federal steward of the Nation's transportation system. DOT consists of multiple modal Operating Administrations (OAs) that carry out mission-related Research, Development, and Technology (RD&T) programs in support of the DOT strategic goals: Safety, State of Good Repair, Economic Competitiveness, Quality of Life in Communities, and Environmental Sustainability. DOT's Technology Transfer Program, which is housed in the Office of the Assistant Secretary for Research and Technology (OST-R), is responsible for coordinating, documenting, and supporting technology transfer activities across the Department.

The DOT defines technology transfer as the process of transferring and disseminating transportation related scientific information to stakeholders who may apply it for public or private use. The DOT's current approach to technology transfer is diverse and unique to each mode of transportation. Each modal OA conducts mission-specific deployment activities tailored to its mode and type of research. Agency specific technology transfer activities may be found online.

Technology transfer activities are executed by DOT agencies and their laboratories:

- Federal Aviation Administration (FAA): William J. Hughes Technical Center (WJHTC), Atlantic City, NJ, and Civil Aerospace Medical Institute, Oklahoma City, OK;
- Federal Highway Administration (FHWA): Turner-Fairbank Highway Research Center (TFHRC), McLean, VA;
- Office of the Assistant Secretary for Research and Technology (OST-R): John A. Volpe National Transportation Systems Center (Volpe Center), Cambridge, MA;
- National Highway Traffic Safety Administration (NHTSA): Vehicle Research and Test Center (VRTC), East Liberty, OH; and
- Federal Railroad Administration (FRA): Transportation Technology Center, Pueblo, CO.

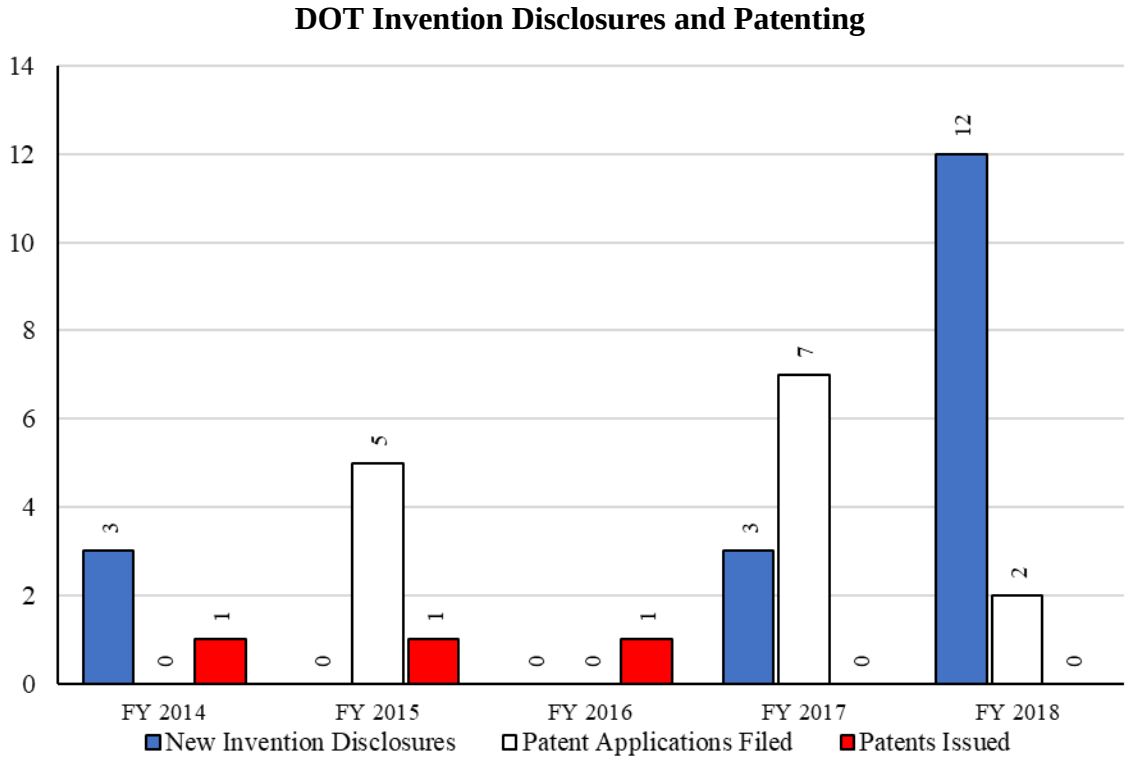
DOT's annual technology transfer report is available online.

More information about DOT's technology transfer activities is available on the following websites.

FAA | FHWA | OST-R | FRA

DOT Invention Disclosures and Patenting

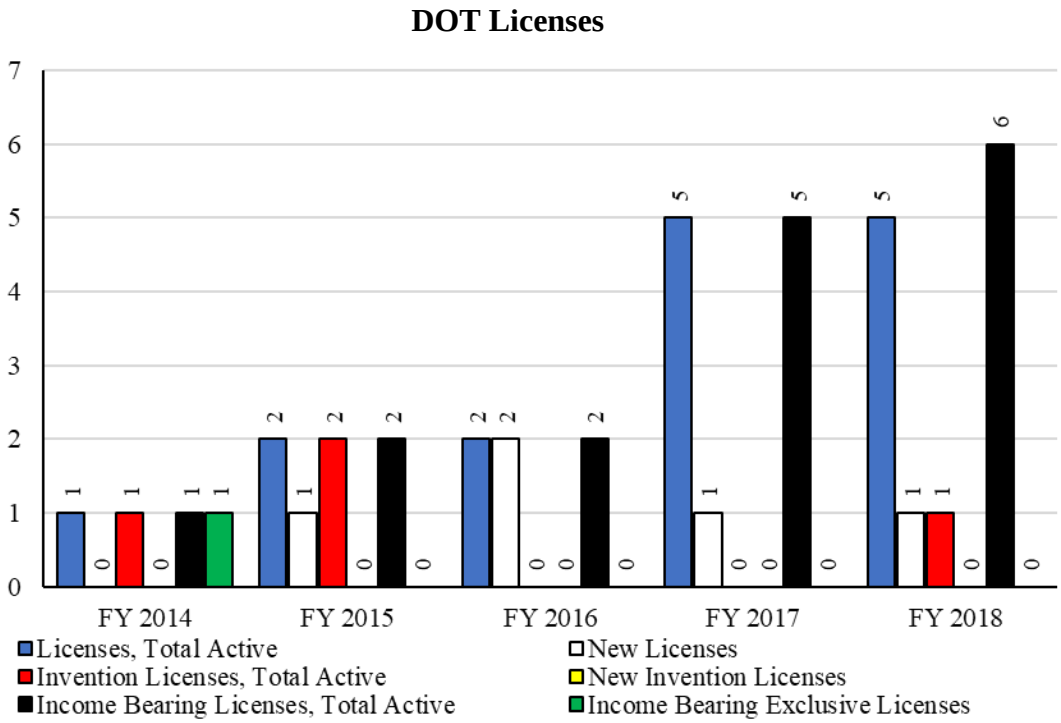
In FY 2018, DOT reported 12 invention disclosures and 2 patent applications. No new patents were awarded.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	3	0	0	3	12
Patent Applications Filed	0	5	0	7	2
Patents Issued	1	1	1	0	0

DOT Licenses

In FY 2018, DOT reported 5 active license agreements and one invention license. All active licenses were reported as income bearing licenses. DOT reported no new invention licenses in FY 2018.

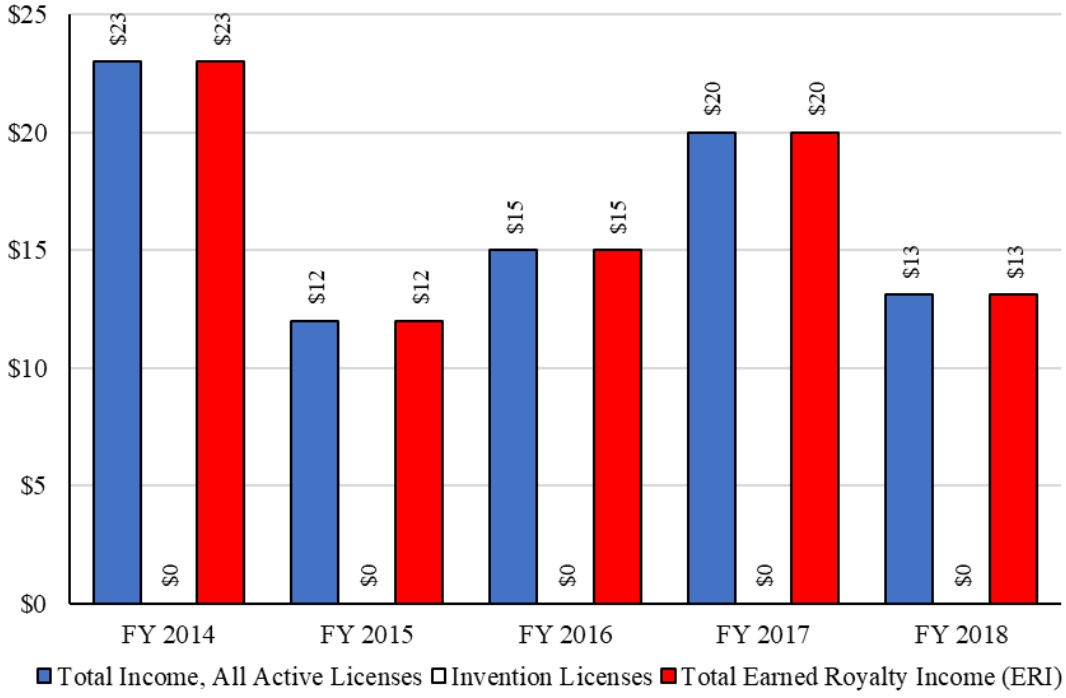


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	1	2	2	5	5
New Licenses	0	1	2	1	1
Invention Licenses, Total Active	1	2	0	0	1
New Invention Licenses	0	0	0	0	0
Income Bearing Licenses, Total Active	1	2	2	5	6
Income Bearing Exclusive Licenses	1	0	0	0	0

DOT Income from Licensing

Between FY 2014 and FY 2018, total income from all active licenses decreased by 43%, from $23 thousand to $13 thousand. In FY 2014 through FY 2018, DOT reported zero income from invention licenses. Total Earned Royalty Income was reported to be $13 thousand in FY 2018, a 43% decrease from FY 2014.

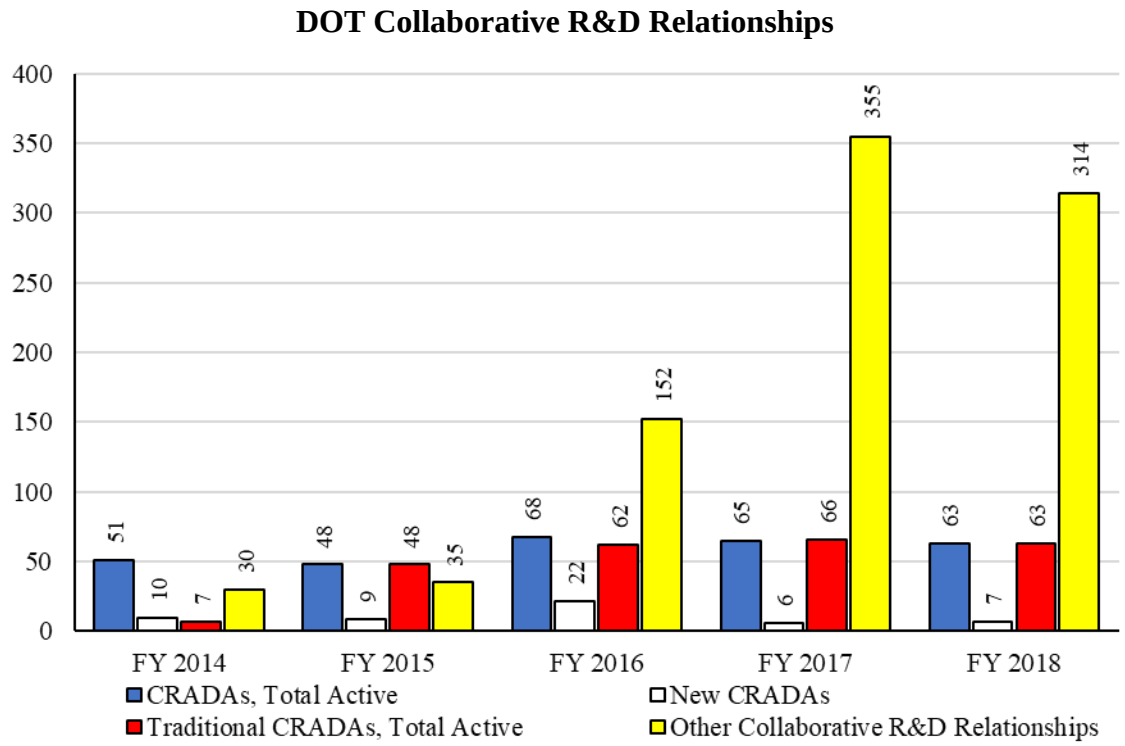
DOT Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$23	$12	$15	$20	$13
Invention Licenses	$0	$0	$0	$0	$0
Total Earned Royalty Income, (ERI)	$23	$12	$15	$20	$13

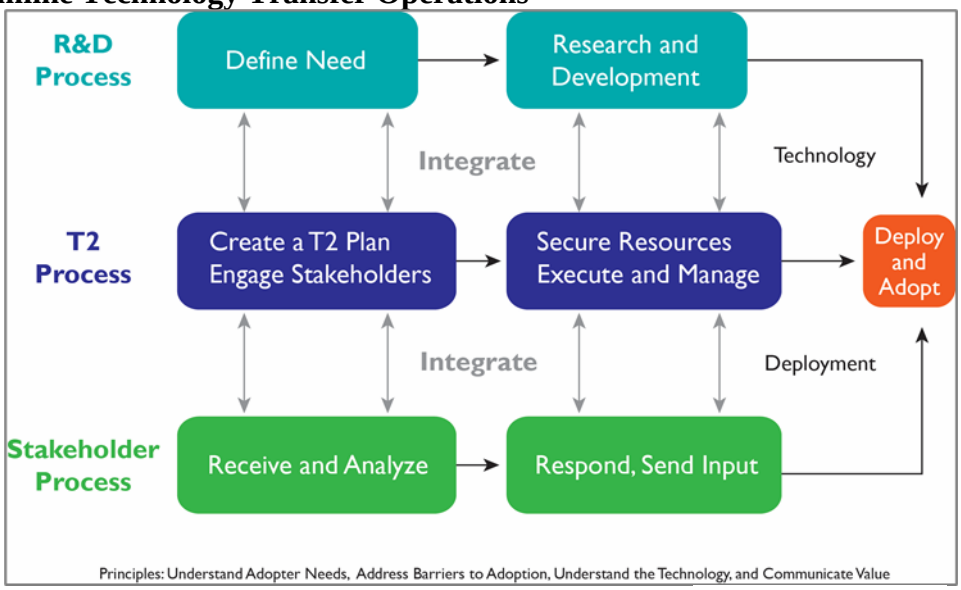
DOT Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs increased by 24%, from 51 to 63 agreements, while new CRADAs agreements declined by 30%, from 10 in FY 2014 to 7 in FY 2018. Traditional CRADAs increased from 7 in FY 2014 to 63 in FY 2018. Other collaborative R&D relationships increased by 947% from 30 in FY 2014 to 314 in FY 2018.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	51	48	68	65	63
New CRADAs	10	9	22	6	7
Traditional CRADAs, Total Active	7	48	62	66	63
Other Collaborative R&D Relationships	30	35	152	355	314

DOT Efforts to Streamline Technology Transfer Operations



Source: U.S. DOT.

The importance of T2 within U.S. DOT is reflected in its Strategic Plan for FY 2018 to FY 2022, which was released in February 2018. Citing Innovation as one of the four main strategic goals in the plan, U.S. DOT strives to lead in the development and deployment of innovative practices and technologies that improve the safety and performance of the Nation's transportation system. Under that strategic goal, Deployment of Innovation is a key objective, and T2 is identified as one of the strategies to be used to accomplish that objective. The relationship of T2 to the Department's research and development (R&D) process and to stakeholder engagement is shown in the figure.

Additional information on DOT efforts to streamline technology transfer operations can be found online in the DOT Technology Transfer Annual Reports.

