Annual Report on Technology Transfer: Approach and Plans, Fiscal Year 2017 Activities and Achievements

U.S. Department of Commerce

Report prepared by:

National Institute of Standards and Technology
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Pursuant to the
Technology Transfer and Commercialization Act of 2000 (Pub. L. 106-404)

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FOREWORD

This report summarizes technology transfer activities and achievements of the Department of Commerce's (DOC) federal laboratories for fiscal year (FY) 2017. 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 in response to the statutory requirement for an annual "agency report on utilization" (15 U.S.C. Section 3710(f)) established under Section 10 of the Technology Transfer Commercialization Act of 2000 (Pub. L. 106-404). All federal agencies that operate or direct one or more federal laboratories or conduct other activities under Sections 207 and 209 of Title 35, United States Code, 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 2013 through FY 2017.

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.

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CHAPTER 1
Department of Commerce Overview

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

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

In addition to the technology transfer efforts of DOC laboratories, DOC is responsible for coordinating technology transfer activities across federal agencies. DOC coordinates the Interagency Workgroup for Technology Transfer (IAWGTT) through the facilitation by NIST of interagency discussion on policy, new approaches to technology transfer, and lessons learned from agency transfer programs.[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/; and
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 2013 – FY 2017

This annual report provides comprehensive statistics on the 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 (Pub. L. 106-404, codified at 15 U.S.C. Section 3710(f)) requires each federal agency, which operates or directs one or more federal laboratories, or conducts activities under 35 U.S.C. Sections 207 and 209, to report annually to the Office of Management and Budget (OMB) on the agency's technology transfer activities performed. 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 2017 has been adjusted, where necessary, to reflect the most accurate estimates for each year reported.

Invention Disclosures and Patenting

In FY 2017, DOC researchers disclosed 43 new inventions. Of these, 40 invention disclosures were from NIST researchers and three were from NOAA researchers. There were 46 patent applications filed (43 for NIST and 3 for NOAA) and 34 patents issued (31 for NIST and three for NOAA).[3]

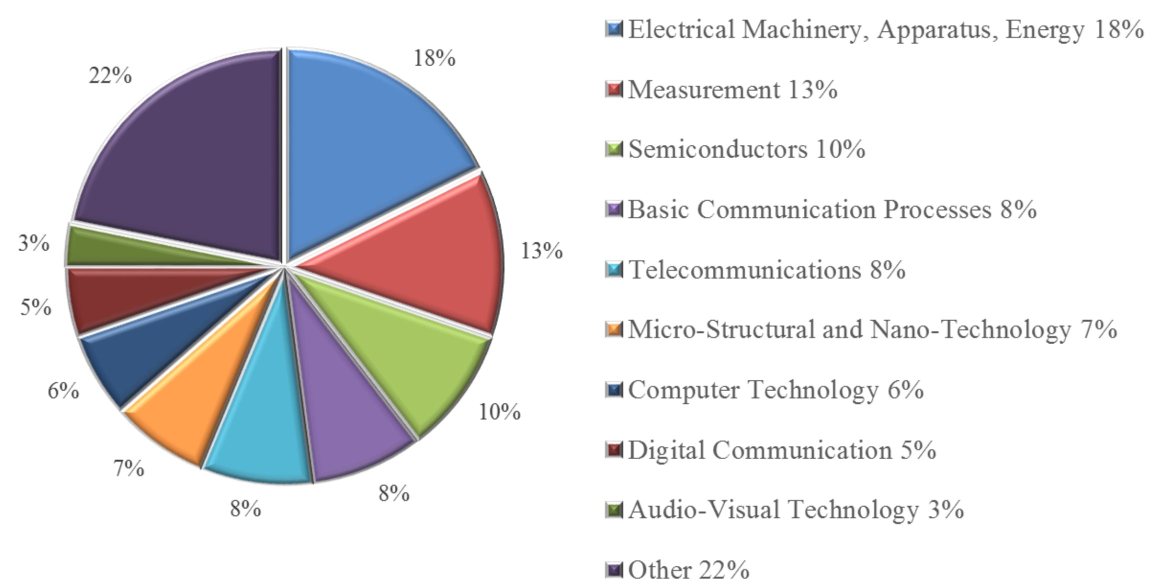
Table 1 – Invention Disclosure and Patenting

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Invention Disclosures					
NIST	33	41	46	46	40
NOAA	8	6	15	18	3
ITS	0	0	0	0	0
Department Total	41	47	61	64	43
Patent Applications Filed					
NIST	23	21	26	21	43
NOAA	3	4	6	4	3
ITS	0	0	0	0	0
Department Total	26	25	32	25	46
Patents Issued					
NIST	20	19	19	15	31
NOAA	1	0	1	1	3
ITS	0	0	0	0	0
Department Total	21	19	20	16	34

[3] Note that the time required for a patent to be granted may take two years or more. Patents issued in FY 2017 were filed in prior years.

In FY 2016 (the most recent year data is available), the top three technical areas covered by NIST patents were Electrical Machinery, Apparatus, Energy (18%), Measurement (13%), and Semiconductors (10%).[4]

Figure 1 – Percent of USPTO Patents Granted to DOC, by Technology Area – FY 2016[5]



Licensing

In FY 2017, DOC reported 68 active patent licenses, the largest number in the last five fiscal years. Of these, NIST had 61 active patent licenses and NOAA had seven active patent licenses.

Table 2 – Profile of Active Licenses

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Active Patent Licenses[(a)]					
NIST	33	33	40	50	61
NOAA	5	5	6	7	7
ITS	0	0	0	0	0
Department Total	38	38	46	57	68

(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 April 2017. Used with permission.

Of the 68 active patent licenses in FY 2017, 35 were income-bearing licenses, which is also the largest number in the last five fiscal years. Of these income-bearing licenses, 19 were exclusive licenses, 14 were non-exclusive, one was an assignment, and 1 was a custody transfer agreement.

Table 3 – Characteristics of Income-Bearing Licenses

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Income-Bearing Licenses					
NIST	21	21	25	26	28
NOAA	5	5	4	5	7
ITS	0	0	0	0	0
Department Total	26	26	29	31	35
Patent Licenses					
NIST	21	21	25	26	28
NOAA	5	5	4	7	7
ITS	0	0	0	0	0
Department Total	26	26	29	33	35
License Types					
Exclusive					
NIST	13	14	15	16	15
NOAA	0	0	1	4	4
ITS	0	0	0	0	0
Department Total	13	14	16	20	19
Partially Exclusive					
Department Total	0	0	0	0	0
Non-Exclusive					
NIST	5	5	8	8	11
NOAA	5	5	3	3	3
ITS	0	0	0	0	0
Department Total	10	10	11	11	14

In FY 2017, DOC's income-bearing licenses provided $140,871 in income. Of this amount, $75,061 came from NIST licenses and $65,810 came from NOAA licenses.

Table 4 – Income from Licensing

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Licensing Income					
NIST	$102,532	$150,995	$124,823	$137,662	$75,061
NOAA	$48,798	$69,151	$39,633	$11,000	$65,810
ITS	$0	$0	$0	$0	$0
Department Total	$151,330	$220,146	$164,456	$148,662	$140,871

Collaborative Relationships for Research and Development (CRADAs)
In FY 2017, there were 2,932 CRADAs involving DOC researchers. There were 413 traditional CRADAs[6] and 2,519 non-traditional CRADAs.[7] Of the 413 traditional CRADAs, NIST was involved in 370, NOAA was involved in 36, and ITS was involved in 52. These traditional CRADAs included 52 joint agreements that dealt with Public Safety 700 MHz Broadband Demonstrations and involved both NIST and ITS.

