Annual Report on Technology Transfer:
Approach and Plans, Fiscal Year 2018 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)

October 2019

This page is intentionally left blank.

FOREWORD

This report summarizes technology transfer activities and achievements of the Department of Commerce's (DOC) federal laboratories for fiscal year (FY) 2018. 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 2014 through FY 2018.

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: http://www.nist.gov/tpo/publications/index.cfm.

This page is intentionally left blank.

TABLE OF CONTENTS

This page is intentionally left blank.

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 2014 – FY 2018

This annual report provides comprehensive statistics on technology transfer activities of DOC laboratories, including information regarding invention disclosures, intellectual property (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, which 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 2018 has been adjusted, where necessary, to reflect the most accurate estimates for each year reported.

Invention Disclosures and Patenting
In FY 2018, DOC researchers disclosed 77 new inventions. Of these, 71 invention disclosures were from NIST researchers and six were from NOAA researchers. There were 56 patent applications filed (54 for NIST and two for NOAA) and 28 patents issued by NIST alone.[3]

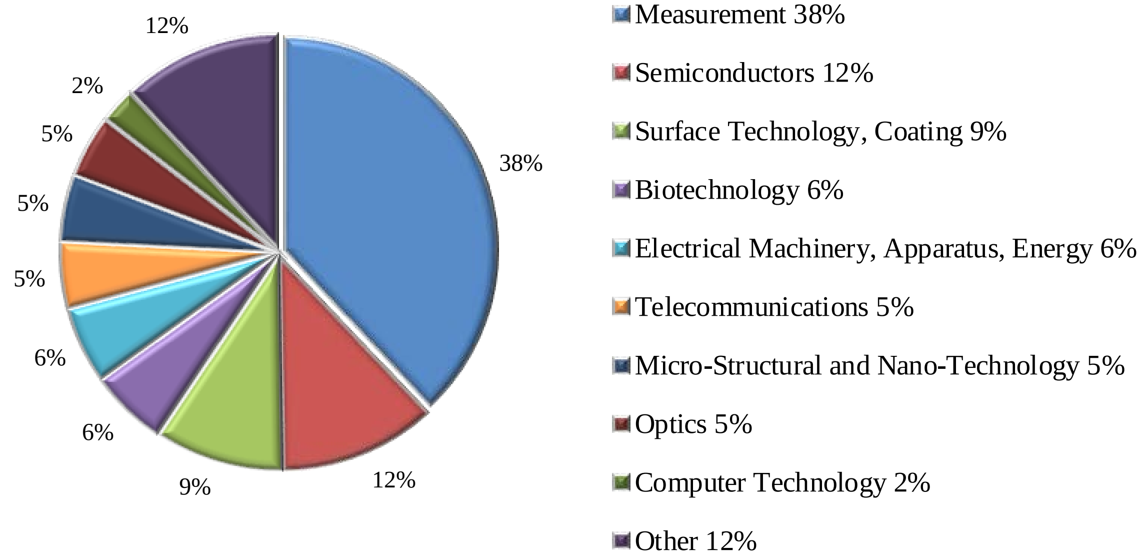
Table 1 – DOC Invention Disclosure and Patenting

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Invention Disclosures					
NIST	41	46	46	40	71
NOAA	6	15	18	3	6
ITS	0	0	0	0	0
Department Total	47	61	64	43	77
Patent Applications Filed					
NIST	21	26	21	43	54
NOAA	4	6	4	3	2
ITS	0	0	0	0	0
Department Total	25	32	25	46	56
Patents Issued					
NIST	19	19	15	31	28
NOAA	0	1	1	3	0
ITS	0	0	0	0	0
Department Total	19	20	16	34	28

[3] Note that the time required for a patent to be granted may be two years or more. Patents issued in FY 2018 were filed in prior years.

In FY 2017 (the most recent year data is available), the top three technical areas covered by DOC patents were measurement (38%), semiconductors (12%), and surface technology, coating (9%).[4]

Figure 1 – Percent of USPTO Patents Granted to DOC, by Technology Area – FY 2017[5]



Licensing

In FY 2018, DOC reported 67 active patent licenses (60 for NIST and seven for NOAA).

Table 2 – Profile of DOC Active Licenses

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Active Patent Licenses[(a)]					
NIST	33	40	50	61	60
NOAA	5	6	7	7	7
ITS	0	0	0	0	0
Department Total	38	46	57	68	67

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

[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 October 2018. Used with permission.

Data revealed that 37 of those active patent licenses were income-bearing, which is the largest number in the last five fiscal years. The income-bearing licenses comprised 22 exclusive licenses, 13 non-exclusive licenses, one assignment, and one custody transfer agreement.

Table 3 – Characteristics of DOC Income-Bearing Licenses

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income-Bearing Licenses					
NIST	21	25	26	28	30
NOAA	5	4	5	7	7
ITS	0	0	0	0	0
Department Total	26	29	31	35	37
Patent Licenses					
NIST	21	25	26	28	30
NOAA	5	4	7	7	7
ITS	0	0	0	0	0
Department Total	26	29	33	35	37
License Types					
Exclusive					
NIST	14	15	16	15	18
NOAA	0	1	4	4	4
ITS	0	0	0	0	0
Department Total	14	16	20	19	22
Partially Exclusive					
Department Total	0	0	0	0	0
Non-Exclusive					
NIST	5	8	8	11	10
NOAA	5	3	3	3	3
ITS	0	0	0	0	0
Department Total	10	11	11	14	13
Assignment					
NIST	1	1	1	1	1
Custody Transfer					
NIST	1	1	1	1	1

In FY 2018, DOC's income-bearing licenses provided $147,414 in income. Of this amount, $111,743 came from NIST licenses and $35,671 came from NOAA licenses.

Table 4 – Income from DOC Licensing

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Licensing Income					
NIST	$150,995	$124,823	$137,662	$75,061	$111,743
NOAA	$69,151	$39,633	$11,000	$65,810	$35,671
ITS	$0	$0	$0	$0	$0
Department Total	$220,146	$164,456	$148,662	$140,871	$147,414

Collaborative Relationships for Research and Development (CRADAs)

In FY 2018, there were 3,363 CRADAs involving DOC researchers. There were 534 traditional CRADAs[6] and 2,829 non-traditional CRADAs active during the year.[7] Of the 534 traditional CRADAs, NIST was involved in 476, NOAA was involved in 43, and ITS was involved in 68. In addition, there were 53 joint agreements between NIST and ITS that dealt with Public Safety 700 MHz Broadband Demonstrations and involved both NIST and ITS.

Table 5 – DOC Collaborative Relationships for Research and Development

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs					
Department Total	2,280	2,670	2,940	2,933	3,363
Traditional CRADAs					
NIST	206	329	294	370	476
NOAA	19	28	33	36	43
ITS	60	54	62	60	68
Department Total[(a)]	206	283	335	414	534
Joint CRADA Agreements (NIST and ITS)	79	128	54	52	53
Non-Traditional CRADAs					
NIST	2,074	2,387	2,605	2,519	2,827
NOAA	0	0	0	0	2
ITS	0	0	0	0	0
Department Total	2,074	2,387	2,605	2,519	2,829

(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.

[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.

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

The fixed base year chosen for this report is FY 2014. 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 2015, we divide the number of patents issued in FY 2015 by the number of patents issued in the base year (FY 2014) and then multiply by 100. Using data from the table on Page 3 of this report, the index value for patents issued in FY 2015 is 105 (rounded).

$$Index\ Value_{FY2015} = \frac{20}{19} \times\ 100 = 105$$

Because the index value of 105 is greater than 100, we can interpret this as a 5% increase in the number of patents issued between FY 2014 and FY 2015. In FY 2016, the index value for patents issued is 84, which we can interpret as a 16% decrease between FY 2014 and FY 2016.

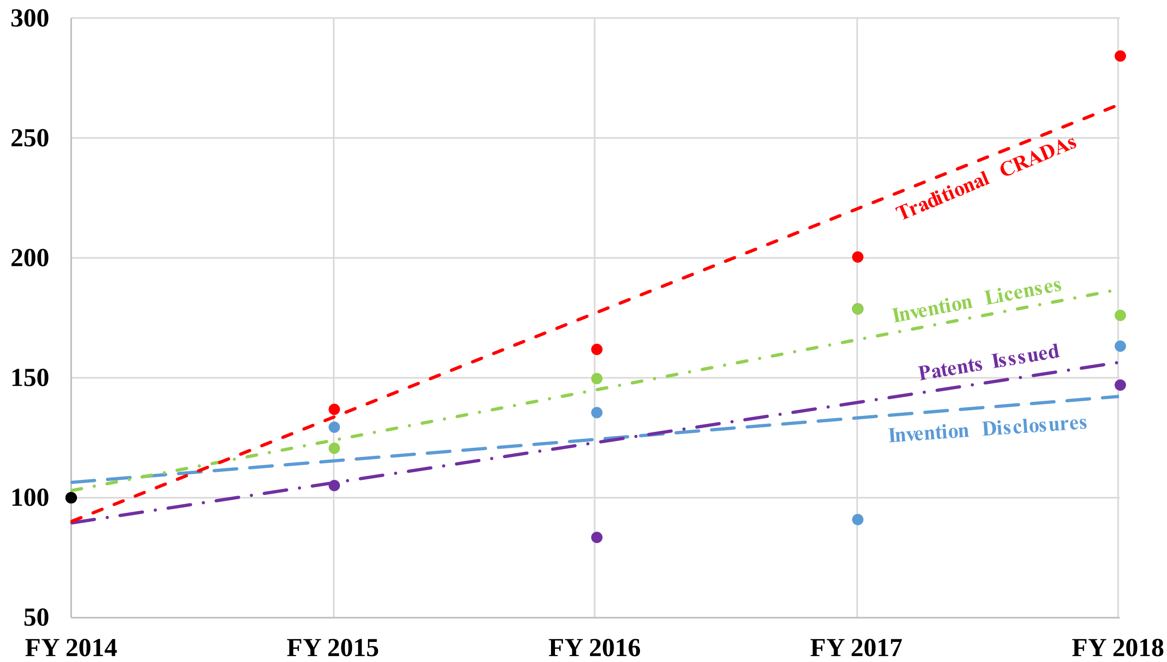
We calculated index values for key metrics (e.g., invention disclosures, patents issued, invention licenses, and CRADAs) and plotted the values in the chart below. To show the trend for a given metric, a straight line is plotted in the middle of the plotted values for that metric.[8] In the chart below, 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 2014, there has been a dramatic increase in DOC's basic technology transfer activities with invention

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

disclosures increasing 64%, patent issued increasing 47%, active patent licenses increasing 76%, and CRADAs increasing 185%.

Figure 2 – Trends in DOC's Technology Transfer Activities (FY 2014 – FY 2018)



Scientific and Technical Publications

Technology transfer mechanisms include more than just counting CRADAs, patents, and licenses.[9] Scientific and technical publications can also lead to technology transfer. In FY 2018, NIST, NOAA, and ITS researchers published 3,220 scientific and technical papers in peer-reviewed journals.

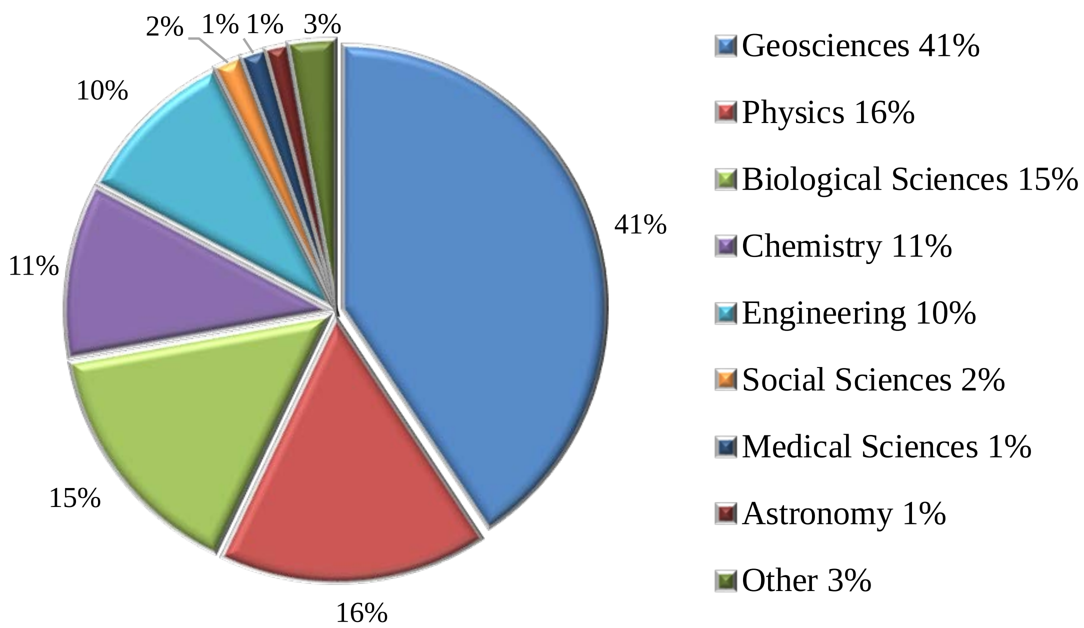
Table 6 – DOC Scientific and Technical Publications