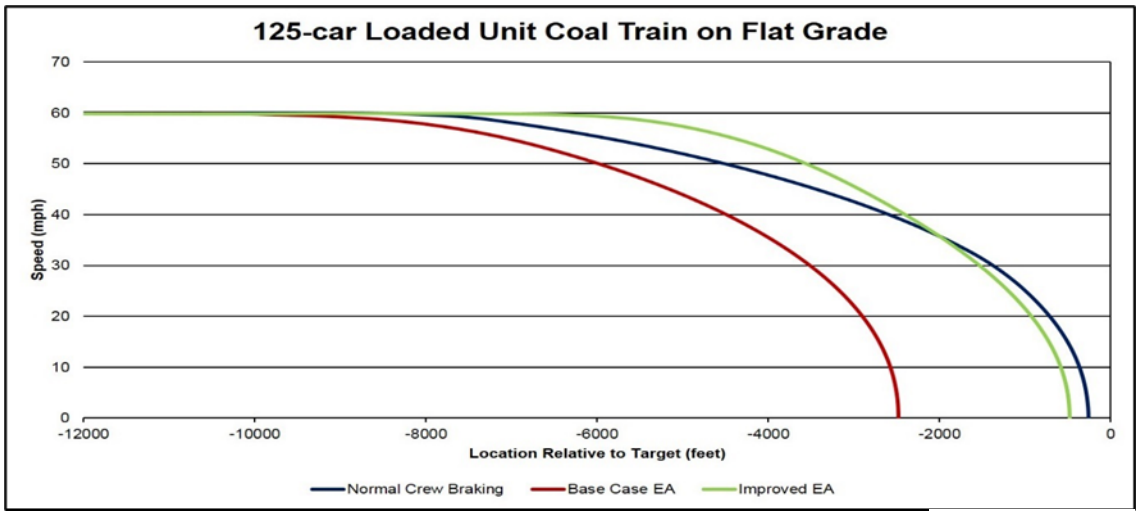
DOT Downstream Success Stories

Federal Railroad Administration (FRA): PTC Braking Algorithm

The PTC is an emerging train control technology intended to enhance safety. The underlying concept of the technology is that movement authorities and speed restrictions are transmitted digitally to the controlling locomotive of each train. The locomotive monitors the train's location with respect to its authority and speed limits. It then automatically applies brakes to prevent the train from violating any limit in the event of human failure. A necessary element of PTC is a braking algorithm that can accurately predict how a train's speed and stopping distance will respond to automatic applications of the brakes.

Evaluating the modeled performance of braking algorithms for freight trains was once a months-long process, which slowed the rate at which railroads could implement improvements in those algorithms. In 2018, FRA funded the development of improved evaluation methodologies for PTC braking algorithms, which were then added to the capabilities of the PTC Test Bed and the Transportation Technology Center in Pueblo, Colorado. The U.S. railroads (including all seven Class I freight railroads operating in the United States) and suppliers are actively using the PTC Test Bed and the subject methodologies to refine the performance of their PTC systems. With the improved evaluation methodologies, a standard set of modeled scenarios can be completed in a matter of days, accelerating the implementation of improvements to braking algorithms.

The figure below shows the potential gain in efficiency by enabling trains to travel at higher speeds for longer periods. In the figure, EA stands for Enforcement Application, which is the train speed at which PTC will enforce and deploy the brakes if the train operator ignores the PTC enforcement warning. The difference between the green and red curves shows the improvement that was achieved as a result of FRA's R&D.



Source: FRA

National Highway Traffic Safety Administration (NHTSA): Development of a Vehicle-Centric Security Credential Management System

Connected vehicle applications will rely upon the exchange of information among vehicles, roadway infrastructure, traffic management centers, and wireless mobile devices. This cooperative exchange of messages generates data that applications use to issue alerts and warnings to drivers about the driving situation around them. It also enables applications to determine mobility and environmental conditions. However, a cooperative system can only work when drivers are able to trust the alerts and warnings issued by their connected-vehicle devices, which are based, at least in part, on information received from other connected-vehicle devices.

To ensure safety and the protection of privacy, a security credential management system (SCMS) is needed to enable users to determine the validity and integrity of information received from other system users. In collaboration with a consortium of automotive original equipment manufacturers (OEMs), the Department designed and developed a proof-of-concept SCMS for V2V and vehicle-to-infrastructure communication. Development of this proof-of-concept helped spur the development of private-sector security solutions that are now serving the marketplace.

As of August 2018, multiple technology companies are leveraging the technological lessons from the SCMS proof-of-concept to provide commercial services to automotive companies that are deploying vehicle-to-everything (V2X) technology. Such commercial services did not exist prior to the Department's R&D of the SCMS proof-of-concept. The SCMS proof-of-concept is also being used for FHWA-funded deployments of V2X, including the Connected Vehicle Pilot sites and participants in the ATCMTD grant program.

Federal Highway Administration (FHWA): Partially Automated Truck Platooning Demonstration

Fuel consumption of commercial trucks is significantly influenced by air resistance at highway speeds. The FHWA's Exploratory Advanced Research (EAR) program, administered by TFHRC, has sponsored research on technologies that enable long-haul trucks to travel together more closely in a "platoon," which reduces aerodynamic drag and improves fuel economy. Even small improvements in fuel efficiency can have a significant payoff given the large number of miles traveled by long-haul trucks in the United States each year. This research has been performed by partnerships that include truck manufacturers and university researchers.

Source: FHWA.

The EAR Program seeks to combine single-vehicle adaptive cruise control with additional onboard sensors and V2V communication, to exchange information between the trucks and automatically adjust engine and brakes in real time as conditions vary. This system, known as cooperative adaptive cruise control (CACC), exchanges operational information between the trucks and can automatically adjust engine and brakes to maintain longitudinal control (speed and separation distance). Drivers are responsible for lateral control (steering and lane-keeping) and monitoring roadway and traffic conditions. The system makes it possible for the CACC-equipped trucks to travel closer together with more precise control than manual operations alone, thus allowing for potential fuel savings.

After four years of research, FHWA and numerous project partners conducted a demonstration of three-truck platoons on I-66 in northern Virginia and continued to analyze the results in FY 2018. The FHWA is continuing to fund research and to engage the trucking industry, in order to identify and answer the key issues that must be addressed prior to market introduction of heavy truck CACC.

Federal Aviation Administration (FAA): S76A Helicopter

Source: Federal Lab Consortium for Technology Transfer.

In collaboration with industry, academic, and government partners, the FAA operates a one-of-a-kind national flying laboratory resource. The Sikorsky S76A helicopter performs flight testing in support of aviation research activities to improve helicopter safety. Research projects using the S76A helicopter support FAA and U.S. Helicopter Safety Team initiatives, including Helicopter Flight Data Monitoring for Aviation Safety, Information Analysis and Sharing, Enhanced Helicopter Vision Systems, and other efforts. The S76A helicopter is instrumented with the latest recording technology for audio, video, and flight data, including dozens of cameras, cockpit microphones, flight data recorders, enhanced vision systems, and head-worn displays. The Federal Lab Consortium for Technology Transfer (FLC) showcased the Sikorsky S76A helicopter in its 2019 FLC Planner.

Department of Veteran Affairs (VA)

The VA is the cabinet level agency whose mission statement strives to fulfill President Lincoln's promise: "To care for him who shall have borne the battle and for his widow, and his orphan."

The VA works to meet that promise through the service and honor of the men and women who are America's Veterans, by holding all employees to the core values of Integrity, Commitment, Advocacy, Respect, and Excellence. The VA has three administrative elements whose goals are to provide encompassing and integrated care for our nation's veterans and their families:

- Veterans Health Administration (VHA), whose mission is to honor America's Veterans by providing excellent health care that improves their health and well-being;
- Veterans Benefits Administration, whose mission is to provide benefits and services to the Veterans and their families in a responsive, timely, and compassionate manner in recognition of their service to the nation; and
- National Cemetery Administration, whose mission is to honor Veterans and their eligible family members with final resting places in national shrines, and with lasting tributes that commemorate their service and sacrifice to our Nation.

For over 90 years, the VA Research program has improved veterans' lives through scientific discovery, health care innovation, and service delivery. The Office of Research and Development (ORD) is the division within the Veteran's Health Administration which aspires to discover knowledge, develop VA researchers and health care leaders, and create innovations that advance health care for our Veterans and the Nation. The research program within the Department of Veterans Affairs has an illustrious past in which its researchers have won three Nobel prizes in medicine, seven Lasker Awards, one Malcolm Baldrige Quality Award, and have also created the largest Genomic Medicine sample collection program in the world (the Million Veteran Program).

As of FY 2018, ORD is headquartered in Washington, DC but includes an estimated 2,500 VA investigators and 10,000 research staff located at over 100 VA Medical Centers nationwide. Over sixty percent of VA Medical Centers have an embedded on-site research program which mirrors the diversity of the VA hospitals in size, scope, and complexity. These research programs receive guidance and competitive intramural funding from VA ORD but manage their research offices and programs independently. The VA research differs from other federal research programs in that it is completely funded with intramural dollars. The VA investigators can apply for other federal and private funds, but non-VA employees or appointees cannot receive VA research funding. The VA hospitals and research programs work with the Office of Academic Affiliations to partner with academic institutions and universities to broaden available resources for both patient care and research. By partnering with others who have common research interests, ORD is able to leverage resources, deepen innovations, and expand the impact of federal research investments.

ORD provides oversight of four research services and three supportive programs, each headed by a director, supervised by the Chief Research and Development Officer (CRADO), who in turn reports to the Deputy Under Secretary for Health for Policy and Services. Together, these offices

form a cohesive whole, directed to explore all phases of veterans' healthcare needs and interact with a number of world-renowned research centers nationwide. The four research services are as follows:

The Biomedical Laboratory Research & Development Service (BLR&D) conducts research that explores basic biological or physiological principles in humans or animals but does not involve intact human beings. For example, it includes research on animal models and investigations of tissues, blood, or other biologic specimens from humans. The Genomic Medicine Program and the Million Veteran Program are housed within BLR&D.

The Clinical Science Research and Development Service (CSR&D) conducts research which is focused on intact human beings as the unit of examination. Examples include interventional and effectiveness studies, clinical, epidemiological, and technological studies.

The Health Services Research and Development Service (HSR&D) pursues research at the interface of health care systems, patients, and health care outcomes. The HSR&D underscores all aspects of VA healthcare: specifically, quality, access, patient outcomes and healthcare costs.

The Rehabilitation Research & Development Service (RR&D) is dedicated to the well-being of America's veterans through a full spectrum of research from approved rehabilitation research projects, through evaluation and commercialization to final clinical application.

As of FY 2018, the three supportive programs housed within ORD include VA Technology Transfer, the VA Non-Profit offices, and the Program for Research Integrity Development and Education (PRIDE) which provides oversight and programmatic certification for human research compliance. Each of these supportive programs provide overall support to all ORD services and programs while also supporting field researchers, and in the case of technology transfer, supports all VA employees with any inventions.

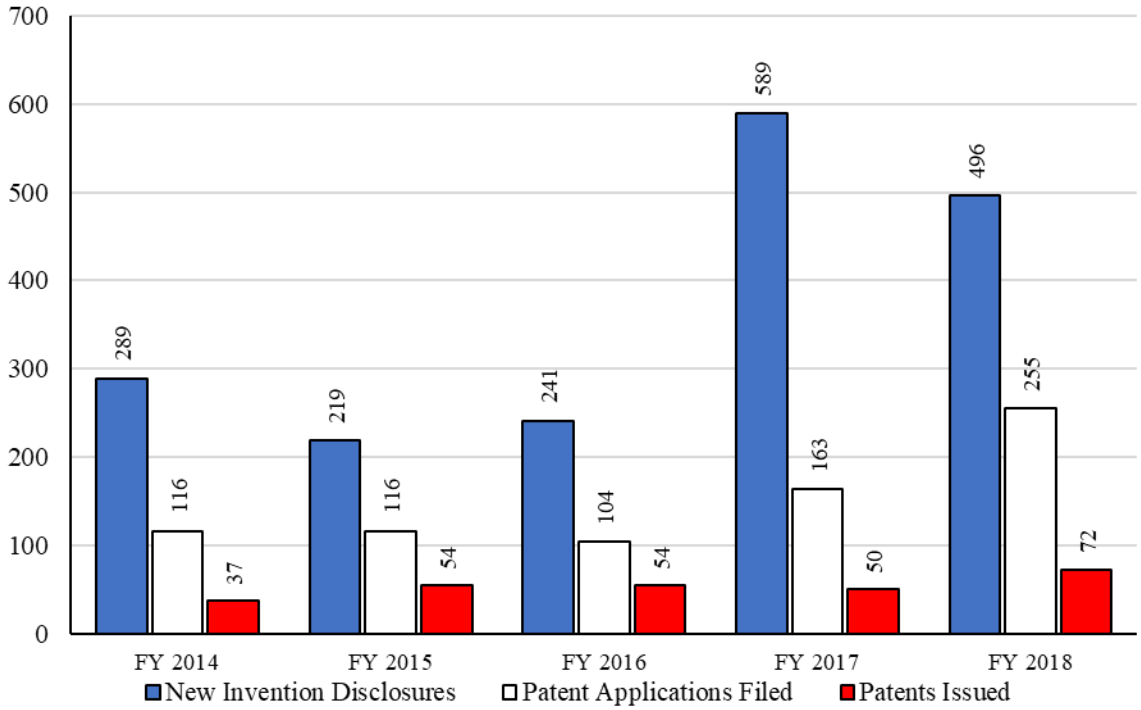
The ORD’s mission is focused on improving the future of healthcare for veterans, and Technology Transfer provides a pathway within VA to move research or employee innovations and inventions from concept to benefitting the veteran, fulfilling Technology Transfer’s mission motto of “Bringing Research Advancements for Veterans to Everyone” (BRAVE).

More information about VA technology transfer activities is available online.

VA Invention Disclosures and Patenting

Between FY 2014 and FY 2018, new inventions disclosed increased by 72%, from 289 in FY 2014 to 496 disclosures in FY 2018. Patent applications filed increased by 120%, from 116 in FY 2014 to 255 in FY 2018, while patents issued increased by 95%, from 37 in FY 2014 to 72 patents in FY 2018.

VA Invention Disclosures and Patenting

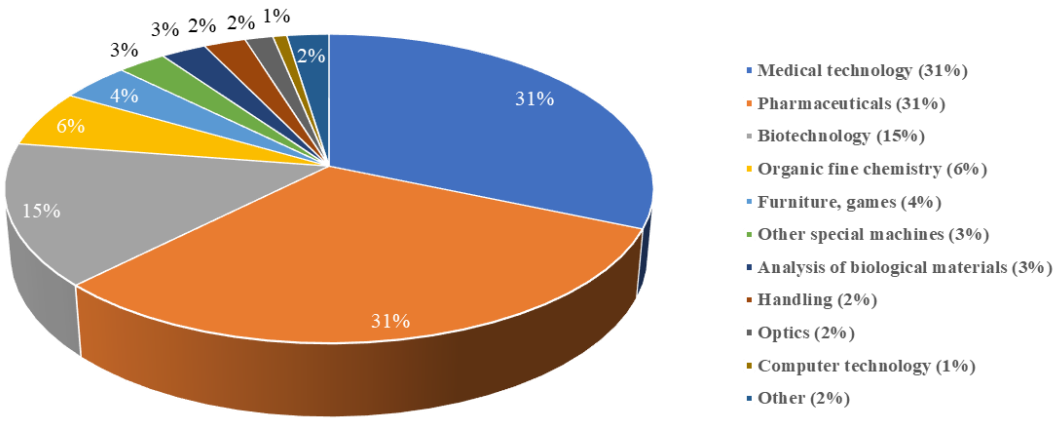


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	289	219	241	589	496
Patent Applications Filed	116	116	104	163	255
Patents Issued	37	54	54	50	72

Patents issued to VA in FY 2018 covered many technology areas including Medical technology (31%), Pharmaceuticals (31%), Biotechnology (15%), Organic fine chemistry, (6%), and Furniture, games (4%).[40]

[40] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

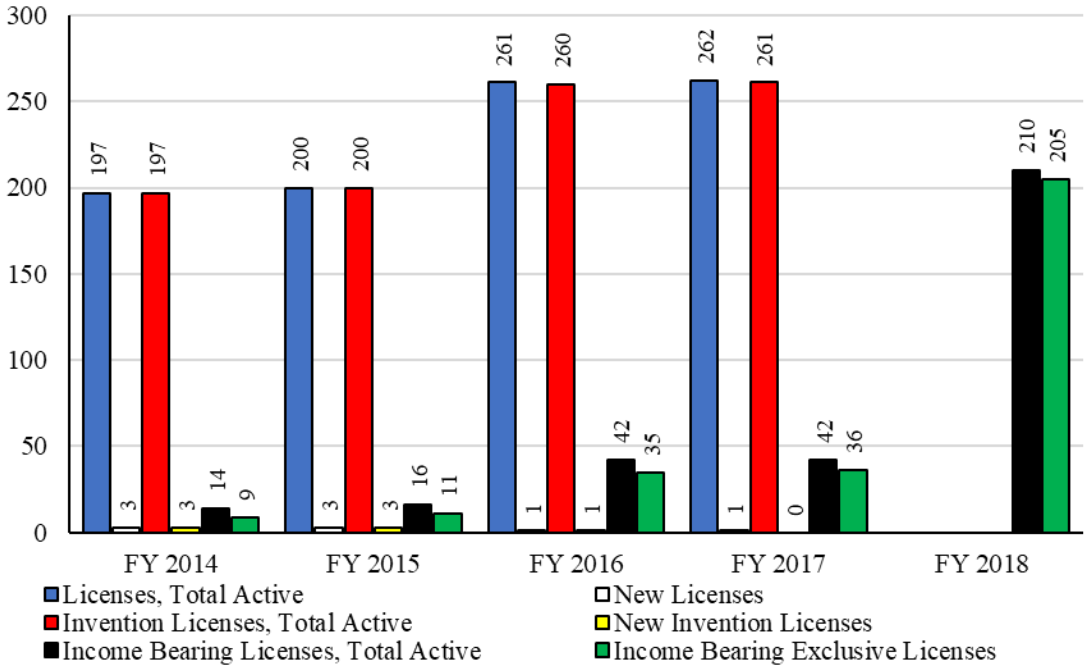
USPTO Patents Assigned to VA by Technology Area: FY 2018



VA Licenses[41]

Between FY 2014 and FY 2018, income bearing licenses increased by 1400%, from 14 to 210 and exclusive income bearing licenses increased by 2178%, from 9 in FY 2014 to 205 in FY 2018.