Table 5 – Collaborative Relationships for Research and Development

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
CRADAs					
Department Total	2,437	2,307	2,752	2,940	2,932
Traditional CRADAs					
NIST	179	206	329	294	370
NOAA	15	19	28	33	36
ITS	91	87	136	62	59
Department Total[(a)]	206	233	365	335	413
Joint CRADA Agreements (NIST and ITS)	79	79	128	54	52
Non-Traditional CRADAs					
NIST	2,231	2,074	2,387	2,605	2,519
NOAA	0	0	0	0	0
ITS	0	0	0	0	0
Department Total	2,231	2,074	2,387	2,605	2,519

(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 2013. 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 2014, we divide the number of patents issued in FY 2014 by the number of patents issued in the base year (FY 2013) and then multiply by 100. Using data from the table on page 3 of this report, the index value for patents issued in FY 2014 is 90 (rounded).

$$Index\ Value_{FY2013} = \frac{19}{21}\ x\ 100 = 90$$

Because the index value of 90 is less than 100, we can interpret this as a 10% decrease in the number of patents issued between FY 2013 and FY 2014. In FY 2015, the index value for patents issued is 95 which we can interpret as a 5% decrease between FY 2013 and FY 2015.

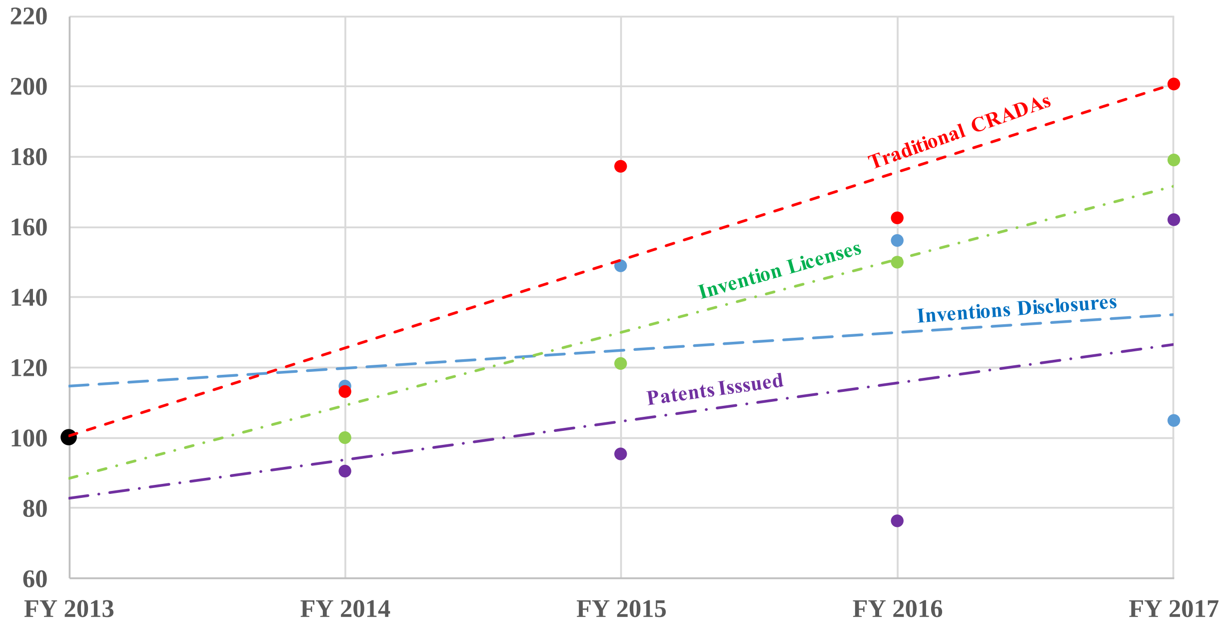
We calculate index values for key metrics (e.g., invention disclosures, patents issued, invention licenses, and CRADAs) and plot the values in the chart below. To show the trend for a given metric, a straight line is plotted in the middle of the plotted values for that metric.[8] In the chart below, 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 despite the decline in invention disclosures in FY 2017, the trend has been increasing over the FY 2013 to

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

FY 2017 period. There has been a more significant increase in the trends for invention licenses and traditional CRADAs and a decreasing trend for patents issued.

Figure 2 – Trends in DOC's Technology Transfer Activities (FY 2013 – FY 2017)



Scientific and Technical Publications

Technology transfer mechanisms include more than just counting CRADAs, patents, and licenses.[9] Scientific and technical publications also can lead to technology transfer. In FY 2017, NIST, NOAA, and ITS researchers published 3,121 scientific and technical papers in peer-reviewed journals.

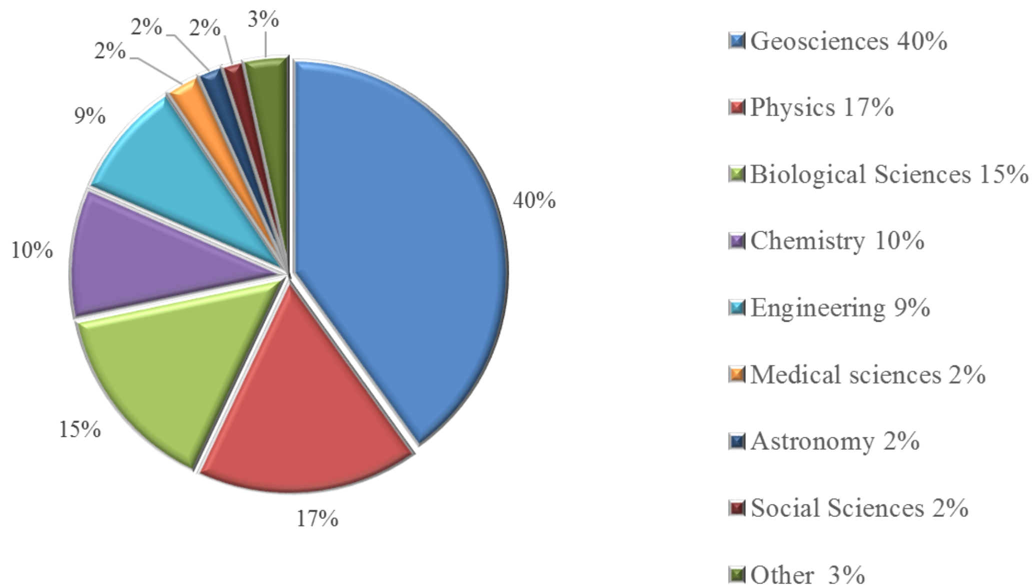
Table 6 – Scientific and Technical Publications

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Technical Publications					
NIST	1,393	1,359	1,323	1,355	1,433
NOAA	1,781	1,759	1,860	1,697	1,678
ITS	24	18	22	4	10
Department Total	3,198	3,136	3,205	3,056	3,121

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

In 2016 (the most recent year for which data is available), the most numerous technology areas covered by DOC publications are Geosciences (40%), followed by Physics (17%) and Biological Sciences (15%), Chemistry (10%), and Engineering (9%).[10]

Figure 3 – Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2016[11]

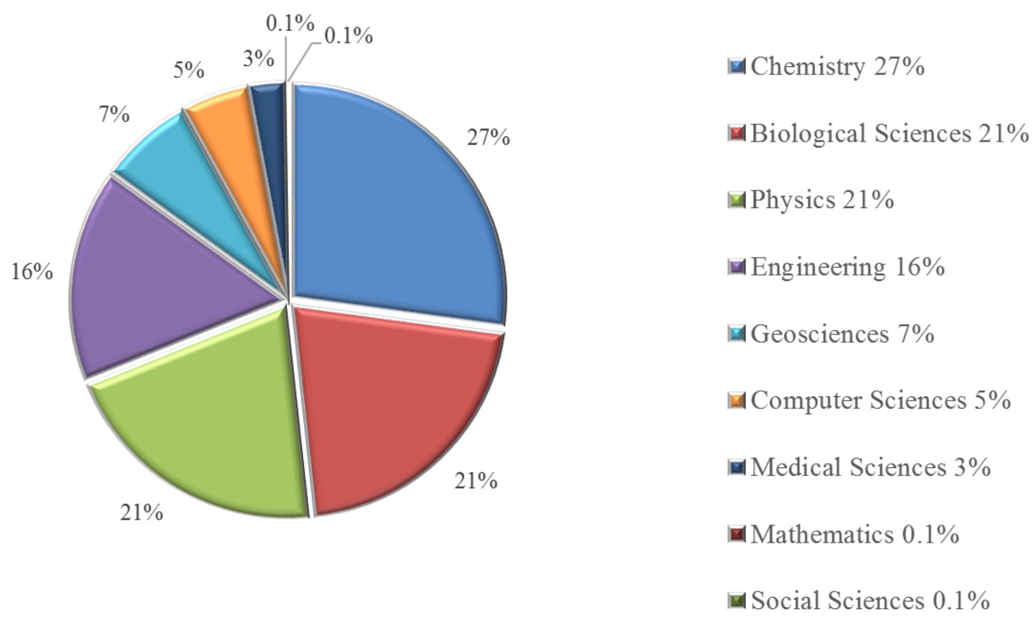


[10] Science and engineering fields are identified in Appendix B.

