Annual Report on Technology Transfer: Approach and Plans, Fiscal Year 2019 Activities and Achievements

U.S. Department of Commerce

Report prepared by:

National Institute of Standards and Technology
National Oceanic and Atmospheric Administration
National Telecommunications and Information Administration
Institute for Telecommunication Sciences

Pursuant to the
Technology Transfer Commercialization Act of 2000 (P.L. 106-404)

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FOREWORD

This report summarizes technology transfer activities and achievements of the Department of Commerce's (DOC) federal laboratories for fiscal year (FY) 2019. At DOC, technology transfer is a significant part of the mission and programmatic activities of the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA), and the National Telecommunications and Information Administration's (NTIA) Institute for Telecommunication Sciences (ITS). Accordingly, this report focuses on the activities of these agencies.

This report has been prepared as required by 15 U.S.C. § 3710(f). All federal agencies that operate or direct one or more federal laboratories or conduct other activities under 35 U.S.C. §§ 207 and 209 are subject to the requirements of this statute.

DOC's overall and laboratory-specific approaches and its plans for technology transfer are summarized in this report. The report focuses on current year activities and accomplishments, and provides statistical information from FY 2015 through FY 2019.

NIST, NOAA, and NTIA's ITS technology transfer offices have contributed to the organization and preparation of the material reported. An electronic version of this report and versions from previous fiscal years are available online at: https://www.nist.gov/tpo/department-commerce.

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CHAPTER 1
Department of Commerce Overview

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. 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. 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 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 American economy.

DOC is also responsible for organizing technology transfer activities across federal agencies. DOC coordinates the Interagency Work Group for Technology Transfer (IAWGTT) through NIST interagency discussion on policy, new approaches to technology transfer, and lessons learned from agency transfer programs.[1] NIST also serves as the host agency for the Federal 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: http://www.nist.gov/tpo/index.cfm
NOAA: http://techpartnerships.noaa.gov/
ITS: http://www.its.bldrdoc.gov.

[1] 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.

Summary of Technology Transfer Activities FY 2015 – FY 2019

This annual report provides comprehensive statistics on technology transfer activities of DOC laboratories, including information regarding invention disclosures, intellectual property (i.e., patents and licenses), collaborative research and development agreements (CRADAs), and other technology transfer mechanisms. Examples of successful downstream results, such as commercially significant technologies from technology transfer activities, are also highlighted.

Section 10 of the Technology Transfer Commercialization Act of 2000 (P.L. 106-404, codified at 15 U.S.C. § 3710(f)) requires each federal agency that operates or directs one or more federal laboratories or conducts activities under 35 U.S.C. §§ 207 and 209 to report annually to the Office of Management and Budget (OMB) on the agency's technology transfer activities. The OMB's Circular A-11 also requires this information. The tables in the following sections present the required data.[2]

[2] Technology transfer data is typically adjusted over time to account for new information resulting from changes in reporting procedures, patent decisions, programmatic changes, etc. Throughout this report, data prior to FY 2019 has been adjusted, where necessary, to reflect the most accurate estimates for each year reported.

Invention Disclosures and Patenting

In FY 2019, DOC researchers disclosed 60 new inventions. Of these, 54 invention disclosures were from NIST researchers and 6 were from NOAA researchers. There were 65 patent applications filed (63 for NIST and 2 for NOAA). NIST received 32 patents and NOAA received 1 patent.[3]

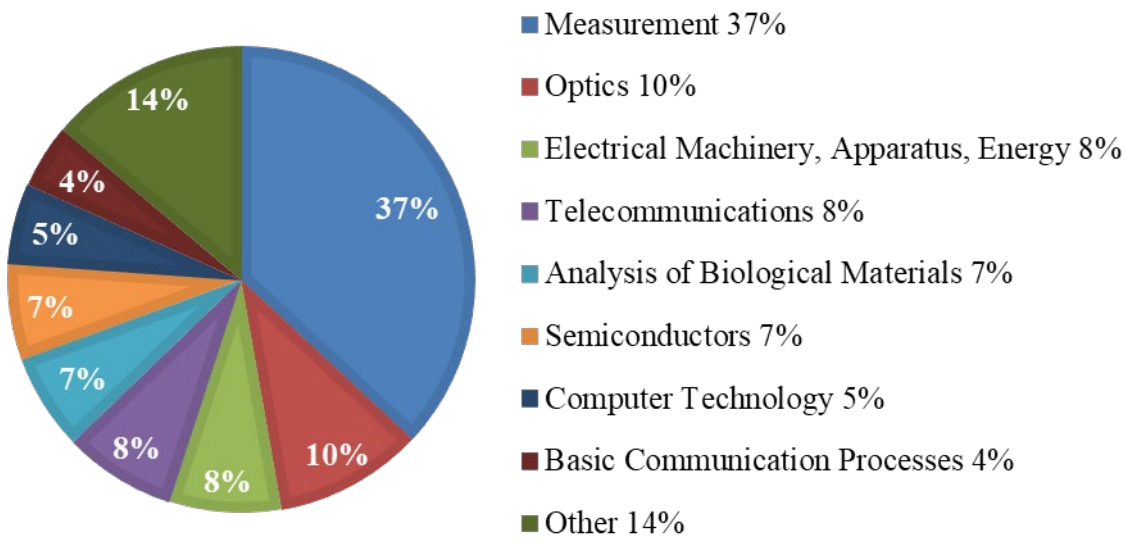
Table 1 – DOC Invention Disclosure and Patenting

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Invention Disclosures					
NIST	46	46	40	71	54
NOAA	15	18	3	6	6
ITS	0	0	0	0	0
Department Total	61	64	43	77	60
Patent Applications Filed					
NIST	26	21	43	54	63
NOAA	6	4	3	2	2
ITS	0	0	0	0	0
Department Total	32	25	46	56	65
Patents Issued					
NIST	19	15	31	28	32
NOAA	1	1	3	0	1
ITS	0	0	0	0	0
Department Total	20	16	34	28	33

[3] Note that the time required for a patent to be granted may be two years or more. Patents issued in FY 2019 were filed in prior years.

In FY 2018 (the most recent year data is available), the top three technical areas covered by DOC patents were Measurement (37%), Optics (10%), and Electrical Machinery, Apparatus, Energy (8%).[4]

Figure 1 – Percent of USPTO Patents Granted to DOC, by Technology Area – FY 2018[5]



Licensing

In FY 2019, DOC reported 74 active patent licenses (68 for NIST and 6 for NOAA).

Table 2 – Profile of DOC Active Licenses

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Active Patent Licenses[(a)]					
NIST	40	50	61	60	68
NOAA	6	7	7	7	6
ITS	0	0	0	0	0
Department Total	46	57	68	67	74

(a) "Active" means an agreement in effect at any time during the fiscal year.

Data revealed that 33 of those active patent licenses were income-bearing. The income-bearing licenses comprised of 20 exclusive licenses, 12 non-exclusive licenses and one custody transfer agreement.

[4] Technology areas are identified in Appendix A.

[5] Patents are credited on a whole-count basis (i.e., each participating federal agency is credited one count). However, fractioning is used at the level of 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. Prepared by Science-Metrix using USPTO data indexed in PatentsView accessed in June 2019. Used with permission.

Table 3 – Characteristics of DOC Income-Bearing Licenses

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Income-Bearing Licenses					
NIST	25	26	28	30	27
NOAA	4	5	7	7	6
ITS	0	0	0	0	0
Department Total	29	31	35	37	33
Patent Licenses					
NIST	25	26	28	30	27
NOAA	4	7	7	7	6
ITS	0	0	0	0	0
Department Total	29	33	35	37	33
License Types					
Exclusive					
NIST	15	16	15	18	16
NOAA	1	4	4	4	4
ITS	0	0	0	0	0
Department Total	16	20	19	22	20
Partially Exclusive					
Department Total	0	0	0	0	0
Non-Exclusive					
NIST	8	8	11	10	10
NOAA	3	3	3	3	2
ITS	0	0	0	0	0
Department Total	11	11	14	13	12
Assignment					
NIST	1	1	1	1	0
Custody Transfer					
NIST	1	1	1	1	1

In FY 2019, DOC's income-bearing licenses provided $136,205 in income. Of this amount, $68,970 came from NIST licenses and $67,235 came from NOAA licenses.

Table 4 – Income from DOC Licensing

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Licensing Income					
NIST	$124,823	$137,662	$75,061	$111,743	$68,970
NOAA	$39,633	$11,000	$65,810	$35,671	$67,235
ITS	$0	$0	$0	$0	$0
Department Total	$164,456	$148,662	$140,871	$147,414	$136,205

Collaborative Relationships for Research and Development (CRADAs)

In FY 2019, there were 2,564 CRADAs involving DOC researchers. There were 493 traditional CRADAs[6] and 2,071 non-traditional CRADAs active during the year.[7] Of the 493 traditional CRADAs, NIST was involved in 434, NOAA was involved in 42, and ITS was involved in 17.

Table 5 – DOC Collaborative Relationships for Research and Development

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
CRADAs					
Department Total	2,670	2,940	2,933	3,363	2,564
Traditional CRADAs					
NIST	329	294	370	476	434
NOAA	28	33	36	43	42
ITS	54	62	60	68	17
Department Total[(a)]	283	335	414	534	493
Joint CRADA Agreements (NIST and ITS)	128	54	52	53	0
Non-Traditional CRADAs					
NIST	2,387	2,605	2,519	2,827	2,070
NOAA	0	0	0	2	1
ITS	0	0	0	0	0
Department Total	2,387	2,605	2,519	2,829	2,071

(a) The total number of traditional CRADAs for the Department has been adjusted to avoid double counting where NIST and ITS are involved together in Joint CRADA Agreements for FY 2015 through FY 2018.

[6] Traditional CRADAs involve collaborative research and development projects by a federal laboratory and non-federal partners.

[7] Non-traditional CRADAs involve laboratory accreditations, material transfer agreements, and calibration services.

Trends in DOC Technology Transfer Activities

One of the reasons for reporting technology transfer metrics is to monitor trends over time. Unfortunately, it is not always possible to identify and compare trends by simply looking at changes in values from one year to the next. Technology transfer activities are not spontaneous events. Inventions typically require years, if not decades, of research before they are disclosed. A review of a patent application may take roughly three to five years before the patent is awarded. It may take several years to license a patent or form the collaborative commitments behind a CRADA.

To assess the trends in key technology transfer metrics, we first convert annual metric values into index values and then plot trend lines using these index values. Index values are calculated by dividing the value of a metric in a given year (year "t") by its value in a base year (year "i"), and then multiplying by 100.

$$Index\ Value_t = \frac{Value_t}{Base\ Value_i} \times 100$$

The fixed base year chosen for this report is FY 2015. The index value for each metric in the base year is equal to 100. In the years that follow, index values change as the value of the metric in year "t" changes while the value in the base year "i" remains the same.

To calculate the index value for patents issued in FY 2016, we divide the number of patents issued in FY 2016 by the number of patents issued in the base year (FY 2015) and then multiply by 100. Using data from the table on Page 3 of this report, the index value for patents issued in FY 2016 is 80.

$$Index\ Value_{FY2016} = \frac{16}{20} \times 100 = 80$$

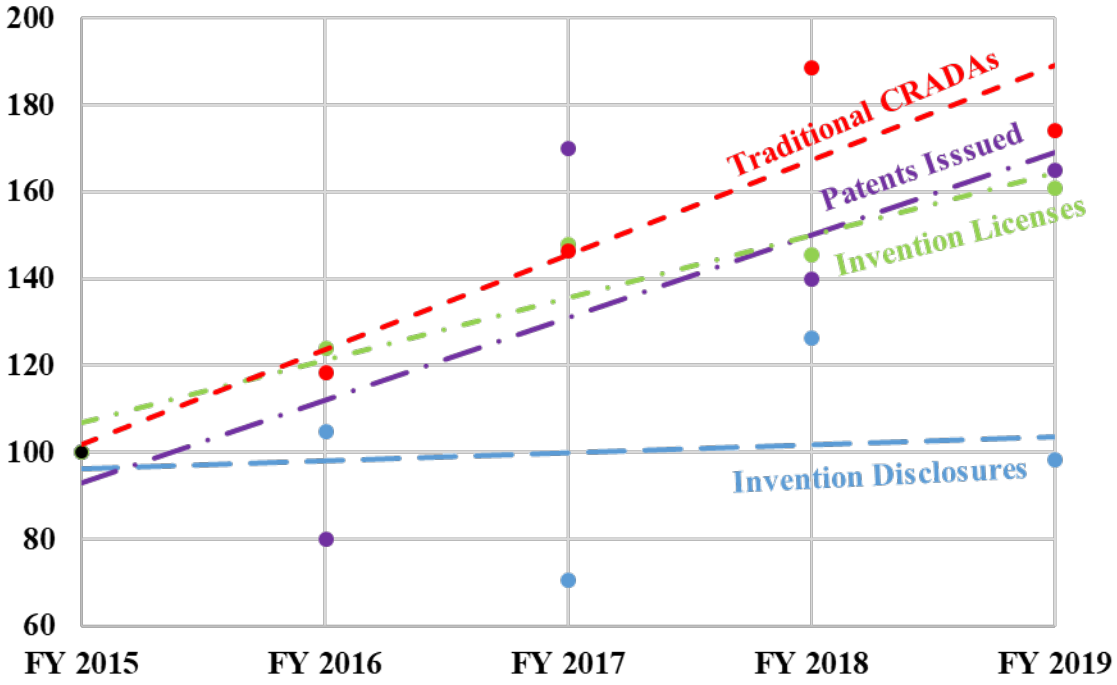
Because the index value of 80 is less than 100, we can interpret this as a 20% decrease in the number of patents issued between FY 2015 and FY 2016. In FY 2017, the index value for patents issued is 170, which we can interpret as a 70% increase between FY 2015 and FY 2017.

We calculated index values for key metrics (e.g., invention disclosures, patents issued, invention licenses, and CRADAs) and plotted the values in the chart below. To show the trend for a given metric, we plot a straight line in the middle of the plotted values for that metric.[8] In the chart below, index values for patents issued are plotted in purple and the trend line for patents issued is plotted in the middle of the purple points. It is important to note that each trend line is drawn independent of other measures. They do not suggest causal relationships, nor do they forecast future trends. A trend line is a simple tool that illustrates the general tendency of a measure over a given period of time.

Trend lines are plotted for invention disclosures (blue), patents issued (purple), invention licenses (green), and traditional CRADAs (red). From this chart, we can see that since FY 2015, there has been an increase in DOC's basic technology transfer activities with patents issued increasing 65%, active invention licenses increasing 61%, and traditional CRADAs increasing 74%. Invention disclosures remained fairly stable, with a 2% decrease over the five-year period.

[8] Trend lines in this report are plotted using Microsoft Excel.

Figure 2 – Trends in DOC's Technology Transfer Activities (FY 2015 – FY 2019)



Scientific and Technical Publications

Technology transfer mechanisms include more than just counting CRADAs, patents, and licenses.[9] Scientific and technical publications are also technology transfer. In FY 2019, NIST, NOAA, and ITS researchers published 3,302 scientific and technical papers in peer-reviewed journals.

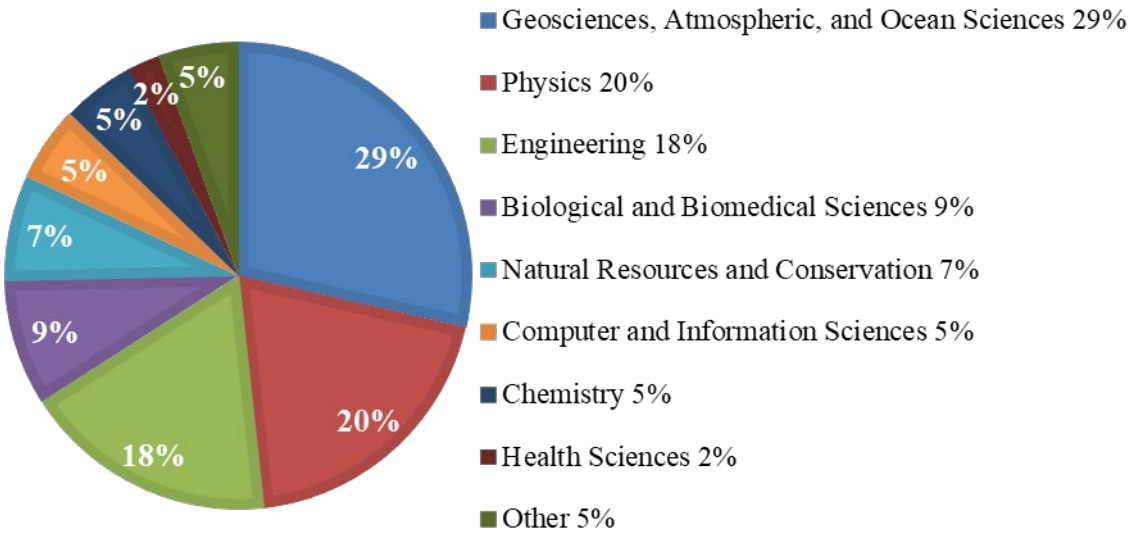
Table 6 – DOC Scientific and Technical Publications

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Technical Publications					
NIST	1,323	1,355	1,433	1,415	1,396
NOAA	1,860	1,697	1,678	1,794	1,895
ITS	22	4	10	11	11
Department Total	3,205	3,056	3,121	3,220	3,302

[9] http://www.nist.gov/tpo/publications/upload/DOC-Tech-Transfer-Plan.pdf

In calendar year (CY) 2018 (the most recent year for which data are available), the most frequent technology areas covered by DOC publications are Geosciences, Atmospheric, and Ocean Sciences (29%), followed by Physics (20%) and Engineering (18%).[10]

Figure 3 – Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2018[11]

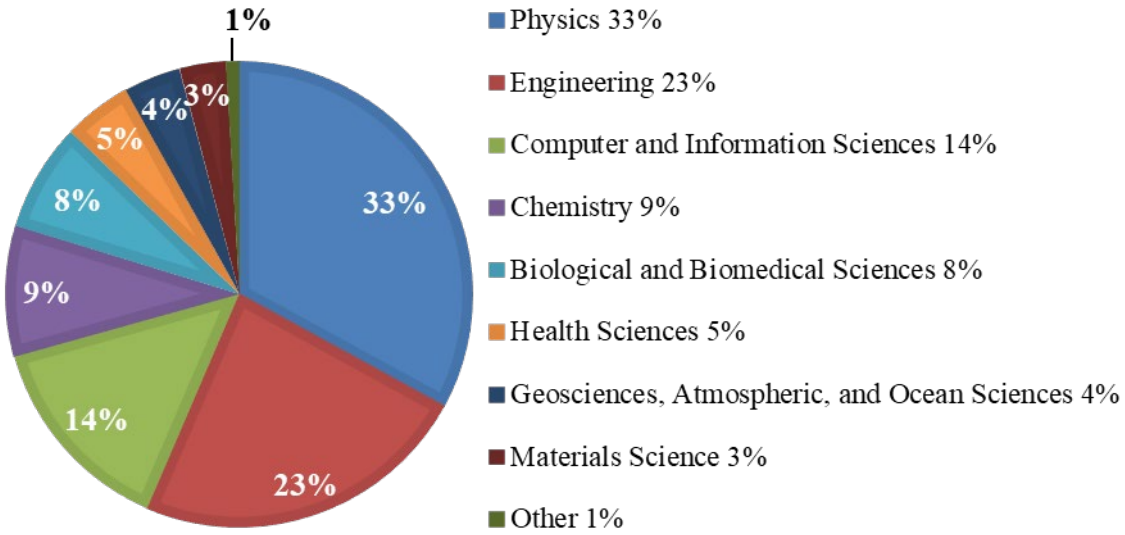


[10] Appendix B identifies science and engineering fields.