VA Licenses



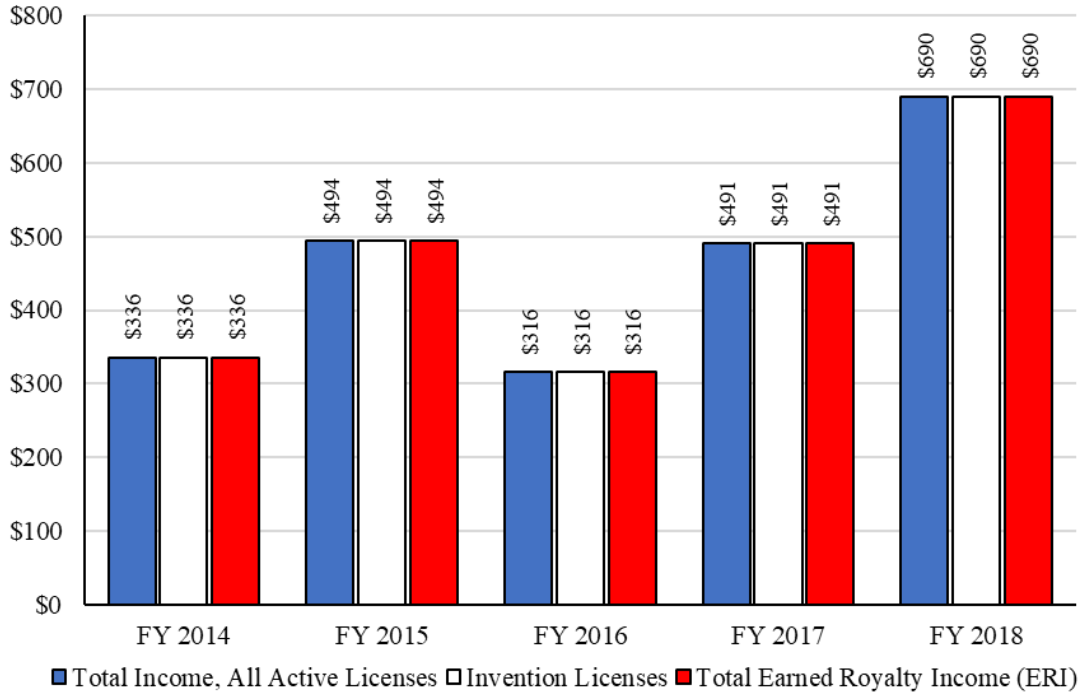
[41] VA is unable to report total active licenses, new licenses, total active invention licenses, and new invention licenses for FY 2018 because this information was not preserved.

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	197	200	261	262	n.a.
New Licenses	3	3	1	1	n.a.
Invention Licenses, Total Active	197	200	260	261	n.a.
New Invention Licenses	3	3	1	0	n.a.
Income Bearing Licenses, Total Active	14	16	42	42	210
Income Bearing Exclusive Licenses	9	11	35	36	205

VA Income from Licensing

Between FY 2014 and FY 2018, VA reported that total income from all active licenses increased by 105%, from $336 thousand in FY 2014 to $690 thousand in FY 2018. Income from invention licenses and earned royalty income were the same as income from all active licenses.

VA Income from Licensing ($ thousands)

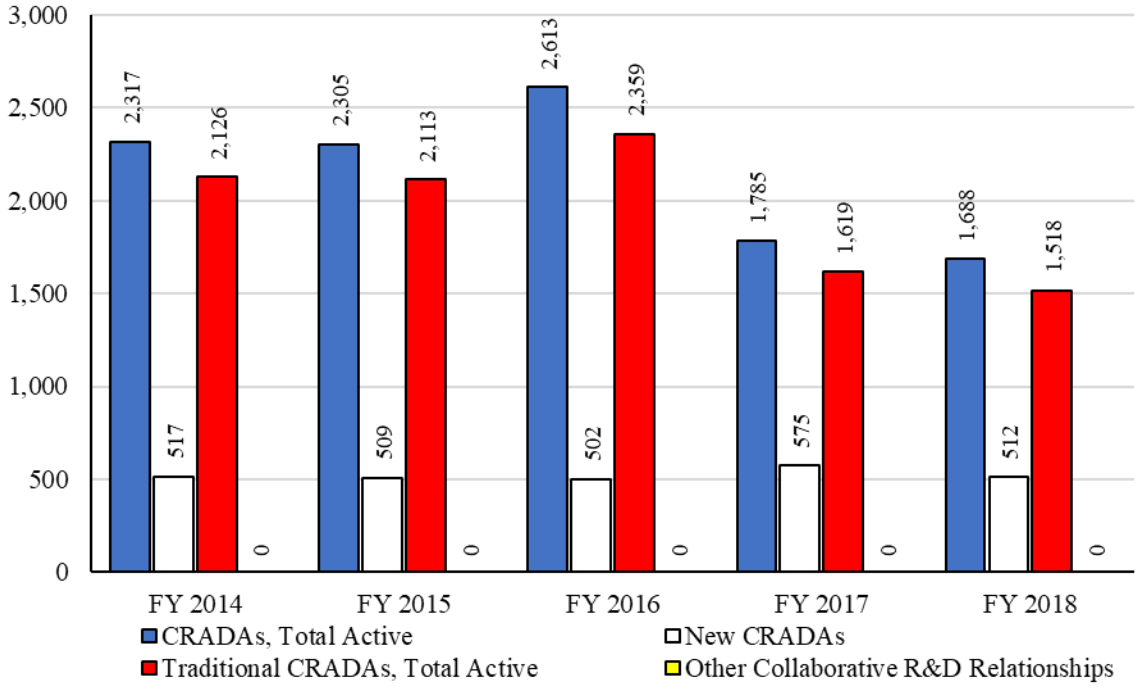


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$336	$494	$316	$491	$690
Invention Licenses	$336	$494	$316	$491	$690
Total Earned Royalty Income, (ERI)	$336	$494	$316	$491	$690

VA Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs decreased by 27%, from 2,317 to 1,688 agreements in FY 2018. New CRADAs decreased by 1%, from 517 in FY 2014 to 512 new agreements in FY 2018. Traditional CRADAs decreased by 29%, from 2,126 in FY 2014 to 1,518 in FY 2018. No other collaborative R&D relationships were reported.

VA Collaborative R&D Relationships



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	2,317	2,305	2,613	1,785	1,688
New CRADAs	517	509	502	575	512
Traditional CRADAs, Total Active	2,126	2,113	2,359	1,619	1,518
Other Collaborative R&D Relationships	0	0	0	0	0

VA Efforts to Streamline Technology Transfer Operations

The TTP launched an online learning module educating VA employees on the basics and benefits of technology transfer. In FY 2018 the CRADO initiated an annual requirement for VA research investigators to complete the training. This training resulted in an increase in the invention disclosure rate and overall awareness of technology transfer at the VAMCs. Feedback from the module has been well received and TTP is planning on developing additional modules focusing on the particulars involving invention disclosures and patents.

The TTP conducted an assessment to determine improvements to existing infrastructure. As a result, TTP entered into a partnership with the Department of Commerce's National Technical Information Service (NTIS) to make technology improvements for efficiency in operations. Through this collaboration, they identified the need to develop an online invention disclosure portal that could intake different types of invention disclosures. In the past, TTP decided to accept the academic affiliate invention disclosure in lieu of the VA form in order to increase the disclosure rate. Each academic affiliate has their own unique disclosure form, thus requiring a custom intake portal that can read the forms. The new intake portal will further streamline operations, eliminate errors, and enable the use of artificial intelligence (AI) for ownership analysis as well as a commercialization potential analysis.

Their assessment also identified a need for improvements to the existing IP database utilized by TTP. This database serves as a knowledge management system that is aligned with TTP's workflows to manage VA's IP portfolio. The TTP is exploring options to have a database that is Cloud based and performs as a Software as a Service (SaaS) to enable on-line collaboration with non-VA partners.

The TTP narrowed the number of patent counsel firms providing services to TTP. This change has dramatically improved the quality of patent applications and reduced the number of TTP personnel hours required to manage the contracts.

VA Downstream Success Stories

An exclusive license was granted to a small biotech firm, Meiogen Biotechnology, for U.S. patent application No. 62/571,900 and PCT application PCT/US18/55888, "Compositions and Methods of Interferon Alpha Binding Proteins." The technology was co-invented by two VA researchers at the Atlanta, GA, VA Medical Center. The invention provides compositions comprising of interferon-alpha binding protein (B18R) and combined anti-retroviral therapy (cART) to treat HIV associated neurogenerative disorder (HAND). The technology is currently undergoing further clinical research. Ultimately, this invention will provide a novel therapeutic option for subjects with HAND.

An exclusive license was granted to Northern Arizona University (NAU) for the VA invention "Otoprotective Uncaria Tomentosa," covered by U.S. patent No. 9,457,009 ("Methods and Compositions for Preventing and Treating Auditory Dysfunctions") and related patent applications. This invention was created by Dr. O'neil Guthrie at the Loma Linda VA Medical Center. The invention provides a novel therapeutic option for otoprotection and/or hearing recovery following injury. The inventor, who is no longer at VA, has continued development of

the invention at NAU. This license agreement is allowing NAU to work with a commercialization partner to further advance the combined innovations of VA and NAU.

An exclusive license option was granted to Axial Biotherapeutics, Inc., for the VA invention "Method of Treating Autism and Therapies for Gastrointestinal and Neurological Disorders," covered by US Patent Nos. 9,168,275 and 9,707,207. This invention was created by Dr. Sydney Finegold at the West Los Angeles VA Medical Center. The invention provides a method of treating autism associated with colonization of pathogenic bacteria in the gastrointestinal tract of a patient with early onset autism.

Environmental Protection Agency (EPA)

The EPA's FTTA Program was established to promote collaboration between private sector and federal researchers. The EPA offers exceptional opportunities to develop and commercialize new technologies. Through the authority given to EPA by the FTTA, EPA facilitates the transfer of new technologies to the marketplace while protecting the intellectual property rights of all parties.

Partners in the FTTA Program have the benefit of collaborating with world-class EPA scientists involved in leading-edge research. Collaboration enhances the quality of research projects and helps move environmental technologies into the marketplace, resulting in better protection of human health and the environment.

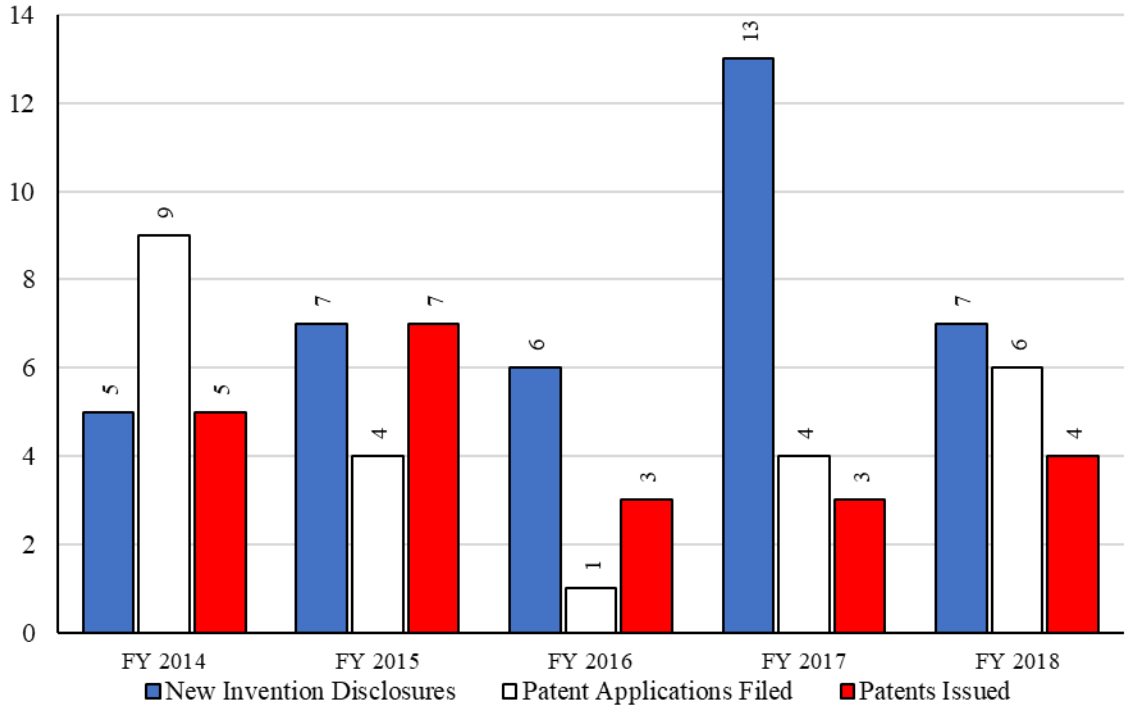
The EPA's annual technology transfer report is available online,

More information about EPA technology transfer activities is available online.

EPA Invention Disclosures and Patenting

Between FY 2014 and FY 2018, new inventions increased by 40%, from 5 disclosures in FY 2014 to 7 in FY 2018. Patent applications filed decreased by 33%, from 9 in FY 2014 to 6 in FY 2018, while patents issued decreased by 20%, from 5 in FY 2014 to 4 in FY 2018.