[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 fields using the CHI classification. Articles are classified by the year they entered the database, rather than the year of publication, and are assigned to a federal agency 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 2016 cite 785 publications authored by DOC researchers. As shown in Figure 4, the largest technology areas citing DOC publications include Chemistry (27%), followed by Biological Sciences (21%), Physics (21%), Engineering (16%), and Geosciences (7%).[12]

Figure 4 – Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2016[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 July 2017 and PatentsView accessed in April 2017. 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, the adoption of a technology into the private sector through a business or other organization.

NIST has designed its technology transfer program to improve the transfer of its technology and work products directly and through collaborations. The following summarizes different

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

technology transfer mechanisms NIST uses to promote innovation and to disseminate broadly the 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. The Patent Review Committee at NIST evaluates each reported invention's potential to promote U.S. innovation and industrial competitiveness. NIST will generally seek patent protection when a patent: (1) would enhance the potential for an invention's commercialization; (2) would have a positive impact on a new field of science or technology and/or the visibility and vitality of NIST; (3) would further the goals of a CRADA or other agreement; (4) would further U.S. manufacturing; or (5) would likely lead to a commercialization license.

Chapter 1 presented summary information on patenting and licensing; additional details on licensing are included below.

NIST research has 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 2017, there were 61 active NIST patent licenses of which 19 of these licenses were issued in FY 2017. Of these 61 active licenses, 19 licenses were issued to small companies (i.e., companies with less than 500 employees).

Table 7 – Profile of NIST's Active Licenses

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Number of Active Licenses[a]	33	33	40	50	61
New Licenses Executed	7	7	11	12	19
Total Invention Licenses Active	33	33	40	50	61
New Invention Licenses Executed	7	7	11	12	19
Total Patent Licenses Active[b]	33	33	40	50	61
New Patent Licenses Executed	7	7	11	12	19
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	7	4	14	19

(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 2017, the average time to negotiate a patent license was 4 months. The minimum time to negotiate a license was 2 months and the maximum time was 6 months.

Table 8 – Licensing Management

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
License Negotiation Time (Patent Licenses) [(a)(b)]					
Average (months)	6.0	4.0	7.0	5.0	4.0
Minimum (months)	2.3	0.2	0.2	1.0	2.0
Maximum (months)	13.5	17.3	38.7	14.0	6.0
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.

Income from licensing 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).

Table 9 – Characteristics of Licenses Bearing Income

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Income Bearing Licenses	21	21	25	26	28
Exclusive	13	14	15	16	15
Partially Exclusive	0	0	0	0	0
Non-Exclusive	5	5	8	8	11
Total Other Income Bearing IP Licenses[(a)]					
Assignment	1	1	1	1	1
Custody Transfer	2	1	1	1	1
Total Income Bearing Invention Licenses	21	21	25	26	28
Exclusive	13	14	15	16	15
Partially Exclusive	0	0	0	0	0
Non-Exclusive	5	5	8	8	11
Total Other Income Bearing IP Licenses					
Assignment	1	1	1	1	1
Custody Transfer	2	1	1	1	1
Total Royalty Bearing Licenses	21	21	25	26	28
Total Royalty Bearing Invention Licenses	21	21	25	26	28
Royalty Bearing Patent Licenses	21	21	25	26	28
Other Royalty Bearing IP Licenses	0	0	0	0	0

(a) Includes licenses to pending patent applications.

In FY 2017, NIST received $75,061 from all active licenses. The median amount received was $2,679. The minimum amount received was $320 and maximum was $40,000.

Table 10 – Income from Licenses

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Income, All Active Licenses[(a)]	$102,532	$150,995	$124,823	$137,662	$75,061
Invention Licenses (Patent Licenses)[(b)]	$102,532	$150,995	$124,823	$137,662	$75,061
Other IP Licenses, Total Active	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)[(c)]	$102,532	$150,995	$124,823	$137,662	$75,061
Median ERI	$10,000	$6,250	$1,600	$5,295	$2,679
Minimum ERI	$640	$640	$640	$62	$320
Maximum ERI	$58,642	$74,575	$62,833	$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)	$102,532	$150,995	$124,823	$137,662	$75,061
Median ERI	$10,000	$6,250	$1,600	$5,296	$2,679
Minimum ERI	$640	$640	$640	$62	$320
Maximum ERI	$58,642	$74,575	$62,833	$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 2017, 46% ($34,673) was distributed to the NIST inventor and the remaining 54% ($40,388) was retained by the NIST inventor's Operating Unit.

Table 11 – Disposition of Invention License Income

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Income Received[(a)]	$102,532	$150,995	$124,823	$137,662	$75,061
Invention Licenses (Patent Licenses)[(b)]					
Licensing Income to Inventor(s)	$38,732	$54,602	$44,936	$45,148	$34,673
	38%	36%	36%	33%	46%
Licensing Income to NIST	$63,799	$96,393	$79,887	$92,514	$40,388
	62%	64%	64%	67%	54%

(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 to 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 (Pub. L. 99-502).[15]

In FY 2017, NIST was involved in a total of 2,899 active CRADAs; 370 were traditional CRADAs[16] and 2,519 were non-traditional CRADAs.[17] There were 2,420 new NIST CRADAs. Of these, 113 were traditional and 2,307 were non-traditional.

Table 12 – NIST Collaborative Relationships for Research and Development

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NIST CRADAs					
Total Active CRADAs	2,410	2,280	2,716	2,958	2,889
New CRADAs Executed	2,252	2,092	2,481	2,587	2,420
Total Active Traditional CRADAs	179	206	329	294	370
New Traditional CRADAs Executed	48	50	143	89	113
Total Active Non-Traditional CRADAs	2,231	2,075	2,389	2,664	2,519
New Non-Traditional CRADAs Executed	2,204	2,043	2,338	2,498	2,307

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 2017, NIST staff authored 1,433 publications in peer-reviewed journals,[18] including 406 papers (28%) published in 110 "top tier" journals where "top tier" includes any journal with a Thomson Reuters' Journal Impact Factor (IF) that falls within the top 10th percentile in its *Web*

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

[18] http://nvl.nist.gov

of Science Subject Category.[19] NIST researchers collaborated and co-authored with researchers from around the world. NIST researchers co-authored papers with 5,464 unique non-NIST authors from 1,334 unique institutions in 67 countries.[20]

Table 13 – NIST Publications in Top-Tier Journals vs. Total NIST Publications

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Number of NIST Papers	1,393	1,359	1,323	1,355	1,433
Number of NIST Papers in Top-Tier Journals	436	444	384	329	406
Percentage of NIST Papers in Top-Tier Journals	31%	33%	29%	24%	28%
Number of Unique Non-NIST Co-Authors	3,920	4,086	4,585	5,116	5,464
Number of Unique Institutions	922	965	1,003	1,037	1,334
Number of Countries	53	62	63	46	67

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]

During FY 2017, 440 members of NIST staff were involved with more than 119 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. NIST reports its activities in standards development to the Office of Management and Budget and to Congress, as required by the National Technology Transfer and Advancement Act of 1995 (Pub. L. 104-113).[23]

[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.
[23] http://gsi.nist.gov/global/index.cfm/L1-1

Table 14 – Participation in Documentary Standards

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Number of Participating NIST Staff	400	464	469	445	440
Number of Standard Organizations with NIST Participants	100	121	165	120	119

The NIST Standards Coordination Office (SCO) maintains the Standards Committee Participation Database for employees to report their participation, including leadership positions, within standards organizations. SCO has been proactively expanding the database to collect information on 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 critically important in engineering structures, optimizing chemical processes, and other industrial applications. Standard Reference data are extracted from the scientific and technical literature, or developed from measurements conducted at NIST laboratories, and are critically evaluated for accuracy and reliability. NIST currently maintains 102 SRD databases that cover many areas of science, including analytical chemistry, atomic and molecular physics, biotechnology, and materials sciences.[24]

In FY 2017, NIST SRD Program distributed 2,229 e-commerce orders, 7,995 units sold via distributor, 154 active distributor agreements, 36 active site licenses, 40 active internet subscriptions, 328 units shipped to the user, and 3,119 products downloaded from the NIST website (1,225 free downloads, 1,894 paid downloads).