[11] Data are presented by calendar year as months of publication are not always available in Scopus. Taxonomy of Discipline (TOD) fields are used to classify articles. The TOD is a classification scheme developed by the National Science Foundation to suit its need for a unified scheme. Science-Metrix developed an alignment of its own classification scheme with the TOD and this alignment replaces the WebCaspar classification which was used in the past to produce bibliometric data for the Science & Engineering Indicators (SEI) reports. Journals are assigned to a unique TOD except for generalist journals, such as Science and Nature, for which articles are instead reclassified individually in TOD fields using an automated procedure based on machine-learning techniques. Articles are credited on a whole-count basis (i.e., each participating federal agency receives one count). Source: Prepared by Science-Metrix using Scopus (Elsevier) accessed in June 2019. Used with permission.

Data are also available on the number of times U.S. patents cite U.S. science and engineering articles authored by DOC staff. U.S. patents issued in FY 2018 cite 1,307 publications authored by DOC researchers. As shown in Figure 4, the largest technology areas citing DOC publications include Physics (33%), followed by Engineering (23%) and Computer and Information Sciences (14%).[12]

Figure 4 – Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2018[13]



The following chapters provide details on other agency-specific technology transfer activities, such as technical support for development of industrial standards and reference materials, public dissemination activities (meetings and workshops), collaborations with guest researchers, etc.

[12] Appendix B identifies science and engineering fields.

[13] Taxonomy of Discipline (TOD) fields are used to classify articles. The TOD is a classification scheme developed by the National Science Foundation to suit its need for a unified scheme. Science-Metrix developed an alignment of its own classification scheme with the TOD and this alignment replaces the WebCaspar classification which was used in the past to produce bibliometric data for the Science & Engineering Indicators (SEI) reports. Journals are assigned to a unique TOD except for generalist journals, such as Science and Nature, for which articles are instead reclassified individually in TOD fields using an automated procedure based on machine-learning techniques. Citations are classified on a whole count basis (i.e., each participating federal agency on a cited article receives one count). Citation counts are based on an 11-year window with a 5-year lag (e.g., citations for 2012 are references in USPTO patents issued in FY 2012 to articles published in 1997–2007). Prepared by Science-Metrix using Scopus (Elsevier) accessed in June 2019 and PatentsView accessed in June 2019. Used with permission.

CHAPTER 2
National Institute of Standards and Technology

NIST has a broad mission: to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

Rapidly evolving sectors like nanotechnology, biotechnology, homeland security, information technology, and advanced manufacturing need sophisticated technical support systems in order to flourish and grow. Therefore, an important part of accomplishing NIST's mission is to anticipate future measurement and standards needs of U.S. industry. NIST laboratories develop measurement techniques, test methods, standards, reference materials, reference data, and other technologies and services that support U.S. industry, scientific research, and the activities of many other federal agencies. In carrying out its mission, NIST works directly with industry partners (individual companies and consortia), universities, standards organizations, other domestic and foreign associations, and other government agencies.

Approach and Plans for Technology Transfer

NIST designs its technology transfer activities to disseminate the results of fundamental research, measurements, and standards research to industry and other interested parties. In order to provide leading-edge scientific and technical work, NIST is required to have expertise in multiple disciplines, maintain high levels of collaboration with organizations and people with diverse capabilities, and have highly specialized facilities and tools. For more than a century, laboratories at NIST (and its direct predecessor agency, the National Bureau of Standards) have successfully collaborated with others to provide the measurement techniques and technical tools needed by America's innovators.[14]

NIST broadly defines technology transfer as:

> ***"… the overall process by which NIST knowledge, facilities, or capabilities in measurement science, standards and technology promote U.S. innovation and industrial competitiveness in order to enhance economic security and improve quality of life."***

NIST's definition of technology transfer reflects the many ways NIST reaches its external partners. The definition includes, *inter alia*: 1) the act of transferring knowledge from one individual to another by means of mentoring, training, documenting, or collaborating; and 2) commercialization, which allows the adoption of a technology into the private sector through a business or other organization.

NIST has designed its technology transfer program to improve processes and work products directly through collaborations. The following summarizes different technology transfer mechanisms NIST uses to promote innovation and to disseminate technologies that result from its research.

[14] Additional details on NIST's technology transfer program are available at http://www.nist.gov/tpo/index.cfm.

NIST Work Products and Collaborative Activities
NIST actively seeks to identify commercially valuable inventions that result from its research. NIST will generally seek patent protection when a patent: (1) enhances the potential for an invention's commercialization; (2) has a positive impact on a new field of science or technology and/or the visibility and vitality of NIST; (3) furthers the goals of a CRADA or other agreement; (4) furthers U.S. manufacturing; or (5) could lead to a commercialization license.

Chapter 1 of this report presented summary information on patenting and licensing. We include additional details on NIST's licensing activities below.

NIST research led to inventions in the following areas: bioscience and health, building and fire research, chemistry, math, physics, electronics and telecommunications, energy, environment and climate, information technology, manufacturing, materials science, nanotechnology, public safety and security, and transportation.

In FY 2019, there were 68 active NIST patent licenses of which 15 were issued in FY 2019. Of these 68 active licenses, 37 licenses were issued to small companies (i.e., companies with fewer than 500 employees). In FY 2019, a lack of Federal appropriations closed NIST's technology transfer office for 35 days. During this time, technology transfer did not occur. This shutdown may explain the decrease in technology transfer activity for this fiscal year.

Table 7 – Profile of NIST Active Licenses

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Number of Active Licenses[(a)]	40	50	61	60	68
New Licenses Executed	11	12	19	11	15
Total Invention Licenses Active	40	50	61	60	68
New Invention Licenses Executed	11	12	19	11	15
Total Patent Licenses Active[(b)]	40	50	61	60	68
New Patent Licenses Executed	11	12	19	11	15
Total Material Transfer Licenses Active (Inventions)	0	0	0	0	1
New Material Transfer Licenses (Inventions)	0	0	0	0	1
Total Material Transfer Licenses Active (Non-Inventions)	0	0	0	0	0
New Material Transfer Licenses Executed (Non-Inventions)	0	0	0	0	0
Total "Other Invention Licenses" Active	0	0	0	0	0
New "Other Invention Licenses" Executed	0	0	0	0	0
Total "Other IP Licenses" Active	0	0	0	0	0
New "Other IP Licenses" Executed	0	0	0	0	0
Copyright Licenses (Fee-Bearing) Active	0	0	0	0	0
New Copyright Licenses Executed	0	0	0	0	0
Active NIST Licenses Issued to Small Companies	4	14	19	23	37

(a) "Active" means an agreement in force at any time during the fiscal year.
(b) Patent licenses include licenses to pending patent applications.

In FY 2019, the average time to negotiate a patent license was 1 month. The minimum time to negotiate a license was 3 days (0.1 month), and the maximum time was 2 months. Overall, this represents, on average, an 85% decrease in the time required to negotiate a license since FY 2015.

Table 8 – NIST Licensing Management

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
License Negotiation Time (Patent Licenses) [(a)(b)]					
Average (months)	7.0	5.0	4.0	2.0	1.0
Minimum (months)	0.2	1.0	2.0	0.3	0.1
Maximum (months)	38.7	14.0	6.0	4.0	2.0
Licenses Terminated for Cause					
Invention Licenses (Patent Licenses)	0	0	0	0	0

(a) License Negotiation Time is defined as the time between the date of license application and the date of license execution. The date of license application is the date the laboratory formally acknowledges the written request for a license from a prospective licensee and agrees to enter into negotiations.

(b) Patent licenses include licenses to pending patent applications.

Licensing income comes from a variety of sources: license issue fees, earned royalties, minimum annual royalties, paid-up license fees, reimbursement for full-cost recovery of goods, and services provided by the laboratory to the licensee, including patent costs. Of the 68 active licenses that existed in FY 2019, 27 were income bearing. This included 16 exclusive licenses, 10 non-exclusive licenses, and one custody transfer.

Table 9 – Characteristics of NIST Licenses Bearing Income

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Income Bearing Licenses	25	26	28	30	27
Exclusive	15	16	15	18	16
Partially Exclusive	0	0	0	0	0
Non-Exclusive	8	8	11	10	10
Total Other Income Bearing IP Licenses					
Assignment	1	1	1	1	0
Custody Transfer	1	1	1	1	1
Total Income Bearing Invention Licenses	25	26	28	30	27
Exclusive	15	16	15	18	16
Partially Exclusive	0	0	0	0	0
Non-Exclusive	8	8	11	10	10
Total Other Income Bearing IP Licenses					
Assignment	1	1	1	1	0
Custody Transfer	1	1	1	1	1
Total Royalty Bearing Licenses	25	26	28	30	27
Royalty Bearing Invention Licenses	25	26	28	30	27
Royalty Bearing Patent Licenses	25	26	28	30	27
Other Royalty Bearing IP Licenses	0	0	0	0	0

In FY 2019, NIST received $68,970 from all active licenses. This is a 38% decrease from the prior year. The median amount received was $4,296. The minimum amount received was $1,000 and maximum was $20,000.

Table 10 – Income from NIST Licenses

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Income, All Active Licenses[(a)]	$124,823	$137,662	$75,061	$111,743	$68,970
Invention Licenses (Patent Licenses)[(b)]	$124,823	$137,662	$75,061	$111,743	$68,970
Other IP Licenses, Total Active	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)[(c)]	$124,823	$137,662	$75,061	$111,743	$68,970
Median ERI	$1,600	$5,295	$2,679	$3,892	$4,296
Minimum ERI	$640	$62	$320	$209	$1,000
Maximum ERI	$62,833	$40,000	$40,000	$40,000	$20,000
ERI from Top 1% of Licenses	n.a.	n.a.	n.a.	n.a.	n.a.
ERI from Top 5% of Licenses	n.a.	n.a.	n.a.	n.a.	n.a.
ERI from Top 20% of Licenses	n.a.	n.a.	n.a.	n.a.	n.a.
Invention Licenses (Patent Licenses)	$124,823	$137,662	$75,061	$111,743	$68,970
Median ERI	$1,600	$5,296	$2,679	$3,892	$4,296
Minimum ERI	$640	$62	$320	$209	$1,000
Maximum ERI	$62,833	$40,000	$40,000	$40,000	$20,000
ERI from Top 1% of Licenses	n.a.	n.a.	n.a.	n.a.	n.a.
ERI from Top 5% of Licenses	n.a.	n.a.	n.a.	n.a.	n.a.
ERI from Top 20% of Licenses	n.a.	n.a.	n.a.	n.a.	n.a.
Other IP Licenses, Total Active	$0	$0	$0	$0	$0

n.a. = not available. Data withheld to protect proprietary information.

(a) Total income includes license issue fees, earned royalties, minimum annual royalties, paid-up license fees, reimbursement for full-cost recovery of goods and services provided by the laboratory to the licensee including patent costs and Standard Reference Data. "Active" means an agreement in force at any time during the fiscal year.

(b) Patent licenses include licenses to pending patent applications.

(c) "Earned Royalty Income" (ERI) is a royalty based on use of a licensed invention (usually, a percentage of sales or of units sold). It is not a license issue fee or a minimum royalty.

Of the total licensing income received in FY 2019, 48% ($33,066) was distributed to the NIST inventor(s) and the remaining 52% ($35,904) was retained by the NIST inventor's Operating Unit.

Table 11 – Distribution of NIST Invention License Income

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Income Received[(a)]	$124,823	$137,662	$75,061	$111,743	$68,970
Invention Licenses (Patent Licenses)[(b)]					
Licensing Income to Inventor(s)	$44,936	$45,148	$34,673	$42,944	$33,066
	36%	33%	46%	38%	48%
Licensing Income to NIST	$79,887	$92,514	$40,388	$68,799	$35,904
	64%	67%	54%	62%	52%

(a) Income includes royalties and other payments received during the fiscal year.
(b) Patent licenses include licenses to pending patent applications.

Cooperative Research and Development Agreements (CRADAs)

Collaborative research and development projects between federal laboratories, academia, and outside partners are an effective means of transferring technology. Beyond the improved know-how and new technologies that result, these joint efforts often help collaborators leverage each other's resources and technical capabilities. They also provide mechanisms for collaborators to gain technical competencies and acquire new skills. CRADAs are agreements between a federal laboratory and one or more partners to collaborate on defined R&D projects. They are a major mechanism for establishing joint relationships with industry, academia, and state and local governments to advance promising new technologies toward commercialization. These agreements are created under the statutory authority of the Stevenson-Wydler Technology Innovation Act of 1980, as amended by the Federal Technology Transfer Act of 1986 (P.L. 99-502).[15]

[15] http://www.nist.gov/tpo/collaborations/crada.cfm

In FY 2019, NIST was involved in a total of 2,504 active CRADAs; 434 were traditional CRADAs[16] and 2,070 were non-traditional CRADAs.[17] There were 1,986 new NIST CRADAs. This included 99 traditional and 1,887 non-traditional.

Table 12 – NIST Collaborative Relationships for Research and Development

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NIST CRADAs					
Total Active CRADAs	2,718	2,958	2,889	3,303	2,504
New CRADAs Executed	2,481	2,587	2,420	2,770	1,986
Total Active Traditional CRADAs	329	294	370	476	434
New Traditional CRADAs Executed	143	89	113	153	99
Total Active Non-Traditional CRADAs	2,389	2,664	2,519	2,827	2,070
New Non-Traditional CRADAs Executed	2,338	2,498	2,307	2,617	1,887
Other Type of Collaborative R&D Relationships					
Guest Scientists and Engineers	3,125	3,273	3,181	3,221	3,180

[16] Traditional CRADAs involve collaborative research and development projects by a federal laboratory and non-federal partners.

[17] Non-traditional CRADAs are used for special purposes, such as laboratory accreditation, materials transfer or calibration services.

Scientific and Technical Publications
Technical publications are one of the major mechanisms NIST uses to disseminate the results of its research to industry, academia, and other agencies.

In FY 2019, NIST staff wrote 1,396 papers in peer-reviewed journals,[18] including 392 papers (28%) published in "top tier" journals, which includes any journal with a Clarivate Analytics Impact Factor (IF) that falls within the top 10th percentile in its *Web of Science* Subject Category.[19] NIST researchers collaborated and co-authored with researchers from around the world, writing papers with 5,247 unique non-NIST authors from 1,142 institutions in 54 countries.[20]

Table 13 – NIST Scientific and Technical Publications

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Number of NIST Papers	1,323	1,355	1,433	1,415	1,396
Number of NIST Papers in Top-Tier Journals	384	329	406	367	392
Percentage of NIST Papers in Top-Tier Journals	29%	24%	28%	26%	28%
Number of Unique Non-NIST Co-Authors	4,585	5,116	5,464	5,277	5,247
Number of Unique Institutions	1,003	1,037	1,334	1,283	1,142
Number of Countries	63	46	67	59	54

NIST also publicizes its planned, ongoing, and recently completed work in outlets followed by the organizations most likely to have an interest in NIST's research and services, such as the trade and technical press. In addition to news releases, websites, and contacts with the media, NIST issues a bi-weekly e-mail roundup of its latest news, called *Tech Beat*.[21]

In addition to the basic methods of transferring technology such as patents, licenses, and CRADAs, NIST researchers routinely transfer technological innovations through the following mechanisms.

Participation in Documentary Standards Committees
Documentary standards are shared sets of rules that specify, for example, a test method or measurement method, a product's properties, or standard practices. Econometric studies have concluded that standards contribute significantly to economic growth, and as one study concluded, "development of standards is integral to innovation; documentary standards contribute to economic growth at least as much as do patents; and the macroeconomic benefits of the development of standards extend beyond the benefits to the companies that use the standards."[22]

[18] https://www.nist.gov/nist-research-library
[19] For additional information see https://clarivate.com/essays/journal-selection-process/.
[20] Unique co-authors and institutions were identified by performing a search for all NIST authored papers in the *Web of Science (WoS)* database. This includes publications in the peer-reviewed literature but excludes most conference proceedings papers and all NIST series publications.
[21] https://www.nist.gov/news-events/news/
[22] Peter Swann, G.M., Report for the UK Department of Business, Innovation, and Skills (BIS), 2010 https://www.gov.uk/government/publications/economics-of-standardisation-update-to-report.

During FY 2019, 440 members of the NIST staff were involved with more than 112 standards organizations. Such participation helps NIST respond to the needs of the private sector and enables its scientists and engineers to bring NIST technology and know-how directly into standards-setting bodies.

Table 14 – NIST Participation in Documentary Standards

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Number of Participating NIST Staff	469	445	440	423	440
Number of Standard Organizations with NIST Participants	165	120	119	116	112

The NIST Standards Coordination Office (SCO) maintains the Standards Committee Participation Database for employees to report their participation, including leadership positions within standards organizations. The SCO is proactively expanding the database to collect information regarding staff tenure on a standards committee, standard(s) developed with NIST staff participation, and other information relevant to NIST's contributions in new and existing documentary standards.

Standard Reference Data

NIST's Standard Reference Data (SRD) Program provides critically evaluated numeric data to scientists and engineers for use in technical problem solving, research, and development. Many types of reference data are extremely important in engineering structures, optimizing chemical processes, and other industrial applications. NIST extracts SRD from scientific and technical literature or develops them from measurements conducted at its laboratories that are carefully evaluated for accuracy and reliability. NIST currently maintains 92 SRD databases that cover many areas of science, including analytical chemistry, atomic and molecular physics, biotechnology, and materials sciences.[23]

[23] http://www.nist.gov/srd/index.cfm

In FY 2019, the NIST SRD Program distributed 2,613 e-commerce orders, 9,880 units sold via distributor, 125 active distributor agreements, 30 active site licenses, 41 active internet subscriptions, 82 units shipped to the user, and 2,835 products downloaded from the NIST website (1,100 free downloads, 2,712 paid downloads).