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Technical Publications					
NIST	1,359	1,323	1,355	1,433	1,415
NOAA	1,759	1,860	1,697	1,678	1,794
ITS	18	22	4	10	11
Department Total	3,136	3,205	3,056	3,121	3,220

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

In calendar year (CY) 2017 (the most recent year for which data is available), the most frequent technology areas covered by DOC publications are Geosciences (41%), followed by Physics (16%), Biological Sciences (15%), Chemistry (11%), and Engineering (10%).[10]

Figure 3 – Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2017[11]

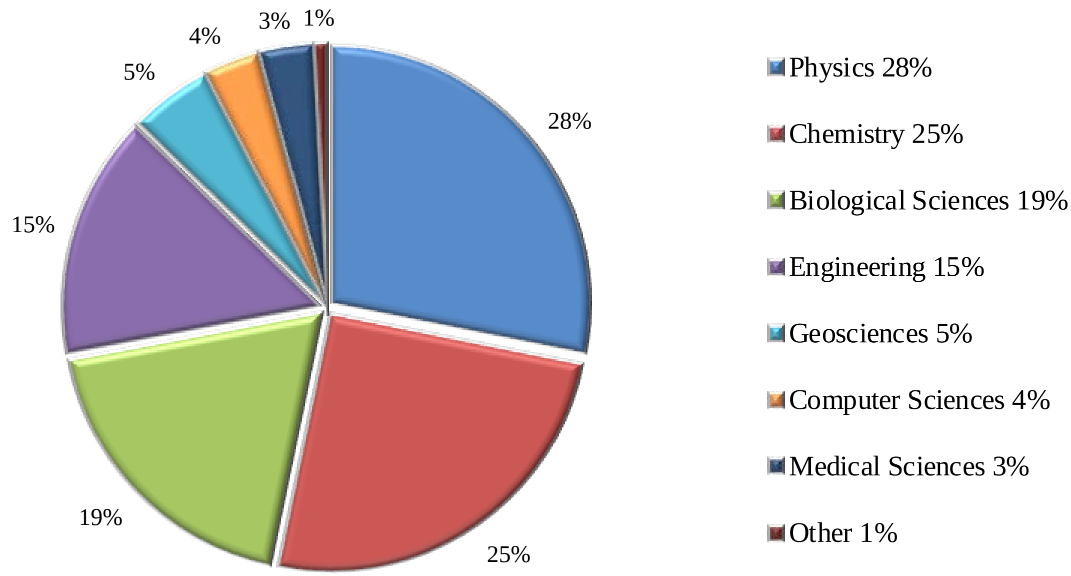


[10] Science and engineering fields are identified in Appendix B.

[11] Data are presented by calendar year as month of publication is not always available in the Web of Science. Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) classified under Caspar (Computer-Aided Science Policy Analysis and Research) fields using the CHI (Computer Human Interaction) classification. Articles are classified by the year they entered the database, rather than the year of publication, and are assigned to a federal agency on the basis of the institutional address(es) listed in the article. Articles are credited on a whole-count basis (i.e., each participating federal agency receives one count). Source: Prepared by Science-Metrix using the Web of Science database (Thomson Reuters). 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 2017 cite 1,170 publications authored by DOC researchers. As shown in Figure 4, the largest technology areas citing DOC publications include Physics (28%), followed by Chemistry (25%), Biological Science (19%), Engineering (15%), and Geosciences (5%).[12]

Figure 4 – Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2017[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] Science and engineering fields are identified in Appendix B.

[13] Cited articles are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) classified under Caspar fields using the CHI classification. Cited articles are classified by the year of publication and are assigned to a federal agency on the basis of the institutional address(es) listed in the article. 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 FY2012 to articles published in 1997–2007). Prepared by Science-Metrix using the Web of Science (Thomson Reuters) accessed in October 2018 and PatentsView accessed in October 2018. 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

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

mechanisms NIST uses to promote innovation and to disseminate technologies that result from its research.

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. Additional details on NIST's licensing activities are included 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 2018, there were 60 active NIST patent licenses of which 11 were issued in FY 2018. Of these 60 active licenses, 23 licenses were issued to small companies (i.e., companies with fewer than 500 employees).

Table 7 – Profile of NIST Active Licenses

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Number of Active Licenses[(a)]	33	40	50	61	60
New Licenses Executed	7	11	12	19	11
Total Invention Licenses Active	33	40	50	61	60
New Invention Licenses Executed	7	11	12	19	11
Total Patent Licenses Active[(b)]	33	40	50	61	60
New Patent Licenses Executed	7	11	12	19	11
Total Material Transfer Licenses Active (Inventions)	0	0	0	0	0
New Material Transfer Licenses (Inventions)	0	0	0	0	0
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	7	4	14	19	23

(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 2018, the average time to negotiate a patent license was two months. The minimum time to negotiate a license was nine days (.3 month), and the maximum time was four months.

Table 8 – NIST Licensing Management

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
License Negotiation Time (Patent Licenses) [(a)(b)]					
Average (months)	4.0	7.0	5.0	4.0	2.0
Minimum (months)	0.2	0.2	1.0	2.0	0.3
Maximum (months)	17.3	38.7	14.0	6.0	4.0
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 60 active licenses that existed in FY 2018, 30 were income bearing. This included 18 exclusive licenses, 10 non-exclusive licenses, one assignment, and one custody transfer.

Table 9 – Characteristics of NIST Licenses Bearing Income

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income Bearing Licenses	21	25	26	28	30
Exclusive	14	15	16	15	18
Partially Exclusive	0	0	0	0	0
Non-Exclusive	5	8	8	11	10
Total Other Income Bearing IP Licenses					
Assignment	1	1	1	1	1
Custody Transfer	1	1	1	1	1
Total Income Bearing Invention Licenses	21	25	26	28	30
Exclusive	14	15	16	15	18
Partially Exclusive	0	0	0	0	0
Non-Exclusive	5	8	8	11	10
Total Other Income Bearing IP Licenses					0
Assignment	1	1	1	1	1
Custody Transfer	1	1	1	1	1
Total Royalty Bearing Licenses	21	25	26	28	30
Total Royalty Bearing Invention Licenses	21	25	26	28	30
Royalty Bearing Patent Licenses	21	25	26	28	30
Other Royalty Bearing IP Licenses	0	0	0	0	0

In FY 2018, NIST received $111,743 from all active licenses. This is a 49% increase from the prior year. The median amount received was $3,892. The minimum amount received was $209 and maximum was $40,000.

Table 10 – Income from NIST Licenses

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income, All Active Licenses[(a)]	$150,995	$124,823	$137,662	$75,061	$111,743
Invention Licenses (Patent Licenses)[(b)]	$150,995	$124,823	$137,662	$75,061	$111,743
Other IP Licenses, Total Active	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)[(c)]	$150,995	$124,823	$137,662	$75,061	$111,743
Median ERI	$6,250	$1,600	$5,295	$2,679	$3,892
Minimum ERI	$640	$640	$62	$320	$209
Maximum ERI	$74,575	$62,833	$40,000	$40,000	$40,000
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)	$150,995	$124,823	$137,662	$75,061	$111,743
Median ERI	$6,250	$1,600	$5,296	$2,679	$3,892
Minimum ERI	$640	$640	$62	$320	$209
Maximum ERI	$74,575	$62,833	$40,000	$40,000	$40,000
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 2018, 38% ($42,944) was distributed to the NIST inventor(s) and the remaining 62% ($68,799) was retained by the NIST inventor's Operating Unit.

Table 11 – Distribution of NIST Invention License Income

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Total Income Received[(a)]	$150,995	$124,823	$137,662	$75,061	$111,743
Invention Licenses (Patent Licenses)[(b)]					
Licensing Income to Inventor(s)	$54,602	$44,936	$45,148	$34,673	$42,944
	36%	36%	33%	46%	38%
Licensing Income to NIST	$96,393	$79,887	$92,514	$40,388	$68,799
	64%	64%	67%	54%	62%

(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 research and development (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 2018, NIST was involved in a total of 3,303 active CRADAs; 476 were traditional CRADAs[16] and 2,827 were non-traditional CRADAs.[17] There were 2,770 new NIST CRADAs. This included 153 traditional and 2,617 non-traditional.

Table 12 – NIST Collaborative Relationships for Research and Development

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NIST CRADAs					
Total Active CRADAs	2,281	2,718	2,958	2,889	3,303
New CRADAs Executed	2,093	2,481	2,587	2,420	2,770
Total Active Traditional CRADAs	206	329	294	370	476
New Traditional CRADAs Executed	50	143	89	113	153
Total Active Non-Traditional CRADAs	2,075	2,389	2,664	2,519	2,827
New Non-Traditional CRADAs Executed	2,043	2,338	2,498	2,307	2,617

[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 2018, NIST staff wrote 1,415 papers in peer-reviewed journals,[18] including 367 papers (26%) published in 110 "top tier" journals, which includes any journal with a Thomson Reuters' Journal 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 5,277 unique non-NIST authors from 1,283 institutions in 59 countries.[20]

Table 13 – NIST Scientific and Technical Publications

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Number of NIST Papers	1,359	1,323	1,355	1,433	1,415
Number of NIST Papers in Top-Tier Journals	444	384	329	406	367
Percentage of NIST Papers in Top-Tier Journals	33%	29%	24%	28%	26%
Number of Unique Non-NIST Co-Authors	4,086	4,585	5,116	5,464	5,277
Number of Unique Institutions	965	1,003	1,037	1,334	1,283
Number of Countries	62	63	46	67	59

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 publishes ***Tech Beat***, a biweekly, plain language newsletter of recent research results.[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 methods, 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 2018, 423 members of the NIST staff were involved with more than 116 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 2014	FY 2015	FY 2016	FY 2017	FY 2018
Number of Participating NIST Staff	464	469	445	440	423
Number of Standard Organizations with NIST Participants	121	165	120	119	116

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. Standard Reference Data are extracted from scientific and technical literature or developed from measurements conducted at NIST 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 2018, the NIST SRD Program distributed 2,670 e-commerce orders, 8,413 units sold via distributor, 157 active distributor agreements, 17 active site licenses, 50 active internet subscriptions, 146 units shipped to the user, and 3,910 products downloaded from the NIST website (1,099 free downloads, 2,811 paid downloads).

Table 15 – NIST Standard Reference Data Program

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Standard Reference Data					
Products available (databases)	111	111	102	97	92
E-Commerce Orders	3,111	2,596	2,689	2,229	2,670
Units Sold via Distributor[(a)]	5,142	9,807	10,573	7,995	8,413
Active Distributor Agreements	101	123	124	154	157
Active Site Licenses	58	57	59	36	17
Active Internet Subscriptions	42	38	49	40	50
Units Shipped via UPS	595	418	311	328	146
Products Downloaded from the NIST Website	3,435	5,751	6,208	3,119	3,910
Free Downloads	1,352	3,615	4,083	1,225	1,099
Paid Downloads	2,083	2,136	2,125	1,894	2,811

(a) The increase in sales between FY 2014 and FY 2015 for "Units sold via distributor" reflects sales related to the release of a new version of the NIST Standard Reference Database 1A, NIST/EPA/NIH Mass Spectral Library and sales from Standard Reference Database 23, Reference Fluid Thermodynamic and Transport Properties.

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 2018, NIST made available 1,140 SRMs and from these, sold 31,503 units.

Table 16 – NIST Standard Reference Materials

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Standard Reference Materials					
Units Available	1,281	1,240	1,194	1,182	1,140
Units Sold	32,636	33,490	31,938	32,348	31,503

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 are the Center for

[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

Nanoscale Science and Technology (CNST) and the NIST Center for Neutron Research (NCNR) and 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. In FY 2018, there were 3,415 research participants at CNST and 2,742 at NCNR.

Table 17 – NIST Research Participants[27]

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NIST Research Participants					
CNST	2,147	2,434	2,917	3,215	3,415
NCNR	2,271	2,436	2,536	2,769	2,742

within PML. The CNST NanoFab user facility will largely remain unchanged and continue to serve both NIST and external users.

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

[27] FY 2018 estimates are preliminary estimates.

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.[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 2018, there were 153 NIST postdocs. Of these, 91 were located on the NIST campus in Gaithersburg, Maryland; 44 were located in Boulder, Colorado; and the remainder were located at five other NIST locations.