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

Table 15 – Standard Reference Data Program

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Standard Reference Data					
Products available (databases)	120	111	111	102	97
E-Commerce Orders	2,658	3,111	2,596	2,689	2,229
Units Sold via Distributor[(a)]	5,495	5,142	9,807	10,573	7,995
Active Distributor Agreements	62	101	123	124	154
Active Site Licenses	30	58	57	59	36
Active Internet Subscriptions	50	42	38	49	40
Units Shipped via UPS	430	595	418	311	328
Products Downloaded from the NIST Website	2,055	3,435	5,751	6,208	3,119
Free Downloads	1,399	1,352	3,615	4,083	1,225
Paid Downloads	2,055	2,083	2,136	2,125	1,894

(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.[25] In FY 2017, NIST made available 1,182 SRMs and from these, sold 32,348 units.

Table 16 – Standard Reference Materials

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Standard Reference Materials					
Units Available	1,299	1,281	1,240	1,194	1,182
Units Sold	32,267	32,636	33,490	31,938	32,348

User Facilities – Research Participants

NIST operates two unique and valuable laboratory facilities – the Center for Nanoscale Science and Technology (CNST) and the NIST Center for Neutron Research (NCNR) – that support U.S. industry, academic institutions, and other NIST and government laboratories. These facilities allow NIST customers to tap directly into NIST measurement expertise to solve their problems

The CNST supports the development of nanotechnology from discovery to production. It operates a national shared-use nanofabrication and measurement facility (the NanoFab), complemented by a multidisciplinary research staff creating next-generation tools for advancing

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

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 2017, there were 3,103 research participants at CNST and 2,769 at NCNR.

Table 17 – NIST Research Participants[27]

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NIST Research Participants					
CNST	1,885	2,147	2,434	2,856	3,103
NCNR	2,148	2,271	2,436	2,536	2,769

Postdoctoral Researchers

Technology transfer not only involves 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] For the purpose of this report, NIST uses the NSF's description of a postdoctoral researcher[29] as one 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 2017, there were 159 NIST postdocs. Of these, 87 were located on the NIST campus in Gaithersburg, Maryland; 47 were located in Boulder, Colorado; and the remainder were located at six other NIST locations.

Table 18 – Postdoctoral Researchers

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NIST Postdocs, Total (NCR)	140	172	174	167	159
Gaithersburg campus	88	115	113	104	87
Boulder campus	32	35	49	43	47
Joint Institute for Laboratory Astrophysics [a]	11	9	5	9	12
Joint Quantum Institute [b]	4	3	2	2	3
Hollings Marine Laboratory [c]	2	1	2	2	2
Institute for Bioscience and Biotechnology Research [d]	1	4	3	3	3
Brookhaven National Laboratory[e]	0	0	0	0	2
Joint Initiative for Metrology in Biology[f]	2	5	5	4	3

[26] https://www.nist.gov/labs-major-programs/user-facilities
[27] FY 2017 estimates are preliminary estimates.
[28] http://www.nist.gov/iaao/postdoc.cfm
[29] http://www.nsf.gov/statistics/seind12

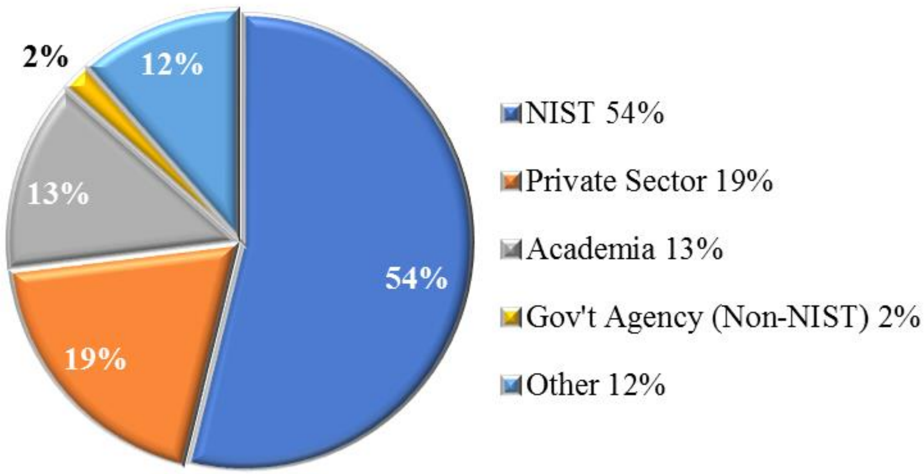
(a) Joint Institute for Laboratory Astrophysics (JILA) was founded in 1962 as a joint institute of CU-Boulder and NIST. JILA is located at the base of the Rocky Mountains on the CU-Boulder campus in the Duane Physics complex. http://jila.colorado.edu/
(b) The Joint Quantum Institute (JQI) was founded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

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 has begun tracking postdocs once they depart NIST. NIST surveyed 52 researchers who were postdocs with the NIST National Research Council (NRC) program in FY 2017. More than half of these postdocs (54%) continued research careers with NIST,[30] 19% moved to the private sector, 13% moved to academia, 2% moved to other government agencies, and others became 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.

[30] Researchers who left their postdoc positions and stayed at NIST (54%) became career conditional / term employees (42%) or became non-career conditional or term employees, i.e. contractors or guest researchers (12%).

Figure 5 – Tracking Researchers after Initial Postdoc Tenure at NIST (FY 2017)



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 these skills, knowledge, and a desire to employ them in innovative ways to new careers and employers. Among these skills is the knowledge of how to collaborate with federal laboratories and what federal resources are available to assist companies in creating and developing new and improved technologies.

In FY 2017, there were 3,181 guest scientists and engineers working at NIST.

Table 19 – Guest Researchers

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NIST Guest Researchers					
Number of Guest Scientists and Engineers	2,963	2,981	3,125	3,273	3,181

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 2017, NVLAP accredited 723 laboratories.

[31] http://www.nist.gov/tpo/collaborations/guestresearchers.cfm
[32] http://www.nist.gov/nvlap/

Table 20 – Accreditation Services

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NVLAP Accreditations					
Number of NVLAP Accreditations	743	774	726	735	723

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 2017, there were 13,802 calibration tests performed by NIST.

Table 21 – Calibration Services

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Calibrations					
Number of Calibration Tests Performed	14,974	15,401	13,906	12,971	13,802

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]

[33] http://www.nist.gov/calibrations/index.cfm
[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 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 post-doctoral researchers, the opportunity to gain hands-on research experience working with NIST researchers. https://www.nist.gov/iaao/nist-professional-research-experience-program-prep

In FY 2017, there were 212 students enrolled in the SURF program, 70 students enrolled in the SHIP program, 107 students enrolled in the Pathways program, 21 students enrolled in the NIST Summer Institute for Middle School Science Teachers, and 36 students enrolled in the PREP program.

Table 22 – STEM Education

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
SURF	205	203	206	213	212
SHIP	55	60	48	70	70
Pathways Program	98	78	97	85	107
Summer Institute for Middle School Teachers	n.a.	22	22	20	21
PREP	n.a.	134	164	204	36

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 2017, the NIST Conference Program arranged 108 conferences that attracted 10,588 researchers to NIST's facilities in Gaithersburg, Maryland and Boulder, Colorado. NIST's Office of Weights and Measures, which promotes uniformity in U.S. weights and measures laws, regulations, and standards, trained 1,832 weights and measures administrators, laboratory metrologists, and field enforcement officials during FY 2017.