Table 15 – NIST Standard Reference Data Program

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Standard Reference Data					
Products available (databases)	111	102	97	92	90
E-Commerce Orders	2,596	2,689	2,229	2,670	2,613
Units Sold via Distributor	9,807	10,573	7,995	8,413	9,880
Active Distributor Agreements	123	124	154	157	125
Active Site Licenses	57	59	36	17	30
Active Internet Subscriptions	38	49	40	50	41
Units Shipped via UPS	418	311	328	146	82
Products Downloaded from the NIST Website	5,751	6,208	3,119	3,910	3,812
Free Downloads	3,615	4,083	1,225	1,099	1,100
Paid Downloads	2,136	2,125	1,894	2,811	2,712

Standard Reference Materials

Standard Reference Materials (SRMs) are a definitive source for various measurements in the United States. Measurements made using SRMs can be traced to a common and recognized set of basic standards that provide the basis for measurement compatibility among different laboratories. The certified property values for SRMs often depend on the development of unique measurement capabilities within NIST.[24] In FY 2019, NIST made available 1,130 SRMs and from these, sold 29,955 units.

Table 16 – NIST Standard Reference Materials

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Standard Reference Materials					
Units Available	1,240	1,194	1,182	1,140	1,130
Units Sold	33,490	31,938	32,348	31,503	29,955

User Facilities – Research Participants

NIST operates two unique and valuable laboratory facilities that support U.S. industry, academic institutions, and other NIST and government laboratories.[25] These facilities, the Center for Nanoscale Science and Technology (CNST) and the NIST Center for Neutron Research

[24] http://www.nist.gov/srm/index.cfm

[25] Beginning October 1, 2018, CNST became part of the Physical Measurement Laboratory (PML). Merging CNST with PML enables more effective management of programs and resources that previously spanned both organizations. Research staff from the CNST NanoLab and PML have been combined to form two new divisions within PML. The CNST NanoFab user facility will largely remain unchanged and continue to serve both NIST and external users.

(NCNR), allow NIST customers to tap directly into NIST measurement expertise to solve problems.

The CNST supports the development of nanotechnology from discovery to production. It operates in a national shared-use nanofabrication and measurement facility (the NanoFab), complemented by a multidisciplinary research staff creating next-generation tools for advancing nanotechnology. The NCNR is a national user facility that provides cold and thermal neutron measurement capabilities to researchers from academia, industry, and other government agencies.[26]

NIST user facility "research participants" are those who directly participate in an NCNR experiment or CNST project. Research participants include those who use the facility on-site or remotely, and their collaborators on the experiment or project. For FY 2019, CNST reported the number of distinct facility users versus the previously reported number of research participants.[27] In FY 2019, there were 314 distinct facility users at CNST and 2,923 research participants at NCNR.

Table 17 – NIST Research Participants

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NIST Research Participants					
CNST	2,434	2,917	3,215	3,415	314[(a)]
NCNR	2,436	2,536	2,769	2,742	2,923

(a) In FY 2019, CNST reported distinct facility users instead of research participants due to organizational restructuring. CNST merged with the Physical Measurement Laboratory to more efficiently advance NIST's mission.

[26] https://www.nist.gov/labs-major-programs/user-facilities

[27] The change in reporting is due to organizational restructuring. CNST merged with the Physical Measurement Laboratory in FY 2019.

Postdoctoral Researchers

Technology transfer involves not only inventions, innovations, data, patents, and licenses, but also the people who perform the actual research and development. Postdoctoral researchers, or "postdocs," working at NIST also play an important role in transferring NIST technology and know-how.[28] NIST uses the NSF's description of a postdoctoral researcher,[29] which is defined as someone who has a temporary position taken within five years after the completion of a doctoral degree to gain scientific, technical, and professional skills. In FY 2019, there were 165 NIST postdocs. Of these, 110 were located on the NIST campus in Gaithersburg, Maryland; 35 were located in Boulder, Colorado; and the remainder were located at five other NIST locations.

Table 18 – NIST Postdoctoral Researchers

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NIST Postdocs, Total (NCR)	179	167	159	153	165
Gaithersburg campus	113	104	87	91	110
Boulder campus	49	43	47	44	35
Joint Institute for Laboratory Astrophysics [(a)]	5	9	12	10	13
Joint Quantum Institute [(b)]	2	2	3	3	1
Hollings Marine Laboratory [(c)]	2	2	2	1	3
Institute for Bioscience and Biotechnology Research [(d)]	3	3	3	3	2
Brookhaven National Laboratory[(e)]	0	0	2	0	0
Joint Initiative for Metrology in Biology[(f)]	5	4	3	1	1

(a) Joint Institute for Laboratory Astrophysics (JILA) was founded in 1962 as a joint institute of CU-Boulder and NIST. JILA is located at the base of the Rocky Mountains on the CU-Boulder campus in the Duane Physics complex. http://jila.colorado.edu/

(b) The Joint Quantum Institute (JQI) was founded in September 2006 as a collaboration between the University of Maryland and NIST, with additional support from the Laboratory for Physical Sciences, a government facility in College Park. http://jqi.umd.edu/

(c) The Hollings Marine Laboratory (HML) is a world-class research facility in Charleston, South Carolina. HML's mission is to provide science and biotechnology applications to sustain, protect, and restore coastal ecosystems, with emphasis on links between environmental condition and the health of marine organisms and humans. http://www.nist.gov/mml/hml/index.cfm

(d) The Institute for Bioscience and Biotechnology Research (IBBR) is a joint research enterprise created to enhance collaboration among the University of Maryland College Park, the University of Maryland Baltimore and NIST. https://www.ibbr.umd.edu//

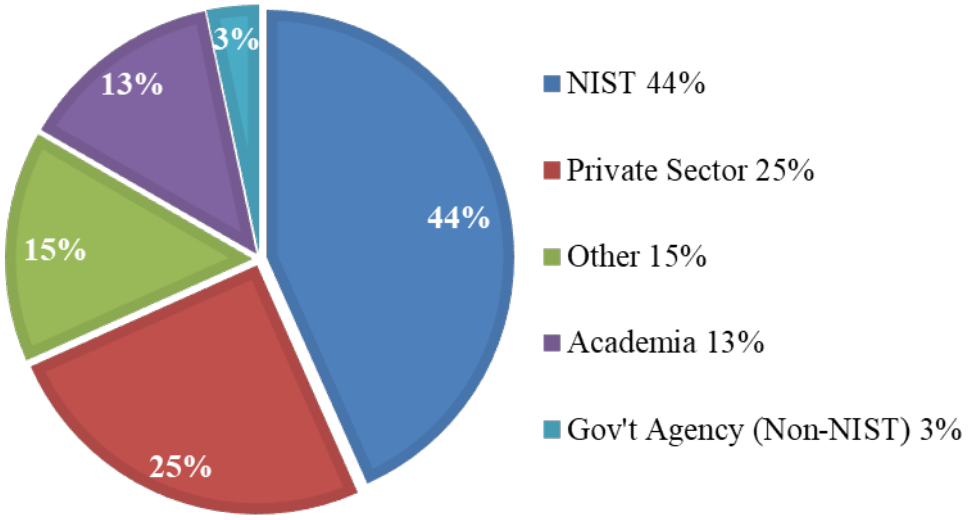
(e) The Brookhaven National Laboratory's National Synchrotron Light Source (NSLS) facility is co-led by DOE and NIST's Material Measurement Laboratory (MML). MML's Synchrotron Science Group develops and disseminates synchrotron measurement science and technology needed by U.S. industry to measure nanoscale electronic, chemical, and spatial structure of advanced materials. https://www.nist.gov/mml/materials-measurement-science-division/synchrotron-science-group

(f) The Joint Initiative for Metrology in Biology (JIMB) is co-led by Stanford University and NIST and is designed to enable significant improvements in the accuracy and comparability of vital data used to make important research, regulatory, clinical, and manufacturing quality control decisions. http://jimb.stanford.edu/

[28] http://www.nist.gov/iaao/postdoc.cfm
[29] http://www.nsf.gov/statistics/seind12

The number of postdocs is a measure of technology transfer, because once their tenure at NIST ends, they take what they have learned and apply it to projects outside of NIST. NIST begins tracking postdocs once they depart NIST. NIST surveyed 60 researchers who were postdocs with the NIST National Research Council (NRC) program in FY 2019. Of these, 44% continued research careers with NIST[30], 25% moved to the private sector, 15% pursued other opportunities such as becoming independent researchers, 13% moved to academia, and 3% moved to other government agencies.

Figure 5 – Tracking NIST Researchers after Initial Postdoc Tenure at NIST (FY 2019)



Guest Researchers

In addition to postdocs, each year, thousands of researchers visit NIST to participate in collaborative projects.[31] NIST hosts many term appointment researchers and non-NIST employees working as guest researchers, collaborators, and student fellows. Like postdoctoral researchers, many guest researchers seek career opportunities in academia, the private sector, or federal agencies after their tenure at NIST. While some guest researchers' work at NIST may result in inventions, all guest researchers leave NIST with technical and research skills that place them on the cutting edge of their disciplines. Each researcher takes the skills and knowledge, and aspires to apply them in innovative ways in their careers. Among these skills is the knowledge of how to collaborate with federal laboratories and what federal resources are available to assist companies in creating and developing new and improved technologies.

[30] Researchers who left their postdoc positions and stayed at NIST (44%) became career conditional / term employees (29%) or became non-career conditional or term employees (i.e. contractors or guest researchers) (15%).
[31] http://www.nist.gov/tpo/collaborations/guestresearchers.cfm

In FY 2019 there were 3,180 guest scientists and engineers working at NIST.

Table 19 – NIST Guest Researchers

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NIST Guest Researchers					
Number of Guest Scientists and Engineers	3,125	3,273	3,181	3,221	3,180

Accreditation Services

The NIST National Voluntary Laboratory Accreditation Program (NVLAP) is a voluntary and fee-supported program to accredit private sector laboratories that are competent to perform tests or calibrations.[32] In FY 2019, NVLAP accredited 674 laboratories.

Table 20 – NIST Accreditation Services

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NVLAP Accreditations					
Number of NVLAP Accreditations	726	735	723	674	674

Calibration Services

The NIST laboratories provide unique physical measurement services for their customers, including calibration services, special tests, and measurement assurance programs. NIST designs its calibration services to help manufacturers and users of precision instruments achieve the highest possible levels of measurement quality and productivity. NIST calibrations often serve as the basis for companies that provide commercial calibration services and calibration equipment.[33] In FY 2019, there were 11,519 calibration tests performed by NIST.

Table 21 – NIST Calibration Services

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Calibrations					
Number of Calibration Tests Performed	13,906	12,971	13,802	11,771	11,519

[32] http://www.nist.gov/nvlap/
[33] http://www.nist.gov/calibrations/index.cfm

Education Outreach Programs and Partnerships
NIST has received recognition as a vital contributor to the efforts to improve science, technology, engineering, and mathematics (STEM) education in the United States. As part of its mission, and to help create a long-term and well-qualified workforce for standards and measurement research, NIST has several education outreach programs and partnerships that enrich basic research programs such as:

- the Summer Undergraduate Research Fellowship (SURF) program;[34]
- the Summer High School Internship (SHIP) program;[35]
- the Pathways Program;[36]
- the NIST Summer Institute for Middle School Science Teachers;[37] and
- the Professional Research Experience Program (PREP).[38]

In FY 2019, there were 173 students enrolled in the SURF program, 55 students enrolled in the SHIP program, 71 students enrolled in the Pathways program, 24 participants in the Summer Institute for Middle School Teachers, and 360 students enrolled in the PREP program.

Table 22 – NIST STEM Education Participation

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
SURF	206	213	212	212	173
SHIP	48	70	70	64	55
Pathways Program	97	85	111	85	71
Summer Institute for Middle School Science Teachers[(a)]	22	20	21	0	24
PREP	164	204	36	200	360

(a) The Summer Institute for Middle School Science Teachers was not held in FY 2018.

Conferences, Seminars, and Workshops
Some of the most important mechanisms for technology dissemination are communication, education, and interaction among researchers, developers, and users of technology. NIST hosts numerous conferences, workshops, and other meetings each year to facilitate the transfer of technology.

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[34] NIST's Summer Undergraduate Research Fellowship (SURF) program provides internships for college students majoring in science, mathematics and engineering. http://www.nist.gov/surfgaithersburg/index.cfm
[35] NIST's Summer High School Internship (SHIP) program provides a summer intern program for high school students who are interested in scientific research. http://www.nist.gov/ohrm/staffing/ship.cfm
[36] The Pathways Programs offers high school, college and trade school students paid opportunities to work in a federal agency and explore different career paths while continuing their education. http://www.nist.gov/ohrm/staffing/students.cfm
[37] NIST's Summer Institute for Middle School Science Teachers provides a two-week workshop for middle school science teachers featuring hands-on activities, lectures, tours, and visits with NIST scientists and engineers in their laboratories. http://www.nist.gov/iaao/teachlearn/index.cfm
[38] NIST's Professional Research Experience Program (PREP) provides undergraduate and graduate students, as well as postdoctoral researchers, the opportunity to gain hands-on research experience working with NIST researchers. https://www.nist.gov/iaao/nist-professional-research-experience-program-prep

In FY 2019, the NIST Conference Program arranged 78 conferences that attracted 8,596 researchers to NIST's facilities in Gaithersburg, Maryland, and Boulder, Colorado. NIST's Office of Weights and Measures, which promotes uniformity in U.S. weights and measures laws, regulations, and standards, trained 665 weights and measures administrators, laboratory metrologists, and field enforcement officials during FY 2019. In addition to formal trainings, NIST staff answer email, telephone, and mail inquiries from researchers requesting information and details about NIST technical developments and research results.

Table 23 – NIST Conferences, Seminars, and Workshops

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NIST Conference Center					
Conferences and Workshops	118	102	108	101	78
Attendance	11,490	10,370	10,588	8,772	8,596
Office of Weights and Measures - Metrology Training					
Total Students	750	498	916	888	665
Seminar Attendance	457	342	466	451	433
Webinar Attendance	266	156	414	437	232
Workshop Attendance	27	0	36	0	0

Trends in Technology Transfer Office Activity

To better understand the year-over-year activity of its technology transfer office, NIST tracks the average number of days to both prepare a patent application and approve a CRADA. In FY 2019, 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 408 days. The average CRADA approval time was 129 days. As noted in the reduced number of technology transfer activities for FY 2019, the lapse in appropriations may have contributed to increased times in preparing patent applications and approving CRADAs this fiscal year.

Table 24 – NIST Activity Trends

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Activity Trends					
Average Number of Days to Prepare a Patent Application[(a)]	410	442	396	337	408
Average Number of Days to Approve a CRADA[(b)]	65	104	108	91	129

(a) The time between the receipt date of an invention disclosure and the filing date of the first non-provisional patent application filed by NIST.

(b) The time between the receipt of the memo related to the award of a CRADA and the time of approval for the memo.

Small Businesses, Startups and Young Entrepreneurial Companies
NIST recognizes the need to provide both funding and technological support for small businesses, startups, and young entrepreneurial companies. NIST and its joint institutes nurture young companies in high-growth technology areas by several means.

In addition to financial support provided by the Small Business Innovation Research (SBIR) program and technical support through CRADAs, NIST recently implemented several new licensing options to aid innovators and lower developmental risk for potential partners who wish to obtain and use NIST technology. For example, the Science/Technology Advancement Research (STAR) license provides a no-cost, non-exclusive field-of-use research license to explore and advance NIST technologies for commercialization.

In FY 2019, NIST patent licenses were held by 32 small businesses. There were 144 small businesses involved in traditional CRADAs and 623 small businesses involved in non-traditional CRADAs. NIST's non-traditional CRADAs involve 17 small businesses involved with material transfer agreements and 606 receiving NVLAP accreditations.[39] There were also 12 small businesses that received Phase I SBIR awards and 7 small businesses that received Phase II SBIR awards.

Small Business Innovation Research (SBIR)
NIST's SBIR program funds science and technology based small businesses in the United States. The program offers qualified small businesses the opportunity to propose innovative ideas that meet specific NIST research and development needs and have the potential for commercialization.[40] NIST has taken the following steps to improve its SBIR program:

1. Streamlining practices to reduce the administrative burden on small businesses and time needed to process and issue awards.
2. Reducing the number of topics and subtopics to balance the work required to obtain proposals while increasing the selection rate for worthwhile proposals. NIST Programmatic Investment Priority Areas in the NIST Three Year Programmatic Plan serve as topics to align SBIR priorities to NIST's mission. The goal is to bring the Phase I SBIR award rate up to the national average of 17%.
3. Implementing a two-step review process to evaluate technical feasibility and to maximize investments, catalyze commercialization, and achieve a strategic focus. The first step is a technical evaluation conducted by NIST laboratories. The second step is prioritization of proposals considered meritorious in the laboratory review through the use of criteria based on the overall NIST strategy and SBIR program goals.
4. Reducing the time from close of solicitation to award issuance by 10%.

[39] Calibration services small business data not available at the time of report publication.
[40] http://www.nist.gov/tpo/sbir/index.cfm

Small and Young Businesses Interacting with NIST

The creation of companies by former NIST staff, NIST collaborators, licensees or others making use of NIST research is another way of transferring NIST's technologies. NIST routinely interacts with and provides special consideration for small businesses (companies with fewer than 500 employees) in order to help them become more competitive and productive. NIST also nurtures small and young companies by transferring its technology and support through its SBIR program.

Table 25 - Number of Small Businesses Interacting with NIST[41]

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Number of Small Businesses Licensing NIST Technologies	4	14	19	23	32
Number of Small Businesses involved in Traditional NIST CRADAs	68	58	116	89	144
Number of Small Businesses involved in Non-Traditional NIST CRADAs	795	823	903	742	814
Number of Small Businesses involved in Phase I SBIR Awards	14	12	12	12	12
Number of Small Businesses involved in Phase II SBIR Awards	6	7	9	10	7
Total	887	914	1,059	876	1,009

NIST also identified 9 young companies (existing for five years or less) that received patent licenses, 32 young companies that collaborated with NIST via an active, traditional CRADA, and 8 young companies that requested calibration services in FY 2019.

[41] Total estimates are preliminary. NIST is currently working on efforts to improve the tracking of interactions with small and young companies.

Economic Assessment

There are two types of metrics used to track technologies transferred from federal agencies: activity metrics and impact metrics. The metrics provided in this report are primarily activity metrics that track transfer activities within the DOC. NIST gathers the data through internal data calls and the data are presented here to show the activities that have occurred within the agency over the past five years. Impact metrics are completely different. They track the impacts that occur outside of the DOC resulting from technologies developed within the DOC. Impact metrics are not gathered by data calls. They are derived by careful studies of the behavior of transferees (e.g., researchers, developers, producers, and end-users) who use the federal technologies to create or embellish products or services over time.