Table 18 – NIST Postdoctoral Researchers

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NIST Postdocs, Total (NCR)	172	179	167	159	153
Gaithersburg campus	115	113	104	87	91
Boulder campus	35	49	43	47	44
Joint Institute for Laboratory Astrophysics [(a)]	9	5	9	12	10
Joint Quantum Institute [(b)]	3	2	2	3	3
Hollings Marine Laboratory [(c)]	1	2	2	2	1
Institute for Bioscience and Biotechnology Research [(d)]	4	3	3	3	3
Brookhaven National Laboratory[(e)]	0	0	0	2	0
Joint Initiative for Metrology in Biology[(f)]	5	5	4	3	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 located at and 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/

---

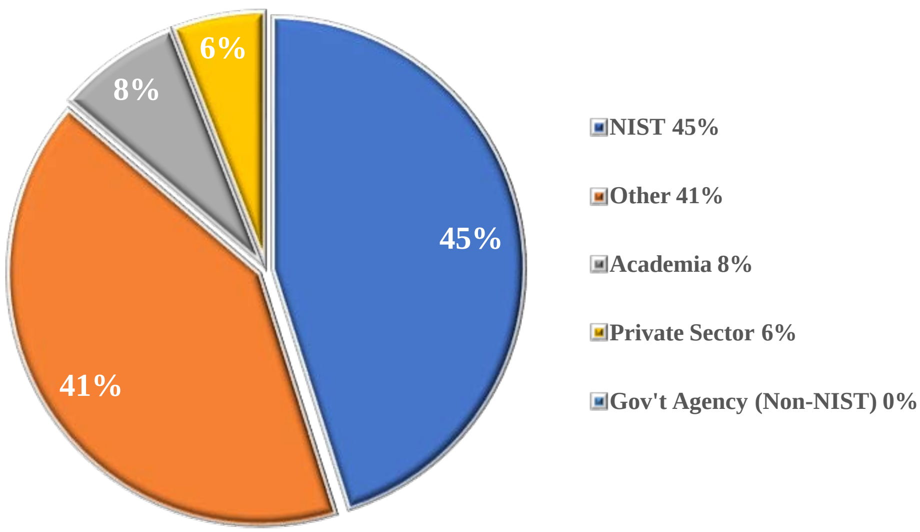
[28] http://www.nist.gov/iaao/postdoc.cfm

[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 51 researchers who were postdocs with the NIST National Research Council (NRC) program in FY 2018. Of these, 45% continued research careers with NIST,[30] 6% moved to the private sector, 8% moved to academia, none moved to other government agencies, and 41% pursued other opportunities such as becoming independent researchers.

NIST is currently studying the economic impact of the NIST-NRC postdoctoral program. This study will survey former NIST postdocs to gather information on patents held and related business pursuits. The data will be analyzed to determine the efficacy of postdocs as a tech transfer mechanism and the feasibility of pursuing additional research into the program's contributions.

Figure 5 – Tracking NIST Researchers after Initial Postdoc Tenure at NIST (FY 2018)



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

[30] Researchers who left their postdoc positions and stayed at NIST (45%) became career conditional / term employees (42%) or became non-career conditional or term employees, i.e. contractors or guest researchers (12%).
[31] http://www.nist.gov/tpo/collaborations/guestresearchers.cfm

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.

In FY 2018 there were 3,221 guest scientists and engineers working at NIST.

Table 19 – NIST Guest Researchers

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NIST Guest Researchers					
Number of Guest Scientists and Engineers	2,981	3,125	3,273	3,181	3,221

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 2018, NVLAP accredited 674 laboratories.

Table 20 – NIST Accreditation Services

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NVLAP Accreditations					
Number of NVLAP Accreditations	774	726	735	723	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 2018, there were 11,771 calibration tests performed by NIST.

Table 21 – NIST Calibration Services

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Calibrations					
Number of Calibration Tests Performed	15,401	13,906	12,971	13,802	11,771

[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 2018, there were 212 students enrolled in the SURF program, 64 students enrolled in the SHIP program, 85 students enrolled in the Pathways program, and 200 students enrolled in the PREP program. The Summer Institute for Middle School Teachers was not held in FY 2018.

Table 22 – NIST STEM Education Participation

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
SURF	203	206	213	212	212
SHIP	60	48	70	70	64
Pathways Program	78	97	85	111	85
Summer Institute for Middle School Teachers	22	22	20	21	0
PREP	134	164	204	36	200

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.

In FY 2018, the NIST Conference Program arranged 101 conferences that attracted 8,772 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,

---

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

regulations, and standards, trained 1,776 weights and measures administrators, laboratory metrologists, and field enforcement officials during FY 2018.

Table 23 – NIST Conferences, Seminars, and Workshops

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NIST Conference Center					
Conferences and Workshops	80	118	102	108	101
Attendance	9,208	11,490	10,370	10,588	8,772
Office of Weights and Measures - Metrology Training					
Total Students	518	750	498	916	888
Seminar Attendance	355	457	342	466	451
Webinar Attendance	133	266	156	414	437
Workshop Attendance	30	27	0	36	0

NIST is expanding its collection of information on metrology training to include training for NIST facility users. Further, NIST staff answers email, telephone, and mail inquiries from researchers requesting information and details about NIST technical developments and research results.

Streamlining Technology Transfer Processes

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

Table 24 – NIST Streamlining Efforts

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Streamlining Efforts					
Average Number of Days to Prepare a Patent Application[(a)]	456	410	442	396	337
Average CRADA Approval Time[(b)]	110	65	104	108	91

(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 2018, NIST patent licenses were held by 23 small businesses. There were 89 small businesses involved in traditional CRADAs and 742 small businesses involved in non-traditional CRADAs. NIST's non-traditional CRADAs involve 34 small businesses involved with material transfer agreements, 101 involved in calibration services and 607 receiving NVLAP accreditations. There were also 12 small businesses that received Phase I SBIR awards and 10 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.[39] 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] http://www.nist.gov/tpo/sbir/index.cfm

Small and Young Businesses Interacting with NIST

Another way of transferring NIST's technologies is through the creation of companies by former NIST staff, NIST collaborators, licensees or others making use of NIST research. 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[40]

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Number of Small Businesses Licensing NIST Technologies	1	4	14	19	23
Number of Small Businesses involved in Traditional NIST CRADAs	37	68	58	116	89
Number of Small Businesses involved in Non-Traditional NIST CRADAs	734	795	823	903	742
Number of Small Businesses involved in Phase I SBIR Awards	12	14	12	12	12
Number of Small Businesses involved in Phase II SBIR Awards	4	6	7	9	10
Total	788	887	914	1,059	876

NIST also identified 42 startup and young companies (existing for five years or less) that have either spun off technologies from NIST or received considerable support in their core area of technical development and were involved in research collaborations with NIST during FY 2018.

[40] 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. They are gathered by internal data calls and 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.[41] This is because the process of assessing impacts, which has long been a goal of policy makers, 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.[42]

In an effort to support further development of impact metrics, the following reports were funded by NIST in FY 2018. They provide measures of technology transfer impact using the three different approaches to assessing economic behavior mentioned above.

The Economic Impacts of the Advanced Encryption Standard 1996-2017[43]

Since 1965, NIST has been responsible for establishing uniform federal automatic data processing standards, or Federal Information Processing Standards (FIPS). FIPS are used to provide guidance to the federal government for computer security, interoperability, and other information technology matters where suitable industry standards do not exist. In 1977, NIST adopted the Data Encryption Standard (DES) as a federal standard to be used for securing all sensitive, unclassified government data from unauthorized access and for encrypting information transferred through communications.

[41] 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

[42] 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

[43] https://www.nist.gov/publications/economic-impacts-advanced-encryption-standard-1996-2017

In 1993, NIST launched efforts to identify a new standard encryption algorithm for the federal government after recognizing that the DES standard was growing vulnerable in the face of advances in cryptanalysis and the exponential growth in computing power. The effort to develop a new Advanced Encryption Standard (AES) involved a five-year, open international competition which included worldwide collaborations within the cryptography community.

The AES has since been used by the federal government and private industry to encrypt and decrypt electronic information. It protects everything from classified data and bank transactions to online shopping and social media apps.

In FY 2018, NIST contracted with RM Advisory Services LLC, to assess the impact of NIST's contributions to the development of the AES program and to provide a retrospective economic impact assessment of these contributions. The study covers the period from 1996-2017 and relies on a detailed survey of key government and private sector leaders who heavily rely on the AES to secure their electronic communications. The survey was directed to three specific user groups: government and private consumers of encryption systems and private integrators who develop and produce encryption hardware or software. The survey was sent to federal and state chief information officers and members of organizations with interest in information security, such as working groups and associations, with 169 responding.

An assessment of survey results found that without NIST's leadership, the evolution of a sufficiently strong and efficient encryption technology and its implementation as AES would have been significantly delayed and the costs of related R&D, production, and commercialization would have been higher. The study also found that without U.S. leadership, the competitive advantage of U.S. information technology companies would have been significantly impaired and U.S. companies would not have dominated global technology business as they do today.

The study also found that the AES program continues to create economic value by transferring its know-how in many forms (e.g., the development and promulgation of publications that specify, maintain, and revise cryptographic modes of operation) into the network of communications and transactions.

In addition to assessing the role that NIST played, the study includes an assessment of the retrospective impact that resulted from NIST's role. In this case, impact was assessed in terms of 1) the cost avoided by having a central, trusted body to take initiative and 2) the cost of developing a stronger, computationally more efficient and flexible replacement of DES.

Survey questions were designed to help quantify several categories of potential avoided costs identified in scoping interviews and historical research. These include:

1. The cost of slower processing speeds
2. Interoperability costs
3. Breach costs
4. Pre-acquisition costs

5. Standards development
6. Lost sales and profits
7. Hardware and software module quality degradation

The economic assessment used a counterfactual scenario to conceptualize economic benefits if the AES program had been postponed or had never occurred. A time series of the estimated annual sum of cost avoided from 1996 to 2017 was interpreted as the economic stream of benefits of the AES program. Those benefits were then compared to the program's actual cost over that period.

The study found that for the organizations responding to the survey, NIST's contribution to the AES program had a benefit-to-cost ratio of approximately 29-to-1. Extrapolating the benefits economy-wide revealed a benefits-to-cost ratio of 1,976-to-1. Alternatively, the impact of NIST's contribution to the AES program is approximately $250 billion to date.

A Preliminary Application of an Input-Output Economic Impact Model to U.S. Federal Laboratory Inventions[44]

A recent study prepared for the Biotechnology Innovation Organization (BIO) and the Association of University Technology Managers (AUTM), entitled "The Economic Contribution of University / Nonprofit Inventions in the U.S.: 1996-2015"[45] used an input-output (I-O) model to estimate the economic impact of academic licensing (i.e. hospitals and research institutions) over a 20-year period (1996-2015). R&D expenditures by these institutions over this period averaged approximately $60 billion per year. The study found that the total contribution of licensors to industry gross output during this period ranged from $320 billion to $1.33 trillion. Gross domestic product for the country ranged from $148 billion to $591 billion, and employment increased by 1.268 million to more than 4.272 million person-years of employment.[46]

In FY 2018, NIST asked the researchers who prepared this study to adapt the same model to assess the impact of federal licensing over a shorter, eight-year period (2009-2015).[47] R&D expenditures for the federal laboratories (i.e. intramural programs and federally funded research and development centers) average approximately $45 billion per year, so at first glance, one would expect the impact from the two groups of licensors might be similar. [48] However, when comparing the two groups, it is important to note the many differences that exist between the way academic institutions and individual federal agencies handle technology transfer operations. Federal agencies have a wide variety of mission statements, policies that support patenting and licensing activities, royalty rates, conflict of interest restrictions that place limits on working with

[44] https://www.nist.gov/sites/default/files/documents/2018/09/20/prelimappioeconimpactmodelfedlabinventions2008-2015.pdf

[45] https://www.autm.net/AUTMMain/media/Partner-Events/Documents/Economic-_Contribution_University-Nonprofit_Inventions_US_1996-2015_BIO_AUTM.pdf

[46] Gross output is the measure of total economic activity in the production of new goods and services in a given period. Gross domestic product is the value of all final goods and services produced in a given period. All dollar amounts are measured in 2009 dollars. Person-years of employment refers to the amount of work done by an individual during a working year. It is not a measure of employment but rather economic activity.

[47] The years for which federal data is available.

[48] The total annual Federal R&D budget which includes funding for extramural projects is approximately $140 billion over this period.

federal laboratories, and policies regarding the negotiation of licensing rates. Most of these restrictions do not exist in the academic world. Consequently, total annual licensing revenues differs significantly with annual licensing income for federal laboratories averaging about 8% of the annual licensing revenues for academic institutions.

The I-O model requires a substantial number of complex assumptions that have a considerable effect on the reported impact estimates, so a great deal of attention has to be given to assigning parameters that best reflect the market environment for each group of licensors. To address these complexities, the model was run under two assumptions. Under the first assumption, no attempt was made to normalize research expenditures, full time technology transfer employees, the character of research, the number of active license agreements, or other property interests. All production was assumed to occur entirely in the United States; none of the licensee sales were final sales and all the intermediate inputs to production are domestic. These were the same assumptions used to produce the AUTM/BIO 2017 report.

Under these assumptions, the total contribution of federal laboratory licensors to industry gross output between 2008 and 2015 ranged from $23.1 billion to $76.5 billion in 2009 U.S. dollars. Total contributions to gross domestic product ranged from $10.6 billion to $34.6 billion in 2009. The total number of person years of employment supported ranged from 73,000 to 215,000 over the eight-year period.

A second set of assumptions was prepared to provide a more realistic scenario for federal licensees. Under this set of assumptions, 20% of licensee production occurs outside the United States, the shares of sales to final demand are a weighted average, not all intermediate inputs are domestic, and publishing, software and computer systems design, and services were added to licensee industries. With this set of assumptions, the total contribution of federal laboratory licensors to industry gross output ranges from $25 billion to $83.6 billion in 2009 U.S. dollars. Total contributions to GDP range from $12.5 billion to $41.3 billion in 2009 U.S. dollars. Estimates of the total number of person years of employment supported range from 86,000 to 265,000 over the eight-year period.

On an average annual basis, despite receiving only 8% of the licensing income that academics receive, the contribution of licensing efforts by federal laboratories to economic impact is approximately 17% of academic impact (19% of gross output, 18% of gross domestic product, and 15% of employment.) These differences are dependent on a wide range of variables, including royalty rates, the number and type of licenses, terms and conditions, program management, etc.