Table 23 – Conferences, Seminars, and Workshops

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NIST Conference Center					
Conferences and Workshops	86	80	118	102	108
Attendance	8,579	9,208	11,490	10,370	10,588
Office of Weights and Measures - Metrology Training					
Seminar Attendance	446	355	457	342	466
Webinar Attendance	110	133	266	156	414
Workshop Attendance	55	30	27	0	36
Students	633	518	750	725	916
Total	1,244	1,036	1,500	1,223	1,832

NIST is expanding its collection of information on metrology training to include training for NIST facility users. Further, NIST staff answers e-mail, 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 396 days. The average CRADA approval time was 108 days.

Table 24 – Streamlining

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Streamlining Efforts					
Average Number of Days to Prepare a Patent Application[(a)]	401	456	410	442	396
Average CRADA Approval Time[(b)]	91	110	65	104	108

(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, Start-ups and Young Entrepreneurial Companies

NIST recognizes the need to provide both funding and technological support for small businesses, start-ups, 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 2017, NIST patent licenses were held by 19 small businesses. There were 116 small businesses involved in traditional CRADAs and 903 small businesses were involved in non-traditional CRADAs. NIST's non-traditional CRADAs involve 20 small businesses involved with material transfer agreements, 233 involved in calibration services and 650 receiving NVLAP accreditations. There were also 12 small businesses who received Phase I SBIR awards and 9 small businesses who 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 1 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 the 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; and
4. Reducing, by 10%, the time from close of solicitation to award issuance.

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 less 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. Over each of the last five fiscal years, NIST has continually increased the number of small business interactions in various technology transfer mechanisms.

Table 25 - Number of Small Businesses Interacting with NIST[40]

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Number of Small Businesses Licensing NIST Technologies	2	1	4	14	19
Number of Small Businesses involved in Traditional NIST CRADAs	31	37	68	58	116
Number of Small Businesses involved in Non-Traditional NIST CRADAs	7	734	795	823	903
Number of Small Businesses involved in Phase I SBIR Awards	9	12	14	12	12
Number of Small Businesses involved in Phase II SBIR Awards	5	4	6	7	9
Total	85	825	955	972	1,156

[39] http://www.nist.gov/tpo/sbir/index.cfm

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

NIST has also identified 44 start-up 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 2017.

Economic Assessment
NIST has had a long history of assessing the economic impact of standards and related technologies transferred from its research and standards programs. Between 2000 and 2011, NIST developed sixteen microeconomic studies that assessed technologies transferred to nine different industries. Each of these studies measured economic impact in terms of the net benefits society experienced or would experience as a result of NIST's research and transfer activities. Measures of net benefits for these studies indicated that typically, for each dollar NIST spent, NIST created $9 in benefits.

In addition to studies on NIST programs and standards, the Technology Partnerships Office also conducts and coordinates reports and studies on the economic impact of tech transfer across multiple agencies, and coordinates both the Department of Commerce's Technology Transfer Report and the Federal Technology Transfer Report on annual tech transfer metrics. In FY 2017, these studies included:

Materials Genome Initiative (MGI)
A study to assess the economic impact of the MGI's technology infrastructure. The study will identify gaps in current infrastructure needed to support the MGI and estimate the economic value of eliminating these gaps. The development of advanced materials is essential to economic security and human well-being and has applications in a wide range of industries such as clean energy, national security, and human welfare, yet it can take 20 or more years to develop and commercialize new materials after their initial discovery.

Advanced Encryption Standard (AES)
A study to assess the need for a robust and common encryption algorithm and the role NIST has played in addressing this need through the development and implementation of the Advanced Encryption Standard (AES), which is a Federal Information Processing Standard (FIPS), and the Secure Hashing Algorithms (2 FIPS). This report will include a review of the market barriers that gave rise to NIST's investments in the development and diffusion of encryption technology, and an evaluation of the economic costs and benefits of NIST's investments in AES infrastructure.

NIST Customer Demographics Study
A study to gain an understanding of the demography of NIST's CRADA partners, licensees, and collaborations customers. Demographic data was retrieved through Dunn and Bradstreet on each institution that interacted with NIST in these three ways. TPO is looking at descriptive variables such as geographic location and classification, age, employment size, and NAICS codes to determine the demographic characteristics and the national distribution of institutions that have worked with NIST.

NIST Postdoc Impact Study
A study to assess 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.

Small Business Innovation Research (SBIR) Survey
A study to assess Phase I and Phase II awards issued under NIST's SBIR program. SBIR grants are intended to stimulate the development of innovative technologies to help federal agencies meet the specific research and development needs of the Nation in many areas. Between 2000 and 2016, NIST provided a total of $53M for SBIR awards - $23M for 281 Phase I awards and $30M for 110 Phase II awards. The results of this study will provide NIST management with valuable insights into the operations and accomplishments of the SBIR program by detailing the extent to which the awards have met their mandated objectives, and ways in which the program could be improved.

NIST Footprint Study
A study to evaluate the economic contributions of NIST as a facility and an employer to the Nation and to the states of Maryland and Colorado. The study found that for each dollar of resources expended by NIST, an additional $1.49 was generated in economic impact. NIST's total economic contribution to the Nation was $2.7B in FY16; NIST supported 12,220 jobs in the state of Maryland and 2,823 in the state of Colorado.

NIST Patent Citations Study
A study that explores the technological impact of NIST-owned and NIST-funded patents, scientific journal articles, and forms of "grey literature" such as standards documents, and conference papers. The study's novel approach measured how frequently NIST technical outputs have been cited by subsequent patents and found that there was more than a ten-fold increase in citations from US patents to NIST technical outputs between 1995 and 2014. Citations from NIST document types (patents assigned to NIST; patents in which NIST has a government interest; peer reviewed papers resulting from NIST-funded research; and NIST grey literature) also increased significantly between 1995 and 2014. While the increase in citations provides an indication of the value of NIST's research, additional research is needed to assess the manner and extent to which these citations have influenced technological development.

Multi-Agency Reports and Studies

Global Positioning System (GPS) Study
A study to assess the economic impact of the Nation's precision timing infrastructure, which is primarily facilitated through GPS. The study will evaluate technology transfer patterns and collaborations that have led to the development and deployment of GPS, the national benefits that have resulted from the role that NIST and other federal agencies played in the evolution of GPS, and the economic impact of a failure of the GPS system for up to 30 days.

Federal Technology Transfer Study
A study to identify and empirically measure impacts from federal technology transfer activities. This study focuses on the development of tools, methods, data, and data infrastructure derived from best practices used throughout the tech transfer community. A major goal of the project is to provide a systematic approach to the empirical analyses of technology transfer mechanisms that can be used by all federal agencies. This will also include efforts to identify barriers to effective technology transfer. The study will demonstrate the effectiveness of the proposed approach by providing multiple case studies of technology transfer impact achieved by several federal agencies. As outlined in the President's Management Agenda[41], one strategic area of focus for the Lab-to-Market Cross Agency Priority (CAP) goal[42] is to "Improve understanding of global science and technology trends and benchmarks". The results of this study will help demonstrate the value of federal research investments and will assist other agencies in conducting similar outcome-based analyses using the same methodology.

Federal ORTA/TTO Study
NIST is working with the Inter-Agency Working Group on Technology Transfer (IAWGTT) to complete a study on Offices of Research and Technical Applications/Technology Transfer Offices (ORTAs/TTOs). This study involves a survey to collect both quantitative and qualitative data from each technology transfer office within the IAWGTT. The reason for collecting the data is two-fold. First, the data are used to create a mutual understanding of the workings of Federal ORTAs/TTOs. Second, the data are used to analyze and discuss how specific organizational and operational activities of technology transfer offices impact technology transfer.

Efforts to Promote Entrepreneurship

Entrepreneur-in-Residence (EIR) Program
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) between the two organizations. Under the PIA, TEDCO vets and recommends suitable candidates for one-year appointments. In FY 2017 there were three NIST-TEDCO EIRs who serve 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 start-up 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 four 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 NIST Chief

[41] https://www.whitehouse.gov/wp-content/uploads/2018/03/Presidents-Management-Agenda.pdf
[42] https://www.performance.gov/CAP/CAP_goal_14.html

Counsel and from the Department of Commerce Ethics Counsel before undertaking their initiative which is being pursued on their own time.