Unfortunately, there are relatively few economic studies that actually focus on identifying, isolating, assessing, and reporting the impact that federally developed technologies have on economies outside of the government.[42] This is because the process of assessing impacts, which has long been a goal of policymakers, is costly and complex, requiring detailed studies that isolate and assess the dispersal of impacts over time.

Nonetheless, there are many different approaches to measuring the impact of technology transfer activities. The most common approach provides a retrospective assessment of survey or publicly available data to measure the return on investment in terms of net present value, social rate of return, and/or the ratio of benefits to cost for given impact periods. Another retrospective approach employs a simulation model to estimate how changes in key variables (such as the number of licenses or the amount of license revenues) affect an economy in terms of changes in gross output, gross domestic production, employment, income, or other measures of economic activity. There are also prospective studies that attempt to forecast future impacts based on an assessment of survey data from qualified end-users.[43]

External researchers, funded by NIST, completed three studies in FY 2019:

1. Overview and Analysis of Technology Transfer from Federal Agencies and Laboratories
   RTI International, funded by NIST, conducted a wide-ranging analysis of technology transfer from the federal government. This work has the stated purpose of presenting "a series of analyses of technology transfer activities across federal agencies and their research laboratories." (p. ES-1) The authors conducted both "broad empirical analyses" and "agency-level mission-specific case studies" (p. 5-1) to analyze and describe technology transfer across the federal government.

   The broad empirical analyses include descriptions of the geospatial distribution of CRADA partners, the relationship between CRADAs and firm revenues, and relationship between firm size and participation in CRADAs. These analyses used administrative data

[42] See Bozeman et al., "The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model." https://www.sciencedirect.com/science/article/pii/S0048733314001127

[43] For discussions on how technology transfer impacts are measured see "Measuring the Impacts of Federal Investments in Research," National Academies Press: https://www.nist.gov/sites/default/files/documents/2017/04/28/Measuring-the-Impacts-of-Federal-Investments-in-Research-2011.pdf, "Methods for Assessing the Economic Impacts of Government R&D," Tassey: https://www.nist.gov/sites/default/files/documents/2017/05/09/report03-1.pdf, or "The Theory and Practice of Public-Sector R&D Economic Impact Analysis," Link et. al: https://www.nist.gov/sites/default/files/documents/2017/04/28/report11-1.pdf

provided by agencies, which included data on patents, licenses, and completed CRADAs. These administrative data were combined with other data from sources like Walls and Associates and data from Dun and Bradstreet. The authors find that firms participating in CRADAs saw increases in inflation-adjusted revenues and that more smaller firms participated in CRADAs than large firms.

The authors conducted nine case studies of technologies transferred from six federal agencies—DoD, DOI, DOC, DOT, HHS, and USDA. They found that in every case, the transfer of federal technology contributed to achieving the mission of the agency and that the public benefited either directly or indirectly from the transferred technology. They also found that in six of the nine cases, the agency was transferring a technology that had been developed for its own needs to the private sector, helping to bring additional resources and capacity to scale up the technology for commercialization.

2. Economic Benefits of the Global Positioning System (GPS)
   This study, completed and published by RTI International in June 2019, quantified the economic benefits of GPS to the private sector due to federal laboratory research and technology transfer contributions. It examined 10 economic sectors in the U.S. economy that utilize GPS daily: agriculture, financial services, location-based services, mining, surveying, telecommunications, telematics, electricity, maritime navigation, and oil and gas industries. The study estimated that GPS has provided the private sector $1.4 trillion in economic benefits (as of 2017) since it became available to the private sector in the 1980s.

3. Maximizing Innovation and Technology Commercialization of Federal Research Investments
   In March 2019, the University of Michigan's Economic Growth Institute published best practices at innovation and economic prosperity (IEP) universities. "Fifty-nine IEP universities participated in the mixed-methods study, which included 51 faculty research interviews, 200 survey respondents, and 10 interviews with federal research labs". (p. 3) Researchers found that IEP universities produced an annual mean volume of invention disclosures, patents, start-ups, and exclusive licenses compared to other public institutions.[44]

   Along with its quantitative findings, the study also identifies best practices for technology transfer at public universities in four main categories: culture, champions, incentives, and collaboration. These best practices can be incorporated into technology transfer offices to increase performance both within universities and federal laboratories.

Efforts to Promote Entrepreneurship

Entrepreneur-in-Residence (EIR) Program

The NIST Entrepreneur-in-Residence (EIR) Program began in 2013 to help the research staff and management understand and become connected to the nation's technologically based entrepreneurship community. This program was developed and is jointly sponsored by NIST

[44] https://economicgrowth.umich.edu/lab-to-market/

and Maryland's Technology Development Corporation (TEDCO) through a Partnership Intermediary Agreement (PIA). Under the PIA, TEDCO vets and recommends suitable candidates for one-year appointments. In FY 2019, four NIST-TEDCO EIRs served on a voluntary basis without compensation.

EIRs offer seminars to NIST employees that cover business formation, funding, protection of intellectual property, and conflict-of-interest issues. EIRs also counsel NIST postdocs and other temporary employees on efforts to identify and explore career opportunities in small and startup technology-oriented businesses. NIST provides additional one-on-one sessions to staff members interested in starting a company that will spin out a NIST technology. Over the past five years, more than 30 staff members have received one-on-one counseling and two are actively engaged in efforts to form a business venture to license a NIST technology for commercial purposes. The two individuals seeking to form a business venture also received guidance from the Office of the Chief Counsel for NIST and from the Department of Commerce, Office of the General Counsel Ethics Law and Programs Division, before undertaking their initiative, which is being pursued on their own time.

In FY 2019, EIRs were involved in a coordinated training program that focused on recognizing innovation and invention opportunities that spawn from mission-oriented research. This training was presented through a series of seminars at various NIST organizational levels and was made available to the research and technical staff and to NIST's postdoctoral community. Also, in 2019, the EIRs attended technology transfer events of the Federal Laboratory Consortium Mid-Atlantic Region as their voluntary time commitments allowed.

N-STEP Program

NIST launched the NIST Science and Technology Entrepreneurship Program (N-STEP)[45] in November 2015 to provide opportunities for motivated researchers to build upon the experience they gained at NIST as they explore entrepreneurial careers that benefit the NIST mission. The program is focused on commercialization of research conducted at NIST by postdocs who are interested in forming companies to independently pursue further translational research and development of technologies specifically related to NIST's mission. These technologies can then be commercialized as products or services to benefit the public.

In FY 2019, eight companies completed their N-STEP projects, and two companies are involved in ongoing projects. N-STEP is funded by NIST and administered by Maryland TEDCO but is a nationwide opportunity.

Challenge and Prize Competitions

Challenge.gov is a listing of challenge and prize competitions, all of which are run by more than 102 agencies across the federal government. NIST participates in this program by offering cash prizes to the public for their help in solving perplexing mission-centric problems.[46] In FY 2019, NIST either launched or continued the following challenges:

1. Expanding the SIM Card Use for Public Safety Challenge;

[45] See http://tedco.md/program/n-step/

[46] For more information see https://www.challenge.gov/about/

2. Tech to Protect Challenge;
3. Haptic Interfaces for Public Safety Challenge;
4. Agile Robotics for Industrial Automation Competition (ARIAC); and
5. Differential Privacy Synthetic Data Challenge.

Awards
NIST staff received the following awards during FY 2019:

ACM Fellow
- Ellen Voorhees and Rob Boisvert

Alexander von Humboldt Foundation, Humboldt Research Fellow
- Frank DelRio

American Ceramic Society, Distinguished Life Member
- Winnie Wong-Ng

American Chemical Society Award in Chromatography
- Lane Sander

American Concrete Institute (ACI) Concrete Research Council Arthur J. Boase Award
- Long Phan

American Crystallographic Association Fellow
- Craig Brown

APCO Leadership in Advocacy Award
- Dereck Orr

Arthur S. Flemming Award
- R. Joseph Kline

ASHRAE Distinguished Service Award
- William Healy

ASME 2019 CIE Young Engineer Award
- William Bernstein

ASM International Fellow
- James Warren

B. Stephen Carpenter Award
- James Norris

Current Opinion in Colloid and Interface Science's Outstanding Young Researchers in Colloid and Interface Science
- Yun Liu

Distinguished Poster Award at the Symposium on Usable Privacy and Security (SOUPS)
- Julie Haney, Susanne Furman, and Yasemin Acar

Early Career Leadership Intern Program to Serve Engineering (ECLIPSAE)
- Michael Brundage

Edward Uhler Condon Award
- Peter Mell and Dylan Yaga

Ernest E. Howard Award
- Therese McAllister

Federal 100 Award

- Lily Chen and Ron Ross

Fire Protection Research Foundation Medal
- Matthew Hoehler

Fullbright U.S. Research Scholar (DOS)
- Dilip Banerjee

GE Edge & Controls Symposium Award
- Ho Yeung

Gears of Government Award (GSA/OMB)
- Emil Simiu, Marc Levitan, Adam Pintar, Daniel Sunday, Joseph Kline, and Donald Windover

IEEE Rose 2019 Best Paper Award
- Robert Bostelman and Soocheol Yoon

IEEE-SA Standards Medallion
- Craig Schlenoff

INCITS Merit Award
- Sal Francomacaro

Institute of Refrigeration J&E Hall Gold Medal
- Mark McLinden

International Society for Neutron Instrument Engineers Logo Winner
- Lawrence Wroten

MAJR Medal
- Mina Seif

Maryland Science Center's Outstanding Young Engineer
- Samantha Maragh and Jason Hattrick-Simpers

Presidential Early Career Award for Scientists and Engineers
- Behrang Hamadani, Elijah Peterson, David Long, Edwin Chan, and Stephen P. Jordan

Presidential Rank Award
- Charles Romine and Donna Dodson

Portland Global Globe Award 2019
- Sokwoo Rhee

PHM Society Contributor of the Year
- Brian Weiss

Quality Information Framework (QIF) Challenge Coin
- John Horst

R&D 100 Award
- June Lau, Dale Newberry, Ryan Marinenko, John Small, Nicholas Ritchie, John Henry Scott, and Ed Vicenzi

Rising Star Award for Outstanding Early-Career Leaders (NARCO)
- Ellen Nadeau

SFPE Educational and Scientific Foundations Jack Bono Award
- Matthew Hoehler

Sigma Xi, NIST Chapter, Annual Postdoctoral Poster Presentation
- Ryan Murphy, Most Outstanding Poster
- Ryan Need, Outstanding Poster in Engineering and Physics

Washington Academy Excellence in Research in Computer Science Award

- Nader Moayeri

Washington Academy Excellence in Research in Mathematics and Computer Science

- Bonita Saunders

Washington Academy Excellence in Research in Applied Mathematics

- Alfred Carasso

Western Michigan University's Alumni Achievement Award

- David Hoogerheide

William P. Slichter Award

- Nada Golmie and Kate Remley

Downstream Outcomes from NIST Technology Transfer Activities

FLOC Takes Flight: First Portable Prototype of Photonic Pressure Sensor[47]

The compact FLOC cavity, only about 2.5 cm long, at the heart of the new portable prototype. This image reveals the two physical channels used for the pressure measurement. When connected to the rest of the FLOC system, one channel is kept in vacuum and the other channel is filled with a gas whose pressure is being measured. Credit: MKS

In collaboration with industry, researchers from NIST have made the first portable prototype of the Fixed-Length Optical Cavity (FLOC), a device that uses light to measure pressure with higher accuracy and precision than most commercial pressure sensors.

This newest version is a milestone on the journey toward the creation of a device that could revolutionize the way pressure is measured with potential uses by many industries, particularly semiconductor chip and aircraft manufacturing.

In 2017, NIST and MKS Instruments, Inc. of Andover, Massachusetts, signed a CRADA to take a laboratory-scale version of the FLOC and create a smaller, more robust prototype that more closely resembles a commercial product. Thanks to the CRADA work, the joint NIST and MKS team has now successfully demonstrated a prototype version small enough to fit into two suitcases, NIST physicist Jay Hendricks said.

"MKS Instruments brings over 50 years of pressure measurement, optical and laser experience to this project, and we are honored to have been selected by NIST to work with them on this important and prestigious development," said Phil Sullivan, CTO of MKS's Pressure and Vacuum Measurement Solutions business. "We anticipate that this work will lead to a new wide-range, compact pressure measurement standard."

Robust, portable FLOC sensors could potentially reduce the cost of producing semiconductor chips such as those used in smartphones, as well as decreasing the cost of air travel. This is because both the chip manufacturing and aerospace industries rely on pressure measurements.

[47] Read the full story here: https://www.nist.gov/news-events/news/2019/02/floc-takes-flight-first-portable-prototype-photonic-pressure-sensor

The FLOC measures pressure by measuring subtle differences in the frequency of light passing through two physical channels called optical cavities: a reference channel in vacuum and a test channel filled with a gas whose pressure is being measured.

In their partnership, NIST and MKS staff assembled the two-channel cavity at the heart of the prototype, while MKS managed the engineering of a miniaturized version of the system.

"We built the national standard version of the FLOC, which is designed to operate in a high-precision laboratory," Hendricks said. "But we turned to industry under a CRADA to speed up the engineering and miniaturization work that needs to go into making something rugged, stable, transportable, low-power and able to work in a variety of different environments.

2019 Governor's Award for High-Impact Research[48]

Credit: R. Wright/University of Colorado

A technology based on innovative laser spectroscopy research at NIST and the University of Colorado has been ruggedized and commercialized here in Colorado for use in the field and can detect methane emissions as small as a quarter of a human breath from over a mile away.

"By working to create collaborations a) among experts in different fields, and b) between researchers and industry, the team produced extraordinary results that has resulted in the spinout company LongPath Technologies," says Terri Fiez Vice Chancellor for Research & Innovation at the University of Colorado – Boulder. "These creative partnerships helped the team do the unthinkable: leverage Nobel Prize winning technology into something that the oil and gas industry could use daily to improve its environmental footprint, save lives and save money." Dr. Marla Dowell, Director of NIST Boulder labs says, "This pathfinding achievement is a success story that could only have occurred in Colorado because of the nexus of extraordinary government and academic research and entrepreneurship."

This work was captured under the CRADA with the University of Colorado – Boulder related to the ARPA-E grant.

[48] https://www.nist.gov/about-us/nist-awards/2019-governors-award-high-impact-research

Researchers Explore Using SIM Cards for Secure Public Safety Data Transmission[49]

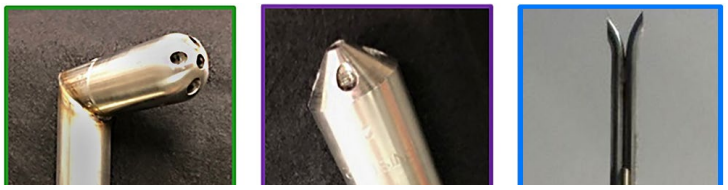
In April 2019, NIST's Public Safety Communications Research (PSCR) division - in partnership with the First Responder Network Authority (FirstNet), IBM, and Nok Nok Labs - launched a prize challenge program targeted at exploring whether the SIM cards common in many commercial mobile phones could be used as storage containers for public safety application credentials.

Recognizing Public Safety's need for convenient, standards-based, two-factor authentication, PSCR engaged qualified contestants in a three-phase Prize Challenge over the course of six months. Challenge teams completed the following phases:

- Phase 1 – Concept Paper: Successful contestants documented a clear understanding of the contest objectives and proposed an approach to securely store and then use first responder authentication credentials on a SIM card.
- Phase 2 – File Stored on SIM Card: Successful contestants demonstrated, via video webinar and screen share, their process of provision, storage of the file on the SIM card, and navigation through the SIM card file structure to the file's location.
- Phase 3 – Verified Authentication: Successful contestants demonstrated their mobile application's ability to access credentials stored on the SIM card and authenticate to FIDO2 services, which were provided in this prize competition by our challenge partners at Nok Nok Labs and IBM.

Participating teams were awarded prizes at each phase of the challenge with up to $100,000 in total available prizes. The judging panel announced challenge winners October 23, 2019, after performing the final evaluation of contestants' mobile applications, source code, hardware devices with SIM cards, and instructions. The judging panel and subject matter experts included individuals from APCO International, First Responder Network Authority, Motorola Solutions, Qualcomm, Texas Department of Public Safety and NIST PSCR.

NIST Presents First Real-World Test of New Smokestack Emissions Sensor Designs[50]



NIST designed two new pitot probes (left and center), one whose sensing surface is cone-shaped and the other whose surface is hemispherical. The probes have five holes, or ports. Comparing pressure readings obtained in each of the five ports allows technicians to calculate the flow rate. An older type of pitot tube, called an S-probe (right), has two ports that face in opposite directions. Credit: NIST

In collaboration with industry, researchers at NIST have completed the first real-world test of a potentially improved way to measure smokestack emissions in coal-fired power plants.

Each year, to meet requirements set by the Environmental Protection Agency (EPA), coal-fired power plants must have their smokestack emissions

[49] https://www.nist.gov/ctl/pscr/funding-opportunities/open-innovation-prize-challenges/2019-expanding-sim-card-use-public

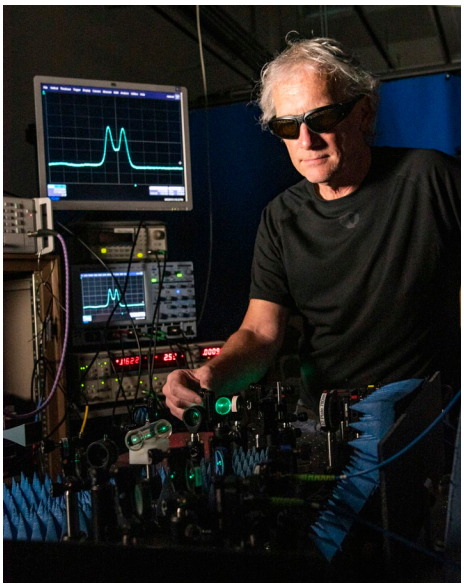
[50] Read the full story here: https://www.nist.gov/news-events/news/2019/06/nist-presents-first-real-world-test-new-smokestack-emissions-sensor-designs

audited, or checked by an independent third party. NIST researchers wanted to make this test quicker to save the plants money during their audits, while also improving accuracy of the sensors; therefore, a NIST team designed new probes for sensing emission flow rates and a new measurement method that could potentially speed up on-site audits by a factor of 10, researchers say.

NIST conducted this work as part of a CRADA with the Electric Power Research Institute (EPRI), an independent nonprofit organization whose members include electric utility companies, businesses and government agencies.