Economic Analysis of National Needs for Technology Infrastructure to Support the Materials Genome Initiative

Established in 2011, the Materials Genome Initiative (MGI) is a multi-agency effort to promote a globally competitive U.S. manufacturing sector by addressing important gaps in the Materials Innovation Infrastructure. Its aim is to enable U.S. companies to more rapidly and efficiently develop and deploy advanced materials, with applications in the development of advanced consumer goods, renewable energy, energy storage, supercomputing. and national defense.

Given NIST's expertise in the integration, curation, and provisioning of critically evaluated data and models, NIST assumed a leadership role within the MGI. For example, in order to foster widespread adoption of the MGI paradigm both across and within materials development ecosystems, NIST is establishing essential data exchange protocols and the means to ensure the quality of materials data and models. These efforts will yield the new methods, metrologies, and capabilities necessary for accelerated materials development.

NIST is also working with stakeholders in industry, academia, and government to develop the standards, tools, and techniques enabling acquisition, representation, and discovery of materials data; interoperability of computer simulations of materials phenomena across multiple length and time scales; and the quality assessment of materials data, models, and simulations. Internally NIST is conducting several path-finder projects to enable integration of key aspects of the materials innovation infrastructure to expose challenges in the construction of this infrastructure, and to serve as exemplars for the broader MGI effort. This includes pilot projects to develop new energy efficient superalloys and advanced composites for transportation applications.

These activities are coordinated by the NIST Material Measurement Laboratory, in partnership with the NIST Information Technology Laboratory, and with broad participation across the Institute. In summary, NIST is establishing (1) the essential materials data and model exchange protocols and (2) the means to ensure the quality of materials data and models, ultimately (3) establishing new methods, metrologies, and capabilities necessary for accelerated materials development. Additionally, through its efforts to (4) integrate these activities, NIST is working to test and disseminate its developed infrastructure and best practices to its stakeholders.[49]

In FY 2018, NIST commissioned a prospective study of the potential impact of the MGI, as well as the importance of NIST contributions to its success. The study "Economic Analysis of National Needs for Technology Infrastructure to Support the Materials Genome Initiative"[50] was prepared by the Research Triangle Institute and presents an analysis of perspectives and opinions of U.S. manufacturers and other industry experts on their needs for new technological infrastructure supporting advanced materials innovation and the potential economic impacts of meeting those needs.

The report estimates that the potential economic benefit of an improved Materials Innovation Infrastructure is between $123 billion and $270 billion per year, based on structured interviews with more than 100 industry experts. Roughly a quarter of these estimated benefits come from making the R&D process more efficient, saving time and reducing risk. The rest of the potential benefits are projected to come from companies targeting more ambitious R&D projects they would not otherwise have done, leveraging that R&D to commercialize improved products and new product lines, and expanding into new markets.

Efforts to Promote Entrepreneurship

Entrepreneur-in-Residence (EIR) Program

[49] https://www.nist.gov/mgi
[50] https://www.nist.gov/sites/default/files/documents/2018/06/26/mgi_econ_analysis.pdf

The NIST Entrepreneur-in-Residence (EIR) Program was initiated 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 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 2018 there were three NIST-TEDCO EIRs who served on a voluntary basis without compensation.

EIRs offer NIST employees seminars 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 will be involved in a coordinated training program that focuses on recognizing innovation and invention opportunities that spawn from mission-oriented research. This training will be presented through a series of seminars at various NIST organizational levels and will be available to the research and technical staff and to NIST's postdoctoral community. Also, in 2019, the EIRs agreed to support and attend technology transfer events of the Federal Laboratory Consortium Mid-Atlantic Region as their voluntary time commitments may allow.

N-STEP Program

NIST launched the NIST Science and Technology Entrepreneurship Program (N-STEP)[51] 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 2018, five companies completed their N-STEP projects, and three companies are involved in ongoing projects. N-STEP is funded by NIST and administered by Maryland TEDCO but is a nationwide opportunity.

Challenges

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 competition by offering

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

cash prizes to the public for their help in solving perplexing mission-centric problems.[52] In FY 2018, NIST launched the following challenges:

1. Unlinkable Data Challenge: Advancing Methods in Differential Privacy
2. Reusable Abstractions of Manufacturing Processes (RAMP) Challenge
3. Agile Robotics for Industrial Automation Competition (ARIAC)
4. The Unmanned Aerial Systems Flight and Payload Challenge
5. Virtual Reality Heads-Up Display Navigation Challenge

Awards
NIST staff received the following awards during FY 2018:

ACS PMSE Fellow
- Christopher Stafford

Allen V. Astin Measurement Science Award
- Mary Bedner, Carolyn Burdette, Johanna Camera, Katrice Lippa, Karen Phinney, and Lane Sander

American Concrete Institute (ACI) Fellowship
- Dale Bentz

Arthur S. Flemming Award
- Ralph Jimenez

ASTM International Award of Merit
- Enrico Lucon

B. Stephen Carpenter Award
- Michael Lombardi

Colloquium for Information Systems Security Education 2018 Government Leadership of the Year Award
- Davina Pruitt-Mentle

Edward Bennett Rosa Award
- Bala Muralikrishnan, Prem Rachakonda, Meghan Shilling, Roger Bostelman, Geraldine Cheok, Joseph Falco, Marek Franaszek, Jeremy Marvel, Kamel Saidi, Ya-Shian Li-Baboud

Edward Uhler Condon Award
- Pavel Kabos and T. Mitch Wallis

Eugene Casson Crittenden Award
- Wyatt Miller

Federal 100 Award
- Naomi Lefkovitz, Donna Dodson, and Joshua Franklin

Fire Protection Research Foundation Medal
- Erica Kuligowski

George A. Uriano Award
- Patricia R. Toth, Allison Barnard Feeney, and Thomas Hedberg, Jr.

George D. Nasser Award from the Precast/Prestressed Concrete Institute

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

- Hai S. Lew

Henry Marion Howe Medal, ASM International
- Thien Phan

INCITS Merit Award
- Wo Chang and Eric Simmon

Isidor Isacc Rabi Award
- Jun Ye

Jacob Rabinow Applied Research Award
- Michael Donahue and Donald Porter

Judson C. French Award
- Catherine Cooksey, Thomas Germer, Heather J. Patrick, Clarence J. Zarobila, John Curry, George Eppeldauer, Jeanne Houston, Vyacheslav Podobedov, Ping-Shine Shaw, and Howard Yoon

National Storm Shelter Association (NSSA) Kiesling Award
- Marc Levitan

Purdue University, Outstanding Industrial Engineer
- Al Jones

Samuel Wesley Stratton Award
- Savelas Rabb and Robert Vocke

SME 2018 Outstanding Young Manufacturing Engineer Award
- Tom Hedberg

Society of Fire Protection Engineers (SFPE) Educational and Scientific Foundation Jack Bono Award
- Dave Butry and Doug Thomas

William P. Slichter Award
- B. Robert Ilic

Downstream Outcomes from NIST Technology Transfer Activities

NIST Updates Forensic Standard Reference Materials

At forensic science labs, analysts literally weigh the evidence. They also measure it in other ways. They use microscopes, DNA profiling kits, chemical analyzers, and other instruments, all of which must be calibrated to ensure accurate measurements. In forensic labs, where those measurements might be used to determine a person's guilt or innocence, accuracy is particularly important.

To help ensure accuracy, NIST manufactures physical standards used to calibrate analytical instruments in much the same way that a precisely manufactured kilogram mass can be used to calibrate a scale. These standard reference materials, or SRMs, take many forms. Recently, NIST updated versions of two forensic SRMs—the standard bullet and the human DNA quantitation standard.

SRM 2460a: The Standard Bullet

The NIST standard bullet isn't a real bullet, but it looks like a typical 9mm bullet that has been fired from a gun. A series of six parallel markings appear on its surface, and if you turn it under a light, you can see that those markings are made up of fine striations. These ridges are reproduced precisely on each standard bullet down to the microscopic level.

The marks simulate the impressions that a gun leaves, like a ballistic signature, on every bullet it fires. For instance, if investigators recover a bullet from a crime scene, they can test-fire a suspect's weapon to produce a second bullet. Then, they compare ballistic signatures to see if the two bullets were fired from the same gun.

In many forensic firearms labs, examiners compare bullets visually under a split-screen microscope. But at state-of-the-art laboratories, they use scanning optical microscopes that measure the 3D features on a bullet's surface, including the microscopic detail within the striations. This provides greater detail and accuracy than a 2D comparison.

A firearms examiner can test whether a 3D surface scanning microscope is properly calibrated by measuring the striations on the NIST standard bullet. They then compare those measurements with data provided by NIST. If their measurements are off, they know that something is amiss.

The prior version of the standard bullet, which was manufactured using a diamond-turning process that engraved the striations onto the bullet, cost more than $2,000 each. With funding from the National Institute of Justice, NIST developed a new manufacturing method that involves casting polyurethane copies in a mold, then plating them with nickel and gold. This new method allows NIST to sell the standard bullet for $350.

SRM 2372a: The Human DNA Quantitation Standard

This SRM comprises three vials, each containing human DNA suspended in a clear solution. The first vial contains DNA from a male, the second from a female, and the third contains both female and male DNA in a three-to-one ratio.

Forensic analysts use this SRM when generating a genetic fingerprint, also called a DNA profile, of a suspect. If blood or other biological evidence is found at a crime scene, the analyst extracts DNA from the evidence, then processes it to generate the profile.

For this to work properly, the analyst needs to know how much DNA is in the extract before they process it. "Put in too little, and you might end up with an incomplete DNA profile," said Erica Romsos, the research scientist at NIST who managed production of this standard. "Put in too much, and you can blow out the signal, making the results difficult to interpret."

The three vials in this standard contain precisely measured quantities of human DNA, which forensic analysts use to calibrate their instruments when measuring how much DNA they extracted from the evidence. This helps ensure that they process the right amount of DNA when generating the profile.

In the new version of this standard, the quantity of DNA in each of the vials was measured using an advanced technique called digital PCR. This gives a more precise measurement than possible in the prior version and allows for more accurate calibrations in the lab. The prior version only listed quantities for the type of DNA that is found in the nucleus of the cell. The new version does this, but also lists the quantity of mitochondrial DNA found outside the nucleus and can be useful when working with evidence that contains damaged or degraded DNA.

Other Forensic SRMs
NIST produces other standards used in ballistics and DNA labs, as well as alcohol solutions used to calibrate breathalyzers, ignitable liquids used in arson investigations, and more. Although the types of forensic SRMs vary, they are all manufactured with the same goal in mind: to help ensure the reliability of the scientific evidence used in criminal investigations.

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

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

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

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

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

NIST Reference Material 8366 for Cancer Biomarker EGFR and MET Measurements

NIST Reference Material 8366 for cancer biomarkers EGFR (epidermal growth factor receptor) and MET (proto-oncogene, receptor tyrosine kinase) gene copy number measurements is available for purchase.

The genes for EGFR and MET are frequently amplified in different types of cancer, and DNA measurements of the gene copy number variations are used for cancer detection, diagnosis, treatment selection, and prognosis. RM 8366 consists of genomic DNA extracted from six human cancer cell lines with different amounts of amplification of the target genes. The reference values for the ratio of the EGFR and MET gene copy number to the copy numbers of reference genes were determined by digital polymerase chain reaction.

The utility of Reference Material 8366 for next-generation sequencing was tested in the Molecular Characterization and Clinical Assay Development Laboratory at Frederick National Laboratory for Cancer Research and Peter MacCallum Cancer Centre in Australia. Reference Material 8366, in addition to NIST Standard Reference Material 2373 - Genomic DNA Standards for HER2 Measurements, expands the NIST portfolio of precision medicine standards to support measurements for the cancer community.

The National Cancer Institute MATCH (Molecular Analysis for Therapy Choice) trial, the biggest precision medicine cancer treatment clinical trial, plans to use components of the NIST reference materials to evaluate cancer measurements in its laboratories.

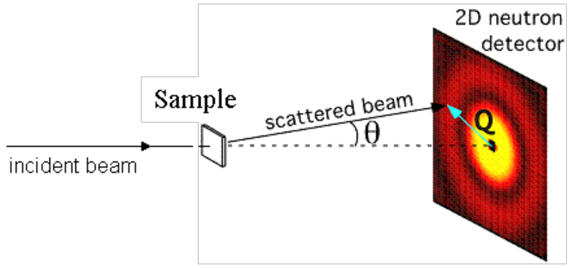
Industry Now Has Access to a Rare Resource

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

NIST's Material Measurement Lab developed a new model for outreach to increase industry access to federally funded scientific instruments. These tools are often under-utilized by private-sector researchers, because they don't have the expertise to use them.

nSoft and the NIST Center for Neutron Research (NCNR) train scientists from industry members to measure materials nondestructively. Members of nSoft develop expertise in neutron science by planning and executing their own experiments at NCNR with guidance from NIST scientists.

Beams of neutrons can pass through soft materials—cancer drugs, vaccines, high performance plastics and composites, agricultural products, and even batteries—without damaging their structure, exposing the molecules from which they are made. Access to research reactors similar to NCNR reactor are limited, and there are only a few experts who know how to conduct experiments and analyze data from neutron studies. In order to alleviate such limitations, NIST launched the nSoft consortium in 2012 to provide access to research reactor and experts at the NCNR.