In FY 2018, 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 post-doctoral community.

N-STEP Program

NIST launched the NIST Science and Technology Entrepreneurship Program (N-STEP)[43] 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 that has been done 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, so that the technologies can be commercialized as products or services to benefit the public.

In FY 2017, N-STEP received eight applications in the form of white paper submissions and funded six companies, including four new startup companies and two existing companies. N-STEP is funded by NIST and administered by Maryland TEDCO but is Nation-wide in scope and not limited to the State of Maryland.

Challenges

Challenge.gov is a listing of challenge and prize competitions, all of which are run by more than 102 agencies across federal government. NIST participates in this challenge competition by offering cash prizes to the public for their help in solving perplexing mission-centric problems[44] In FY 2017, NIST sponsored the following Challenges:

NIST Reference Data Challenge (NIST's Director's Office)

- Purpose: Drive use of NIST reference data in apps, build awareness about NIST data.

RAMP (NIST's Electronics Laboratory)

- Purpose: Increase use of a standard NIST helped develop to describe and model manufacturing processes.
- Quasi-partners include the American Society of Mechanical Engineers, American Society for Testing and Materials, and the National Science Foundation.

Virtual Public Safety Test Environment Challenge (NIST's Communications Technology Laboratory and Public Safety Communications Research Division)

- Purpose: Design a virtual reality test system that could be used to test new first responder technologies.

PerfLoc (NIST's Information Technology Laboratory and Public Safety Communications Research Division)

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

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

- Purpose: Develop indoor localization app that can help first responders navigate in different building environments.
- NIST-hosted website includes a leaderboard and testing data generated by NIST.

The Future of Public Safety Technology 100k Video Series (NIST's Communications Technology Laboratory and Public Safety Communications Research Division)

- Purpose: Incentivize video and media experts to help PSCR champion open innovation in the context of public safety communications research.

Awards

In FY 2017, NIST staff received the following awards:

- Craig Brown: Samuel Wesley Stratton Award, NIST
- Nick Butch: Presidential Early Career Award for Scientists and Engineers, White House
- Marcus Cicerone: Flemming Award, White House
- Mike Coble: Fellow, American Academy of Forensic Science
- Adam Fleisher: Ivan P. Kaminow Young Professional Prize, Optical Society of America
- Andrew Gayle and Robert Cook: Paper of the Year Award, Journal of Material Research
- Katherine Gettings: Fellow, American Academy of Forensic Science
- Jack Glover: F12 Award of Excellence and Emerging Professional, American Society of Testing and Materials International
- Justin Gorham: Emerging Professional, American Society of Testing and Materials International
- Michael Halter: ISAC Scholar, International Society for Advancement of Cytometry
- Andrew Herzing: K.F.J. Heinrich Award, Microanalysis Society of America
- Chemical Informatics Group: Supercomputing Award, DOE Advanced Manufacturing Office
- Bob Keller: Governor's Award for High Impact Research, CO-Labs
- Eric Kilpatrick: Outstanding Abstract Award, American Association for Clinical Chemistry
- Eric Lemmon: Achievement Award, American Gas Association
- Laurie Locascio: Earle B. Barnes Award for Leadership in Chemical Management, American Chemical Society
- John Marino: Best of BIOT Award, American Chemical Society Division of Biochemical Technology
- Mark McLinden and Andrei Kazakov: Rocky Mountain Eagle Award, Colorado Federal Executive Board
- Kalman Migler: Award, Washington Academy of Sciences
- Jan Obrzut: 1906 Award, National Committee of the International Electrochemical Commission
- Vladimir Oleshko, et al.: Best Paper Award, Microscopy Society of America
- William Osborn: named National Academy of Engineering Top Young Engineers in 2017, U.S. Frontiers of Engineering Symposium by the National Academy of Engineering
- Elijah Petersen: SNO Emerging Investigator, Sustainable Nanotechnology Organization
- Anne Plant: Fellow, American Association for the Advancement of Science

- Jeanita Pritchett: Henry C. McBay Outstanding Teacher Award, National Organization for the Professional Advancement of Black Chemists and Chemical Engineers
- Dean Ripple: Award of Appreciation, American Society of Testing and Materials International
- Chris Stafford: Fellow, American Physical Society
- Matthew Staymates, Greg Gillen, Bill MacCrehan, Jessica Staymates: Global Innovation in Digital Technologies, Netexplo
- Terry Udovic: Bronze Medal, DOC
- Jim Warren: Kavli Distinguished Lectureship in Materials Science, Materials Research Society
- Winnie Wong-Ng: 2017 Distinguished Fellow, International Centre for Diffraction
- Justin Zook: Presidential Early Career Award for Scientists and Engineers, White House

Downstream Outcomes from NIST Technology Transfer Activities

Nanocollaboration Leads to Big Things
Roche Sequencing Solutions engineer Juraj Topolancik was looking for a way to decode DNA from cancer patients in a matter of minutes. Rajesh Krishnamurthy, a researcher with the startup company 3i Diagnostics, needed help in fabricating a key component of a device that rapidly identifies infection-causing bacteria. Ranbir Singh, an engineer with GeneSiC Semiconductor Inc., in Dulles, Virginia, sought to construct and analyze a semiconductor chip that transmits voltages large enough to power electric cars and spacecraft.

These researchers all credit the NanoFab, located at the Center for Nanoscale Science and Technology (CNST). The NanoFab provides cutting-edge nanotechnology capabilities for NIST scientists that is also accessible to outside users, with supplying the state-of-art tools, know-how and dependability to realize their goals.

Topolancik, the Roche Sequencing Solutions engineer, needed high precision etching and deposition tools to fabricate a device that may ultimately improve cancer treatment. His company's plan to rapidly sequence DNA from cancer patients could quickly determine if potential anti-cancer drugs and those already in use are producing the genetic mutations necessary to fight cancer. "We want to know if the drug is working, and if not, to stop using it and change the treatment," says Topolancik.

In the standard method to sequence the double-stranded DNA molecule, a strand is peeled off and resynthesized, base by base, with each base—cytosine, adenine, guanine and thymine—tagged with a different fluorescent label. "It's a very accurate but slow method," says Topolancik. Instead of peeling apart the molecule, Topolancik is devising a method to read DNA directly, a much faster process. Borrowing a technique from the magnetic recording industry, he sandwiches the DNA between two electrodes separated by a gap just nanometers in width.

According to quantum theory, if the gap is small enough, electrons will spontaneously "tunnel" from one electrode to the other. In Topolancik's setup, the tunneling electrons must pass through the DNA in order to reach the other electrode. The strength of the tunneling current identifies the bases of the DNA trapped between the electrodes. It is an extremely rapid process, but for the technique to work reliably, the electrodes and the gap between them must be fabricated with extraordinarily high precision.

That is where the NanoFab comes in. To deposit layers of different metals just nanometers in thickness, Topolancik relies on the NanoFab's ion beam deposition tool. And to etch a pattern in those ultrathin, super smooth layers without disturbing them—a final step in fabricating the electrodes—requires the NanoFab's ion etching instrument.

"These are specialty tools that are not usually accessible in academic facilities, but here [at the NanoFab] you have full, 24/7 access to them," says Topolancik. "People here care about you, they want you to succeed because that's the mission of the NanoFab." As a result, he notes, "I can get done here in two weeks what would take half a year any place else."

When Krishnamurthy, whose company is based in Germantown, Maryland, needed an infrared filter for the bacteria-identifying chip, proximity was but one factor in reaching out to the NanoFab. "Even more important was the level of expertise you have here," he says. "The attention to detail and the trust we have in the staff is so important—we didn't have to worry if they would do a good job, which gives us tremendous peace of mind," Krishnamurthy notes.
The NanoFab also aided his project in another, unexpected way. Krishnamurthy had initially thought that the design for his company's device would require a costly, highly customized silicon chip. But in reviewing design plans with engineers at the NanoFab, "they came up with a very creative way" to use a more standard, less expensive solution that would achieve the same goals, he notes.