EPA Invention Disclosures and Patenting

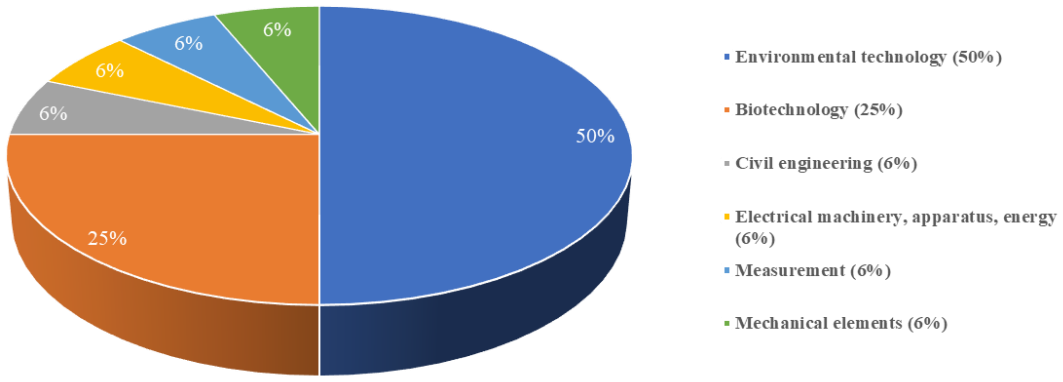


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	5	7	6	13	7
Patent Applications Filed	9	4	1	4	6
Patents Issued	5	7	3	3	4

Patents issued to EPA in FY 2018 covered many technology areas including Environmental Technology (50%), Biotechnology (25%), Civil engineering (6%), Electrical machinery, apparatus, energy (6%), and Measurement (6%).[42]

[42] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

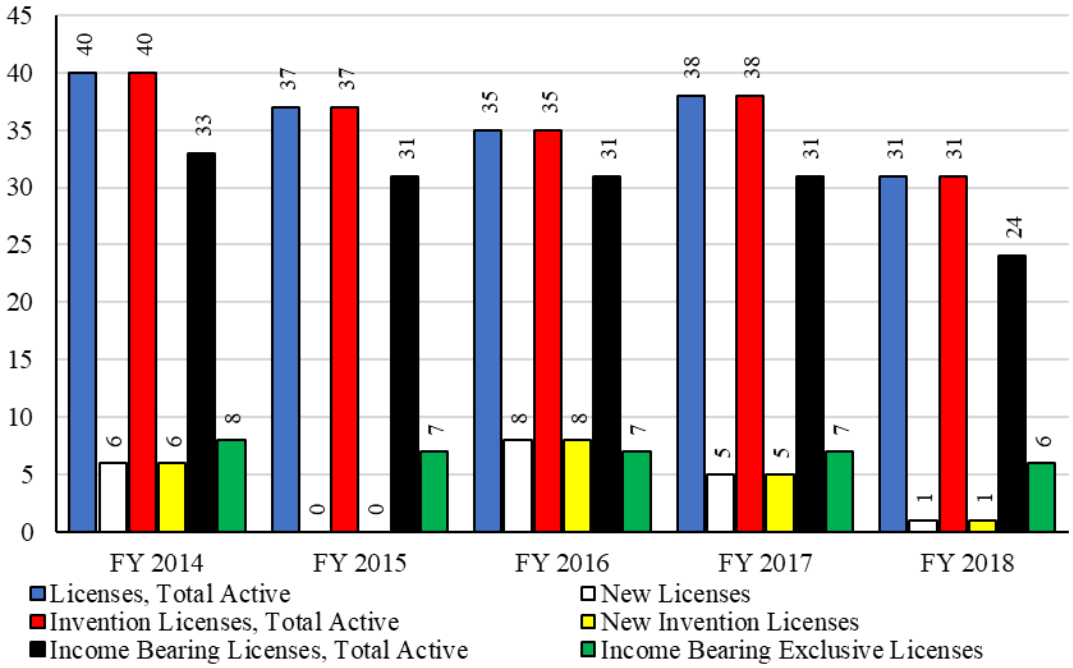
USPTO Patents Assigned to EPA by Technology Area: FY 2018



EPA Licenses

Between FY 2014 and FY 2018, total active licenses decreased by 23%, from 40 licenses in FY 2014 to 31 licenses in FY 2018. New licenses decreased by 83%, from 6 to 1. All active licenses were invention licenses. Income-bearing licenses declined by 27%, from 33 in FY 2014 to 24 in FY 2018, while exclusive income-bearing licenses declined by 25%, from 8 to 6.

EPA Licenses

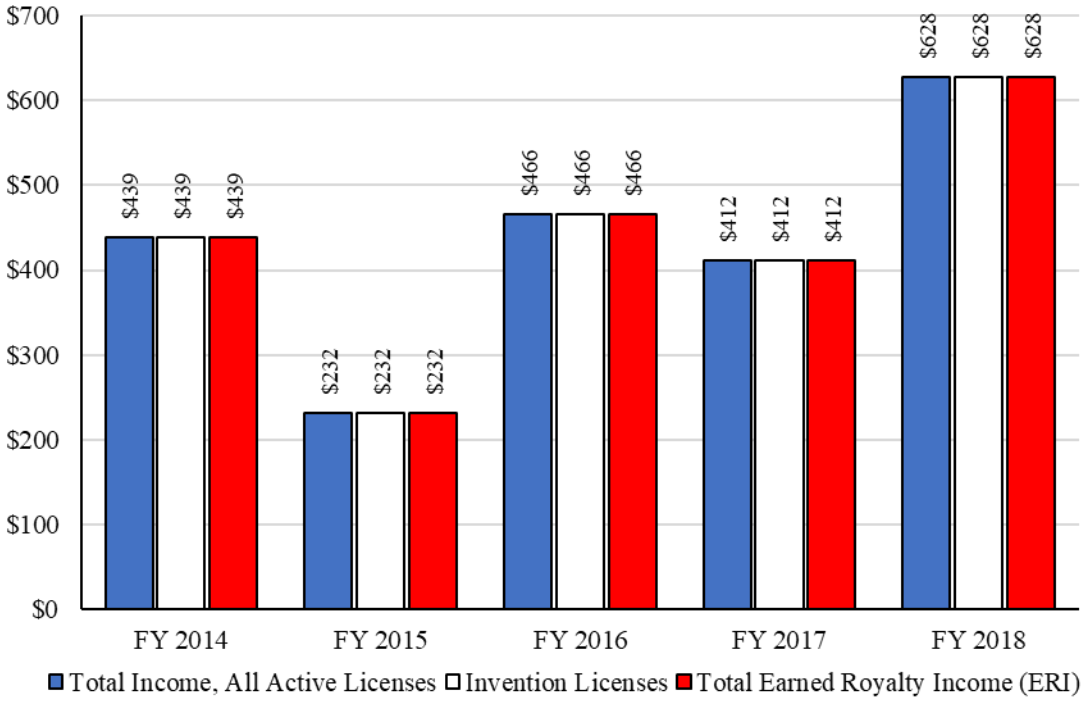


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	40	37	35	38	31
New Licenses	6	0	8	5	1
Invention Licenses, Total Active	40	37	35	38	31
New Invention Licenses	6	0	8	5	1
Income Bearing Licenses, Total Active	33	31	31	31	24
Income Bearing Exclusive Licenses	8	7	7	7	6

EPA Income from Licensing

Between FY 2014 and FY 2018, EPA reported that total income from all active licenses increased by 43%, from $439 thousand in FY 2014 to $628 thousand in FY 2018. All income from licenses came from invention licenses. Total earned royalty income increased 42%, from $439 thousand in FY 2014 to $628 thousand in FY 2018.

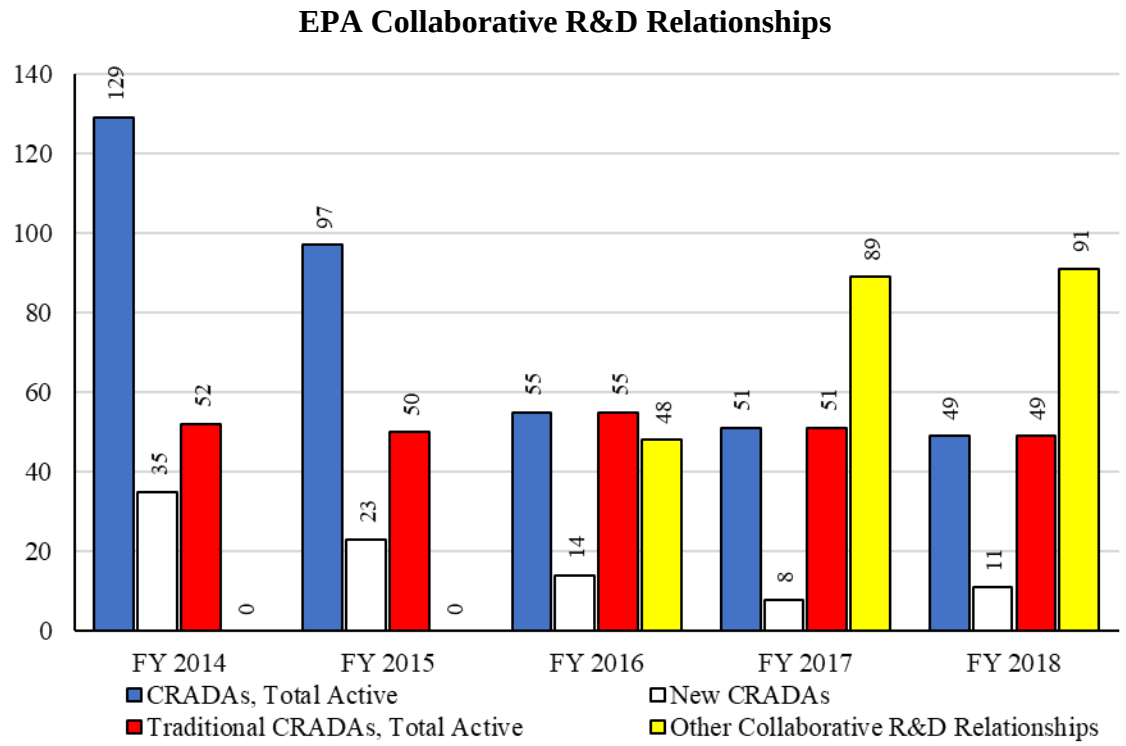
EPA Income from Licensing ($ thousands)



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$439	$232	$466	$412	$628
Invention Licenses	$439	$232	$466	$412	$628
Total Earned Royalty Income, (ERI)	$439	$232	$466	$412	$628

EPA Collaborative R&D Relationships

Between FY 2014 and FY 2018, total active CRADAs decreased by 62% to 49 agreements in FY 2018, from a previous 129 in FY 2014. New CRADAs decreased by 69%, from 35 in FY 2014 to 11 new agreements in FY 2018. Traditional CRADAs decreased by 6%, from 52 in FY 2014 to 42 in FY 2018. In FY 2018, 91 other collaborative R&D were reported.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	129	97	55	51	49
New CRADAs	35	23	14	8	11
Traditional CRADAs, Total Active	52	50	55	51	49
Other Collaborative R&D Relationships	0	0	48	89	91

EPA Downstream Success Stories

EPA's Technology Removes Ammonia from Drinking Water

Under the Safe Drinking Water Act, the Environmental Protection Agency (EPA) sets maximum contaminant levels that apply at the entry point into a distribution system rather than within the distribution system. Because monitoring contaminants is not normally conducted at the consumer's tap, their presence can go undetected. If nitrification resulting from elevated ammonia levels in the source water occurs in the distribution system, elevated levels of nitrites and nitrate can reach the consumer.

EPA designed and patented a technology to oxidize ammonia in drinking water before it reaches the distribution system, which avoids nitrification in the distribution system and other problems associated with the presence of ammonia. Since 2014, EPA's National Risk Management Research Laboratory in Cincinnati, Ohio, has partnered with AdEdge Water Technologies, LLC, a small business in Duluth, Georgia, to further develop and commercialize the technology. Together, the EPA and AdEdge have collaborated to evaluate a two-stage aerobic treatment system for the removal of ammonia from drinking water. The treatment approach enhances the natural nitrification process during which, in the presence of oxygen, ammonia is converted to nitrite and then to nitrate. AdEdge holds a license on this technology and has marketed it as NoMonia, an innovative water treatment technology to remove ammonia, arsenic, iron, and manganese.

Many regions in the United States have excessive ammonia in groundwater from natural and agricultural sources. While ammonia in water does not pose a direct health concern, nitrification of significant amounts of ammonia may. Ammonia in water may create high chlorine demand for disinfection (if addressed by breakpoint chlorination). In the presence of total organic carbon, excess chlorine is a concern because it creates a disinfection by-product. High ammonia levels may interfere with the removal of other regulated contaminants such as arsenic, iron, and manganese. Ammonia in raw water may also result in nitrification in the distribution systems, and can cause corrosion, poor taste, and odor issues. Legacy treatment approaches for the removal of ammonia, such as ion exchange or reverse osmosis, generate high total dissolved solids (TDS) wastewater, a challenge that the NoMonia biological treatment process eliminates.

As a product of the collaboration, a pilot demonstration was concluded in August 2017 in Gilbert, Iowa. The pilot demonstration provided the city, AdEdge, and the EPA with multiple data sets to further establish critical design parameters for a full-scale treatment system. AdEdge is working with the community and their engineering firm to design a full-scale system based on the pilot results. Additional pilot demonstrations are anticipated in other areas, such as Illinois and Minnesota. The technology has also been licensed by WesTech Engineering, Inc.

Federal Laboratory Consortium for Technology Transfer (FLC) Award for Post-Fire Assessment Tool

The Federal Laboratory Consortium (FLC) for Technology Transfer awarded the 2018 Interagency Partnership Award to the Environmental Protection Agency, in conjunction with USDA's Agricultural Research Service, National Interagency Fire Center (NIFC), Bureau of Land Management, National Weather Service (NWS), and the University of Arizona. Scientists

from all parties transferred the Automated Geospatial Watershed Assessment (AGWA) tool to NIFC member agencies to speed the completion of post-fire watershed assessment. The tool identifies and targets treatments and resources where they are most needed to reduce threats of destructive surface erosion, flooding, and property loss. Functionality has been incorporated into the Automated Geospatial Watershed Assessment Tool (AGWA) to assess the impacts of wildland fire on runoff and erosion.

The AGWA is a GIS interface jointly developed by Phillip Guertin, Professor, University of Arizona; David C. Goodrich, Research Hydraulic Engineer, Agricultural Research Service; Shea Burns, Senior Research Specialist, University of Arizona; B. Scott Sheppard, Hydrologist, Tongass National Forest; Jane Barlow, GIS Analyst, Tucson Water; Thomas T.J. Clifford, Assistant Field Manager, Boise District Office; Carl Unkrich, Hydrologist, Agricultural Research Service; and William G. Kepner, Research Ecologist, U.S. Environmental Protection Agency. Through an intuitive interface, the user selects an outlet from which AGWA delineates and discretizes the watershed using a Digital Elevation Model (DEM). The watershed model elements are then intersected with terrain, soils, and land cover data layers to derive the requisite model input parameters. Based on a small sample of pre- and post-fire rainfall-runoff data, a method was developed to adjust model parameters as a function of the pre-fire vegetation cover and fire severity maps.

A pioneering aspect of the technology transfer process involved embedding AGWA team members with Interagency Burned Area Emergency Response (BAER) teams on actual post-wildfire deployments. This allowed AGWA team members to increase their understanding of BAER workflow, information requests, decision processes, and reporting requirements. Between fire seasons, the AGWA team attended BAER pre-season workshops and taught a two-day AGWA training course with computer tutorials derived from prior wildfires. Feedback during the training sessions prioritized improvements that would further enhance AGWA for BAER team use. Thus far, AGWA has been downloaded over 15,600 times and can track usage across 178 countries on six continents and 5,281 cities. In another advantageous application of AGWA's technology transfer, BAER leaders requested the assistance of the NWS with post-fire flash flood warnings. As a result, the AGWA/KINEROS2 model has been evaluated in seven NWS Weather Forecast Offices for real-time flash flood forecasting in 47 watersheds. All agencies involved in this effort embraced the technology transfer of AGWA through in-kind support, extensive interagency communication, and a passion to improve the nation's response to the increased number of wildfires.

Sensor Network Leak Detection at Industrial Facilities – Collaborating to Detect Fugitive Emissions

Industrial facilities, such as petrochemical facilities, experience unintended leaks that release fugitive emissions into the air. These fugitive emissions are currently regulated by federal and, in some cases, state rules that require manual monitoring of industrial equipment on a specific frequency (e.g., quarterly or annually) followed by equipment repairs to address the emissions. These fugitive emissions can degrade air quality, produce waste, and create unsafe working conditions. It is therefore beneficial from the shared perspective of industrial facilities, workers, regulators, and nearby communities, to develop cost-effective detection and management of fugitive emissions. If unanticipated emissions that require mitigation can be detected and fixed in

a timely manner, stakeholders benefit from safer working environments, cost savings through reduced product loss and more efficient work practices, lower air shed pollutant impacts, and improved transparency and community relations.

The EPA Next Generation Emission Measurement team is working collaboratively with industry, state and local regulators, instrument/information companies, and academic groups to explore new technical approaches for in-facility fugitive emission detection and mitigation. As the major project in this topic area, an EPA Cooperative Research and Development Agreement (CRADA) was initiated in 2017 with Flint Hills Resources (FHR), a refinery operator, and Molex, a connector and sensor company. The "Leak Detection and Repair (LDAR) Innovation CRADA" seeks to develop, test, and deploy new remote sensing approaches for fugitive leak detection that will enable the emissions management strategies of the future. The CRADA asks the question: "Can we use next generation emission monitoring technology to do a better job of protecting the environment and worker safety and save companies money?" The CRADA specifically investigates the utility and implementation variability of in-facility sensor network approaches as alternatives to currently required manual LDAR procedures that are expensive to perform. For a typical refinery this can exceed $4 million annually, and there is often considerable lag time between leak checks performed during each required LDAR cycle.

The team assembled for the CRADA consists of industrial facility and program management experts, refinery processing, LDAR, sensor design, and data analytics scientists and engineers. With this well-rounded research team, work is progressing quickly. As of December 2018, four concept tests were designed and completed. Two of the tests were conducted at the EPA next generation emission monitoring test range in Research Triangle Park, NC, and the third and fourth tests were conducted at a small FHR facility in Texas. Using simulated leaks (controlled release of isobutylene and ethylene gas), each test produced valuable information on the ability of prototype sensor networks to detect leaks of various emission levels and compared results with manual leak detection (Method 21) and optical gas imaging (OGI).