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

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

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

Facilitating Research, Development, and Commercialization of Large-Scale 3D Imaging Systems

Working through ASTM, NIST led the development of a new technical standard, E3125-2017, *Standard Test Method for Evaluating the Point-to-Point Distance Measurement Performance of Spherical Coordinate 3D Imaging Systems in the Medium Range*, that provides instrument manufacturers and users with a common set of tests for specifying the performance of large-scale 3D imaging systems. These systems enable the large-scale precision manufacturing of aircraft, ships, and construction equipment and the renovation and construction of buildings and other outdoor structures. This standard is available for reference in procurement documents in support of purchases of scanner hardware and scanner measurements. It also furnishes imaging system manufacturers with objective and accepted measures to guide product improvement. The standards development effort was particularly noteworthy as the immediacy of the need led the team to realize the standard in approximately three years, when typically twice that amount of time is required.

NIST SURF III Helps Develop Extreme Ultraviolet Lithography (EUVL) as the Next Generation Technology for the Microelectronics Industry to Keep Pace with Moore's Law

The demand to continually increase the number and density of transistors on a chip has driven the microelectronics industry to jump from using 193 nm ultraviolet light (6.4 eV photons) to using 13.5 nm extreme ultraviolet light (92.5 eV photons) to pattern the circuits. Major hurdles in transitioning to EUVL include concern about the damage to the optics by the highly energetic EUV photons. Facilitated by CRADAs with industry partners, NIST researchers used the EUV radiation produced at the NIST Synchrotron Ultraviolet Radiation Facility (SURF III) to characterize precision EUV optics under development, quantify any damage to the optics caused by the EUV radiation, develop physics-based models to explain the damage, and evaluate efforts to mitigate this damage.   The NIST effort played a major role in finding solutions to EUV damage to optics and eliminating such damage as a major concern.

CRADA Partner Demonstrates Prototype Commercial Photonic Pressure Standard Based on NIST Patented Technology

A CRADA partner, facilitated by a Cooperative Research and Development Agreement with NIST, demonstrated a compact prototype photonic pressure standard at the vendor exhibition at the AVS 65th International Symposium and Exhibition, October 23rd-25th, in Long Beach, California. Such a standard could serve a broad range of applications that demand highly accurate pressure measurements over a broad range of pressures. A major benefit of the technology is that it is mercury-free, whereas conventional technology for such accurate pressure measurements requires hundreds of pounds of toxic liquid mercury.

Detailed Examination by NIST of Standard Method to Calibrate Mass Flow Controllers Reveals Errors that Impact Semiconductor Manufacturing

Mass Flow Controllers are widely used by the semiconductor industry to accurately meter the small amounts of various exotic gases used to precisely fabricate micro-to-nanoscale thin films, trenches, holes, and other features required in modern microelectronics and MEMS manufacturing. Concerns raised about the accuracy of mass flow controller calibration methods by a semiconductor equipment manufacturer led NIST researchers to look more closely at the issue. The researchers discovered that the widely applied rate-of-rise (RoR) method used to calibrate mass flow controllers can cause significant errors at the low flow rates used by the micro and nanofabrication industries. Such errors have the potential to produce poor fabrication results, leading to millions of dollars of wasted product per production run. NIST scientists researched, developed, and tested a method to quantify and correct the errors made by the RoR calibrations approach and made the results from their study available to industry.

3D Laser Scanning Artifact Commercialized by U.S. Manufacturer

To develop the world's first laser scanner performance test standard, NIST staff developed a prototype target to enable the performance testing of large-volume 3D laser scanning systems in a manufacturing facility. 3D large-volume laser scanning systems are used in shipbuilding, aerospace, and large civil construction industries to ensure the mechanical components are produced with sufficiently accurate dimensions and that they fit and function as designed. The NIST artifact was designed to reveal errors associated with the laser scanning system, while minimizing the errors introduced by the target itself. The artifact was designed with low-priced components and uses novel algorithms developed by NIST. The initial artifact design was conceived by NIST staff and fabricated at NIST. The concept benefited from extensive discussions with staff from the

National Research Council of Canada and feedback from industry partners. The NIST concept was commercialized by a U.S. manufacturer, who began marketing the product in November 2017.

NIST Calibrations Help Missile Defense Aerospace Manufacturers Meet Contract Requirements

NIST provided on-site infrared calibrations of cryogenic space chambers maintained at aerospace contractor sites and used in the testing of sensors deployed on ballistic missile defense seekers. NIST calibrated the chamber by deploying special infrared radiometers to take highly accurate measurements of infrared radiation emitted by the test blackbody source mounted inside the chamber at an aerospace contractor site. The NIST effort was supported by funding from the Missile Defense Agency and aided by a DoD CRADA partner.

NIST Synchrotron Ultraviolet Radiation Facility (SURF III) Helps Satellite Sensor Manufacturer

Space-based sensors that monitor the ultraviolet radiation from the sun in support of space-weather forecasting and monitoring require calibration against a light source that outputs an accurately known amount of radiation from the ultraviolet to the extreme ultraviolet regions of the spectrum. NIST's SURF III Facility is the only place in the United States and only one of two places in the world that can provide such calibrations for space weather applications. NIST continues to make the SURF III Facility available to the University of Colorado Laboratory for Atmospheric and Space Physics (LASP), the prime builders of satellite solar sensors for NOAA and NASA, for use in the testing and calibration of their sensors. The NIST effort, funded by NOAA or NASA, helps LASP meet contract requirements.

Cement SRMs

NIST staff recently developed two new cement SRMs: one that contains slag, a byproduct of iron production, and one that contains fly ash, a byproduct of burning coal for power generation. Recent research indicates that slag and fly ash can be used to create improved cement that requires less water to mix into concrete, sets faster, flows more easily through pumps, and creates a stronger and less permeable concrete. The new fly ash and slag cement SRMs are examples of how NIST continues to respond to the evolving needs of the $1 trillion global cement industry.

Exoskeletons and Exosuits

NIST staff were instrumental in providing key leadership for a new ASTM International Committee on exoskeletons and exosuits. In factories and warehouses, workers are using exoskeletons to reduce the chances of injury from repetitive and strenuous tasks. The military is experimenting with them to prevent injuries and extend the strength and endurance of the warfighter, and patients who have suffered from strokes and spinal injuries are using them to increase their mobility and independence. NIST development of standard methods of evaluating exoskeleton/exosuit safety and performance has accelerated the acceptance and use of these technologies.

Smart Grid Information Model

NIST researchers were instrumental in the publication of the ISO 17800 Facility Smart Grid Information Model and driving its adoption. The Facility Smart Grid Information Model is an essential standard for communication between buildings and a smart electrical grid, enabling information modeling of building systems and new building control technologies for more cost-effective management of electricity production, purchase, storage, and consumption.

Aerial System Test Methods and Performance Metrics

The Aerial Firefighting Center of Excellence, Colorado, adopted 10 aerial system test methods and performance metrics developed by NIST. They replicated NIST's test methods and performance metrics for Small Unmanned Aircraft System Basic Maneuvering, Sensing, and Energy suites of test methods and displayed them at the Association for Unmanned Vehicle Systems International (AUVSI) conference and exposition. There are also plans to travel around the state using the test methods developed by NIST to measure aerial system capabilities and remote pilot proficiency. This will help validate the test methods and support the standardization process through the ASTM International Standards Committee on Homeland Security Applications (Response Robots) chaired by NIST staff.

Machine Tool Health Tracking

NIST is collaborating with Indiana Technology and Manufacturing Companies (ITAMCO), a gear manufacturer that delivers precision-machined components to Original Equipment Manufactures around the world, to further develop NIST's patent-pending portable inertial measurement unit (IMU)-based machine performance measurement technology. Under a Cooperative Agreement, a NIST IMU system currently on loan to ITAMCO is being used over a one-year period for data collection on motion axes of three different machine tools that are used regularly for gear manufacturing. Diagnostics will be performed on the ITAMCO IMU datasets to assess the viability of tracking the health of linear axes for machine tools in production environments. ITAMCO has a research license with NIST to explore commercialization of the IMU-based system.

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, Maryland, and staffed across the United States. NOAA's service-based Line Offices include: 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 (OAR).

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 fresh water 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 outer-agency technology transfer 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 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. The Plan has been refined in 2018 to more closely align with the Department of Commerce Strategic Plan. The TPO established the following four goals and related objectives for driving program success.

Goal 1: Increase Innovation within NOAA and the Nation

- Support Lab-to-Market Cross Agency Priority (CAP) Goal Deliverables
- Facilitate integration of NOAA Labs into their local innovation ecosystems
- Conduct T2 and Intellectual Property Training for NOAA staff

Goal 2: Enhance Job Creation within the U.S. Economy

- Kick off annual NOAA Innovation Fairs to increase the adoption rate for NOAA technologies in the U.S. private sector
- Continue SBIR-Technology Transfer (TT) projects to facilitate adoption of NOAA technology
- Conduct targeted communications to spur commercialization of NOAA's patented technologies

Goal 3: Enhance Resilience and Security

- Encourage public and private exchange and adoption of cutting-edge technology in severe weather forecasting
- Support public and private partnerships in Aquaculture
- Facilitate the private use of NOAA data to develop new commercial products and services

Goal 4: Improve Integration, Function and Profile of the NOAA TPO

- Identify and establish Innovation Managers within each Lab/Center and Program
- Revise and issue NOAA T2 Policy Guidance
- Launch NOAA Innovators Educational Series

Data Products and Services

NOAA data supports a wide range of multi-billion-dollar economic sectors in the United States 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. Numerous resources, such as the Climate Disk, and datasets, including the Global Historical Climatology Network–Daily (GHCN-D), provide a foundation for these decisions.

NOAA National Centers for Environmental Information (NCEI) Launches Success Story and Economic Impact Series

American and international businesses from many different sectors use NOAA's data to make professional decisions, making it highly likely that you are an indirect consumer of NOAA's climate and weather data by using products and services in the marketplace.

For example, think about the corn-on-the-cob that you grill on the barbecue in the summertime. More than likely, it was grown with the help of a nitrogen fertilizer management tool that uses NOAA's temperature and precipitation data. Another example are the safety precautions air travelers are reminded of before every flight. Those were informed by aviation analysis using NOAA's Next Generation Weather Radar data (NEXRAD). Insurance policies for your home were designed using various NOAA datasets that record the occurrence of severe weather events (i.e., hail, tornadoes, and hurricanes). The ways that climate and weather data may enhance your quality of life are numerous, even if the connections are not obvious.

NCEI launched Success Stories on user engagement, to explore the value of its free and publicly available provision of climate and weather data. Each success story explores a different sector including agriculture,[53] transportation,[54] natural resource management,[55] reinsurance,[56] retail and manufacturing,[57] drought,[58] logistics and transportation,[59] and weather service providers.[60]

The findings of these studies are presented in a detailed report, a short four-to-eight-minute video, and a colorful infographic. Each study details how these data are used, and the benefits realized from their applications. NCEI's data help businesses operate more efficiently, safely, environmentally, and economically bolstering their bottom lines and making the most of their enterprise. This in turn benefits the American public, the consumers of these goods and services.[61]

NOAA Big Data Project (BDP): Successes and Next Steps

NOAA's Big Data Project (BDP) is currently in its last year under the Cooperative Research and Development Agreements (CRADAs) with Amazon Web Services (AWS), Google Cloud Platform (GCP), IBM, Microsoft Azure, and the Open Commons Consortium (OCC). Following on the CRADAs, the BDP is working to determine a sustainable operational phase of the project based on lessons learned over the past four years. As part of this process, NOAA issued a Request for Information (RFI) about the BDP and topics related to NOAA's cloud initiatives. The RFI was designed to determine whether providing and accessing the data via the cloud service providers is beneficial, and if so, the details on the benefits. NOAA received 25 responses—the bulk of which were very positive and supportive of the project. All five Collaborators responded to the RFI as well as an individual Ph.D. candidate, some startup companies, small companies, and a few large companies.

---

[53] https://www.ncdc.noaa.gov/success/adapt-n-agriculture
[54] https://www.ncdc.noaa.gov/success/aviation
[55] https://www.ncdc.noaa.gov/success/coral-reef-watch
[56] https://www.ncdc.noaa.gov/success/reinsurance
[57] https://www.ncdc.noaa.gov/success/retail-manufacturing
[58] https://www.ncdc.noaa.gov/success/drought-and-livestock
[59] https://www.ncdc.noaa.gov/success/Logistics%20%26%20Transportation
[60] https://www.ncdc.noaa.gov/success/weather-service-providers
[61] https://www.ncdc.noaa.gov/success

As a result of the RFI and other reports, the BDP team started to learn more about ways end users are utilizing the data accessed through the project. Of the different use cases the team has heard about, the majority are related to users accessing and utilizing Geostationary Operational Environmental Satellite (GOES) 16 weather satellite data and the Next Generation Weather Radar (NEXRAD) Level II archive data. NEXRAD was the first major success of the BDP when it was transferred through the project and made publicly available on the cloud platforms of AWS, GCP, and OCC, mainly in part due to its large size (300 TB).

Providing access to the data on cloud platforms with co-located computing resources allowed the average citizen to access and analyze this massive data set without a similarly massive computer network. In 2018, Dokter et al.[62] noted this benefit in their study examining the seasonal abundance and survival rates of migratory birds in North America using NEXRAD data accessed via AWS. In particular, the authors noted that previous means of access were often prohibitive in terms of the time needed to access and analyze the data, limiting the ability to produce continent-wide analyses.