"The impact in the short term is that we didn't have to pay as much [to build and test] the device at the NanoFab, which matters quite a bit because we're a start-up company," says Krishnamurthy. "In the long run, this will be a huge factor in [enabling us to mass produce] the device, keeping our costs low because, thanks to the input from the NanoFab, the source material is not a custom material."

Singh came to the NanoFab with a different mission. His company is developing a semiconductor device durable enough to transmit hundreds to thousands of volts without deteriorating which will be used to power electric cars and spacecraft. He relies on the NanoFab's metal deposition tools and high-resolution lithography instruments to finish building and assess the properties of the device.

"Not only is there a wide diversity of tools, but within each task there are multiple technologies," Singh adds. For instance, he notes, technologies offered at the NanoFab for depositing exquisitely thin and highly uniform layers of metal—which Singh found crucial for making reliable electrical contacts—include both evaporation and sputtering, he says.
The wide range of metals available for deposition at the NanoFab, uncommon at other nanotech facilities, was another draw. "We needed different metals compared to those commonly used on silicon wafers and the NanoFab provided those materials," notes Singh.

NIST Invents Fundamental Component for 'Spintronic' Computing

NIST has been granted a patent for technology that may hasten the advent of a long-awaited new generation of high-performance, low-energy computers.

Conventional microelectronic devices, for the most part, work by manipulating and storing electrical charges in semiconductor transistors and capacitors. One highly promising alternative approach, called "spintronics," utilizes the quantum spin of the electron to hold information in addition to the charge. The two different spin orientations (typically designated "up" and "down") are analogous to positive and negative electrical charges in conventional electronics. Because changing an electron's spin requires very little energy and can happen very fast, spintronics offers the possibility of significant energy reduction.

"Our invention," says co-inventor Curt Richter of NIST's Engineering Physics Division, "is designed to provide one key component in spintronic systems. It's a very simple, fundamental building block that can be used in a variety of different ways. It can serve as an on-off switch for spin currents, as an interconnect between different spintronic components, and as an interface between magnetic and electronic features to realize multifunctional devices."

This property has been exploited to make microscopic "spin valves"—typically a channel with a magnetic layer at each end. The relative polarity of the two magnets turns the valve on or off: If both magnets have the same alignment, the spin-polarized current passes through the channel. If the magnets have opposite alignments, current cannot flow.

John Kramar, Acting Chief of NIST's Engineering Physics Division, calls the work "a very exciting invention that provides a great solution for the switching-energy problem for spin valves. It removes a significant technological barrier for spintronics to become a strong contender for beyond-CMOS microelectronics."

NIST Patents First DNA Method to Authenticate Mouse Cell Lines

Cell lines that have been contaminated or misidentified due to poor laboratory technique and human error lead to inaccurate research studies, retracted publications, and wasted resources. In fact, many scientific funding organizations, such as the National Institutes of Health, now require scientists to verify their cell lines for identity and quality before research grants are awarded. To help address this challenge, NIST is working with partners to design tools, establish datasets, and further develop and standardize NIST's system to authenticate mouse cell lines.

One of the first milestones in NIST's effort is the recently granted U.S. patent (No. 9,556,482) for an authentication method using NIST-identified short tandem repeat (STR) markers (tiny repeating segments of DNA found between genes) for mouse cell lines. The method can be used to verify that a cell line is derived from a particular mouse in the same way forensic experts can confirm the identify of a person using DNA evidence.

NIST partnered with the ATCC (formerly the American Type Culture Collection), a global leader in biological materials management and standards, to further develop the STR technology for authentication and establish the Mouse Cell Line Authentication Consortium. The Consortium will test and validate the patented authentication method.

NIST Concept for an Artifact to Test Laser Scanners Commercialized by Bal-Tec

To properly calibrate laser scanners used in particularly sensitive operations, organizations need to perform a labor intensive and time consuming test. Based on feedback, staff from NIST's Engineering Physics Division developed a novel prototype that significantly reduces testing time. NIST work led to Bal-Tec Inc., a U.S. manufacturer of metrology equipment, developing a commercial version of the test.

Bal-Tec commercial version of NIST artifact.

NIST Upgrades Widely Used Database of Molecular 'Fingerprints'

When scientists need to identify an unknown compound, they do what a police detective might do. They get fingerprints—in this case, the "molecular fingerprints" of the unknown compound—and run them through a database of fingerprints from known compounds to look for a match.

One of the world's largest and most widely used databases of molecular fingerprints is the NIST Mass Spectral Library, and that library just got larger still. On June 6, 2017, NIST added fingerprints from more than 25,000 compounds to the library, bringing the total number to more than 265,000. This library contains fingerprints of organic compounds, both natural and man-made.

"This library is used by scientists and engineers in virtually every industry," said Stephen Stein, the NIST chemist who oversees the Mass Spectral Library. He rattled off just a few uses: diagnosing medical conditions, conducting forensic investigations, identifying environmental pollutants and developing new fuels. "And anything having to do with food," he said, since the taste of a food is determined by the complex mixture of organic molecules within it. "The flavor and fragrance industries live and die by this stuff."

Among the important compounds whose fingerprints are included in this upgrade are many dangerous drugs. These include dozens of synthetic cannabinoids—aka "synthetic marijuana"—which can cause psychotic episodes, seizures, and death. Also included are more than 30 types of fentanyl, the synthetic opioid that is driving an epidemic of overdoses nationwide.

Having the fingerprints of these compounds in the Mass Spectral Library will help law enforcement and public health officials fight the spread of these new and dangerous substances.

NIST has released the latest version of the Mass Spectral Library, and the software needed to run it, to more than 60 distributors that bundle the data and software into mass spectrometry instruments. Owners of existing instruments can also download the latest version from distributors online.

NIST Offers Technical Training for the Judiciary

MML's Applied Chemicals and Materials Division recently provided a short course on Vapor Sampling and Characterization for 13 members of the judiciary on June 8 and 9, 2017, under the auspices of the National Courts and Science Institute (NCSI).


The judges enjoyed temporarily trading their black robes for lab coats.

NCSI is a nonprofit foundation that provides scientific training to the judiciary, enabling judges to better understand scientific evidence. Judges who complete training are designated Resource Judges, or upon completion of multiple training modules, Fellows of the Institute. These specially trained judges then mentor other judges throughout the judiciary on specific scientific topics. Two state supreme court justices, five state appellate judges and six trial judges participated in NIST's training.

The judges heard lectures on vapor characterization, chemical analysis, mixture behavior, and measurement uncertainty. Five laboratory sessions featured experiments on all the techniques, in which the judges exchanged their black robes for white lab coats. The capstone lab was called the six-pack: six samples of fire debris (made by burning gasoline, diesel fuel, or no accelerant) were chosen by a dice throw, and the judges had to figure out what, if any, ignitable liquid was used in the fire.

Finally, the judges participated in the mock *voir dire*, preliminary examination of potential expert witnesses. The judges came away better equipped to handle scientific evidence. One appellate jurist expressed that he wished he had taken the course before he presided over an arson appeal a few months ago. There are currently 60 more judges on the waiting list for two offerings of the course next May.

NIST-Developed Method Provides Critical Metrology Solution to Semiconductor Industry

A NIST-developed metrology method using X-rays to measure the shape of the nanoscale devices at the core of all the electronics that surround our daily life is helping the semiconductor industry to "see" what they are making as they develop next generation electronic devices.

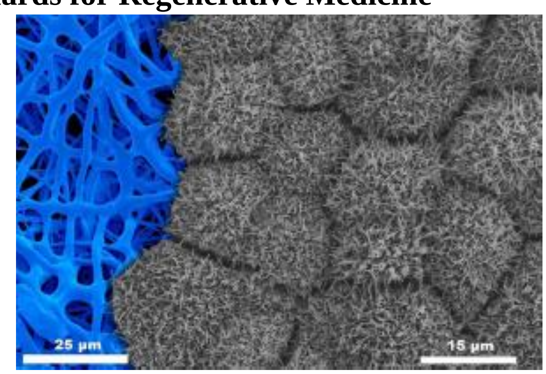
NIST has worked closely with semiconductor manufacturers and equipment manufacturers to develop metrology solutions for the industry's challenges. The NIST-developed X-ray measurement, called critical dimension small angle X-ray scattering (CDSAXS), can determine the shape of nanostructures with sub-nm accuracy.