"Coal-fired electric generating units may benefit from the current NIST work by having improved standards and techniques to measure mass emissions more accurately, with increased confidence that all entities are reporting on a uniform basis," said EPRI program manager Tom Martz. He added that the potential time savings "is not something we can accurately quantify at this time, but this will be a key objective of future work."

NIST Team Shows Atoms Can Receive Common Communications Signals[51]



NIST researcher Chris Holloway adjusts a mirror to align a laser beam used in an atom-based receiver for digitally modulated communication signals. Credit: Burrus/NIST

Researchers at NIST have demonstrated a new type of sensor that uses atoms to receive commonly used communications signals. This atom-based receiver has the potential to be smaller and work better in noisy environments than conventional radio receivers, among other possible advantages.

The NIST team used cesium atoms to receive digital bits (1s and 0s) in the most common communications format, which is used in cell phones, Wi-Fi and satellite TV, for example. In this format, called phase shifting or phase modulation, radio signals or other electromagnetic waves are shifted relative to one another over time. The information (or data) is encoded in this modulation.

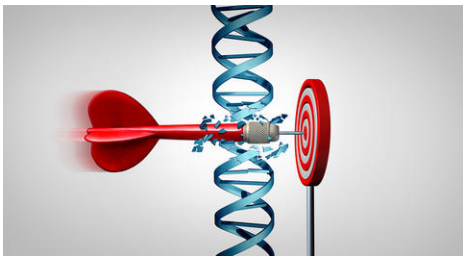
"The point is to demonstrate one can use atoms to receive modulated signals," project leader Chris Holloway said. "The method works across a huge range of frequencies. The data rates are not yet the fastest out there, but there are other benefits here, like it may work better than conventional systems in noisy environments."

As described in a new paper, the quantum sensor received signals based on real-world phase-shifting methods. A 19.6 gigahertz transmission frequency was chosen because it was convenient for the experiment, but it also could be used in future wireless communications systems, Holloway said.

[51] Read the full story here: https://www.nist.gov/news-events/news/2019/09/nist-team-shows-atoms-can-receive-common-communications-signals

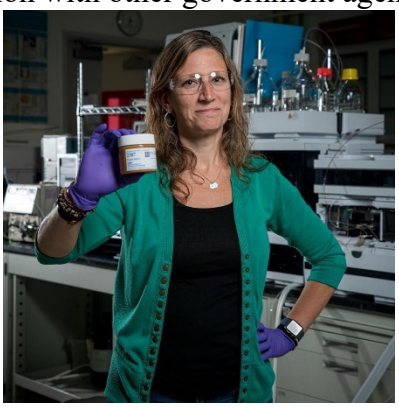
NIST Advances Gene Editing

Targeted genome editing, a method used to alter the DNA of living cells at desired locations, is poised to revolutionize science and medicine. To fight diseases, scientists are developing novel genome-edited therapeutics, including those for use in regenerative medicine and infectious diseases. Many commercial applications, including agriculture and chemical production, are also leveraging this technology. Whether genome editing will be used in healthcare, agriculture, or basic research, robust quantitative measurements are needed to enable high confidence characterization of DNA alterations. In FY 2019, NIST formed a new consortium to address this challenge, bringing together experts from across the genome editing field including stakeholders in industry, academia, and government to assess their measurement needs. These discussions have identified common pre-competitive measurements and standards needed to establish greater confidence in the characterization of genome editing outputs. The NIST-led Genome Editing Consortium was established to evaluate genome editing assay pipelines, develop benchmark materials, generate benchmark data, develop suggested minimal information reporting for public studies, and generate a common lexicon for genome editing studies. The consortium is comprised of 34 members, including 7 small businesses, 22 mid-sized to large companies, 2 hospitals, and 3 government agencies.



NIST Advances Food Safety

Food contaminants can sicken consumers, cause outbreaks of disease, and result in costly investigations and recalls with subsequent loss of trust in manufacturers and suppliers. Consumer confidence and safety depend on sophisticated analysis and underlying metrology to both intentional and unintentional adulteration and to confirm the identity of food products. Food industry sales in the U.S. amounted to nearly $5.75 trillion in 2017. The Food Safety Program at NIST was established in FY19 to provide analytical chemistry and quantitative biology to ensure that food is free of contaminants and allergens and is authentic, promoting U.S. manufacturer's participation in domestic and foreign markets and safeguarding the health of consumers. Key to the program's future success is collaboration with other government agencies and industry, leading to a 2019 workshop with over 200 attendees including representatives from agribusiness, food and beverage providers, regulators, and instrumentation vendors. In FY 2019, NIST also developed new reference materials for the food industry. This included Standard Reference Material 1565, which can be used by laboratories to reliably detect poisonous compounds in corn that are produced by mold, known as mycotoxins. Mycotoxins can cause economic losses for farmers and food producers if left undetected and allowed to spread. Humans ingesting these mycotoxins can develop flu-like symptoms, with some extreme cases proving deadly.



A Safer Way for Police to Test Drug Evidence[52]

Before fentanyl became a common street drug, police often tested evidence by scooping a bit of powder into a solution that would change color if any drug was present. These tests are now discouraged for safety reasons (fentanyl can be dangerous if even a small amount is inhaled), and suspected drugs have to be sent to a crime lab before arrests can be made. In FY 2019, NIST scientists developed a way for police to quickly and safety test whether a package contains illegal drugs without having to handle any suspicious contents directly. This method, which involves an external swipe from the outside of the package, was validated by state forensic laboratories in Maryland and Vermont and can reliably predict whether a package contains fentanyl, even if mixed with cocaine, heroin, or other chemical substances. This swipe technique will do more than help police get faster answers when investigating drug crimes. It will also help at crime labs, which still rely on color tests to get an idea of what is in a container so that they chose the right type of laboratory analysis; however, those color tests don't detect many of the new designer drugs that make up an increasing fraction of their caseloads. The swipe test developed by NIST will work for this, however, optimizing workflow at crime labs across the U.S.

Start-Up Company Set to Commercialize Unique Binding Proteins

In FY 2019, NIST announced the discovery of a set of proteins that bind specifically to different N-terminal amino acids. These binding proteins could form the basis for a new, revolutionary approach for proteomics research, single-molecule protein sequencing. A patent application was filed in April 2019 and a start-up company was granted a license for commercialization of the NIST technology. The company is developing innovative approaches and technologies for next-generation protein analysis.

[52] See the full story here: https://www.nist.gov/news-events/news/2019/09/safer-way-police-test-drug-evidence

CHAPTER 3
National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration's (NOAA) mission is to understand and predict changes in climate, weather, oceans, and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources. This mission will become ever more critical in the 21st century as national issues related to climate change; limited freshwater supply, ecosystem management, and homeland security intensify.

The NOAA technology and innovation enterprise consists of more than 50 laboratories, programs, and offices headquartered in Silver Spring, MD, and staffed across the United States, supporting NOAA's four service-based Line Offices: the National Marine Fisheries Service, the National Ocean Service, the National Weather Service, and the National Environmental Satellite, Data, and Information Service, as well as thematic programs including Climate, Aquaculture, Arctic, Ocean Exploration and Research, Weather and Air Quality, and Ocean Acidification. While the service-based Line Offices each have an R&D component, the entire enterprise is also supported by a dedicated R&D Line Office: The Office of Oceanic and Atmospheric Research.

Research across NOAA's laboratories is primarily aimed at improving the ability of the operational components to accomplish their respective missions. Recent examples demonstrating the direction of NOAA's research are severe storm (hurricane, tornado, derecho winds) and drought forecasting, physical forecasts for renewable energy siting, predicting freshwater resources, tsunami warnings, air quality measurement, solar emission forecasting, monitoring and estimating of fish stocks and species health, coastal habitat monitoring and pollution, invasive species monitoring, coral reef health, ocean acidification, coastal/ocean disaster response and restoration, charting ocean bottom topography, and a wide variety of climate research and the impacts of a changing climate on human health, coastal zone management, and oceans. Research results are routinely transitioned to NOAA's operational components to improve prediction, management, and other mission activities.

Approach and Plans for Technology Transfer

The vast majority of NOAA's transfer of technology outside of the organization happens through peer-reviewed scientific publications and the provision of data and software-based decision-support tools which are delivered directly to the public and stakeholders in service to the NOAA mission of protecting lives and property. The remainder of NOAA's technology transfers are the result of partnerships, grants, and other formal technology transfer mechanisms such as patent license agreements.

Program and Portfolio Management

The NOAA Technology Partnerships Office (TPO), housed under the NOAA Office of Oceanic and Atmospheric Research (OAR), manages a central technology transfer program for all NOAA Labs, Centers, Programs, and external partners.

In 2017, the TPO developed a revised five-year strategic plan to ensure the program is effectively serving its customers and management. TPO refined the plan in 2018 to more closely

align with the Department of Commerce Strategic Plan and was included in the annual report. The following are selected progress to plan updates for 2019:

Goal 1: Increase Innovation within NOAA and the Nation
Activity 3: Conduct T2 and Intellectual Property Training for NOAA staff

Progress Update:
The Technology Partnerships Office and NOAA's Office of General Counsel launched an Intellectual Property Road Tour of NOAA's Labs and Science Centers in 2019. Full training was provided to NOAA's Earth System Research Laboratory in Boulder, Colorado, and the National Severe Storms Laboratory in Norman, Oklahoma. The training was broken into two segments, one for federal employees at the Labs and one for university staff from the NOAA Cooperative Institutes. Both sessions focused on the requirements of the Bayh-Dole Act and the rules and regulations related to the public release of software and models. The sessions were very well received, and the activity has generated badly needed policy discussions on software release and licensing at the NOAA management level.

Goal 2: Enhance Job Creation within the U.S. Economy
Activity 1: Kick-off annual NOAA Innovation Fairs to increase the adoption rate for NOAA technologies in the U.S. private sector

Progress Update:

(Credit: NOAA)

The Technology Partnerships Office successfully executed its first iNOAAvation Center at Blue Tech Week in San Diego, California. The NOAA exhibit featured five of NOAA's SBIR Phase II companies, two NOAA Investigators from the National Marine Fisheries Service, as well as a broad selection of NOAA's innovative technologies. Staff from the TPO were on hand to guide visitors to the most appropriate technologies and meetings. Staff from the International Trade Administration's U.S. Export Assistance Center were also included in the Center to provide assistance with export-related questions.

Blue Tech Week attracts a growing audience from across the United States and globally for a series of intimate executive-level events that bring together representatives of

academia, industry, and policymakers ("the Triple Helix"). Both the NOAA reps and NOAA's SBIR company representatives were able to participate in the many sessions provided by the organizers.

Goal 3: Enhance Resilience and Security
Task 3: Facilitate the private use of NOAA data to develop new commercial products and services

Progress Update:
The TPO worked closely with staff from NOAA's Big Data Program to successfully transition NOAA's Big Data CRADA partners to longer-term, sustainable agreements in 2019. This transition was the culmination of the 4-year CRADAs with the major U.S. Cloud Service Provers (Google, Amazon, IBM, Microsoft, and the Open Cloud Consortium) to investigate the value of making NOAA's data products more accessible to the public through Cloud platforms. NOAA's Big Data Program will now continue to push these efforts forward under the new structure. A key focus for the Program will be to expand the availability understanding of NOAA's ocean data. As with the original CRADA's the goal of these activities will be to increase the commercial use and value of these vast data sets.

Goal 4: Improve Integration, Function, and Profile of the NOAA TPO
Task 2: Revise and issue NOAA T2 Policy Guidance

Progress Update:
In 2019, NOAA's TPO began socializing a broad update to NOAA Administrative Order (NAO) 201-103, which governs all NOAA's technology transfer activities. This will constitute the first comprehensive re-write of the NAO since it was originally developed in 1992. Among other outcomes, the new NAO will streamline the CRADA development and approval process in NOAA, which is a key objective under the Administration's Return on Investment Initiative. Approval for the rewrite is a multi-month project but will ideally result in a flexible framework that will allow for more timely adjustments to NOAA's processes in the future.

NOAA Work Products and Collaborative Activities

Data Products and Services
NOAA data support a wide range of multibillion dollar economic sectors in the U.S. and the global economy and is possibly the most impactful example of technology transfer we provide. Express couriers, rail systems, retailers, and third-party weather forecasts rely on this free and publicly available information to determine routes, weather risks, seasonal merchandising, and scheduling. Ocean and coastal data give the fishing industry tools to determine prime fishing locations through private forecasters who build fishing reports using archived data. NOAA has continued to improve and expand public access to its data. The NOAA Big Data Project is a prime example of these efforts.

NOAA Partners with 3 Big Cloud Providers to Disperse Environmental Data[53]
NOAA has announced a set of collaborations with major cloud providers, promising to "generate untold opportunities for scientific and economic advances."

NOAA's new multi-year agreements with Amazon Web Services, Google Cloud, and Microsoft will dramatically expand "rapid and reliable" no-cost public access to NOAA data, which accumulates at a rate of tens of terabytes per day, gleaned from satellites, radar, weather models, and more. The providers' contracts require them to provide free and open access to the data, but also allow them to charge for additional services related to the data, such as computational power.

"NOAA's wealth of world-class environmental data will now be more accessible through partnerships with commercial cloud providers, which will allow the agency to better manage a rapidly increasing volume of data going forward," said Neil Jacobs, NOAA's Acting Administrator. "Cloud-based storage and processing is the future. Not only will this improved accessibility enhance NOAA's core mission to protect life and property, but it will also open up new and exciting areas of research at universities and significant market opportunities for the private sector."

These new agreements are part of NOAA's Big Data Project, which is the first public-private partnership of its kind in U.S. government. The Big Data Project received a Best in Class 2019 Government Innovation Award last month in the category of Public Sector Innovation, recognizing "innovative ways that government applies technology to better meet its mission and serve the public."

Decision Support Tools

NOAA's labs and programs develop a wide variety of dedicated software tools and websites that bring data to the public in a user-friendly format to enable effective decision support. In many cases, these sites are developed in conjunction with academia and private sector partners.

OceanReports App Answers Aquaculture Siting Questions in Seconds[54]
Imagine you could draw a box anywhere in the ocean and instantly decide whether it might be a suitable site for aquaculture. Thanks to a new tool, OceanReports, aquaculture stakeholders—including seafood farmers, coastal managers and regulators, and environmental organizations—can now do just that.

[53] The full story is here: https://www.fedscoop.com/noaa-cloud-providers-environmental-data/
[54] https://www.fisheries.noaa.gov/feature-story/new-app-answers-aquaculture-siting-questions-seconds

Coastal net pens off the coast of Maine. (Credit: NOAA)

Developed by NOAA's National Ocean Service and partners, the app can query more than 100 marine datasets. Within seconds, it generates custom spatial reports and infographics for any ocean space or "neighborhood." These datasets include everything from ocean current speed to deep-sea corals and sponge observations in that area.

Though intended for all ocean industries, the development team built the app specifically with aquaculture in mind. "OceanReports is helping pave the way for sustainable aquaculture development in coastal areas," said Nicole LeBoeuf, National Ocean Service Acting Assistant Administrator. "It exemplifies how powerful, easy-to-use tools will play an increasing role in ensuring the security and health of our ocean."

Cooperative Institutes

NOAA supports a network of 16 Cooperative Institutes at 42 universities and research institutions across 23 states and the District of Columbia. Some Cooperative Institutes are located near NOAA laboratories or science centers, creating a strong, long-term collaboration between federal and university scientists. The work done through the Cooperative Institutes directly supports NOAA's mission activities and results in similar technology transfer opportunities. NOAA's Technology Partnerships Office works closely with the technology transfer offices from the Institutes to jointly manage intellectual property and seek out licensing partners.

NOAA and University Partners Educating the World through Science on a Sphere Explorer™ and SOS Explorer™ Mobile

The Science on a Sphere (SOS) Explorer™ and SOS Explorer™ Mobile - developed by Federal and University staff with the Global Systems Division (GSD) of the Earth System Research Laboratory in Boulder, CO - are free and low-cost software and apps that share earth science data with a global audience using visually stunning movies on a virtual globe.


(Credit: NOAA)

SOS Explorer™ and its mobile companion leverage the expansive data catalog from the NOAA's patented Science on a Sphere®, also developed at GSD. SOS Explorer™ and its mobile companion were developed to expand SOS's reach to a far greater audience comprising educators, students, small museums, and the public.

SOS Explorer™ was released in 2017, as a low-cost software system that has museum-quality stability and usability while providing an interactive globe on a flat panel computer or TV display. It incorporates immersive virtual reality hardware, 3D beyond-earth objects such as satellite locations and Aurora Borealis, as well as flat mapping, which are not attainable with the room-sized Science on a Sphere®. The SOS Explorer™ is currently reaching thousands of viewers per year through its 30 installations in museums and schools since its first release in 2017.

SOS Explorer™ Mobile is an interactive globe that can be downloaded to a mobile device and was released as a free app in 2019. These versions successfully provide over 115 popular Science on a Sphere® datasets to users. SOS Explorer™ Mobile has been downloaded over 20,000 times since its release on Sept 1, 2019. GSD estimates the SOS Explorer™ Mobile will have over 50,000 downloads in its first year ending September 2020.

Inventions, Patents, and Licenses

NOAA was awarded U.S. Patent No. 10,438,788 - SYSTEM AND METHODOLOGY FOR EXPRESSING ION PATH IN A TIME-OF-FLIGHT MASS SPECTROMETER in 2019. This is the second patent awarded for this invention.

Additionally, NOAA researchers disclosed two software innovations, one biological discovery, and three hardware inventions. Two of the innovations are owned by NOAA partners under Bayh-Dole, one other was returned to the inventor in cooperation with the funded university. NOAA filed provisional patent applications on two of the remaining innovations, while the last of the six is still being evaluated.

Table 26 – NOAA Invention Disclosures and Patents[55]

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Invention Disclosures					
Inventions Disclosed	15	18	3	6	6
Patents					
U.S. Patent Applications Filed	6	4	3	2	2
U.S. Patents Received	1	1	3	0	1
Foreign Patent Applications Filed	0	0	0	0	0
Foreign Patents Received	0	1	0	0	0

NOAA now maintains an active patent portfolio of 18 technologies, ten of which are being marketed for licensees or are being actively commercialized.

NOAA currently manages 6 active licenses. In addition, two licenses are under the direction of its university partners, and one more temporary research license is currently in place. In total, NOAA's licensing portfolio consists of nine (9) active licenses.