Other analyses also used NEXRAD data to generate a system to forecast bird migration, generate a tutorial on how to distinguish between migrating birds and insects within the radar data, as well as study associations between tornadoes and factors such as seasonality, regionality, etc. Examples such as these highlight the utility and benefits of providing alternative means of access to NOAA's data.

Decision Support Tools

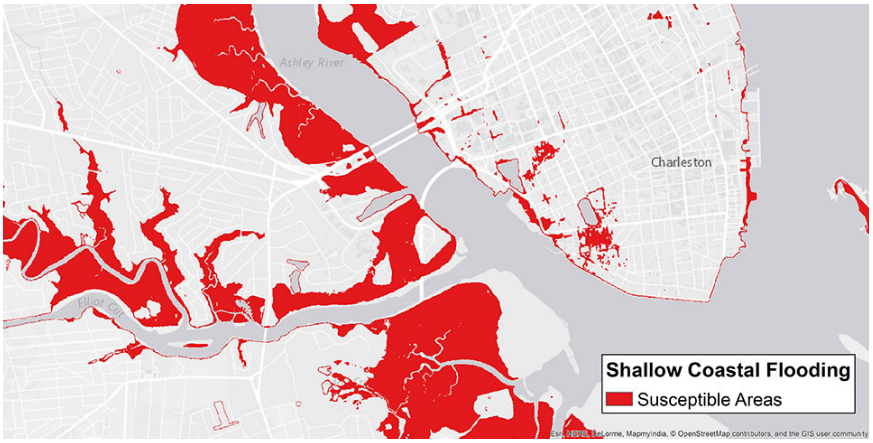
NOAA's labs and programs develop a wide variety of dedicated software tools and websites which bring data to the public in a user-friendly format to enable effective decision-support. In many cases, these sites are developed in conjunction with academia and private sector partners.

Coastal Flood Exposure Mapper Supports Decision Makers and Business

NOAA's Coastal Flood Exposure Mapper is a free online tool that provides maps, data, and information to assess risks and vulnerabilities related to coastal flooding and hazards. The tool is available for the entire U.S. East Coast and Gulf of Mexico.

---

[62] https://www.nature.com/articles/s41559-018-0666-4.epdf?author_access_token=SLwj630lIhZMS-yqWAbdVtRgN0jAjWel9jnR3ZoTv0OYwjpgQugHALo6RbogqlWrIyJbZw6I2aHn7mV7VihLh70gEkW93OqsXiItndUpPWnUSzYoptNHeSL6QEPazIioAWvrjrJLTB76LQjzBGygGw%3D%3D



With the Coastal Flood Exposure Mapper, you may select a location and a flood scenario of your choosing: Federal Emergency Management Agency flood designations, shallow coastal flooding associated with high tides, or flooding associated with sea level rise or storm surge. Flood maps are then overlaid with any of three exposure maps to show how floodwaters might impact area assets.[63]

NOAA Work Products and Collaborative Activities

Inventions, Patents, and Licensing

NOAA did not receive any new U.S. patents for innovations in 2018. NOAA researchers disclosed four software innovations and two new hardware inventions, which are both being reviewed for possible patent application filings. In addition, the TPO filed two non-provisional patent applications for cases disclosed in 2017.

Table 26 – NOAA Invention Disclosures and Patents

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Invention Disclosures					
Inventions Disclosed	6	15	18	3	6
Patents					
U.S. Patent Applications Filed	4	6	4	3	2
U.S. Patents Received	0	1	1	3	0
Foreign Patent Applications Filed	1	0	0	0	0
Foreign Patents Received	0	0	1	0	0

[63] https://oceanservice.noaa.gov/news/apr15/flood-exposure.html

NOAA now maintains an active patent portfolio of 18 technologies, 10 of which are being marketed for licensees or are being actively commercialized. The portfolio consists of seven active, income bearing licenses. The TPO also signed two short-term, royalty-free Research and Development licenses during FY 2018 under its SBIR-Technology Transfer commercialization activities.

Table 27 – NOAA Licenses

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Licenses					
Total Active Licenses	5	6	7	7	7
Total New Licenses	0	2	3	0	0
Income Bearing Licenses					
Total Active Income Bearing Licenses	5	4	5	7	7
New Income Bearing Licenses	0	3	3	2	0
Total Active Invention Licenses	5	4	7	7	7
New Invention Licenses	0	0	3	1	0
Exclusive Licenses	0	1	4	4	4
Partially Exclusive Licenses	0	0	0	0	0
Non-Exclusive License	5	3	3	3	3
Elapsed time for Granting Licenses					
Average (months)	0	3	9	3	n.a.
Minimum (months)	0	0	5	1	n.a.
Maximum (months)	0	0	14	5	n.a.

Table 28 – NOAA License Income

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
License Income					
Total License Income	$69,151	$39,633	$11,000	$65,810	$35,671
Total Invention License Income	$69,151	$39,633	$11,000	$65,810	$35,671
Earned Royalty Income (ERI)					
ERI top 1%	$50,000	$39,633	$7,000	$60,000	$33,321
ERI top 5%	$50,000	$39,633	$7,000	$60,000	$33,321
ERI top 20%	$50,000	$39,633	$7,000	$60,000	$33,321
Minimum ERI	$1,000	$39,633	$1,000	$210	$250
Maximum ERI	$50,000	$39,633	$7,000	$60,000	$33,321
Median ERI	$13,830	$39,633	$5,000	$2,800	$2,100
Disposition of Earned Royalty Income					
Total amount of ERI received	$69,151	$39,633	$11,000	$5,600	$35,671
Percent of ERI distributed to inventors	$22,845	$12,588	$4,000	$1,736	$13,643
	33%	32%	36%	31%	38%
Percent of ERI distributed to agency or lab	$46,306	$27,045	$7,000	$3,864	$22,028
	67%	68%	64%	69%	62%
Licenses terminated for cause	0	0	0	0	0

Cooperative Research and Development Agreements

NOAA's Labs, Centers and Programs executed 11 new Cooperative Research and Development Agreements (CRADAs) in 2018. Five of these agreements were with small businesses. Factoring in the new and expiring agreements, the total NOAA CRADA portfolio is now 45 active CRADAs.

Table 29 – NOAA Cooperative Research and Development Agreements

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
CRADAs					
Active CRADAs	19	28	33	37	45
Newly Executed CRADAs	8	14	9	15	11
Active CRADAs with small businesses	0	0	18	26	22
Small Businesses in Active CRADAs	0	0	18	26	22
Traditional CRADAs					
Active Traditional CRADAs	19	28	33	36	43
Newly Executed Traditional CRADAs	8	14	9	14	10
Non-traditional CRADAs					
Active Non-traditional CRADAs	0	0	0	0	2
Newly Executed Non-traditional CRADAs	0	0	0	0	1

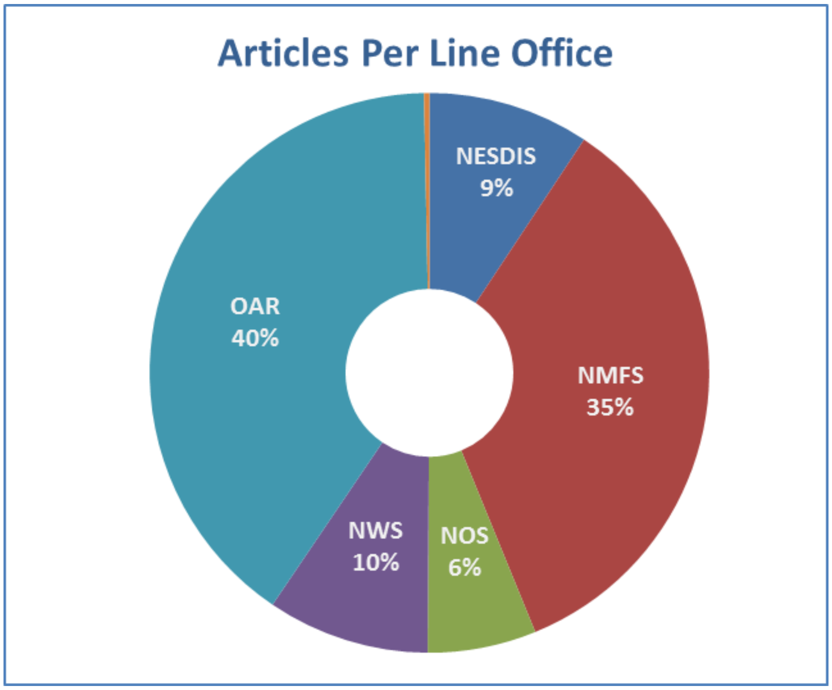
Table 30 – NOAA Involvement with Small Businesses, Startups, and Young Companies

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Small businesses supported					
Total Number of Small Businesses Supported	0	0	23	30	22
Total Number of Startup and Young Companies Supported	1	1	2	1	0

Publications[64]

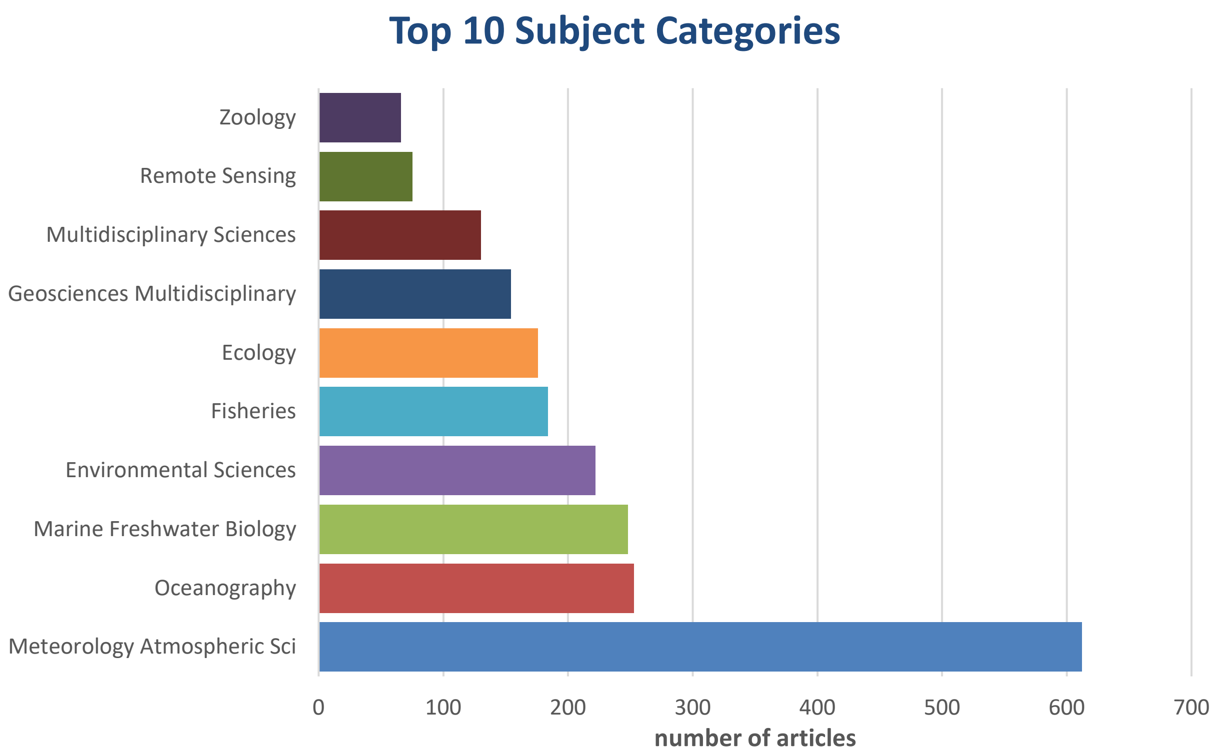
In FY 2018, peer-reviewed publications by NOAA federal scientists totaled **1,794**. The following charts show the breakdown of publications.

Figure 6 – Number of Publications by Research Unit as a Percentage of All NOAA-Authored Publications in FY2018



[64] NOAA publications data for 2018 were derived on October 5, 2018, 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 all NOAA publications. This reporting includes only those publications by NOAA scientists that were captured by the search queries. A single publication with authors from one or more-line office is counted as a publication for each line office.

Figure 7 – Number Of NOAA-Authored Peer-Reviewed Articles Per Subject Category[65]



[65] Subject categories are defined, and assigned to articles by Web of Science based on the journal in which each article was published. These categories overlap, so **a single article can be assigned to multiple subject categories**. Only the top 10 subject categories by publication counts are shown.

Economic Impact

In 2018, the NOAA TPO contracted for a study to determine the effectiveness and economic impact of its Cooperative Research and Development Agreements. While the final results had not been tallied in time for this report, preliminary figures for economic impact have been very promising, as shown in the table below.

Table 31 – Estimated Economic Impact of NOAA's CRADA Activity

Category of Final Demand	Amount	Total Output	Value-Added	Earnings	Jobs
Total External Investment (millions)	$99.50	$192.40	$94.10	$50.20	782
Actual Sales (millions)	$1.30	$2.50	$1.20	$0.70	11
Anticipated Sales (all years; millions)	$10.10	$19.50	$9.50	$5.10	80

Downstream Success Stories from NOAA Technology Transfer Activities

High Precision Devices Receives Phase II Small Business Innovation Research (SBIR) Award to Commercialize NOAA NOy Cavity Ringdown Instrument

High Precision Devices, a small company located in Boulder, Colorado, successfully completed Phase I of its commercialization plan under NOAA's SBIR-Technology Transfer activity and has been granted a Phase II award to complete the commercial development of NOAA's patented NOy-Cavity Ring-Down Spectrometer.