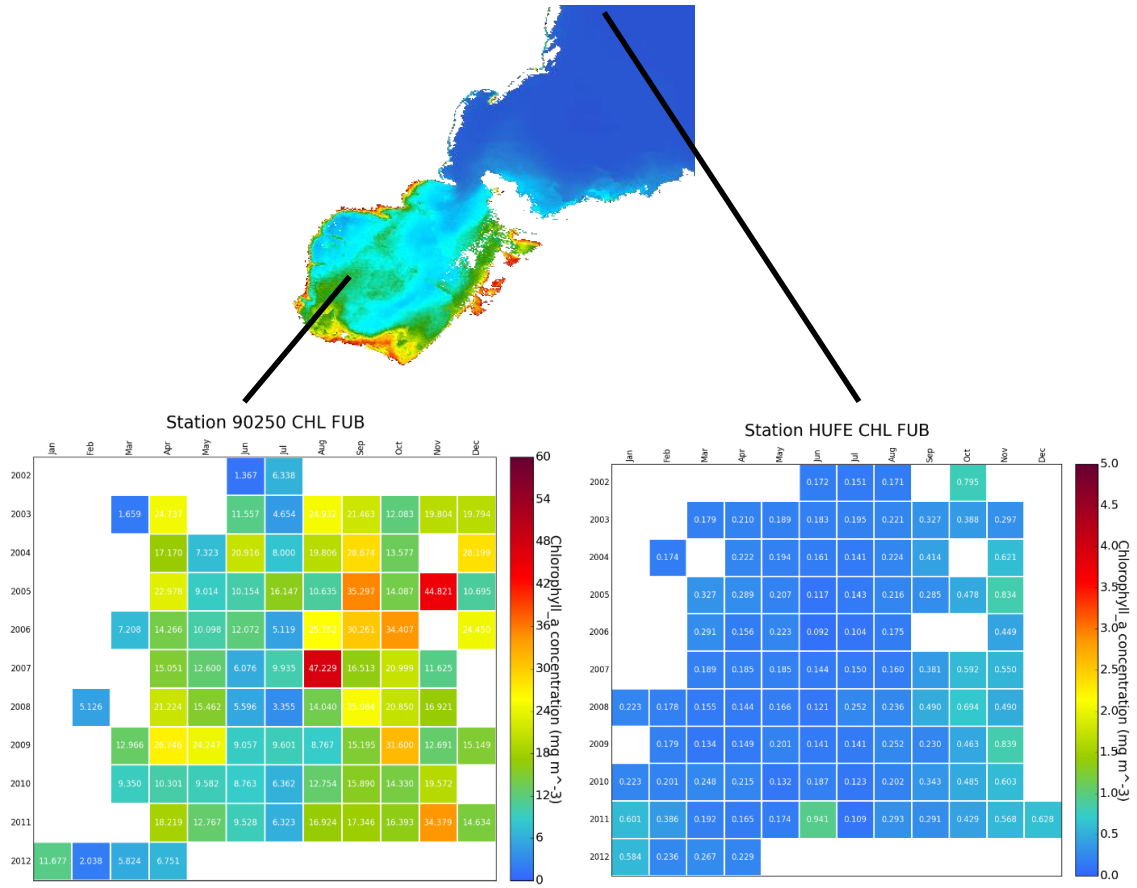
The first four tests provided important information used by Molex to develop a next-generation sensor design for use in a pilot test at two FHR refinery process units in 2019. When the new system detects a low-level leak, it estimates and then refines a potential location via triangulation of sensors, and then sends an alert to designated personnel. An unanticipated result from the third test was the sensor network began to immediately detect a previously unknown emission source on the site that could not be detected with Method 21 or OGI, proving the inherent value of the concept on monitoring fugitive emissions levels in a process unit.

The partners anticipate the following outcomes from the second phase of the CRADA:

- Validation of the sensor-based approach as an alternative LDAR method through detecting large leaks more quickly, e.g., within a few hours to a couple of days;
- Development and validation of sensor placement, performance validation, and a response procedure following sensor detection;
- Evaluation of the effectiveness of the new method in monitoring fugitive emissions in industrial facilities as compared to current practices; and
- Establishment of a data management and quality assurance system to support the sensor hardware and software.

EPA Partners to Use European Satellite Data to Improve Inland Water Monitoring
Under a Cooperative Research and Development Agreement (CRADA) initiated in 2015, EPA's National Exposure Research Laboratory and Brockmann Consult have been testing various satellite algorithms for deriving chlorophyll-a in lakes and reservoirs based on the European Space Agency Copernicus Sentinel satellite missions. The lab views satellite remote sensing as a key innovation in exposure science. New approaches are needed to facilitate the collection of real time, reliable water quality information that relates to ecological pressures, human health, well-being, and economies. Using the European Sentinel satellites has provided unprecedented monitoring capabilities for inland waters.

New methods and approaches are required to turn data from the Sentinel satellites into information for water management. This CRADA has been a case study to demonstrate the applicability of Sentinel data to different lake types and management issues. Optical remote sensing techniques can improve monitoring by providing information on the spatial and temporal dynamics of water quality. Brockmann Consult is working to develop enhanced service infrastructure to ingest and process the large amount of data and to make them accessible to a larger user community in a user-friendly way. This CRADA allows the EPA lab to access to big data from the European Space Agency Sentinel missions to address relevant management science questions, and Brockmann Consult to learn how users may access, use, and interpret Sentinel datasets.



Pictured above center is a section of Lake Huron where an algorithm originally developed in the European Union was tested for U.S. waters and validated against data from the Water Quality Portal. The bottom two charts are the monthly chlorophyll-a averages for two different sites within Lake Huron. The bottom left chart represents more dynamic and eutrophic waters and the bottom right location is more homogeneous with lower chlorophyll-a concentrations.

National Aeronautics and Space Administration (NASA)

Written into the 1958 Space Act that established NASA is a directive to "provide for the widest practicable and appropriate dissemination" of the results of its missions. It has thus always been part of NASA's DNA to capture and share with the public its discoveries, data, and new technologies, encouraging industry to adopt these innovations as a way of repaying the nation's investment in space and aeronautics. To this end, the agency established a formal Technology Transfer (T2) Program in 1962 that has been in continuous operation ever since, making it NASA's longest-running mission.

Over the decades, subsequent laws and regulations have reiterated and strengthened the requirement that NASA find efficient and effective ways to broadly share the benefits of its discoveries and technology. In response, NASA's Technology Transfer Program has continuously evolved and developed new tools to serve its goals and manage its workflow.

The program processes more than 1,500 new technology disclosures created by NASA innovators each year, assessing each for its commercial potential and patenting those that are particularly promising. It manages the agency's technology portfolio, negotiates license agreements, and handles requests for NASA software. Meanwhile, T2 publishes an annual outreach publication called *Spinoff* to share with the public new success stories of technology transfer and commercialization. *Spinoff* has featured more than 2,000 NASA spinoffs since its debut in 1976.

The NASA's effective marketing and promotion of its portfolios has led to a steady increase in public and government interest in NASA technology for secondary applications. Patent licensing, invention disclosures, and software usage agreements continue to follow a historically-positive trend. Managing this increased interest requires constant and continuous process improvements across all areas of the technology transfer pipeline. Below are some highlights of the program's achievements in 2018.

Program Achievements in 2018

Transferring the NASA Technology Transfer System (NTTS) Software Platform to Federal Agencies

NASA's Technology Transfer System (NTTS) is an enterprise software tool developed in-house over the last decade to manage the workflow of capturing, maintaining, and transferring new technologies and software. The platform provides T2 personnel with tools to facilitate the whole of the technology transfer process, and it enables NASA to track T2 activities in fine-grained, quantifiable detail. As NTTS has evolved, other government agencies, universities, and even commercial operations have approached the agency to see whether they can acquire the software for their use. Thus, in 2018, the T2 program formally began exploring avenues to share NTTS.

NTTS Overview

To give an overview of the system's capabilities, the following paragraphs describe in brief the tools and products NTTS supplies to NASA's T2 program.

Website content management.
The Technology Transfer Program used NTTS as the basis of a redesign of its flagship website—NASA's T2 Portal—which now serves as a public-facing web portal to access program data (https://technology.nasa.gov). Because the program uses NTTS as a centralized database to host all of its content, T2 has been able to spin off additional technology-transfer-related websites using a common set of user interfaces and application programming interfaces (APIs). As of FY 2018, there are a number of NASA technology portals, public websites powered by NTTS, including among others:

- *Field center websites.* Nine NASA field center T2 offices have their own portals, featuring the same user interface as the agency-level website but drawing only center-specific content from NTTS for their content.
- *Software catalog.* NASA's comprehensive catalog of software—the first of its kind among federal agencies—was first assembled in late 2014, creating a splash in press coverage and sparking a sharp increase in software usage agreements executed with the space agency. The NTTS hosts all of the catalog's content and now powers the catalog's website (https://software.nasa.gov). More recently, a module has been added to NTTS that automates the process to initiate a software usage agreement, using a simple, intuitive web-based application, saving work for NASA and getting software into the hands of potential users faster.
- *T2 public APIs.* The same tools used by the program to build some of the above websites are made available to developers who wish to build and integrate services with the Technology Transfer Program's abundant data resources.

NTTS Internal Web Application for Intramural Reporting.
The NTTS contains a suite of internal-only web applications and private APIs that allow NASA-designated users to perform administrative tasks and day-to-day operations as part of their intramural technology transfer activities.

Electronic New Technology Report (e-NTR).
The e-NTR is a web application designed to make new technology reporting as easy as possible for researchers. It significantly reduces the number of questions researchers must answer, compared to previous paper-based forms, and guides them through the process via an intuitive interface.

Innovator Dashboard.
Based on feedback from researchers, NASA realized that one way to incentivize invention disclosures was to provide better information and status updates regarding what happens to technologies after they have been reported. The Innovator Dashboard allows NASA researchers to see at a glance all of the technologies they have reported and their current status—how many are being or have been patented, for instance, or new publications regarding the technology, or whether a license agreement is in process.

Business and Marketing Communications Tools.
The NASA has been able to leverage NTTS capabilities to automate and enrich the creation of compelling marketing collateral. One of the Technology Transfer Program's crowning

achievements in this area was the development of a standardized technology fact sheet template whose content can be generated in real-time from up-to-date NTTS content.

Automated Licensing System.
In the four years following the launch of a consolidated patent portfolio on the T2 portal, the agency experienced more than a 100 percent increase in annual patent licenses executed. We believe making license opportunities visible and easier to take advantage of plays a key role in increasing the rate of transfer from government to industry. Looking to build on this success, the program's development team built an automated licensing system on top of NTTS called ATLAS (Automated Technology Licensing Application System) to streamline and automate the tedious and complicated process of licensing technologies. It provides a clean, intuitive, and easy-to-navigate interface for interested individuals and businesses.

Metrics Reports.
By pulling data from NTTS, a wealth of information can be extracted for internal analysis on nearly every facet of program operations. Tracking this quantifiable data over time provides a solid basis for identifying strengths and weaknesses, setting goals for improvements, and strategizing future operations.

Transferring NTTS
In 2018, NASA and the Air Force Research Laboratory (AFRL) entered into a reimbursable agreement to provide the Air Force with a customized NTTS platform and data system for their needs. Delivery of the finished product is expected within 24 months, and the Air Force will then work with NASA to provide the software to other DOD agencies.

In addition to AFRL, in 2018 and into 2019 NTTS was transferred via Software Usage Agreements (SUAs) to the following U.S. Agencies:

- Environmental Protection Agency
- Food & Drug Administration
- Centers for Disease Control & Prevention
- National Institutes of Health
- Defense Health Agency
- Department of Energy National Energy Technology Lab

Significant Program Metrics
In FY 2018, key program metrics covering technology transfer remain strong, including the following:

New Technology Reports.
New Technology Reports saw a 5 percent increase from the previous year. This success can be attributed to the agency's efforts in conducting monthly in-reach events at each NASA field center, educating approximately 2,800 innovators in 2018 on their duty to report new technologies while increasing their awareness of recently updated T2 products that benefit them, such as e-NTR. Attendees also received some of our popular print products: Inventor Notebooks,

posters, and calendars—which T2 has found is a cost-effective way to incentivize invention disclosures.

U.S. Patent Applications Filed.
New patents filed continued to meet the program's recent annual average in 2018. It is worth noting that, even though the T2 program has continued to file about the same number of patents each year, our license numbers have climbed significantly over time. This is the fruit of a more strategic approach to patenting inventions, where NASA is now careful to patent and maintain only those technologies the agency believes have significant potential for licensing and commercialization. Our approach helps save taxpayer dollars from being potentially wasted on patent maintenance fees for inventions that are unlikely to produce a license.

Patent Licenses.
Prior to NASA's concerted effort to increase patent licensing, the agency averaged 22 licenses executed per year (as of fiscal years 2010–2012). Thanks to program improvements since that time, including many tools described above, the T2 Program has achieved a new level of performance. In FY 2018 the program continued a positive trend of patent licenses executed, bringing the annual average to 101 licenses over each of the past three years, an increase of 359 percent from the previous average performance.

Software Usage Agreements.
Software Usage Agreements (SUAs)—that is, instances where NASA releases software to a requestor—also continued a historically-positive trend. From FY 2016–2018, NASA saw an average of 3,554 SUAs, a 220 percent increase from an average of 1,111 SUAs during FY 2010–2012. Much of this success can be traced to the formation of the Software Catalog and website mentioned above; thanks to these central repositories, it is easier than ever for users to discover, request, and acquire NASA software.

In July 2018, the T2 Program also launched an innovative web platform called the Remote Sensing Toolkit. This online toolkit helps users discover, and create tools using NASA software to analyze, NASA satellite data.

Positive Findings from 2018 OIG Audit
In FY 2012, NASA's Office of the Inspector General (OIG) audited the T2 Program and made several recommendations related to NASA's technology transfer policy. In particular, OIG cited NASA's need to implement procedures to ensure that all relevant personnel are fully aware of their responsibilities in the policy, the need to coordinate with programs and projects on commercialization planning, and the need for periodic training across the agency on technology transfer responsibilities as described in the NASA technology transfer policy.

A follow-up audit was performed in 2018, in which OIG found that the program had made concerted efforts in recent years to improve the overall awareness of NASA's Technology Transfer Program through increased communication and outreach, meeting the recommendations provided following the 2012 audit. Those efforts have resulted in a considerable increase in the numbers of NTRs submitted, patent applications filed, and licenses negotiated. The report's

findings conclude that NASA's T2 Program made the right steps following the 2012 audit to address the original findings.

Program Consolidation Efforts

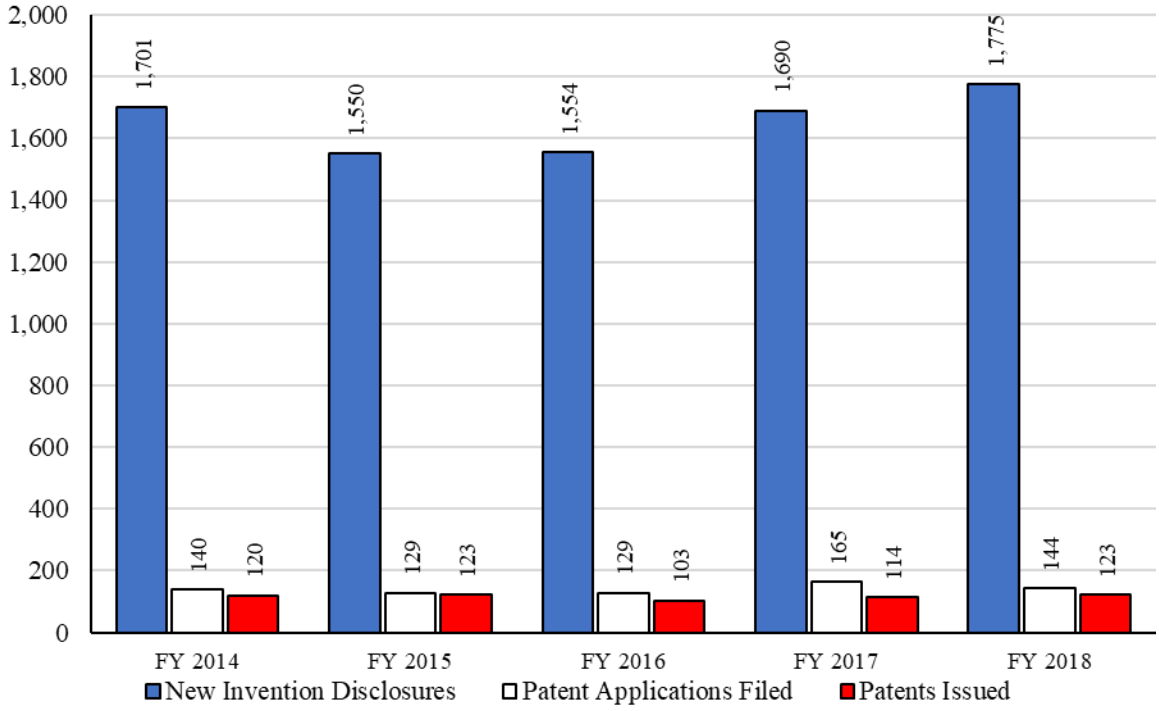
In order to compensate for several years of budget decreases, standardize and streamline routine processes, simplify customer interactions with our program, and increase security, in 2018 the T2 Program initiated a consolidation effort, reorganizing key program functions such that they are centralized at a host NASA field center rather than spread across the agency. In 2018, we identified four areas in need of consolidation and assigned tasks to the host centers to be completed by the end of 2019:

- Contract closeout: Going forward, the T2 office at Glenn Research Center will manage contract and grant closeout for the entire agency.
- SUA processing: Going forward, the T2 office at Stennis Space Center will process all SUAs for the entire agency.
- Commercialization assessment contract: Going forward, the T2 office at Marshall Space Flight Center will conduct commercial assessments of intellectual property for the entire agency. By creating a single contract to provide these assessments, we hope to remove inconsistencies in results and improve strategic coordination across all centers.
- Marketing: In 2018, the T2 Program began organizing a formal marketing team from multiple field centers, coordinated by headquarters personnel. Prior to this year, marketing activities have been scattered among the field center T2 offices and largely uncoordinated. Agency-level marketing campaigns will be implemented to increase web traffic, increase awareness of the program, and develop new leads and licenses.