Table 27 – NOAA Licenses[56]

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Licenses					
Total Active Licenses	6	7	7	7	6
Total New Licenses	2	3	0	0	1
Income Bearing Licenses					
Total Active Income Bearing Licenses	4	5	7	7	6
New Income Bearing Licenses	3	3	2	0	0
Total Active Invention Licenses	4	7	7	7	6
New Invention Licenses	0	3	1	0	0
Exclusive Licenses	1	4	4	4	4
Partially Exclusive Licenses	0	0	0	0	0
Non-Exclusive License	3	3	3	3	2
Elapsed time for Granting Licenses					
Average (months)	3	9	3	n.a.	n.a.
Minimum (months)	0	5	1	n.a.	n.a.
Maximum (months)	0	14	5	n.a.	n.a.

[55] Values include software and hardware IP, but do not include Bayh-Dole disclosures from NOAA grantees or contractors

[56] Totals do not include R&D licenses. Science of a Sphere installations are not included in license totals.

Table 28 – NOAA License Income[57]

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Income from Licenses					
Total Income, All Active Licenses	$39,633	$11,000	$106,394	$35,671	$67,235
Invention License Income	$39,633	$11,000	$106,394	$35,671	$67,235
Total Earned Royalty Income (ERI)	$39,633	$11,000	$46,184	$35,671	$67,235
Minimum ERI	$39,633	$1,000	$2,000	$250	$1,000
Maximum ERI	$39,633	$7,000	$33,684	$33,321	$58,535
Median ERI	$39,633	$5,000	$10,500	$2,100	$3,850
ERI from Top 1% of Licenses	$39,633	$7,000	$33,684	$33,321	$58,535
ERI from Top 5% of Licenses	$39,633	$7,000	$33,684	$33,321	$58,535
ERI from Top 20% of Licenses	$39,633	$7,000	$44,184	$33,321	$58,535
ERI to Inventor(s)	$12,588	$4,000	$1,736	$13,643	$25,070
	32%	36%	4%	38%	37%
ERI to NOAA	$27,045	$7,000	$3,864	$22,028	$42,165
	68%	64%	8%	62%	63%
Licenses Terminated for Cause	0	0	0	0	0

[57] For FY 2017, total income reflects two licenses from NOAA Cooperative Institutes, which earned income but did not include royalty distributions to federal staff.

Cooperative Research and Development Agreements (CRADAs)

NOAA's Labs, Centers, and Programs executed 10 new CRADAs in FY 2019. Five of these agreements were with small businesses. Factoring in the new and expiring agreements, the total NOAA CRADA portfolio sits at 43 active CRADAs.

Table 29 – NOAA Cooperative Research and Development Agreements[58]

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
CRADAs					
Total Active CRADAs	28	33	37	45	43
New CRADAs Executed	14	10	15	11	10
Active CRADAs with Small Businesses	0	18	26	22	24
Small Businesses in Active CRADAs	0	18	26	22	24
Traditional CRADAs					
Active Traditional CRADAs	28	33	36	43	42
New Traditional CRADAs Executed	14	9	14	10	10
Non-Traditional CRADAs					
Active Non-Traditional CRADAs	0	0	0	2	1
New Non-Traditional CRADAs Executed	0	1	0	1	0

Return on Investment - Economic Impact of NOAA's CRADA Activity

NOAA's CRADA activity languished in the early 2000s due to staffing shortages in the Office of Research and Technology Applications. In 2009, a new program manager was appointed, and the office was renamed to the Technology Partnerships Office (TPO). The number of CRADAs has grown steadily from that time and has now stabilized in the 40-50 agreement range.

In 2018, the TPO contracted with Eastern Research Group (ERG) to deliver an economic valuation report for NOAA's SBIR Program and a limited selection of NOAA's CRADA portfolio. The CRADA portfolio analysis was limited by the fact that many agreements were newly initiated or were ongoing when the study was conducted. The TPO determined these agreements were not mature enough to be considered, so they were excluded from the scope. In 2019, ERG delivered its final valuation report. Following is a summary of the CRADA results.

Survey

ERG implemented a survey of SBIR awardees and CRADA collaborators which covered several aspects of the participants' involvement in the NOAA programs, including:

- The focus and/or target market of the SBIR/CRADA project;
- Commercial status of the product/service (SBIR);

[58] Non-traditional CRADAs include Facilities Usage Agreements.

- Revenues earned from the project from various sources;
- Non-monetary benefits;
- Other funding associated with the project;
- Satisfaction with the NOAA program; and
- Perceived success of participating in the program.

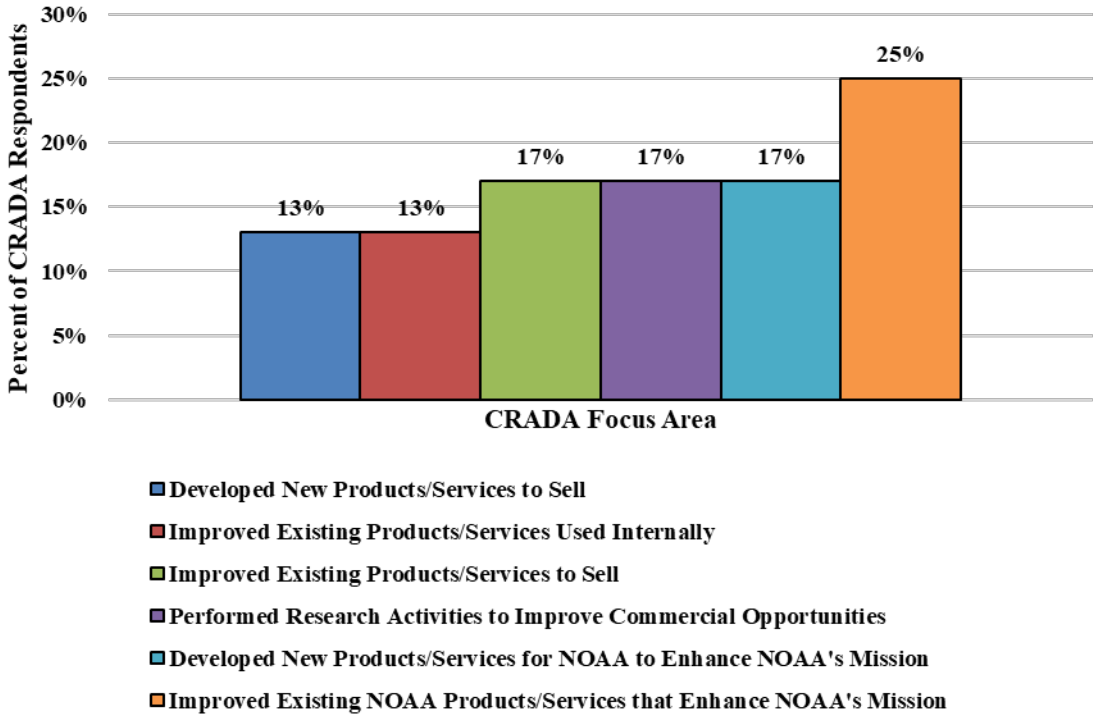
Table 4 summarizes the total surveys sent and received for each program, starting with the total number of in-scope companies. ERG was able to obtain 49 SBIR responses and nine CRADA responses; these numbers translated to response rates of 49 percent and 45 percent for the SBIR and CRADA programs, respectively.

Table 4. Summary of Survey Response Counts

Explanation of Recipient Counts	SBIR	CRADA
Initial Count of Survey Recipients	132	25
Removed Due to Infeasibility of Participation	33	5
Total Possible Survey Responses	99	20
Total Responses Received	49	9
Response Rate	49%	45%

The focus of CRADA projects included in the survey is presented in Figure 6, below. Respondents were able to select more than one focus area; thus, the total percentage exceeds 100 percent.

Figure 6: CRADA Focus Areas



Revenue from New Products and Services

Three respondents (13%) indicated that a focus of their CRADA was developing new products or services (including data) that their company would be able to sell to customers (See Figure 2). Of these respondents, two indicated that their product/service was under development, and the other indicated that their product/service was undergoing pre-market testing and was not currently being sold. No company who responded to the survey was currently selling their CRADA-developed product/service of focus in the CRADA. Given that the products/services were not currently commercially available, the responses for current and expected sales values for these products/services were zero dollars.

Revenue from Improving Existing Products and Services

Four respondents (17%) indicated that a focus of their CRADA was aimed at improving existing products/services that could be sold commercially or used internally at their company (See Figure 2). Two of these respondents indicated that their product/service is currently being sold. Companies reported that approximate sales over the last year of these improved products/services ranged from $25 to $2.5M for the collaborating companies. One respondent indicated that the improved product/service led to a 100 percent increase in sales over the last year, with the other company indicating that 50 percent of sales were attributable to the improved product/service. Expected sales for the two improved products/services were estimated at $50 and $10M, respectively.

Revenues from Internal Products and Services

Of the four respondents (17%) who indicated that the focus of their CRADA was aimed at improving existing products/services, one indicated that the CRADA led to improvements or changes to products or services that are currently being sold. The approximate sales of this product/service were estimated to be between $25,000-$35,000. The respondent indicated that 100 percent of sales over the last year were attributable to the improved product/service.

Non-Monetary Benefits

When asked if there were any non-monetary benefits the participating company gained from being involved in the CRADA agreement with NOAA, six of the nine survey participants described specific benefits:

- Testing and confirmation of product performance;
- Supporting native aquatic species and supporting ecosystem restoration;
- Publicity;
- New data collection methods;
- Accelerated research and development cycles; and
- Increasing public awareness and safety related to hazardous events.

Leveraged Funding

Two CRADA collaborators received additional resources (investment funding) from external sources (e.g., venture capital) to assist with conducting their CRADA. One received $90 million and the other received $4.36 million.

Satisfaction and Success

Survey results show that the majority of respondents felt that their CRADA project was beneficial to their company's commercial success. Respondents could rate the impact of the CRADA as "very beneficial," "beneficial," "marginally beneficial," or "not beneficial." Of the nine respondents, seven rated their CRADA as "beneficial," one rated it as "very beneficial," and one rated it as "not beneficial."

Eight respondents described the level of collaboration between NOAA and their company in conducting their CRADA project as "very collaborative"; the other respondent described their level of collaboration as "moderately collaborative." In addition, eight respondents also indicated that they were "very satisfied" with interactions with NOAA under their CRADA agreement with the remaining respondent being "somewhat satisfied" with their NOAA interactions.

Table 30 – NOAA Involvement with Small Businesses, Startups, and Young Companies

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Number of Small Businesses Supported	0	23	30	22	24
Total Number of Startup and Young Companies Supported	1	2	1	0	0

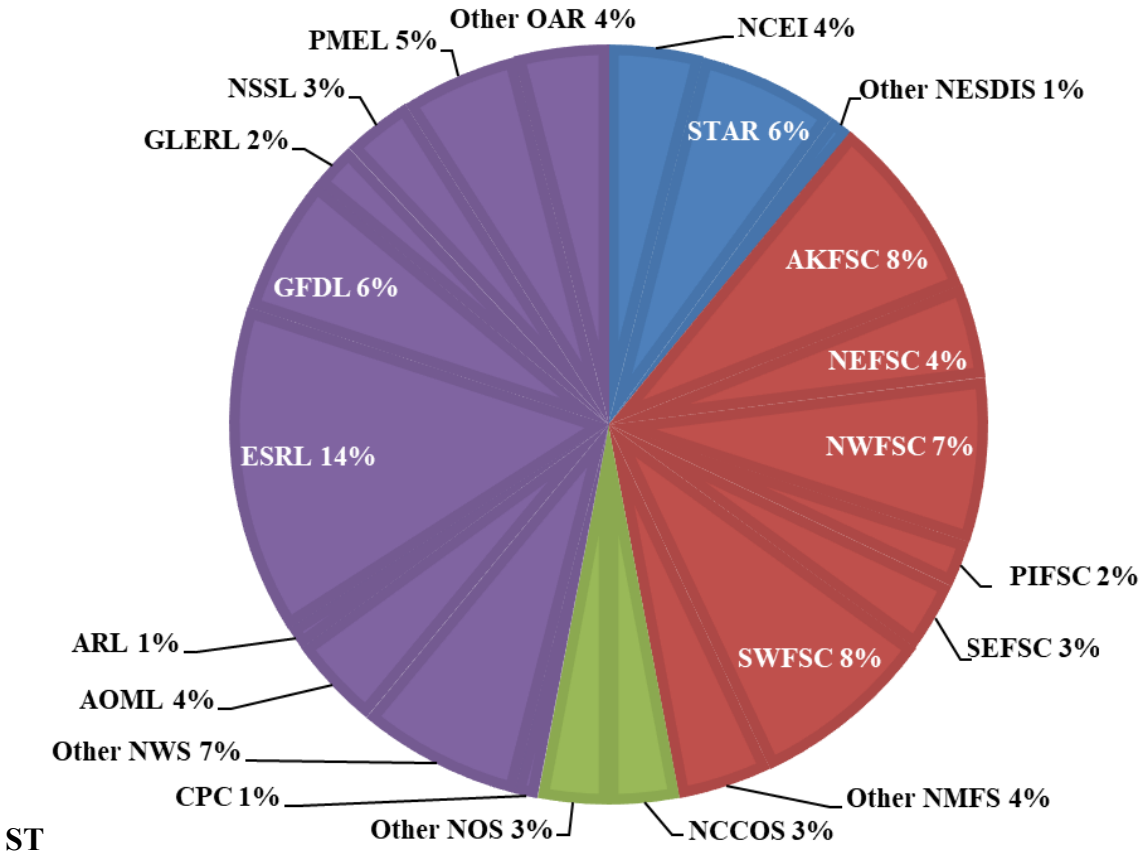
Publications[59]

In FY 2019, peer-reviewed publications by NOAA federal scientists totaled 1,895. The following charts show the breakdown of publications, including publications from NOAA-funded sources.

[59] NOAA publications data for 2019 were derived on December 2, 2019, using queries through the Web of Science database. As a result of variations in titles and nomenclature, these data **do not** provide a comprehensive measure of

	NOAA Authored Publications	NOAA Funded Publications (including authored pubs)	NOAA Funded Publications (excluding authored pubs)	All NOAA Publications
Q1	500	731	486	986
Q2	380	475	287	667
Q3	418	577	368	786
Q4	597	764	459	1,056
Total	**1,895**	**2,547**	**1,600**	**3,495**

Figure 7: Publications per Lab/Division[60]



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Downstream Success Stories from NOAA Technology Transfer Activities

Saildrone: Unmanned Surface Vessel (USV), Alameda, CA

all NOAA publications. This reporting includes only those publications by NOAA scientists that were captured by the search queries. Publications authored by multiple divisions or assigned to multiple subjects have been counted multiple times in these tables.

[60] Number of publications by research unit as a percentage of all NOAA-authored publications in FY 2019. A single publication with authors from one or more line office is counted as a publication for each line office.

Scientists and researchers have traditionally relied upon large research vessels for oceanographic data collection and monitoring activities. The data these vessels provide improve the scientific understanding of physical and biological aspects of the ocean. It also contributes to scientific disciplines whose work intersects with ocean processes, such as meteorology and climatology. The data has an array of practical applications, such as improving weather forecasts and aiding in species management.

Photo Credit: Saildrone

However, these vessels can be costly and have other drawbacks as well. For example, they require time for scheduling and planning voyages and can cause research restrictions due to their size and maneuverability. Despite these drawbacks, the information these vessels provide is imperative, so the search for a better method ensued.

The California-based company, Saildrone, sought collaboration with NOAA's Pacific Marine Environmental Laboratory (PMEL) to maximize the scientific applications of the wind-powered, unmanned surface vessel (USV) they developed.

Project

PMEL foresaw the potential for their USV technology to expand NOAA's ocean observing research capabilities. After Saildrone produced a prototype of an autonomous sailing vehicle the seeds of a collaborative relationship were planted. The goal of the CRADA was to combine NOAA PMEL's experience implementing large-scale observing networks with an enhanced version of a Saildrone able to attain high-quality scientific observations that would be accepted by the global scientific community. The ongoing CRADA is a collaborative process between PMEL and Saildrone resulting in multiple waves of technology/product development focusing on NOAA's data collection or monitoring missions. These waves include:

- A meteorological and oceanographic sensor package, where the focus was on the development of sensors to capture a range of ocean (e.g., ocean currents, pH) and atmospheric (e.g., wind speed, air temperature) measurements;
- Active acoustics to monitor marine mammals;
- A carbon sensor, where the focus was on a high-precision carbon dioxide (CO2) sensor; and
- A surface flux sensor to measure air and water turbulence.

With the potential for additional waves of product development, the Saildrone team conveyed that the future roadmap for sensor development will be driven, in part, by the Global Ocean Observing Network's Essential Ocean Variables (EOVs), which help prioritize and maximize data across ocean observing platforms and networks.

Benefits

The data collected by Saildrones generates a variety of ecosystem service benefits. For example, the data can be used to enhance NOAA fisheries' capabilities, allowing better management of fisheries for species health, preservation, or public consumption. The data improves geospatial coverage of carbon in the ocean, which can be used to inform processes like ocean acidification and its impacts on plants and animals. Also, Saildrones can augment the ability to detect oil spills; helping spur spill response to minimize negative impacts to ocean organisms and ecosystems.

The development of the Saildrone has generated significant economic impacts for the company and the State of California that filter out to the country. Internally, the CRADA helped Saildrone increase private investment due to the perceived scientific rigor associated with NOAA's involvement in product development, helping achieve over $90 million in direct, private investment into the technology. The influx of product interest and sales helped Saildrone expand its workforce from 8 to over 100 employees since June 2014. The manufacturing of Saildrones, which occurs entirely in the US, has also created jobs stretching from advanced manufacturing to advanced engineering, and the economic impact trickles outward to supply chains across the nation.

NOAA Support

Saildrone credits the CRADA knowledge-sharing process with accelerating company research and development. The collaboration with NOAA has also added a layer of product legitimacy for investors, given the agency's reputation for conducting rigorous science.

Shellfish Research and Living Marine Resource Restoration in Puget Sound

Photo Credit: NOAA

In Puget Sound of Washington, Olympia oysters, kelp, and pinto abalone serve as ecosystem engineers; building and maintaining habitat critical for not only themselves, but numerous other species who rely upon the ecosystems that they create. Through their existence, these organisms also generate an array of benefits for humans that span from food production to employment to storm protection and recreation. However, each of these critical organisms is teetering on the brink of endangerment or disappearance in the Puget Sound.

Currently in Puget Sound, less than five percent of dense Olympia oyster beds remain at the intertidal area; floating kelp beds have nearly disappeared from the southern portion of the Sound; and the pinto abalone population has been on a steep decline, decreasing 98 percent between 1992 and 2017 according to the Washington Department of Fish and Wildlife.

In 2011, The Puget Sound Restoration Fund (PRSF) approached NOAA with the idea of expanding their hatchery capacity in order to increase their production of oyster seed, kelp, and abalone.