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

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

Meteorological Assimilation Data Ingest System (MADIS)
The Meteorological Assimilation Data Ingest System (MADIS) is a global database and delivery system developed by NOAA Research in 2001 and transitioned into NOAA NWS operations in 2015. MADIS serves the greater meteorological community by supporting the collection, integration, quality control, and distribution of NOAA and non-NOAA observations. MADIS continues to grow and improve through version releases each year. For 2018, the system upgrades improved forecast accuracy by providing higher density and higher quality atmospheric observations from public and non-public sources.[66]

Partnerships to Improve Flooding Forecasts in Urban Areas
When big storms hit California, current technology does not provide forecasters with the detailed information needed to inform reservoir operations, flood protection, combined sewer-stormwater systems, and emergency preparedness. The Advanced Quantitative Precipitation Information (AQPI) system is a collaborative federal, state, and local partnership funded by the state of California. AQPI is deploying experimental radars for estimating precipitation (two out of five are currently in place), streamflow and soil moisture observations for estimating runoff, and producing experimental forecasts of extreme precipitation and coastal inundation in the urban regions surrounding San Francisco Bay. As part of AQPI, NOAA is able to evaluate several models, including the High-Resolution Rapid Refresh (HRRR) forecast model performance in complex terrain, National Water Model sensitivity to experimental radar precipitation estimates, and applications of a coastal coupled version of the National Water Model. The system will aid water managers in mitigating flood, water supply, and water quality risks across the nine-county region surrounding San Francisco Bay. AQPI is anticipated to achieve a significant benefit to cost ratio through a combination of avoided flood damage costs from early warnings; forecast-informed operations to maximize reservoir capture for water supply and fisheries flows; minimization of water quality impacts from combined sewer overflows; and enhancement of public safety for various transportation modes (pedestrian, highways, marine, and airports). These benefits are anticipated to become increasingly important as costs associated with extreme weather events continue to escalate.[67]

New Techniques and Tools to Expand Aquaculture
NOAA is developing new techniques and tests to expand aquaculture production. Researchers with NOAA Fisheries have been helping aquaculturists, notably, GreenWave Organization's Thimble Island Ocean Farm, develop culturing strategies to grow a new crop: sugar kelp. Sugar kelp is developed for a variety of uses, from food, to potential biofuels, as well to diversify the portfolio for shellfish growers and others in the seafood sector. Aquatic plant farming, primarily seaweed, also represents a significant sector of global aquaculture production (30.1 million metric tons, valued at $11.6 billion).[68]

Seaweed farming is just now emerging in the United States and shows promise to become an important contributor to future U.S. marine aquaculture production. Researchers are helping this company and its academic partner, the University of Connecticut, develop techniques for

[66] https://madis.ncep.noaa.gov/madis_rwis.shtml
[67] https://www.esrl.noaa.gov/psd/outreach/resources/handouts/aqpi.pdf
[68] https://www.nefsc.noaa.gov/press_release/pr2017/features/sugar-kelp/

growing the kelp across its entire life cycle—from spore culture to maturity—and harvesting strategies. Developing new crops is not the only way to expand aquaculture. When the sewage treatment plant on Connecticut's Mystic River was upgraded in 2015, few residents imagined local shellfish farmers might benefit, let alone oyster and clam growers across the country. Now this is a possibility, depending on the results of a novel water quality-testing project led by New Hampshire Sea Grant in partnership with Connecticut Sea Grant which could open nearly 800 acres now off limits for commercial shellfishing. While river water quality improved following the treatment plant upgrades, researchers have to demonstrate that levels of harmful bacteria and viruses in the water meet public health safety standards before currently-closed areas can be opened to harvest. Sea Grant's work in the Mystic River supports Connecticut's shellfish industry, which generates more than $30 million in farm-gate sales annually and provides more than 300 jobs statewide. Test results thus far show favorable results, and this method could ultimately be adopted by shellfish managers working under National Shellfish Sanitation Program regulations.[69]

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

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

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

EcoCast: A Dynamic Tool to Support Economically Viable Fisheries

New computer-generated daily maps will help fishermen locate the most productive fishing spots in near real time, while warning them where they face the greatest risk of entangling sea turtles, marine mammals, and other protected species. Scientists developed the maps, products of a system called EcoCast, to help reduce accidental catches of protected species in fishing nets.

[69] https://seagrant.uconn.edu/2018/03/07/cleaner-mystic-river-could-give-shellfish-farmers-room-to-grow/

Traditional ocean management strategies tend to be static with boundaries that are fixed in space and time. To capture broad-scale oceanic processes and protect highly migratory species, for example, these regions become larger than necessary with opportunity costs for commercial fisheries.

EcoCast uses a dynamic management strategy, which better aligns scales of management to the scales of variability of the features and resources being managed. By incorporating real-time satellite, buoy, modeled, and observed data, EcoCast provides management recommendations that reflect current marine state.

EcoCast will help fishermen, managers, scientists, and others understand in near real time where fishing vessels have the highest probability of catching targeted species and where there is risk of catching protected species. In doing so, EcoCast aims to improve the economic and environmental sustainability of fisheries that sometimes inadvertently catch and kill sensitive species.

Currently, NOAA Fisheries closes a large area off the West Coast to the swordfish fishery seasonally to protect leatherback turtles, which travel widely and can be caught incidentally in the nets. With EcoCast, fishery managers could outline small "dynamic closures" that shift according to the likely locations of the species they are trying to protect. Since they concentrate protection where it is needed most, dynamic closures for leatherback sea turtles could be two-to-10 times smaller than the current static closures, while still safeguarding the species that need protection.

EcoCast is available now and is being developed by a consortium of scientists, managers, and members of the fishing industry. The EcoCast team is made up of scientists from several universities (San Diego State University, University of California Santa Cruz, University of Maryland, Old Dominion University, Stanford University) and NOAA Fisheries, working in direct collaboration with resource managers, fishing industry, and other stakeholders. Fishermen have participated throughout the development of EcoCast, which boosts its usefulness to the fishing fleet.[70]

NOAA Data Engages, Educates, and Inspires

NOAA is supporting the efforts of eight Native American tribes in the Missouri River basin to build capacity in water resources management through tools such as NOAA's Drought Monitor and precipitation and flooding data, and by exchanging knowledge with the tribes to produce the first-ever regional climate summary to help them integrate climate knowledge and data into decision making. In March 2018, four tribes in northeastern Kansas and southeastern Nebraska released their first regional climate summary, which includes temperature and precipitation, river and stream data, soil moisture, and other environmental health indicators. The long-term goals of this work are: to build the tribes' capacity for water management, to increase understanding of vulnerabilities to extreme events, and to plan response-and-resiliency efforts.[71]

New Tools for Aquaculture Siting in the Gulf of Mexico

---

[70] https://swfsc.noaa.gov/news.aspx?ParentMenuId=200&id=23061

[71] https://www.ncei.noaa.gov/news/outside-science-ncei-engages-educates-and-inspires

NOAA developed the Gulf AquaMapper, a web-based tool for exploration, permitting, and siting of offshore aquaculture in the Gulf of Mexico. The Gulf AquaMapper is a geodatabase featuring aquaculture-relevant GIS data for biological, navigational, military, social, economic, physical, and chemical parameters. The product provides a user-friendly interface that serves as a single resource for private industry and coastal managers focused on identifying suitable areas for aquaculture development. Multiple data layers, such as shipping lanes, military operating area boundaries, and marine reserves, can be viewed simultaneously for a more comprehensive assessment of competing uses, and maps can be printed and shared to inform a more detailed site assessment to verify environmental conditions and establish site-specific designs. The mapper marks the first spatial planning tool designed specifically for aquaculture in the Gulf of Mexico and integrates more than 50 types of data. With this tool, NOAA seeks to streamline the permitting process by reducing logistical and economic inefficiencies for coastal managers and aquaculture investors. This is one of 30-plus tools in NOAA's Coastal Aquaculture Planning Portal with specific applications for planning and siting of aquaculture operations and industries.[72]

NOAA Advances Precision Navigation Services to Enhance U.S. Commerce
Comparable to the way car technology supports drivers, NOAA launched a new program to develop the next generation of marine navigation tools that provide mariners with the information they need to safely and efficiently transport maritime commerce. This next generation of products is referred to as precision navigation. Precision navigation seamlessly integrates high-resolution bathymetry with real-time and forecast data—such as water levels, currents, salinity, temperature, and precipitation—to produce a stronger decision support tool to equip mariners for critical go/no-go decisions. This program involves various types and sources of data, requires the coordinated efforts of several NOAA offices, and was first implemented in the Port of Long Beach, California. In 2018, NOAA established a team dedicated to assist with expanding the program to ports nationwide. Future plans will expand and implement precision navigation into the Lower Mississippi River Port Complexes, as well as in the Port of New York/New Jersey which supports $184.4 billion in commerce. Researchers are currently conducting a socio-economic study to examine the return on investment of the precision navigation program.[73]

Installation of NOAA's Physical Oceanographic Real Time Data (PORTS®) at Port of Miami Advances Maritime Commerce
PortMiami partnered with NOAA NOS to install PORTS®, a new Physical Oceanographic Real Time System in the Spring 2018 to ensure big ships can safely navigate the port. PortMiami is among America's busiest ports and is recognized across the globe as the Cruise Capital of the World and Global Gateway. PortMiami contributes more than $41.4 billion annually to Miami-Dade County and generates 324,000 direct, indirect, and induced jobs. The new system, consisting of three new current meter sensors in PortMiami's channel, will provide critical real-time information to big-ship operators for the safe transit into PortMiami by avoiding collisions and groundings.[74]

---

[72] https://coastalscience.noaa.gov/news/new-aquamapper-tool-available-permitting-siting-aquaculture-gulf-mexico/
[73] https://noaacoastsurvey.wordpress.com/2018/06/15/new-noaa-precision-navigation-program-increases-safety-efficiency-for-maritime-commerce/
[74] https://www.miamidade.gov/releases/2018-03-27-seaport-ports-navigation-system.asp

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.

New Science on a Sphere installation at the Marine Education Center, Gulf Coast Research Laboratory at the University of Southern Mississippi (Credit: NOAA)

Table 32 – NOAA's SOS Installations

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
SoS Installations					
Total Number in Operation	110	126	135	144	155
New Domestic	4	6	3	6	3
New International	5	10	6	3	8
Total New Installs	9	16	9	9	11

User Facilities

While NOAA does not regularly have facilities available for public use, in 2018 it signed two CRADAs which allowed for aquaculture research to be conducted by our private sector partners in our fisheries facilities in the Northwest and Northeast United States.

In addition, NOAA regularly collaborates with the private sector and academia to test new technologies for its operational environment through its networks of testbeds and proving grounds.

NOAA Testbeds

NOAA's testbeds and proving grounds facilitate the transition of promising research capabilities to operational implementation through development testing in testbeds, and pre-deployment testing and operational readiness/suitability evaluation in operational proving grounds. NOAA maintains 12 individual testbeds related to weather, climate, and severe weather activities. The annual Federal Funding Opportunities for these testbeds attract technologies from academia, the private sector, and NOAA labs. Testbeds also provide essential funding for bridging the gap between R&D and implementation into operational use.

NOAA Sterling Virginia Field Support Center

The Sterling Field Support Center (SFSC) provides operational support to field personnel and the private sector through a combination of sensor testing, analysis and contact center support. The staff of the SFSC comprises a diverse mix of meteorologists, electrical technicians, and engineers. Collectively, SFSC personnel have many years of practical experience working with National Weather Service sensors and related equipment. The SFSC is responsible for the research, testing, and development of a variety of meteorological systems. These systems include the Automated Surface Observing System (ASOS), Radiosonde Replacement System (RRS), and Cooperative Observer Program (COOP).

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

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.[75]

[75] https://ioos.noaa.gov/

Launch of the Ocean Acidification Information Exchange

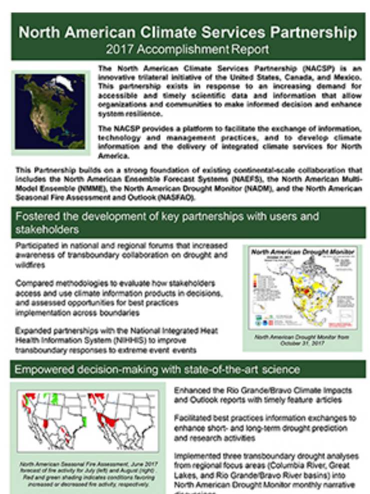
The Ocean Acidification Information Exchange is a new online portal launched by the Interagency Working Group on Ocean Acidification and the Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS), with funding from NOAA and BOEM, in response to the Federal Ocean Acidification Research and Monitoring Act of 2009. The Ocean Acidification Information Exchange is different from most websites. Instead of providing one-way transfers of information to website readers, the Information Exchange encourages interaction among its users. The website's more than 650 members address ocean and coastal acidification through collaboration and information sharing, building a well-informed community that is the foundation for successful adaptation to this environmental challenge. For example, a post about a new observing system in Tampa Bay kick-started a collaboration between a chemist and biologist on laboratory experiments on Florida stone crab, one of the state's most important commercial fisheries. Anyone working on ocean or coastal acidification is welcome to join the site, including scientists, citizen scientists, aquaculturists, fishing industry, technology developers, educators, NGO employees, resource managers, policy makers, concerned citizens, and data managers.[76]

Climate Program Office

The Climate Program Office 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. The Office supports research that is conducted in regions across the United States, at national and international scales, and globally.[77]

North American Climate Services Partnership: 2017 Accomplishments Report

An innovative trilateral partnership between the United States, Mexico, and Canada was established to respond to an increasing demand for accessible and timely scientific data and information in order to make informed decisions and build resilience in our communities. Building from a strong foundation of existing continental-scale collaboration, the NACSP provides a platform for improving the development of products and services through international collaboration. Activities in the NACSP include enhancing prediction and modeling capabilities, strengthening products tailored for specific sectors, and responding to user needs in key regional settings.