NASA Invention Disclosures and Patenting

Between FY 2014 and FY 2018, new inventions disclosed increased by 4% from 1,701 in FY 2014 to 1,775 disclosures in FY 2018. Patent applications filed increased by 3%, from 140 to 144, while patents issued increased by 3%, from 120 to 123 patents in FY 2018.

NASA Invention Disclosures and Patenting

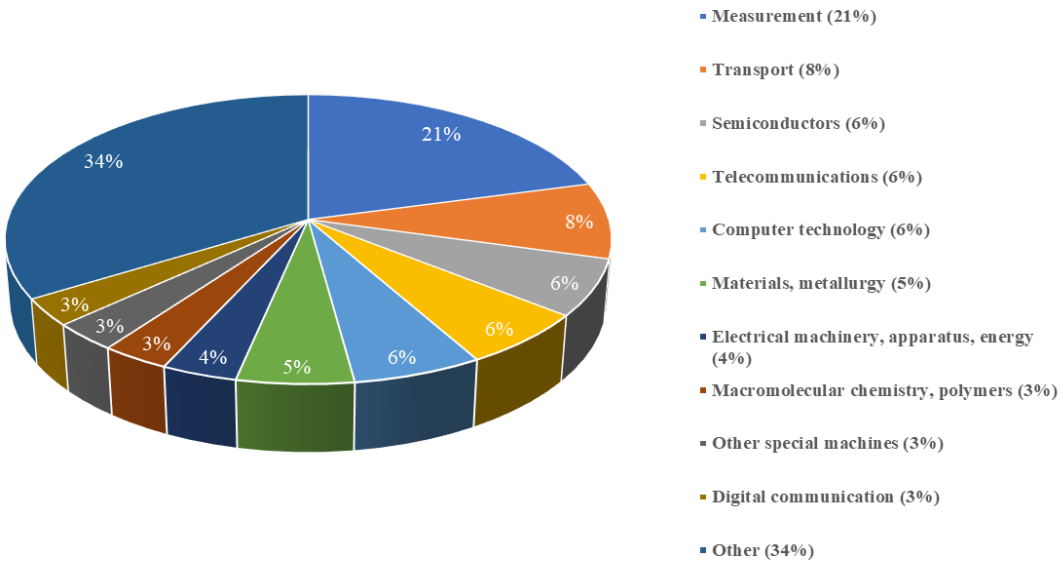


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
New Invention Disclosures	1,701	1,550	1,554	1,690	1,775
Patent Applications Filed	140	129	129	165	144
Patents Issued	120	123	103	114	123

Patents issued to NASA in FY 2018 covered many technology areas including Measurement (21%), Transport (8%), Semiconductors (6%), Telecommunications (6%), and Computer technology (6%).[43]

[43] Source: Prepared by Science-Metrix using USPTO data indexed in PatentsView in 2019. Used with permission.

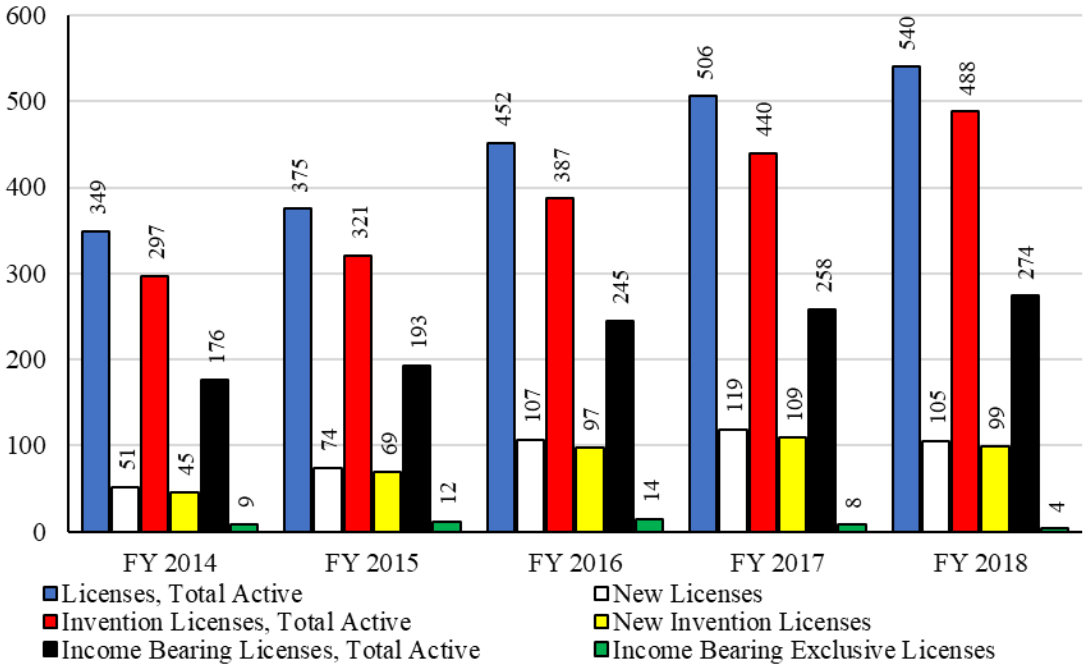
USPTO Patents Assigned to NASA by Technology Area: FY 2018



NASA Licenses

Between FY 2014 and FY 2018, total active licenses increased by 55%, from 349 in FY 2014 to 540 licenses in FY 2018, while new licenses increased by 106% to 105. Total active invention licenses increased by 64%, from 297 to 488 while new invention licenses increased by 120%, from 45 to 99. Total active income bearing licenses increased by 56%, from 176 to 274, while income-bearing exclusive licenses decreased by 56%, from 9 in FY 2014 to 4 in FY 2018.

NASA Licenses

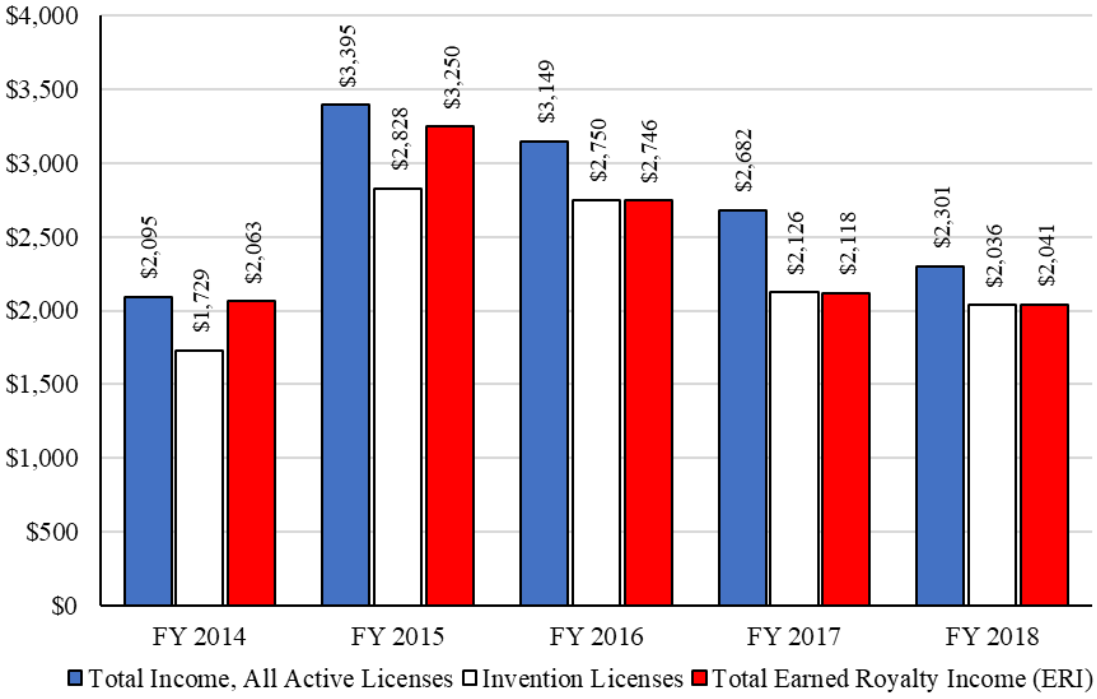


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses, Total Active	349	375	452	506	540
New Licenses	51	74	107	119	105
Invention Licenses, Total Active	297	321	387	440	488
New Invention Licenses	45	69	97	109	99
Income Bearing Licenses, Total Active	176	193	245	258	274
Income Bearing Exclusive Licenses	9	12	14	8	4

NASA Income from Licensing

Between FY 2014 and FY 2018, NASA reported that the total income from all active licenses increased by 10%, from $2.1 million in FY 2014 to $2.3 million in FY 2018. The income from invention licenses increased by 18%, from $1.7 to $2.0 million. Total earned royalty income decreased by 1%, from $2.1 million in FY 2014 to $2.0 million in FY 2018.

NASA Income from Licensing ($ thousands)

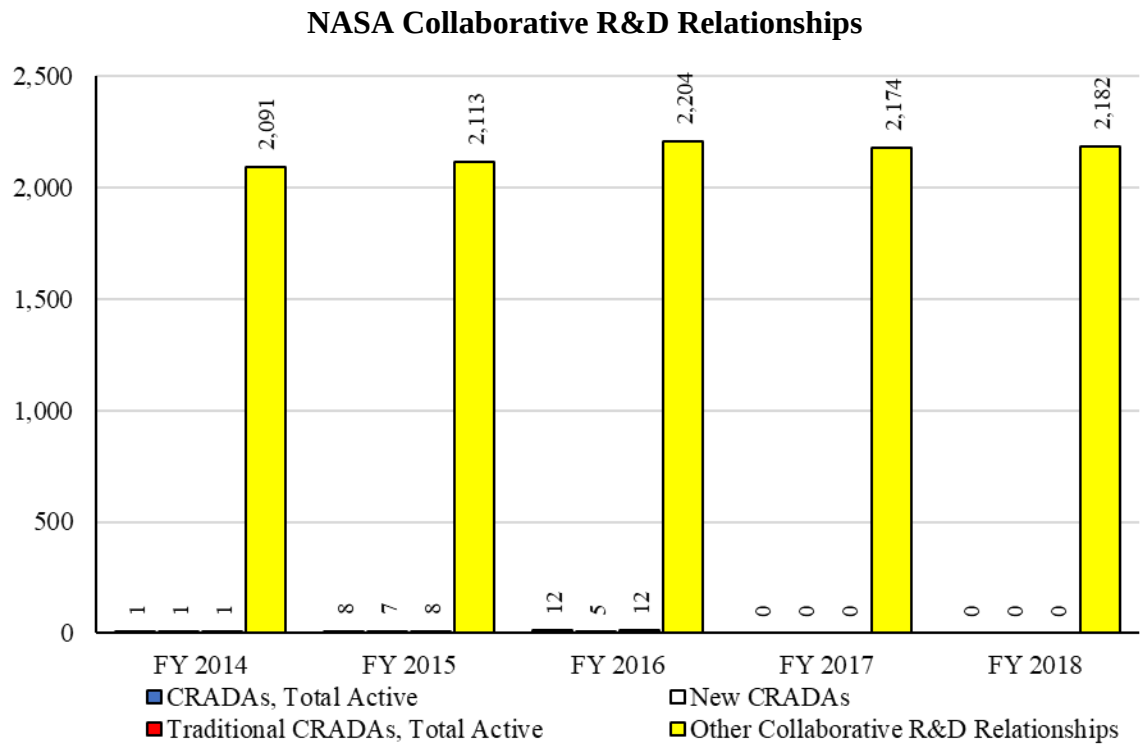


	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses	$2,095	$3,395	$3,149	$2,682	$2,301
Invention Licenses	$1,729	$2,828	$2,750	$2,126	$2,036
Total Earned Royalty Income, (ERI)	$2,063	$3,250	$2,746	$2,118	$2,041

NASA Collaborative R&D Relationships

The National Aeronautics and Space Act (Space Act), 51 U.S.C. §§ 20101-20164, provides NASA with the unique authority to enter into a wide range of "other transactions," frequently in the form of Space Act Agreements. The NASA uses Space Act Agreements to engage in collaborative research projects with various partners to advance NASA's mission and program objectives, including international cooperative space activities. Space Act Agreements differ from traditional cooperative research and development agreements (CRADAs) and therefore in this report, Space Act Agreements are included under the category "Other Collaborative R&D Relationships."

Between FY 2014 and FY 2018, Space Act Agreements increased 4%, from 2,091 agreements in FY 2014 to 2,182 in FY 2018.



	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs, Total Active	1	8	12	0	0
New CRADAs	1	7	5	0	0
Traditional CRADAs, Total Active	1	8	12	0	0
Other Collaborative R&D Relationships	2,091	2,113	2,204	2,174	2,182

NASA Downstream Success Stories
Always in popular demand, *Spinoff* has featured more than 2,000 commercial products since its debut in 1976. In 2018, *Spinoff* told the stories of 49 companies across 20 U.S. states that are selling products derived from NASA technology. Fresh content is published regularly on *Spinoff*'s website, which receives 2–3 million unique visitors per month, and is also routinely featured on NASA's homepage. *Spinoff* also maintains a robust social media presence.

Free print copies of the publication are distributed to the White House, each member of Congress, the United Nations, other government agencies and laboratories, universities, as well as members of the public who request the book. The entire publication is available in multiple formats online at https://spinoff.nasa.gov.

Examples of successful technology transfer stories featured in *Spinoff* 2018 include:

Radar Device Detects Heartbeats Trapped under Wreckage
The NASA often analyzes weak signals hidden in noise, like alterations in a satellite's path that indicate gravity fluctuations in a planet. With funding from other government agencies, the Jet Propulsion Laboratory adapted the technology to create FINDER, which uses radar to detect the breathing and heartbeats of victims trapped under rubble. Edgewood, Maryland-based R4 Inc., licensed the technology and continues to develop it. The device has already seen its first sales and saved its first earthquake victims.

Sterilizing Fogger Cleans Ambulances with a Breeze
When paramedics come racing, the last thing anybody worries about is where the ambulance was earlier that morning. But traces of those earlier calls could be lingering—and they could be spreading disease. With help from the Regional Economic Development Program at Glenn Research Center, Kent, Ohio-based Emergency Products + Research designed a device that sterilizes the rig and gear to make it safer for the patients and the paramedics. It's already being adopted across the country.

Innovative Design Propels Small Jet Faster, Farther with Less Fuel
Honda is best known for budget-friendly, fuel-efficient family cars—not high-powered jets. But that's just what Honda Aircraft, a division of Honda based in Greensboro, North Carolina, sells. The HondaJet's innovative design was validated at Langley Research Center's National Transonic Facility, one of only two wind tunnels like it in the world. The NASA facilities and expertise gave Honda confidence to move into production. Since late 2015, the company has delivered more than 100 of its affordable and speedy private jets around the world.