Project
A CRADA between PSRF, the NOAA Manchester Native Shellfish Hatchery, and the Northwest Fisheries Science Center Manchester Laboratory was established in 2014. NOAA provided dedicated facilities having key attributes for project work (e.g., shellfish hatchery access with adequate flows of seawater) and technical expertise (e.g., species genetics) and PSRF was responsible for securing project staff and implementing project activities. With the aim to increase the scale of research and restoration activities focused on the Olympia oyster, kelp, and pinto abalone in Puget Sound, PSRF and NOAA focused project research and restoration activities in three areas:

- Producing Olympia oyster larvae and seed that is planted to restore native oyster beds;
- Establishing a kelp lab for further applied research; and
- Establishing new pinto abalone operations at NOAA's Manchester Research Station to increase the number of abalone able to be produced and, subsequently, introduced into the wild.

Since the inception of the CRADA, over 10 million oyster seeds have been produced and planted in priority areas. Olympia oysters are the only oyster species native to the Pacific Northwest region of the US and they are critical to the delicate ecosystem as they help regulate water quality, cycle nutrients, and create habitat for seagrasses and fish. The kelp lab and research efforts enabled PSRF to secure a 5-year grant worth $1.5 million from the Paul G. Allen Family Foundation to investigate seaweed cultivation as a potential strategy for mitigating ocean acidification through the removal of carbon dioxide (CO2).

Operations made possible through the CRADA have tripled the production of pinto abalone, the only abalone species native to Puget Sound, when compared to pre-CRADA volumes. The abalone grazing, digesting, and excreting micro- and macro-algae clear habitat space for settlement of new organisms, improve nutrient cycling, and provide food to prey species.

The CRADA also has also resulted in economic benefits from oyster product sales. PSRF indicated that product sales over the last year totaled $25,000, all of which can be attributed to work done through the CRADA.

NOAA Support
PSRF Executive Director, Betsy Peabody, described the CRADA with NOAA as being "life-changing." She articulated that NOAA has worked with PSRF step-by-step to accomplish a shared vision. NOAA's support for PSRF's work has come in several forms. NOAA has provided the facilities needed to conduct research and restoration activities, technical assistance critical to advancing the work being conducted, and an influx of resources as PRSF has grown, or outgrown various situations or circumstances, throughout their CRADA experience.

NOAA Hosts Earth Prediction Innovation Center (EPIC) Community Workshop[61]

NOAA is working closely with entities in the weather enterprise (public, private, and academic) to inform the planning, development, and strategy for an Earth Prediction Innovation Center (EPIC) with the goal of accelerating community-developed scientific and technological advancements into the operational applications for Numerical Weather Prediction (NWP).

Photo Credit: NOAA

To engage the community and inform the next steps for the EPIC Program, NOAA's Office of Weather and Air Quality (OWAQ) hosted the EPIC Community Workshop at the University of Colorado, Boulder University Memorial Center from August 6-8, 2019. The objectives of the workshop were to co-create a vision for EPIC to accelerate the transition of research to operations; share the current status and future of community-based Earth System Modeling; understand NOAA's developmental process for EPIC; create shared next steps in the development of EPIC and identify emerging technologies for Earth System Modeling.

Over twenty NOAA staff from multiple Offices assisted in executing the Community Workshop which had over 180 in-person attendees. While government employees made up a majority of the Community Workshop participants, we had individuals from academia (60 participants), as well as the private sector (35 participants), join us in the discussion. The Community Workshop was streamed via webinar and was attended by 113 individuals. In total, we engaged nearly 300 participants.

Other Activities, Performance Measures Deemed Important by the Agency

Science On a Sphere®

Science on a Sphere® (SOS) is a room-sized, global display system (US Patent 6,937,210) that uses computers and video projectors to display planetary data onto a six-foot diameter sphere, analogous to a giant animated globe. Researchers at NOAA developed Science on a Sphere® as an educational tool to help illustrate Earth System science to people of all ages. Animated images of atmospheric storms, climate change, and ocean temperature can be shown on the sphere, which is used to explain complex environmental processes in a way that is simultaneously intuitive and captivating.

[61] https://owaq.noaa.gov/Resources/News/ArtMID/446/ArticleID/54/An-Overview-The-Earth-Prediction-Innovation-Center-EPIC-Community-Workshop

"Science on a Sphere" Ribbon Cutting Ceremony
From left to right: Mark Auslander (MSU Museum Director),
Diane Byrum (MSU Board of Trustees Chair),
April Clobes (MSU Federal Credit Union President and CEO),
Teresa Sullivan (MSU Interim Provost) (Credit: MSU)

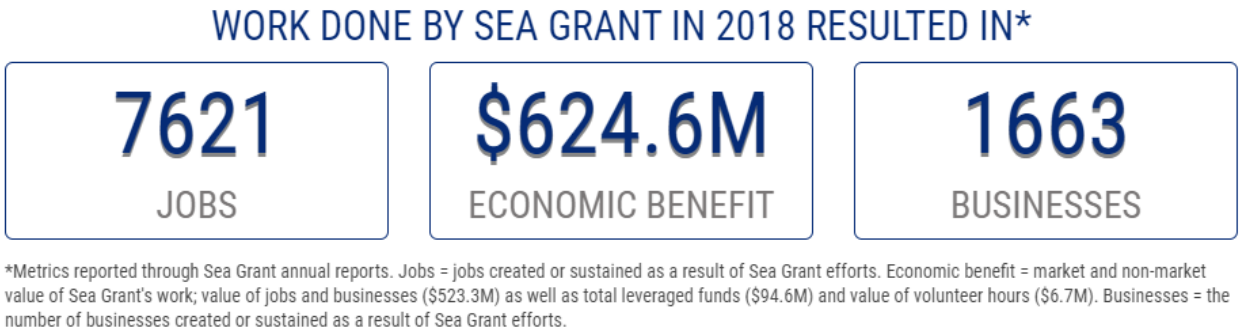
Table 32 – NOAA's SOS Installations

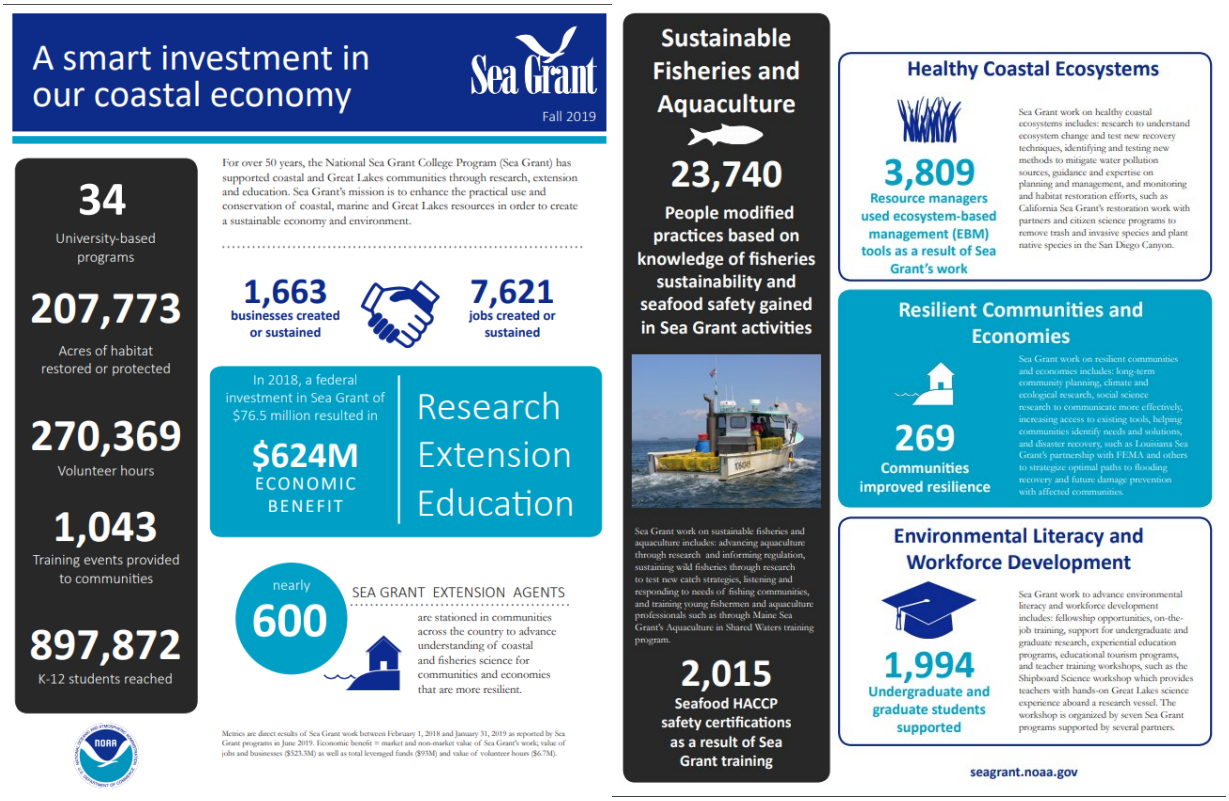
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
SoS Installations					
Total Number in Operation	126	135	144	155	165
New Domestic	6	3	6	3	7
New International	10	6	3	8	8
Total New Installs	16	9	9	11	15

NOAA-Funded (Extramural) R&D

NOAA Sea Grant

The National Sea Grant College Program was established by the U.S. Congress in 1966 and works to create and maintain a healthy coastal environment and economy. The Sea Grant network consists of a federal/university partnership between NOAA and 33 university-based programs in every coastal and Great Lakes state, Puerto Rico, and Guam. The network draws on the expertise of more than 3,000 scientists, engineers, public outreach experts, educators, and students to help citizens better understand, conserve and utilize America's coastal resources.





U.S. Integrated Ocean Observing System Program (*IOOS®*)

IOOS is a national-regional partnership working to provide new tools and forecasts to improve safety, enhance the economy, and protect our environment. Integrated ocean information is available in near real-time, as well as retrospectively.

IOOS Funds a Study of US Business Activity in Ocean Measurement, Observation, & Forecasting[62]

The ocean enterprise (for-profit and not-for-profit businesses that support ocean measurement, observation, and forecasting) is a critical component of maritime commerce and the blue economy. These businesses develop the infrastructure necessary to generate new data and to work with publicly available data to deliver value-added products and services to ensure the safe, responsible, and successful running of maritime commerce. From the instruments that make strides in ocean observing every day to the app that tells a tourist whale-watching expedition if today is a safe day to go out, the ocean enterprise is a significant component of maritime industry. The Ocean Enterprise is rarely recognized as its own because the work they do is widely distributed across a range of disciplines not typically classified as maritime operations. The objective of its publication is to raise visibility and awareness of this important industry cluster and to better understand

[62] https://ioos.noaa.gov/project/ocean-enterprise-study/

its linkages with NOAA and the U.S. Integrated Ocean Observing System (IOOS®) program.

The study[63] encompasses private sector enterprises that are:

- Providers of infrastructure including:
    - Manufacturers of sensors, instruments, and platforms
    - Those building, deploying, and operating observing systems
    - Providers of the data infrastructure that manages and communicates ocean data
    - Organizations that develop and maintain the data management systems, software tools, and models that are used to turn these data into useful information
- Intermediaries that make use of ocean, coastal, and Great Lakes measurements, observations and models as an input to the creation of value-added information products

Characterizing business activity within this sector is important to understanding the scope and scale of business activity supporting public missions and private sector growth within the overall economy. There were no major surprises, but many interesting findings including the locations, size, and functions of firms in this sector, including:

- Identifying more than 400 firms in the United States as operating in the sphere of Ocean Enterprise.
    - This includes businesses inland (e.g. Nebraska, Kansas, and Montana) all contributing to the ocean enterprise, but not previously captured by regional studies.
- The Ocean Enterprise generated $7 billion (USD) in revenue annually
- 86% of businesses have been operating five or more years in the Ocean Enterprise. More than 54% of them expect growth in their Ocean Enterprise business in the next year.

Climate Program Office

The Climate Program Office (CPO) manages the competitive research program in which NOAA funds high-priority climate science to advance understanding of Earth's climate system and its atmospheric, oceanic, land, and snow and ice components. This science contributes to knowledge about how climate variability and change affect our health, economy, and well-being. CPO supports research that is conducted in regions across the United States, at national and international scales, and globally.

Regional Integrated Sciences and Assessments (RISA) program team and partners win 2019 Colorado Governor's Award for High-Impact Research[64]

[63] Full Report: https://cdn.ioos.noaa.gov/media/2017/12/oceanenterprise_feb2017_secure.pdf

[64] https://cpo.noaa.gov/News/News-Article/ArtMID/6226/ArticleID/1808/CPO-RISA-team-and-partners-win-2019-Governor%e2%80%99s-Award-for-High-Impact-Research)

In the last 100 years, the leading cause of dam failure and the resulting loss of life has been overtopping due to inadequate or improperly designed spillways. With increases in severity and frequency of extreme precipitation events, current modeling practices for rain and snowfall have shown to be inadequate for assessing possible public safety issues regarding dams and spillways.

Left to right: Eric James of CIRES and ESRL GSD, Kelly Mahoney of ESRL PSD, Rob Cifelli of ESRL PSD, and Jeff Lukas of CPO's Western Water Assessment RISA team and CIRES (Trevor Alcott of ESRL GSD, absent) (Credit: NOAA).

Leveraging 21st century scientific and engineering advances and applying creative approaches, a unique federal-state-private sector team of nationally recognized scientists, engineers, public safety officials, and dam owners designed and implemented an innovative scientific approach to understanding extreme precipitation in the Rocky Mountain region.

The effort was part of a larger project sponsored by the Colorado Division of Water Resources and the New Mexico Office of the State Engineer to update decades-old extreme precipitation estimates using modern technical methods and current scientific understanding. The team developed engineering and decision support tools that provide a scientifically defensible basis for determining the risk of extreme precipitation events to guide dam spillway design and to enhance community resilience in a changing climate.

Education and Outreach

NOAA Environmental Literacy Program instructs Maine's coastal communities to use NOAA data to help prepare for sea-level rise[65]

In July, over 60 residents of Cumberland County, Maine, packed into a room in the local Cliff Island Post Office. There, the Gulf of Maine Research Institute (GMRI) led them through an exploration of Maine's climate past, using it as an entry point to help the residents better understand their state's climate present and future.

[65] https://www.noaa.gov/education/stories/maine-s-coastal-communities-use-noaa-data-to-prepare-for-sea-level-rise


(Credit: NOAA)

Most people in Maine, including the attendees of this event, live along the Gulf of Maine, where coastal waters have warmed more than anywhere else in the United States. This warming water and the ensuing sea level rise contribute to severe storms and king tides (the highest high tides of the year) that hurt the community's residents, industries, and ecosystems.

To help Maine residents understand and prepare for these threats, GMRI sought out assistance from NOAA's Environmental Literacy Program (ELP), which supports the use of education as a tool to help people and their communities become more resilient to extreme weather and climate events. Through an ELP grant, GMRI created an interactive learning experience called "Preparing coastal communities for sea-level rise." This program integrated NOAA data into story maps—interactive digital tools that combine geographic data and narrative—to engage people in understanding sea-level rise, its causes, its future projections, and its impacts on local communities.

NOAA Technology Transfer Awards

NOAA selected one project to receive the Agency's Technology Transfer Award in 2019. This project exemplified the highest standard for developing new technology in cooperation with private sector partners in the service of NOAA's mission.

Gabriel Brooks - For leadership in implementing technology transfer for Passive Integrated Transponder (PIT) tag detection in fish across the Pacific Northwest.

CHAPTER 4
National Telecommunications and Information Administration: Institute for Telecommunication Sciences

The Institute for Telecommunication Sciences (ITS) is the research and engineering laboratory that provides technical engineering support to NTIA. ITS also serves as a principal federal resource for solving telecommunications concerns of other federal agencies, state and local governments, private corporations and associations, and international organizations through Interagency Agreements and CRADAs. Roughly three-quarters of ITS research programs are undertaken under such agreements. This includes assisting the FCC and federal defense, public safety, and other agencies that use federal and non-federal spectrum.

Approach and Plans for Technology Transfer

ITS efforts in technology transfer and commercialization foster cooperative telecommunications research in areas where U.S. companies can directly benefit from improved competitiveness and market opportunities. ITS uses three principal means for achieving technology transfer:

- Cooperative R&D;
- Technical publications, sample data sets, and software tools available on the ITS website and GitHub; and,
- Leadership and technical contributions in the development of telecommunications standards.

ITS Work Products and Collaborative Activities

Cooperative Research and Development

ITS is authorized under the Federal Technology Transfer Act of 1986 (FTTA) to enter into CRADAs with private industry, universities, and other interested parties. ITS CRADAs protect proprietary information, grant patent rights, and provide for user licenses to private entities. They also provide the legal basis for shared use of government facilities and resources with the private sector.

In FY 2019, as it has for decades, ITS participated in CRADAs with private sector organizations to design, develop, test, and evaluate advanced telecommunication concepts. CRADAs provide ITS with insights into industry's needs for productivity growth and competitiveness. This enables ITS to adjust the focus and direction of its programs for effectiveness and value. The private industry partner benefits by gaining access to the results of research in commercially important areas that it would not otherwise be able to undertake.

To date, major contributions to citizens achieved through CRADAs include broadband commercial radio service (including testing and evaluation of spectrum access systems and environmental sensing capability sensors), personal communication services (PCS), local multipoint distribution service (LMDS), ultra-wideband (UWB), objective audio and video Quality of Experience (QoE) metrics, advanced antennas for wireless systems, remote sensing and global position (GPS) technologies, high resolution laser radar (LADAR), autonomous

networks for unmanned aerial vehicles (UAVs), and broadband air-interface and core network capabilities for Long Term Evolution (LTE) mobile communications. These have aided U.S. efforts to rapidly introduce new socially constructive communications technologies.

ITS was a partner in the original Public Safety Communications Research (PSCR) program with the NIST Communications Technology Laboratory (CTL). That program focused on improving first responder communications and interoperability through the development of communication standards and through research, development, testing, and evaluation (RDT&E) of mission critical communication systems. This joint program operated for over two decades on behalf of sponsors at the Department of Homeland Security (DHS) and the Department of Justice (DOJ). Public Safety 700 MHz Broadband Demonstration Agreements (CRADAs) protected the intellectual property of vendors and manufacturers while operating various elements of an LTE network in the PSCR test bed and over-the-air (OTA) network (both hosted and managed by ITS) in order to test interoperability of public safety communications equipment under simulated field conditions, with the participation of public safety practitioners. The Broadband II Consortium expired in late FY 2018 and has not been renewed; since the vast majority of CRADAs ITS entered into in prior reporting years related to the Consortium, total number of CRADAs in FY 2019 were significantly lower.