North American Climate Services Partnership
2017 Accomplishment Report

The North American Climate Services Partnership (NACSP) is an innovative trilateral initiative of the United States, Canada, and Mexico. This partnership exists in response to an increasing demand for accessible and timely scientific data and information that allow organizations and communities to make informed decision and enhance system resilience.

The NACSP provides a platform to facilitate the exchange of information, technology and management practices, and to develop climate information and the delivery of integrated climate services for North America.

This Partnership builds on a strong foundation of existing continental-scale collaboration that includes the North American Ensemble Forecast Systems (NAEFS), the North American Multi-Model Ensemble (NMME), the North American Drought Monitor (NADM), and the North American Seasonal Fire Assessment and Outlook (NASFAO).

Fostered the development of key partnerships with users and stakeholders

Participated in national and regional forums that increased awareness of transboundary collaboration on drought and wildfires

Compared methodologies to evaluate how stakeholders access and use climate information products in decisions, and assessed opportunities for best practices implementation across boundaries

Expanded partnerships with the National Integrated Heat Health Information System (NIHHIS) to improve transboundary responses to extreme event events

North American Drought Monitor from October 31, 2017

Empowered decision-making with state-of-the-art science

North American Seasonal Fire Assessment, June 2017 forecast of fire activity for July (left) and August (right). Red and green shading indicates conditions favoring increased or decreased fire activity, respectively.

Enhanced the Rio Grande/Bravo Climate Impacts and Outlook reports with timely feature articles

Facilitated best practices information exchanges to enhance short- and long-term drought prediction and research activities

Implemented three transboundary drought analyses from regional focus areas (Columbia River, Great Lakes, and Rio Grande/Bravo River basins) into North American Drought Monitor monthly narrative discussions

[76] https://www.oainfoexchange.org/index.html
[77] https://climate.noaa.gov/

A two-page summary gives an overview of the NACSP and highlights key accomplishments during 2017, as well as key goals for collaboration in 2018.[78]

Awards and Recognition

NOAA received one award in FY 2018 through the Federal Laboratory Consortium's regional network, in addition to the following award for the Earth System Research Lab in Colorado.

Wind Forecast Improvement Project 2 Wins FLC Far West Outstanding Partnership Award

The Wind Forecast Improvement Project-2 (WFIP2) team, led by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Energy (DOE), successfully leveraged resources, instruments, and researchers across all NOAA Earth System Research Laboratory (ESRL) Divisions, the NOAA Air Resources Laboratory Field Research Division, other federal agencies, private companies, and universities to achieve up to 15-25% improvement in wind forecasts produced by weather models, depending on weather conditions. The public and private partnership forged by WFIP2 resulted in foundational improvements to NOAA weather models used by the energy industry to cost-effectively and reliably integrate higher levels of renewable energy.

Scientists with the WFIP2 field campaign deployed more than 100 instruments in the Columbia River Gorge and Basin from October 2015 to March 2017 to help pinpoint forecast errors in areas of complex terrain, such as mountains, canyons, and coastlines (see Figures 1 and 2). The WFIP2 model development team used these observations to fine-tune the model in ways that improved forecasts of winds at the height of the wind turbines. These modifications were transferred into version 3 of NOAA's High-Resolution Rapid Refresh (HRRR) regional weather model that became operational at the NOAA National Weather Service (NWS) in July 2018. These models support decision-making in the NWS and in other industries including energy and renewable energy, aviation, and surface transportation to make operations more safe and efficient.

[78] https://cpo.noaa.gov/News/News-Article/ArtMID/6226/ArticleID/1651/North-American-Climate-Services-artnership-2017-Accomplishments-Report

Instruments near the Wasco, Oregon site. (Front to back, left to right): Windcube lidar (deployed by CU/ATOC); ceilometer (deployed by University of Notre Dame); 915-Mhz wind profiling radar, trailer, and 10-meter tower with additional instruments (deployed by NOAA ESRL PSD).
Photo courtesy of Justin Sharp.

Specific to the energy industry, improved forecasts facilitate optimized use of different energy sources across a range of time scales. For example, if power grid operators know that they can rely on a certain amount of energy being produced by wind plants in the next day, they can decide to reduce generation from conventional power plants, thereby saving money and minimize related air pollution. Feedback from private-sector stakeholders is included below to show the value of these improvements.

> "Improvements to weather-prediction models that produce higher-resolution forecasts with greater frequency are helping Xcel Energy and the electric power industry cost effectively and reliably integrate higher levels of renewable generation. We can also use more accurate weather forecasts to reduce costs and improve reliability by proactively sending crews to respond to storm damage before it occurs."
> – Drake Bartlett of Xcel Energy.

NOAA Technology Transfer Awards
NOAA selected two projects to receive the Agency's Technology Transfer Award in 2018. These projects exemplified the highest standard for developing a new technology in cooperation with private sector partners in the service of NOAA's mission.

Kirk Liang - For development of an innovative suite of satellite command & telemetry processing modules for use by commercial, federal, and international agencies.

Vera Trainer, Nicolaus Adams, Brian Bill, Brendan Sylvander - For implementation of an effective sampling and mapping program for early warning of harmful algal blooms in 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 research and development
- Technical publications, sample data sets, and software tools available on the ITS website and GitHub
- 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 cooperative research agreements 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 2018, 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 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 have been achieved through CRADAs. 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). PSCR is 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 more than two decades on behalf of sponsors at the Department of Homeland Security (DHS) and the Department of Justice (DOJ). Since the First Responder Network Authority (FirstNet) became operational, ITS's public safety research scope expanded to supporting FirstNet's work through development of the standards for, and RDT&E of, equipment that may be used to both build and communicate over a nationwide broadband wireless network dedicated to public safety agencies.

The vast majority of CRADAs ITS entered into in the past seven years were the Public Safety 700 MHz Broadband Demonstration Agreements. These agreements allowed vendors, including equipment manufacturers and wireless carriers, who intend to supply 700 MHz LTE equipment and service to public safety organizations to operate various elements of an LTE network in the PSCR testbed 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. At the beginning of FY 2018, 55 CRADAs were in place under this program. The CRADAs protected the intellectual property of vendors and manufacturers, encouraging participation in testing that simulates real multi-vendor environments in the field. The Broadband II Consortium expired in late FY 2018 and has not been renewed.

Table 33 – Collaborative Relationships for Research & Development

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Number of active CRADAs	60	54	62	60	68
Number of newly executed CRADAs	11	53	12	8	13
Active CRADAs with small businesses involvement	12	15	17	17	18
Number of small businesses involved in active CRADAs	12	15	17	17	18

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. Technical publications are released after going through an internal peer review process managed by the ITS Editorial Review Board (ERB). In FY 2018, 45% of manuscripts released through the ERB process were published in scientific journals or conference proceedings and 55% 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 website 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 PDF downloads of publications rather than pageviews of the bibliographic summaries. In FY 2018, ITS technical publications were downloaded 5,513 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. 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 2018 ITS had 12 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. ITS is exploring 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 website 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. The C++ implementation of the Extended Hata (eHata) Urban Propagation Model was used 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 website. 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, super wideband, and fullband speech systems as well as narrowband. ABC-MRT and ABC-MRT16 tools and MRT databases are available for download through the ITS website, as well as a variety of other sample clips for audio quality testing.

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 ANSI, to estimate the quality of video impairments, providing users an inexpensive alternative to viewer panels for testing new transmission technologies. In FY 2018, 332 users downloaded the VQM software. The Web-Enabled Subjective Test (WEST) software package facilitates gathering subjective testing data from multiple locations and multiple portable or computing devices. This software is also freely available for download from the ITS website and from a public GitHub repository from which 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 website 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 free of privacy concerns, and 4K sports content uploaded by Sky Broadcasting in the UK. More than 2,460 different video clips were downloaded from the library in FY 2018. 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, and collection began in FY 2011. This number experienced a significant spike in FY 2013, probably due to the publication of a number of journal articles describing CDVL. Annual rates of between 150 and 200 users are consistent with the target audience for this library.

Table 34 – Other Performance Measures Deemed Important by the Agency

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Technical Publications Released	18	22	4	10	11
Technical Publications Downloaded	7,707	9,048	8,748	6,214	5,513
Consumer Digital Video Library Users Downloading	184	212	169	202	260
Video Quality Metric Software Users Downloading	685	507	496	372	332
Propagation Modeling Software Downloads	717	798	781	1,160	1,325
Other Software/Data Downloads	489	493	591	955	661

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-R, a treaty organization, are based on research conducted at ITS. Also, key national quality-of-service standards developed under the American National Standards Institute (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 2018, ITS staff held 25 positions on 24 different working groups in six standards bodies, including 10 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 contributed three voting members to the IEEE Standards Association Wireless Regional Area Networks Working Group Standard for Spectrum Characterization and Occupancy Sensing Project. ITS also continued its technical leadership and contributions to communications standards for public safety, particularly for first responders, through participation in 3GPP.

Downstream Outcomes from ITS Technology Transfer Activities

Telecommunication Standards

ITU-R Study Group 3 held Working Party meetings in Montreal in FY 2018. ITS provided technical leadership and guidance in the creation and approval of 21 consensus U.S. contributions, with three of them originating from ITS employees. The broad range of U.S. contributions included improvements to modeling links (such as earth-space paths), modeling phenomena (such as atmospheric absorption and hydrometeors), and clarification of statistical mathematical concepts.

Intense participation by ITS staff in the 3GPP standards development process on behalf of FirstNet resulted in Proximity Services and Group Communications requirements being included in 3GPP Release 12 and Mission Critical Push to Talk requirements being included in 3GPP Release 13, which was frozen in mid FY 2016. In FY 2017, ITS participation in 3GPP continued to focus on two Commerce priorities: advocating on behalf of FirstNet to help ensure that 3GPP LTE and next generation standards meet public safety's communications requirements; and advancing U.S. commercial and economic interests by providing technical input to promote strong unbiased standards that support fair competition in next generation/5G cellular technologies. In FY 2018, ITS continued its participation in 3GPP with the focus shifting to 5G standards development and support of the U.S. Department of Transportation as it evaluates the efficacy of a new vehicle-to-vehicle communications technology being proposed for vehicular safety messaging based on ITS's earlier work in Proximity Services for public safety.

Table Mountain Research

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

- In FY 2018, capabilities were added to the Table Mountain test facilities in support of NOAA's Radio Frequency Interference Monitoring System (RFIMS) program. ITS helped NOAA develop the technical specifications for a Request for Proposals to develop, produce, install, and maintain a radio frequency interference monitoring system to mitigate the risk of potential interference by commercial wireless carriers that are slated to begin sharing the spectrum with NOAA satellite operations in 2020. A 2.4-meter Earth Station satellite dish capable of capturing Polar Operational Environmental Satellite (POES) satellite imagery was used to test the degree of interference that could be tolerated, and a robust command and control system was built to command, verify, and log interference transmitted to RFIMS candidate solutions under test. A 6.5 m Geostationary Operational Environmental Satellite (GOES) receiver dish is being procured to support future Meteorological Satellite Testbed activities. ITS built a Spectrum Survey System (SSS) to prototype near-real time monitoring, data collecting, and reporting methods that might be used by RFIMS. This system can also be used to analyze potential sharing concerns in other frequency bands.

- In FY 2018, several companies used the Table Mountain site under a CRADA to safely test and demonstrate LADAR technologies under development in atmospheric conditions and at distances relevant to potential applications, to fully test the functionality of new antenna designs during product development, and to safely and accurately test an Adaptive Tactical Laser System (ATLAS) compensated beacon adaptive optics (CBAO) system under development. Applications for these technologies include detection and tracking of wind shear and wake vortices, remote wind measurements for the offshore wind energy industry, mission-critical communications, electronic warfare, direction finding/geolocation, and sensing of hazardous liquids and gases.

- For the past 11 years, the University of Colorado's Research and Engineering Center for Unmanned Vehicles safely and accurately tested collective and autonomous sensing and communication technologies for small unmanned aircraft used for atmospheric science applications such as the study of tornadogenesis.

Video Quality Research

Both CDVL and the VQM tools are used by industry and academia 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 currently 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 in 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[79]

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.

---

[79] 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[80]

Astronomy

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

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

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

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

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

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

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

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

---

[80] Sources: The Patent Board™, and National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR) database system, http://webcaspar.nsf.gov. Science and Engineering Indicators 2012. Used with permission.