Design Software Transforms How Commercial Jetliners Are Built
Computational fluid dynamics (CFD) software that simulates aerodynamics has been a major boon to aircraft designers. The NASA funded the creation of Pegasus 5, a preprocessor that greatly decreases the work necessary to prepare a design for CFD analysis. Ames Research Center took over the program and refined it with Seattle-based Boeing Commercial Airplanes, which has used it to design a number of its airliners. Pegasus 5 opens up CFD preprocessing to less experienced users, speeds it up, and drastically reduces user error.

Organic Compound Turns Toxic Waste into Harmless Byproducts

A team of university researchers discovered that a particular metabolite neutralizes hydrazine, a hazardous chemical often used as rocket propellant. Extensive NASA testing, mostly by Kennedy Space Center, proved the safety of using alpha-ketoglutaric acid to neutralize hydrazine, and after Kennedy developed procedures for doing so, the university licensed the resulting product to let Marietta, Georgia-based Hydrazine Neutralizing Solutions Inc., market it as ZeenKleen. Customers for the product line include nuclear power plants and, potentially, the plastic and pharmaceutical industries.

Early NASA "Dream Computer Program" Still Optimizes Designs

Half a century after it was created at Goddard Space Flight Center, NASTRAN remains at the cutting edge of computer-aided engineering as perhaps NASA's most successful software spinoff. It has helped design everything from cars and turbines to buildings and roller coasters. Its code is also incorporated into many commercial programs, including Newport Beach, California-based MSC Software's Apex platform, which makes modeling and simulation up to 10 times faster and allows computer-aided engineering to be introduced earlier in the design process.

Chapter 3
Conclusion

Technology transfer is an active and essential mission of federal R&D laboratories. By leveraging our Nation's innovative nature and investing in science and technology, we strengthen our economy and U.S. competitiveness in world markets. In recent years, agencies have engaged in efforts to increase the rate and efficacy of technology transfer activities and thereby improve the economic and societal impact from federal R&D investments.

This report provides a summary of the technology transfer activities of all 11 federal agencies that are actively involved in R&D. This summary is derived from each agency's annual technology transfer reports that are located online.[44]

Statistical data provided in this report indicate that for all agencies covered by this report, between FY 2014 and FY 2018 there has been a 11% increase in invention disclosures, a 4% increase in patent applications, and an 9% increase in patents issued. In FY 2018, the largest number of federal patents issued involved the technical areas of measurement (13%), biotechnology (8%), electrical machinery, apparatus, energy (7%), other special machines (6%), pharmaceuticals (5%), and telecommunications (5%).

Between FY 2014 and FY 2018, total active licenses increased by 6%, new licenses increased by 47%, invention licenses decreased by 7%, and new invention licenses increased by 41%. Income-bearing licenses decreased by 5%, and exclusive income-bearing licenses increased by 72%.

Between FY 2014 and FY 2018, income from all licensing decreased by 23%, income from invention licenses decreased by 23%, and total earned royalty income decreased by 14%.

Between FY 2014 and FY 2018, CRADAs increased by 25%, and new CRADAs increased by 25%. Traditional CRADAs increased by 0.5% and other collaborative R&D relationships increased by 0.5%.

In CY 2018, federal researchers published 70,957 papers. More than half of these papers were in the fields of health sciences (26%), biological and biomedical sciences (19%), engineering (15%) and physics (12%). In FY 2018, 18,896 papers cited in U.S. patents were authored or coauthored by federal researchers. Of these papers, 91% involved research in the fields of biological and biomedical sciences (36%), health sciences (23%), physics (13%), engineering (12%), and chemistry (7%).

In summary, this report shows that agencies have made steady progress in their efforts to improve the transfer of technologies from federal laboratories. Collectively, agencies reported increases in the majority of technology transfer measures described in this report; however, respondent agencies collectively reported a decrease in licensing income from FY 2014 to FY

[44] Values reported in this section reflect data for agencies for which all data were available. Agencies with incomplete data were not included in these calculations to accurately describe changes over time.

2018. Additionally, agencies are now engaged in efforts to assess the impact of these efforts to show how federal technology transfer promotes economic growth, the creation of new products, and increased employment opportunities.

Appendix A

Federal Invention Disclosure and Patenting

Agency	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
USDA	New Inventions Disclosed	117	222	244	166	320
	Patent Applications Filed	119	125	109	111	120
	Patents Issued	83	94	60	68	67
DOC	New Inventions Disclosed	47	61	64	43	77
	Patent Applications Filed	25	32	25	46	56
	Patents Issued	19	20	16	34	28
DoD	New Inventions Disclosed	902	743	782	978	839
	Patent Applications Filed	898	875	858	869	1,060
	Patents Issued	648	620	624	630	600
DOE	New Inventions Disclosed	1,588	1,645	1,760	1,794	1,748
	Patent Applications Filed	1,144	949	999	937	868
	Patents Issued	822	755	856	817	854
HHS	New Inventions Disclosed	351	321	320	354	322
	Patent Applications Filed	216	222	269	289	253
	Patents Issued	453	501	579	554	624
DHS	New Inventions Disclosed	44	12	24	25	22
	Patent Applications Filed	6	12	17	19	17
	Patents Issued	3	5	3	2	8
DOI	New Inventions Disclosed	6	7	8	12	9
	Patent Applications Filed	4	8	4	5	7
	Patents Issued	2	3	1	3	6
DOT	New Inventions Disclosed	3	0	0	3	12
	Patent Applications Filed	0	5	0	7	2
	Patents Issued	1	1	1	0	0
VA	New Inventions Disclosed	289	219	241	589	496
	Patent Applications Filed	116	116	104	163	255
	Patents Issued	37	54	54	50	72
EPA	New Inventions Disclosed	5	7	6	13	7
	Patent Applications Filed	9	4	1	4	6
	Patents Issued	5	7	3	3	4
NASA	New Inventions Disclosed	1,701	1,550	1,554	1,690	1,775
	Patent Applications Filed	140	129	129	165	144
	Patents Issued	120	123	103	114	123

Total	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
	New Inventions Disclosed	5,053	4,787	5,003	5,667	5,627
	Patent Applications Filed	2,677	2,477	2,515	2,615	2,788
	Patents Issued	2,193	2,183	2,300	2,275	2,386

Federal Licenses

Agency	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
USDA	Licenses, Total Active	413	427	441	448	472
	New Licenses	31	37	31	40	40
	Invention Licenses, Total Active	362	362	370	373	386
	New Invention Licenses	29	22	25	31	27
	Income Bearing Licenses, Total Active	412	421	439	437	471
	Income Bearing Exclusive Licenses	299	292	307	302	324
DOC	Licenses, Total Active	38	46	57	68	67
	New Licenses	7	13	15	19	11
	Invention Licenses, Total Active	38	46	57	68	67
	New Invention Licenses	7	13	15	19	11
	Income Bearing Licenses, Total Active	26	29	31	35	37
	Income Bearing Exclusive Licenses	14	16	20	19	22
DoD	Licenses, Total Active	430	560	515	552	480
	New Licenses	24	69	35	162	168
	Invention Licenses, Total Active	280	431	286	514	n.a.
	New Invention Licenses	6	69	57	24	n.a.
	Income Bearing Licenses, Total Active	203	203	185	396	306
	Income Bearing Exclusive Licenses	n.a.	n.a.	209	196	151
DOE	Licenses, Total Active	5,861	6,310	5,410	4,045	4,742
	New Licenses	573	648	621	567	662
	Invention Licenses, Total Active	1,560	1,336	943	916	844
	New Invention Licenses	171	155	145	128	100
	Income Bearing Licenses, Total Active	4,215	4,577	3,963	3,057	3,323
	Income Bearing Exclusive Licenses	141	98	231	190	181
HHS	Licenses, Total Active	1,555	1,767	1,750	1,806	1,867
	New Licenses	212	279	278	334	335
	Invention Licenses, Total Active	1,186	1,354	1,721	1,354	1,411
	New Invention Licenses	117	232	221	282	292
	Income Bearing Licenses, Total Active	845	843	837	907	978
	Income Bearing Exclusive Licenses	34	119	145	130	143
DHS	Licenses, Total Active	2	4	5	5	5
	New Licenses	0	3	1	0	0
	Invention Licenses, Total Active	2	4	5	5	5
	New Invention Licenses	0	3	1	0	0
	Income Bearing Licenses, Total Active	1	4	1	1	2
	Income Bearing Exclusive Licenses	0	0	0	0	0

Federal Licenses (continued)

Agency	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
DOI	Licenses, Total Active	18	20	22	15	17
	New Licenses	0	3	0	0	2
	Invention Licenses, Total Active	16	18	20	13	n.a.
	New Invention Licenses	0	3	0	0	n.a.
	Income Bearing Licenses, Total Active	14	18	17	13	13
	Income Bearing Exclusive Licenses	5	7	8	7	n.a.
DOT	Licenses, Total Active	1	2	2	5	5
	New Licenses	0	1	2	1	1
	Invention Licenses, Total Active	1	2	0	0	1
	New Invention Licenses	0	0	0	0	0
	Income Bearing Licenses, Total Active	1	2	2	5	6
	Income Bearing Exclusive Licenses	1	0	0	0	0
VA	Licenses, Total Active	197	200	261	262	n.a.
	New Licenses	3	3	1	1	n.a.
	Invention Licenses, Total Active	197	200	260	261	n.a.
	New Invention Licenses	3	3	1	0	n.a.
	Income Bearing Licenses, Total Active	14	16	42	42	210
	Income Bearing Exclusive Licenses	9	11	35	36	205
EPA	Licenses, Total Active	40	37	35	38	31
	New Licenses	6	0	8	5	1
	Invention Licenses, Total Active	40	37	35	38	31
	New Invention Licenses	6	0	8	5	1
	Income Bearing Licenses, Total Active	33	31	31	31	24
	Income Bearing Exclusive Licenses	8	7	7	7	6
NASA	Licenses, Total Active	349	375	452	506	540
	New Licenses	51	74	107	119	105
	Invention Licenses, Total Active	297	321	387	440	488
	New Invention Licenses	45	69	97	109	99
	Income Bearing Licenses, Total Active	176	193	245	258	274
	Income Bearing Exclusive Licenses	9	12	14	8	4

Total	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
	Licenses, Total Active	8,904	9,748	8,950	7,750	8,226
	New Licenses	907	1,130	1,099	1,248	1,325
	Invention Licenses, Total Active	3,979	4,111	4,084	3,982	3,233
	New Invention Licenses	384	569	570	598	530
	Income Bearing Licenses, Total Active	5,940	6,337	5,793	5,182	5,644
	Income Bearing Exclusive Licenses	520	562	976	895	1,036

Federal Income from Licensing ($ thousands)

Agency	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
USDA	Total Income, All Active Licenses	$4,928	$5,067	$4,784	$5,703	$3,835
	Invention Licenses	$4,733	$4,842	$4,456	$5,378	$3,495
	Total Earned Royalty Income, (ERI)	$3,611	$3,510	$3,633	$3,504	$2,716
DOC	Total Income, All Active Licenses	$220	$164	$149	$141	$147
	Invention Licenses	$220	$164	$149	$141	$147
	Total Earned Royalty Income, (ERI)	$220	$164	$149	$141	$147
DoD	Total Income, All Active Licenses	$11,280	$9,169	n.a.	n.a.	n.a.
	Invention Licenses	$10,468	$8,203	$554	n.a.	n.a.
	Total Earned Royalty Income, (ERI)	$9,294	$7,621	$5,823	$7,415	$6,802
DOE	Total Income, All Active Licenses	$37,885	$33,137	$31,149	$36,567	$21,085
	Invention Licenses	$32,869	$28,966	$27,364	$33,436	$17,237
	Total Earned Royalty Income, (ERI)	$23,384	$21,245	$16,273	$13,216	$10,239
HHS	Total Income, All Active Licenses	$137,249	$151,727	$132,833	$134,567	$110,709
	Invention Licenses	$133,814	$147,512	$130,701	$132,536	$108,276
	Total Earned Royalty Income, (ERI)	$116,765	$114,102	$110,193	$135,963	$111,628
DHS	Total Income, All Active Licenses	$3	$5	$12	$20	$36
	Invention Licenses	$0	$0	$12	$20	$36
	Total Earned Royalty Income, (ERI)	$3	$5	$12	$20	$36
DOI	Total Income, All Active Licenses	$58	$106	$83	$50	$51
	Invention Licenses	$58	$106	$83	$50	$51
	Total Earned Royalty Income, (ERI)	$58	$106	$83	$50	$51
DOT	Total Income, All Active Licenses	$23	$12	$15	$20	$13
	Invention Licenses	$0	$0	$0	$0	$0
	Total Earned Royalty Income, (ERI)	$23	$12	$15	$20	$13
VA	Total Income, All Active Licenses	$336	$494	$316	$491	$690
	Invention Licenses	$336	$494	$316	$491	$690
	Total Earned Royalty Income, (ERI)	$336	$494	$316	$491	$690
EPA	Total Income, All Active Licenses	$439	$232	$466	$412	$628
	Invention Licenses	$439	$232	$466	$412	$628
	Total Earned Royalty Income, (ERI)	$439	$232	$466	$412	$628
NASA	Total Income, All Active Licenses	$2,095	$3,395	$3,149	$2,682	$2,301
	Invention Licenses	$1,729	$2,828	$2,750	$2,126	$2,036
	Total Earned Royalty Income, (ERI)	$2,063	$3,250	$2,746	$2,118	$2,041

Total	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
	Total Income, All Active Licenses	$194,516	$203,508	$172,956	$180,653	$139,495
	Invention Licenses	$184,666	$193,347	$166,851	$174,590	$132,596
	Total Earned Royalty Income, (ERI)	$156,196	$150,741	$139,709	$163,350	$134,991

Federal Collaborative R&D Relationships

Agency	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
USDA	CRADAs, Total Active	267	301	238	330	212
	New CRADAs	60	80	79	91	61
	Traditional CRADAs, Total Active	267	301	238	330	182
	Other Collaborative R&D Relationships	5,629	4,730	5,628	6,125	3,369
DOC	CRADAs, Total Active	2,307	2,752	2,940	2,932	3,363
	New CRADAs	2,111	2,548	2,608	2,443	2,770
	Traditional CRADAs, Total Active	233	365	335	413	534
	Other Collaborative R&D Relationships	2,981	3,125	3,273	3,181	3,497
DoD	CRADAs, Total Active	3,263	2,377	2,603	2,995	4,976
	New CRADAs	686	786	774	813	949
	Traditional CRADAs, Total Active	2,748	2,130	2,273	2,424	3,010
	Other Collaborative R&D Relationships	515	247	330	571	1,966
DOE	CRADAs, Total Active	729	746	783	935	1,027
	New CRADAs	174	185	264	330	311
	Traditional CRADAs, Total Active	698	732	739	910	n.a.
	Other Collaborative R&D Relationships	0	0	0	0	n.a.
HHS	CRADAs, Total Active	532	400	590	588	577
	New CRADAs	98	112	134	112	87
	Traditional CRADAs, Total Active	378	202	391	462	465
	Other Collaborative R&D Relationships	154	150	147	126	112
DHS	CRADAs, Total Active	158	230	343	397	272
	New CRADAs	88	98	114	106	118
	Traditional CRADAs, Total Active	121	200	272	272	272
	Other Collaborative R&D Relationships	31	30	71	71	0
DOI	CRADAs, Total Active	601	826	873	841	740
	New CRADAs	423	586	511	477	422
	Traditional CRADAs, Total Active	35	38	37	58	53
	Other Collaborative R&D Relationships	292	318	319	247	249
DOT	CRADAs, Total Active	51	48	68	65	63
	New CRADAs	10	9	22	6	7
	Traditional CRADAs, Total Active	7	48	62	66	63
	Other Collaborative R&D Relationships	30	35	152	355	314
VA	CRADAs, Total Active	2,317	2,305	2,613	1,785	1,688
	New CRADAs	517	509	502	575	512
	Traditional CRADAs, Total Active	2,126	2,113	2,359	1,619	1,518
	Other Collaborative R&D Relationships	0	0	0	0	0
EPA	CRADAs, Total Active	129	97	55	51	49
	New CRADAs	35	23	14	8	11
	Traditional CRADAs, Total Active	52	50	55	51	49
	Other Collaborative R&D Relationships	0	0	48	89	91
NASA	CRADAs, Total Active	1	8	12	0	0
	New CRADAs	1	7	5	0	0
	Traditional CRADAs, Total Active	1	8	12	0	0
	Other Collaborative R&D Relationships	2,091	2,113	2,204	2,174	2,182

Total	Metric	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
	CRADAs, Total Active	10,355	10,090	11,118	10,919	12,967
	New CRADAs	4,203	4,943	5,027	4,961	5,248
	Traditional CRADAs, Total Active	6,666	6,187	6,773	6,605	6,146
	Other Collaborative R&D Relationships	11,723	10,748	12,172	12,939	11,780

Appendix B

Technology Area Classification
Mapping of International Patent Classifications to Technology Area[45]

Analysis of Biological Materials – Includes the investigation or analysis of specific methods not covered by other groups. Materials analyzed include food, water, metals, explosives, oils, paints, paper, textiles, concrete, resins, wood, and biological materials.