Table 33 – Collaborative Relationships for Research & Development

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Number of Active CRADAs	54	62	60	68	11
Number of Newly Executed CRADAs	53	12	8	13	8
Number of Active CRADAs with Small Businesses Involvement	15	17	17	18	4
Number of Small Businesses Involved in Active CRADAs	15	17	17	18	4

Technical Publications

Publication has historically been the means through which ITS has transferred research results to other researchers, the commercial sector, and government agencies. Many ITS technical publications—both reports and monographs published by NTIA and peer-reviewed articles in scientific journals—have become standard references in several telecommunications areas. Technical publication remains a principal means for ITS technology transfer; software releases are becoming increasingly important and publication downloads have been decreasing as software downloads increase. Technical publications are released after going through an internal peer review process managed by the ITS Editorial Review Board (ERB). In FY 2019, 56% of manuscripts released through the ERB process were published in scientific journals or conference proceedings and 44% were published as NTIA reports. While official NTIA publications allow greater in-depth analysis of research results, journal articles and conference papers have equal, and sometimes greater, reach in transferring new tools and discoveries.

Technical Publications Downloaded

ITS makes all of its publications available to the public through its Web site and provides online users with advanced search capabilities that will locate relevant publications by keyword. To ensure a meaningful and realistic metric, ITS counts actual downloads of publication PDFs rather than pageviews of the bibliographic summaries. In FY 2019, ITS technical publications were downloaded 4,895 times.

Transfer of Technical Methods
High-precision measurements are key to creating and validating radio propagation models. ITS and its predecessors have been collecting measurement data for more than a century, creating a unique expertise in measurement science and techniques. In FY 2018, ITS published a Technical Handbook that described the principles of collecting accurate spectrum measurements. In FY 2019, ITS published on YouTube a series of 20 videos on Spectrum Measurement Theory and Techniques that combine theory and hands-on demonstration, which were viewed 1,083 times.

Licensing
Since FY 2008, ITS no longer licenses software technology. Instead, software is made available via open source download. Therefore, no licensing metrics are reported.

Software and Data Downloads
Increasingly, technology transfer occurs through the publication of software rather than traditional technical reports. ITS makes several software and data tools available via open source download. Reliable and robust methods of counting downloads of these tools took some time to develop. Video quality metric (VQM) downloads were reported for the first time in FY 2013 and other downloads were reported for the first time in FY 2014. In FY 2017, ITS increased its use of the GitHub open source code hosting platform, and in FY 2019 ITS had 21 public repositories. While this allows more interaction with potential users of the software and can perhaps be said to broaden the audience, the open source paradigm also makes it more difficult to understand the impact of the software. While there is presently no generally accepted impact metric for GitHub repositories, ITS has added a count of the number of public repositories as a proxy until a more meaningful impact metric is determined. ITS continues to explore the development of metrics for GitHub-posted code.

Propagation Prediction: ITS is, and has been for decades, a world leader in the development of models and methods for accurate prediction of radio propagation. Propagation prediction algorithms are freely shared through publication. In addition, software developed to predict propagation for planned communications systems through input of specific parameters to these algorithms has been developed and shared over the years, and some data sets that can be used to test and validate propagation prediction models are also available. The majority of software/data downloads on the ITS web site are for propagation prediction tools. In FY 2017, ITS made public the first important software implementation of a propagation model to be released via the GitHub platform. ITS used the C++ implementation of the Extended Hata (eHata) Urban Propagation Model to inform regulation, and the repository was forked by the Wireless Innovation Forum (WInnForum), which redistributed it to industry member for use in developing the Spectrum Access Systems (SAS) that will enable spectrum sharing using the three-tier architecture proposed for the 3.5 GHz (CBRS Band).

Audio Quality Testing: Two ITS-developed objective estimators of speech intelligibility that follow the paradigm of the Modified Rhyme Test (MRT) are freely available for download from the ITS web site. The Articulation Band Correlation MRT (ABC-MRT), released in 2013, consumes a tiny fraction of the resources required by MRT testing and provides excellent estimates of MRT intelligibility results (Pearson correlations of .95–.99) for narrowband speech

transmissions. ABC-MRT16, released in FY 2017, not only updated the audition model, but also extended the estimator to wideband, superwideband, and fullband speech systems as well as narrowband. ABC-MRT and ABC-MRT16 tools and MRT databases are available for download through the ITS web site and were downloaded 144 times in FY 2019. A variety of sample clips for audio quality testing are also made available and were downloaded 140 times in FY 2019.

Video Quality Measurement Software: ITS video quality measurement software tools use an objective video quality measurement method, which has been made a national standard by the American National Standards Institute (ANSI), to estimate the quality of video impairments, providing users an inexpensive alternative to viewer panels for testing new transmission technologies. During FY 2019, ITS transferred the VQM software to GitHub as compiled binary files; combined downloads from the ITS web site and GitHub totaled 194. Downloads of this package have been steadily decreasing as its age makes it less relevant; work is underway to produce a modernized version. The Web-Enabled Subjective Test (WEST) software package facilitates gathering subjective testing data from multiple locations and multiple portable or computing devices. The compiled software is also freely available for download from the ITS web site and the source code is available from a public GitHub repository, whence it has been forked several times.

Consumer Digital Video Library Users Downloading Clips

In FY 2010, ITS began development of the Consumer Digital Video Library (CDVL), a web site hosted and maintained by ITS that provides researchers access to high quality, uncompressed video clips royalty-free for use in video processing and video quality product development and testing. The technical committee for this collaborative project includes industry and academic representatives as well as ITS staff. ITS launched the site with 1,000 clips and clips continue to be added by ITS and other collaborators. Significant recent additions include: a collection of public safety video clips filmed during training exercises and so free of privacy concerns; 4K sports content uploaded by Sky Broadcasting in the UK; and studio quality original test sequences uploaded by Netflix. Over 2,460 different video clips were downloaded from the library in FY 2019. Users must register for each download or upload session. The number of registrants who perform downloads each year was selected as the most significant measure of the impact of this resource; annual rates of around 200 users are consistent with the target audience for this library.

Table 34 – Other Performance Measures Deemed Important by the Agency

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Technical Publications Released	22	4	10	11	11
Technical Publications Downloaded	9,048	8,748	6,214	5,513	5,980
Consumer Digital Video Library Users Downloading	212	169	202	260	258
Video Quality Metric Software Users Downloading	507	496	372	332	194
Propagation Modeling Software Downloads	798	781	1,160	1,325	1,352
Other Software/Data Downloads	493	591	819	661	714
Public GitHub Repositories	3	4	8	17	21

Development of Telecommunication Standards

ITS works with industry to apply research results to the development of telecommunication performance standards and guidelines. For several decades, ITS has provided leadership and

technical contributions to organizations, both national and international, responsible for developing telecommunication standards. ITS's technical inputs are relied upon as technically advanced and sound, and as unbiased by commercial interests.

ITS works collaboratively with the International Telecommunication Union (ITU), the Alliance for Telecommunications Industry Solutions (ATIS), the 3rd Generation Partnership Project (3GPP), the IEEE Standards Association, and various Federal public safety groups to develop, interpret, analyze, and implement standards and regulations. This method of ITS technology transfer directly addresses improvement of U.S. competitiveness in telecommunications. For example, a plurality of the technical recommendations of the ITU-Radio Communication Sector (ITU-R), a treaty organization, are based on research conducted at ITS. Also, key national quality-of-service standards developed under the ANSI T1 committee for video, audio, and digital data incorporate research results obtained at ITS. ITS continues to chair numerous committees and working groups in the ITU, 3GPP, and other telecommunication standards organizations, providing technical leadership that is trusted by the commercial-sector participants.

In FY 2019, ITS staff held 21 positions in six standards bodies, including 9 Chair/Co-chair/Vice-chair positions. ITS staff filled key leadership positions in the ITU-R, including Head of the U.S. Delegation to Study Group (SG) 3 (Radio Propagation), International Chair and U.S. Chair of SG3 Working Parties 3K and 3L (Point-to-area and ionospheric propagation), and U.S. Chair of Working Party 3J (Propagation fundamentals). ITS also continued its technical leadership and contributions to communications standards for emerging 5G technologies through participation in 3GPP.

Downstream Outcomes from ITS Technology Transfer Activities

Innovative Commercial Services

ITS research, technology transfer, and testing were critical to the recent initial commercial deployments of the new Citizens Broadband Radio Service (CBRS). When the FCC, in consultation with NTIA, created an innovative new three-tiered access and authorization framework to accommodate shared Federal and non-Federal use of the 3.5 GHz band, no roadmap existed for creating and authorizing the new Sharing system between high power Federal radars and commercial mobile services. ITS research and publications on electromagnetic compatibility between LTE and radars, LTE hotspot emission measurements, on-shore detections of off-shore radars, and effects of high-power radars on low noise amplifiers informed the development of technical requirements.

Initial estimates indicated that geographically very large exclusion zones would be needed to protect Federal maritime radars from harmful interference from commercial wireless networks, precluding access to new services for nearly 60% of the U.S. population. ITS, working with NTIA's Office of Spectrum Management (OSM), conducted analyses to decrease the initial exclusion zones by 77%. ITS worked closely with the WInnForum to analyze the methodology they proposed to further facilitate dynamic protection and sharing, opening up more population-dense coastal geographic areas where commercial services could co-exist with Federal radars and making a commercial service in the band economically viable.

ITS worked with the industry-led standards organization on development of technical standards for a technology-neutral commercial broadband service, including providing critical propagation software through publication of the C++ implementation of the eHata propagation model. At the request of the FCC, ITS developed a certification testing system for environmental sensing capability sensors (ESCs) critical for protection of Federal radar systems, and conformance tests for the spectrum access systems (SAS) that leveraged the WInnForum SAS certification system. ITS published a technical memorandum detailing procedures and processes for ESC testing and published a SAS test software-based study guide via GitHub. Under CRADAs with industry partners, ITS conducted certification testing on ESCs and SASs. These test reports paved the way for the FCC, after consultation with the DoD and NTIA-OSM, to authorize initial commercial operations at 3.5 GHz on September 16, 2019.

Telecommunication Standards

Models used to predict wireless propagation are fundamental to enabling spectrum sharing. The ITU-R's primary objective is to ensure interference-free operations of radiocommunications systems. The ITU-R publishes internationally standardized propagation prediction models that are used to harmonize spectrum assignments internationally and to manage space-related spectrum assignments. Increasing spectrum crowding demands increased accuracy and granularity of these models, which are developed through the participation of technical committees from all the treaty nations.

ITS leads efforts at ITU-R Study Group 3 (Radiowave Propagation) to ensure that U.S. interests and policy objectives are given due consideration by international technical experts and to promote informed decisions founded on physics and mathematics. ITS holds two of the four International Chairs of Study Group three and acts as Head of the US Delegation to the Study Group 3 meetings. In May of 2019, ITS employees participated in the final meeting of ITU-R Study Group 3 leading up to the 2019 World Radio Conference (WRC19), in which nations of the world gather to make critical decisions regarding the global regulation and use of spectrum.

Of particular interest for this WRC were: 5G analysis and discussions on modeling millimeter-wave propagation, which is growing in importance as mid-band spectrum becomes increasingly congested and countries look to deploy millimeter-wave bandwidth systems; air-to-ground propagation modeling needed to coordinate the exponential expansion of satellite communications systems; and examination of radio noise, including analysis of different measurement datasets. As a technical contribution from the U.S., ITS employees submitted a substantial revision to Recommendation P.528, *A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands*. This revision replaced static curves requiring manual interpolation with a purely mathematical model for arbitrary inputs. ITS also provided a software implementation of the model and publicly released the source code at github.com/NTIA/p528, a compiled DLL at github.com/NTIA/p528/releases, and a pre-built executable that launches a graphical front end for this software implementation at github.com/NTIA/p528-gui. The ITS software implementation was adopted by the ITU-R as integral to the revised Recommendation P.528.

Direct participation by ITS in the 3rd Generation Partnership Project (3GPP), the dominant cellular communications standards development organization, allows NTIA to advance U.S. commercial, economic, and government interests by providing technical input to promote strong unbiased standards that support fair competition in next generation/5G cellular technologies. For a number of years, ITS has provided technical guidance to other government agencies in advocating for standardization of service features specific to public safety, emergency communications, and transportation. A particular focus in FY 2019 was to ensure that NTIA and other interested agencies obtained a comprehensive understanding of the 3GPP New Radio (5G NR—the global standard for the air interface of 5G networks) capabilities, the services 5G NR was built to deliver, and deployment scenarios in both licensed and unlicensed spectrum for the evolution to 5G.

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 2019, additional capabilities were added to the Table Mountain test facilities in support of NOAA's Radio Frequency Interference Monitoring System (RFIMS) program. 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. Work began on the installation of a 6.5 m Geostationary Operational Environmental Satellite (GOES) receiver dish to support Meteorological Satellite Testbed activities. A 2.4 m Earth Station satellite dish capable of capturing Polar Operational Environmental Satellite (POES) satellite imagery was previously installed to test the degree of interference that could be tolerated, with a robust command and control system to command, verify, and log interference transmitted to RFIMS candidate solutions under test. A Spectrum Survey System (SSS) has been used over the past two years 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 2019, 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 eleven years, the University of Colorado's Research and Engineering Center for Unmanned Vehicles safely and accurately tested collective and autonomous sensing and communication technologies to facilitate 4D sight through a ground-to-space sensing column with unmanned aircraft systems (UAS) operating in the atmosphere integrated

with ground-based and space-based observation systems. These capabilities are intended to be applied for myriad of purposes ranging from improved climate and weather forecasting to better-informed government policymaking.

Video Quality Research

Industry and academia use both CDVL and the VQM tools for research into new techniques for transmitting video. Lack of access to video footage appropriate for testing new video distribution technologies had been a significant impediment to video processing R&D until the launch of CDVL. The clips may be used to test codecs, to evaluate new display technologies, or for validation testing of new standards. For example, ITU-T Study Group 12 has used CDVL clips for research into the development of parametric models and tools for multimedia quality assessment and the MPEG committee opened a conversation with ITS about using the CDVL video clips for validation testing of new video coding standards. Currently, simulated public safety content comprises 40% of CDVL's content. Real public safety content is nearly impossible to obtain due to litigation concerns, and first responders use consumer grade electronics. Access to this simulated content promotes development and standardization of commercial video technologies that meet public safety's requirements.

SUMMARY

Technology transfer is an essential mission of the Department of Commerce and uses our nation's innovation and investment in science and technology to strengthen our economy and competitiveness in world markets. This report details the results of collaborative technology activities originating from the Department's federal laboratories. Federal research is a complex process that provides the opportunity for new ideas and innovations to achieve practical application for the benefit of U.S. citizens. The success stories in this report provide examples of how society benefits from technology transfer activities across the Department's federal laboratories. As knowledge advances and the needs of the economy change, the Department of Commerce, through its federal laboratories, will continue to play a role in keeping America at the forefront of innovation and supporting our economy by aiding in the transfer and commercialization of innovative technologies.

Appendix A

Technology Area Classifications

Mapping of International Patent Classifications to Technology Area[66]

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.

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.

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 Ingra-red radiation, visible light, or ultraviolet light.

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.

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[66] Derived from The World Intellectual Property Organization's International Patent Classification (IPC) Correspondence Table (http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/xls/ipc_technology.xls) and IPC Searchable Classification Database, Version 2016.01 (https://www.wipo.int/classifications/ipc/ipcpub/

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.

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

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.

Appendix B

Fields and Subfields of S&E Publications Data[67]

Agricultural Sciences: agronomy and agriculture; dairy and animal science; food science; horticulture

Astronomy and Astrophysics: astronomy and astrophysics

Biological and Biomedical Sciences: anatomy and morphology; biochemistry and molecular biology; bioinformatics; biophysics; biotechnology; developmental biology; ecology; entomology; evolutionary biology; genetics and heredity; immunology; medicinal and biomolecular chemistry; microbiology; microscopy; mycology and parasitology; nutrition and dietetics; ornithology; physiology; plant biology and botany; toxicology; virology; zoology

Chemistry: analytical chemistry; general chemistry; inorganic and nuclear chemistry; organic chemistry; physical chemistry; polymers

Computer and Information Sciences: artificial intelligence and image processing; computation theory and mathematics; computer hardware and architecture; distributed computing; information systems; networking and telecommunications; software engineering

Engineering: aerospace and aeronautics; automobile design and engineering; biomedical engineering; building and construction; chemical engineering; civil engineering; design practice and management; electrical and electronic engineering; environmental engineering; geological and geomatics engineering; industrial engineering and automation; logistics and transportation; mechanical engineering and transports; mining and metallurgy; nanoscience and nanotechnology; operations research; optoelectronics and photonics

Geosciences, Atmospheric, and Ocean Sciences: geochemistry and geophysics; geology; marine biology and hydrobiology; meteorology and atmospheric sciences; oceanography; paleontology

Health Sciences: allergy; anesthesiology; arthritis and rheumatology; cardiovascular system and hematology; complementary and alternative medicine; dentistry; dermatology and venereal diseases; emergency and critical care medicine; endocrinology and metabolism; environmental and occupational health; epidemiology; gastroenterology and hepatology; general and internal medicine; general clinical medicine; geriatrics; gerontology; health policy and services; legal and forensic medicine; medical informatics; neurology and neurosurgery; nuclear medicine and medical imaging; nursing; obstetrics and reproductive medicine; oncology and carcinogenesis; ophthalmology and optometry; orthopedics; otorhinolaryngology; pathology; pediatrics;

[67] The fields are based on the Taxonomy of Disciplines (TOD) developed by the National Science Foundation (NSF). Science-Metrix used its own classification of 176 subfields developed more than a decade ago and worked with NSF to align its subfields to the TOD scheme. Details about the process can be found at https://www.science-metrix.com/sites/default/files/science-metrix/publications/bibliometric-indicators-for-the-sei-2020-technical-documentation.pdf.

pharmacology and pharmacy; psychiatry; public health; rehabilitation; respiratory system; speech-language pathology and audiology; sport sciences; substance abuse; surgery; tropical medicine; urology and nephrology; veterinary sciences

Materials Science: materials

Mathematics and Statistics: applied mathematics; general mathematics; numerical and computational mathematics; statistics and probability

Natural Resources and Conservation: Environmental sciences; fisheries; forestry

Physics: acoustics; applied physics; chemical physics; fluids and plasmas; general physics; mathematical physics; nuclear and particle physics; optics

Psychology: behavioral science and comparative psychology; clinical psychology; experimental psychology; general psychology and cognitive sciences; human factors; psychoanalysis; social psychology

Social Sciences: Agricultural economics and policy; criminology; cultural studies; development studies; econometrics; economic theory; economics; education; family studies; gender studies; geography; international relations; languages and linguistics; political science and public administration; science studies; social sciences methods; sociology; urban and regional planning