Audio-Visual Technology – Includes but is not limited to advertising, signs, labels or name-plates, seals, arrangements or circuits for control of indicating devices using static means to present variable information, scanning details of television systems, color television systems, still video cameras, loudspeakers, microphones, stereophonic systems, and printed circuits.

Basic Communication Processes – Includes but is not limited to generation of oscillations, modulation, amplifiers, control of amplification, impedance networks, tuning resonant circuits, pulse technique, and general coding, decoding, or code conversion.

Basic Materials Chemistry – Includes but is not limited to preservation of bodies of humans or animals or plants, nitrogenous fertilizers, explosive or thermic compositions, detonating or priming devices, means for generating smoke or mist, manufacture of matches, organic dyes, coating compositions, natural resins, preparation of glue, adhesives, drying or working-up or peat, cracking hydrocarbon oils, production of acetylene by wet methods, lubrication compositions, and detergent compositions.

Biotechnology – Includes but is not limited to compounds of unknown constitution, peptides, apparatus for enzymology or microbiology, micro-organisms or enzymes, fermentation or enzyme-using processes to synthesize a desired chemical compound or composition or to separate optical isomers from a racemic mixture, and measuring or testing processes involving enzymes or micro-organisms.

Chemical Engineering – Includes but is not limited to boiling, evaporating, sublimation, cold traps, crystallization, solvent extraction, displacing liquids, degasification of liquids, filters comprising of loose filtering material, cartridge filters of the throw-away type, processes of filtration, regeneration of the filtering material or filter elements outside the filter for liquid or gaseous fluids, separation of different isotopes of the same chemical element, chemical or physical laboratory apparatus for general use, spreading solid materials using liquids or using pneumatic tables or jigs, centrifuges, flotation, spraying apparatus, treating textile materials by liquids, bleaching, drying solid materials or objects by removing liquid therefrom, and plasma technique.

[45] Derived from The World Intellectual Property Organization's International Patent Classification (IPC) Correspondence Table and IPC Searchable Classification Database, version 2016.01.

Civil Engineering – Includes but is not limited to construction of roads, sports ground, platforms and refuge islands, landing stages for helicopters, machines for making railways, bridges, devices providing protection against weather, street cleaning, ship-lifting devices, foundations, excavations, embankments, dredging, water installation, sewers, water-closets or urinals with flushing devices, general building constructions, building materials, skylights, gutters, stairs, floors, locks, handcuffs, swimming pools, hinges for doors, windows, or wings, safes or strong-rooms for valuables, bank protection devices, ladders, earth or rock drilling, mining or quarrying, large underground chambers, and safety devices.

Computer Technology – Includes but is not limited to digital computers in which all the computation is affected mechanically, digital fluid-pressure computing devices, optical computing devices, electric digital data processing, analog computers, recognition of data, counting mechanisms, image data processing or generation, speech analysis or synthesis, speech recognition, and static stores.

Control – Includes but is not limited to systems for controlling or regulating non-electric variables, ticket-issuing apparatus, time or attendance registers, handling or coins or of paper currency or similar valuable papers, con-freed or like apparatus, signaling or calling systems, traffic control systems, educational or demonstration appliances, ciphering or deciphering apparatus for cryptographic or other purposes involving the need for secrecy, and railway or like time or fare tables.

Digital Communication – Includes but is not limited to transmission of digital information, selective content distribution, and wireless communication networks.

Electrical Machinery, Apparatus, Energy – Includes but is not limited to incandescent mantles, lighting devices or systems, nonportable lighting devices or systems, cables, conductors, insulators, magnets, inductances, transformers, capacitors, electric switches, electric discharge tubes or discharge lamps, electric incandescent lamps, spark gaps, emergency protective circuit arrangements, dynamo-electric machines, electric heating, static electricity, and generation of electric power by conversion of Infra-red radiation, visible light, or ultraviolet light.

Engines, Pumps, Turbines – Includes but is not limited to steam engines, rotary-piston or oscillating-piston machines or engines, steam engine plants, cyclically operating valves for machines or engines, lubricating of machines or engines in general, cooling of machines or engines in general, internal-combustion piston engines, gas-turbine plants, jet-propulsion plants, starting of combustion engines, machines or engines for liquids, wind motors, positive- and non-positive displacement pumps, generating combustion products of high pressure or high velocity, fusion reactors, nuclear reactors, nuclear power plant, conversion of chemical elements, obtaining energy from radioactive sources, and nuclear explosives.

Environmental Technology – Includes but is not limited to fire-fighting, separating dispersed particles from gases, combinations of devices for separating particles from gases or vapors, disposal of solid waste, reclamation of contaminated soil, gathering or removal of domestic or like refuse, water treatment, cremation furnaces, and measurement of nuclear or x-radiation.

Food Chemistry – Includes but is not limited to new plants or processes for obtaining them, treatment of flour or dough for baking, preserving by canning, dairy products, edible oils or pats, coffee, tea, cocoa, coca products, protein compositions for foodstuffs, feeding-stuffs specially adapted for animals, brewing of beer, recovery of by-products of fermented solutions, wine, preparation of vinegar, production of sugar juices, extraction of sucrose from molasses, and drying sugar.

Furniture, Games – Includes but is not limited to tables, desks, office furniture, chairs, child furniture, special furniture, household or table equipment, furnishings for windows or doors, kitchen equipment, sanitary equipment, toilet accessories, domestic washing or cleaning, apparatus for physical training, design or layout of courts, bowling games, card games, indoor games, merry-go-rounds, swings, toys, devices for theaters and circuses, racing and riding sports equipment and accessories.

Handling – Includes but is not limited to labeling or tagging machines, containers for storage or transport of articles of materials, transport or storage devices, handling thick or filamentary material, elevators, escalators, moving walkways, cranes, capstans, winches, tackles, pulley blocks, hoists, applying closure members to bottles, and filling or emptying of bottles, jars, cans, casks, barrels, or similar containers.

IT Methods for Management – Includes data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory, or forecasting purposes.

Machine Tools – Includes but is not limited to chemical means for extinguishing fires, rolling of metal, working or processing of metal wire, making forged or pressed metal products, making metal chains, making gears or toothed racks, thread cutting, soldering, welding, abrasive or related blasting with particulate material, tools for grinding, hand-held nailing or stapling tools, handles for hand implements, workshop equipment, saws for wood or similar material, working veneer or plywood, dovetailed work, removing bark or vestiges of branches, and accessory machines or apparatus for working wood or similar materials.

Macromolecular Chemistry, Polymers – Includes but is not limited to polysaccharides, treatment or chemical modification of rubbers, derivatives of natural macromolecular compounds, use of inorganic or non-macromolecular organic substances as compounding ingredients, and compositions of macromolecular compounds.

Materials, Metallurgy – Includes but is not limited to foundry molding, casting of metals, working metallic powder, non-metallic elements, ammonia compounds, cyanogen compounds, compounds of alkali metals, chemical composition of glasses, manufacture of iron or steel, processing of pig-iron, production or refining of metals, alloys, and changing the physical structure of non-ferrous metals or non-ferrous alloys.

Measurement – Includes but is not limited to measuring linear dimensions, measuring distances, surveying, navigation, gyroscopic instruments, measuring volume, weighing, measurement of mechanical vibrations, measurement of intensity or velocity, measuring temperature or quantity of heat, measuring force, testing static or dynamic balance of machines or structures, sampling,

investigating strength properties of solid materials by application of mechanical stress, investigating density or specific gravity of materials, investigating flow properties of materials, investigating or analyzing materials by use of optical or thermal means, and investigating or analyzing materials by the use of nuclear magnetic resonance, electron paramagnetic resonance or other spin effects.

Mechanical Elements – Includes but is not limited to fluid-pressure actuators, fluid dynamics, devices for fastening or securing constructional elements or machine parts, shafts, couplings for transmitting rotation, springs, means for damping vibration, belts, cables, ropes, chains, fittings, gearing, pistons, cylinders, pressure vessels, valves, devices for venting or aerating, pipes, frames, casing, lubricating, safety devices in general, steam traps, gas-holders of variable capacity, vessels for containing or storing compressed gases, pipe-line systems, and control devices or systems insofar as characterized by mechanical features.

Medical Technology – Includes but is not limited to diagnosis, surgery, identification, dentistry, veterinary instruments, filters implantable into blood vessels, physical therapy apparatus, containers specially adapted for medical or pharmaceutical purposes, methods or apparatus for sterilizing materials, devices for introducing media into or onto the body, electrotherapy, radiation therapy, ultrasound therapy, and x-ray technique.

Micro-Structural and Nano-Technology –Includes but is not limited to micro-structural devices or systems, processes or apparatus specially adapted for the manufacture or treatment of micro-structural devices or systems, specific uses or applications of nano-structures, and nano-structures formed by manipulation of individual atoms, molecules, or limited collections of atoms or molecules as discrete units.

Optics – Includes but is not limited to optical elements, spectacles, apparatus or arrangements for taking photographs, photosensitive materials for photographic purposes, apparatus for processing exposed photographic materials, photomechanical production of textured or patterned surfaces, electrography, devices used to stimulate emission, and holographic processes or apparatus.

Organic Fine Chemistry – Includes but is not limited to cosmetics or similar toilet preparations, general methods of organic chemistry, acyclic or carbocyclic compounds, heterocyclic compounds, steroids, derivatives or sugars, nucleosides, nucleic acids, and combinatorial chemistry.

Other Consumer Goods – Includes but is not limited to machines for making cigars, smoke filters, match boxes, shirts, corsets, outerwear, suspenders, artificial flowers, wigs, masks, feathers, hats and head coverings, characteristic features of footwear, buttons, pins, buckles, jewelry, coins, walking sticks, umbrellas, purses, luggage, hairdressing or shaving equipment, apparatus or methods for life-saving, bookbinding, filing appliances, implements for writing or drawing, apparatus or tools for artistic work, saddles, stirrups, upholstering methods, ropes or cables in general, musical instruments with associated blowing apparatus, and methods or devices for protecting against, or for damping, noise or other acoustic waves in general.

Other Special Machines – Includes but is not limited to soil working in agriculture or forestry, planting, sowing, fertilizing, harvesting, mowing, threshing, cultivation of vegetables, manufacture of dairy products, animal husbandry, shoeing of animals, machines or equipment for making, slaughtering, processing meat, machines or apparatus for treating harvested fruit, preparing grain for milling, shaping clay or other ceramic compositions, working stone or stone-like materials, shaping or joining of plastics, additive manufacturing, manufacturing or shaping of glass, sugar extraction, weapons for projecting missiles without the use of explosive or combustible propellant charge, small arms, apparatus for launching projectiles or missiles from barrels, weapon sights, targets, explosive charges, blasting, and ammunition fuses.

Pharmaceuticals – Includes but is not limited to preparations for dentistry, medicinal preparations characterized by special physical form, medicinal preparations containing organic and inorganic active ingredients, medicinal preparations containing peptides, preparations for testing in vivo, electrically conductive preparations for use in therapy or testing in vivo, radioactive non-metals and metals, specific therapeutic activity of chemical compounds or medicinal preparations, and containing or obtained from roots, bulbs, leaves, bark, seeds, grains, flowers, stems, branches, or twigs.

Semiconductors – Includes semiconductor devices and electric solid-state devices not otherwise provided.

Surface Technology, Coating – Includes but is not limited to apparatus and processes for applying liquids or other fluent materials to surfaces, layered products, coating metallic material, enameling of metals, nonmechanical removal of metallic material from surfaces, cleaning or de-greasing of metallic material by chemical methods other than electrolysis, and single-crystal growth.

Telecommunications – Includes but is not limited to transmission systems for measured values, waveguides, resonators, aerials, transmission, broadcast communication, multiplex communication, secret communication, jamming of communication, telephonic communication, and scanning, transmitting, or reproducing documents.

Textile and Paper Machines – Includes but is not limited to appliances or methods for making clothes, manufacture of brushes, making articles of paper or cardboard, processes for the manufacture or reproduction of printing surfaces, typewriters, stamps, printing plates or foils, mechanical treatment of processing of leather in general, preliminary treatment of fibers, spinning or twisting, crimping or curling fibers, shedding mechanisms, auxiliary weaving apparatus, knitting, braiding or manufacturing of lace, sewing, embroidering, mechanical or pressure cleaning of carpets, decorating textiles, and paper-making machines.

Thermal Processes and Apparatus – Includes but is not limited to methods of steam generation, superheating of steam, methods or apparatus for combustion using fluid or solid fuel, burners, grates, feeding fuel to combustion apparatus, regulating or controlling combustion, ignition, domestic stoves or ranges, air-conditioning, fluid heaters, ice production, steam or vapor condensers, other heat exchange apparatus, and cleaning of internal or external surfaces of heat-exchange or heat-transfer conduits.

Transport – Includes but is not limited to vehicle wheels, vehicle tires, vehicle suspension arrangements, windows, windscreens, arrangement or mounting of propulsion units or of transmissions in vehicles, propulsion of electrically-propelled vehicles, power supply lines or devices along rails for electrically-propelled vehicles, vehicles adapted for load transportation, arrangement of signaling or lighting devices, vehicle brake control systems, air-cushion vehicles, locomotives, body details or kinds of railway vehicles, rail vehicle suspensions, shifting or shunting of rail vehicles, guiding railway traffic, hand-propelled vehicles, vehicles drawn by animals, trailers, cycle stands, cycle saddles or seats, brakes specially adapted for cycles, rider propulsion of wheeled vehicles or sledges, ships or other waterborne vessels, offensive or defensive arrangements on vessels, marine propulsion or steering, auxiliaries on vessels, lighter-than-air aircraft, airplanes, helicopters, equipment for fitting in or to aircraft, flying suites, parachutes, and cosmonautics.

Appendix C

Fields and Subfields of S&E Publications Data[46]

Agricultural Sciences – dairy animal sciences, agricultural and food sciences

Astronomy – astronomy

Biological Sciences – general biomedical research, miscellaneous biomedical research, biophysics, botany, anatomy and morphology, cell biology, cytology, and histology, ecology, entomology, immunology, microbiology, nutrition and dietetics, parasitology, genetics and heredity, pathology, pharmacology, physiology, general zoology, miscellaneous zoology, general biology, miscellaneous biology, biochemistry and molecular biology, virology

Chemistry – analytical chemistry, organic chemistry, physical chemistry, polymers, general chemistry, applied chemistry, inorganic and nuclear chemistry

Computer Sciences – Computer Sciences

Engineering – aerospace engineering, chemical engineering, civil engineering, electrical engineering, mechanical engineering, metals and metallurgy, materials engineering, industrial engineering, operations research and management, biomedical engineering, nuclear technology, general engineering, miscellaneous engineering and technology

Geosciences – meteorology and atmospheric sciences, geology, earth and planetary sciences, oceanography and limnology, marine biology and hydrobiology, environmental sciences

Mathematics – applied mathematics, probability and statistics, general mathematics, miscellaneous mathematics

Medical Sciences – endocrinology, neurology and neurosurgery, dentistry, environmental and occupational health, public health, surgery, general and internal medicine, ophthalmology, pharmacy, veterinary medicine, miscellaneous clinical medicine, anesthesiology, cardiovascular system, cancer, gastroenterology, hematology, obstetrics and gynecology, otorhinolaryngology, pediatrics, psychiatry, radiology and nuclear medicine, dermatology and venereal disease, orthopedics, arthritis and rheumatism, respiratory system, urology, nephrology, allergy, fertility, geriatrics, embryology, tropical medicine, addictive diseases, microscopy

Other Life Sciences – speech/language pathology and audiology, nursing, rehabilitation, health policy and services

[46] Sources: SRI International; Science-Metrix; National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR) database system. Science and Engineering Indicators 2016, Appendix Table 5-24. Used with permission.

Psychology – clinical psychology, behavioral and comparative psychology, developmental and child psychology, experimental psychology, human factors, social psychology, general psychology, miscellaneous psychology, psychoanalysis

Physics – acoustics, chemical physics, nuclear and particle physics, optics, solid state physics, applied physics, fluids and plasmas, general physics, miscellaneous physics

Social Sciences – economics, international relations, political science and public administration, demography, sociology, anthropology and archaeology, area studies, criminology, geography and regional sciences, planning and urban studies, general social sciences, miscellaneous social sciences, science studies, gerontology and aging, social studies of medicine