NIST has had 5 CRADAs with companies including Intel and Lam Research to develop and transfer CDSAXS methods to the semiconductor industry. NIST also hosted a two-day short course where NIST staff trained almost 30 semiconductor industry scientists on the fundamentals and application of CDSAXS. The short course included hands on demonstrations of the measurement on NIST's custom built instrument.

Semiconductor equipment manufacturers are ramping up their instrument development and have applied for over 30 patents related to CDSAXS. Initial commercial systems are now available and will soon be characterizing wafers at manufacturing facilities.

New Public-Private Partnership to Develop Standards for Regenerative Medicine

NIST has partnered with the Standards Coordinating Body for Gene, Cell and Regenerative Medicines and Cell-based Drug Discovery (SCB) to develop industry-wide standard methods and protocols for characterizing and manufacturing these cutting-edge therapies, with an aim of accelerating their use as mainstream treatments for a variety of human diseases and injuries.



The field of regenerative medicine manipulates genes, cells, and tissues to repair or replace diseased, damaged, or missing organs, skin, bone, and other cells and tissues. Regenerative medicine has the potential to alleviate the shortage of donor organs and restore appearance and full function to patients who have experienced severe burns or physical trauma.

Because of the complexity of regenerative medicine treatments, they have been slow to transition from the laboratory to the clinic. The traditional measurements of efficacy, potency, purity, and quality that work with traditional pharmaceuticals are not always sufficient for regenerative medicine treatments. To address these issues, NIST and the SCB, a non-profit founded by the

Alliance for Regenerative Medicine, signed a Memorandum of Understanding, formed a partnership to explore the regenerative medicine industry’s needs and develop standards and other products to increase confidence in measurements of gene- and cell-based therapies and manufacturing processes.

CHAPTER 3
National Oceanic and Atmospheric Administration

NOAA's 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, supporting NOAA's four service-based Line Offices: the National Marine Fisheries Service, the National Ocean Service, the National Weather Service, and the National Environmental Satellite, Data, and Information Service, as well as thematic programs including Climate, Aquaculture, Arctic, Ocean Exploration and Research, Weather and Air Quality, and Ocean Acidification. While the service-based Line Offices each have an R&D component, the entire enterprise is also supported by a dedicated R&D Line Office: The Office of Oceanic and Atmospheric Research (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, a wide variety of climate research and the impacts of a changing climate on human health, coastal zone management, and oceans. Research results are routinely transitioned to NOAA's operational components to improve prediction, management, and other mission activities.

Approach and Plans for Technology Transfer

The vast majority of NOAA's transfer of technology outside of the organization happens through peer-reviewed scientific publications and the provision of data and software-based decision-support tools which are delivered directly to the public and stakeholders in service to the NOAA mission of protecting lives and property. The remainder of NOAA's technology transfers are the result of partnerships, grants, and other formal technology transfer mechanisms such as patent license agreements. The following is an overview of NOAA's technology transfer activity, both formal and informal, during Fiscal Year 2017.

Data Products and Services

NOAA scientists provide details of their research and technology to the public in the form of information products and services. These include weather and climate forecast data, El Niño prediction and monitoring, tides and currents, satellite imagery, fishery statistics, information on protected species, air quality, coastal conditions, beach temperatures, nautical charts, and databases on climate, oceans, ice, atmosphere, geophysics and the sun. These data are provided, often in real-time, through the network of NOAA data centers and websites.

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 websites are developed in conjunction with academia and private sector partners.

Engaging Citizens to Improve Weather Forecasts Worldwide
An exemplary application of citizen science, the Meteorological Phenomena Identification Near the Ground (mPING) project is a crowd-sourcing, mobile phone app that allows anyone to submit precipitation observations to the NOAA National Severe Storms Laboratory (NSSL). These observations are used to validate and improve radar-based precipitation type (e.g., rain, sleet, snow, freezing rain, etc.) methodologies developed by NSSL in support of NOAA National Weather Service (NWS) forecasters. A database has been developed for efficient and secure ingest and distribution of mPING observations via an open application program interface (API), which allows other app developers to access and distribute the data. Since January 2017, over 254,000 reports have been submitted to the database.


Reduced visibility due to blowing dust or sand: Visibility reduction caused by strong winds lofting sand and dust, most often from dry and barren soil. Photo: NOAA

During this same time, the database has been queried 41 million times, of which two percent were from NWS entities (38,600,000 are from a commonly-used commercial app called RadarScope that uses the open API, while the rest are from other entities). Finally, mPING improved the skill of winter precipitation type forecasts for ice pellets and freezing rain (out to eighteen hours) by a factor of four to six over older techniques.

Cooperative Institutes
NOAA supports a network of 16 Cooperative Institutes at 43 universities and research institutions across 20 states, the District of Columbia, Puerto Rico, and the US Virgin Islands. Some Cooperative Institutes are located near NOAA laboratories or science centers, creating a strong, long-term collaboration between federal and university scientists. The work done through the Cooperative Institutes directly supports NOAA's mission activities. NOAA's Technology Partnerships Office (TPO) works closely with the technology transfer offices from the Cooperative Institutes to jointly manage intellectual property and seek out licensing partners.

Visiting Scientists - International Collaborations
In addition to NOAA's Cooperative Institutes, a number of NOAA labs transfer technology by hosting both domestic and international visiting scientists. To ensure that the United States

benefits from and fully exploits scientific research and technology developed abroad, NOAA collaborates and shares information with organizations in countries throughout the world. Through these international relationships, NOAA receives technology that may eventually benefit U.S. industries and public users. For example, the understanding and forecasting of global phenomena that occur in the atmosphere, oceans, and on the sun, require worldwide collaboration and information sharing. This sharing is accomplished through formal agreements with individual countries and participation in international organizations, such as the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), and the International Astronomical Union (IAU).

NOAA participates in international scientific programs, such as in the Global Earth Observation System, and shares technology and scientific data. This effort involves nearly 50 countries, the European Commission, and 29 international organizations. NOAA also provides technical assistance and training to individuals from other countries and participates in an international visiting scientist program. Further, NOAA shares environmental data through its participation in the World Data Center program.

User Facilities

While NOAA does not currently offer its facilities for public use, NOAA does regularly collaborate 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 and 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’s joint technology transfer initiative (JTTI) seeks to prioritize the transition of promising weather research into operations, applications, and commercialization. Congress enacted $10 million in support of this program in FY 2017.

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 is comprised of 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).

NOAA Sea Grant
Sea Grant is a network of 33 university-based programs that support coastal and Great Lakes communities through research, extension and education to turn science into real world impacts. (http://seagrant.noaa.gov/)

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. (https://ioos.noaa.gov/)

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 regionally in the United States, nationally, and globally. (http://climate.noaa.gov/)

Managing and Tracking NOAA's Intellectual Property Portfolio
The NOAA TPO, housed under OAR, manages a central technology transfer program for all NOAA Labs, Centers, Programs, and external partners. To ensure the program is effectively serving its customers, management has developed a five-year strategic plan that will seek to track and improve performance across four key areas:

- Developing and Nurturing Lab/Center Innovation Ecosystems
- Increasing External Awareness and Recognition for NOAA's Technology Transfer
- Improving Staff Understanding and Utilization of Technology Transfer
- Streamlining Policy and Management for Technology Transfer across NOAA

The program will monitor and report on progress across each of these areas in future technology transfer reports.

Work Product and Collaborative Activities

Inventions, Patents, and Licensing
In 2017, NOAA was awarded three new U.S. patents for innovations. NOAA researchers disclosed an additional three new inventions, which resulted in two provisional patent application filings. The TPO also converted a provisional application from 2016 to a non-provisional patent application in 2017.

NOAA now maintains an active patent portfolio of 18 technologies, ten of which are being marketed for licensees or are being actively commercialized. NOAA also signed a royalty-free research and development license during FY 2017, so its portfolio consists of eight active licenses, seven of which are income bearing.

Table 26 – Invention Disclosures and Patents

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Invention Disclosures					
Inventions Disclosed	8	6	15	18	3
Patents					
U.S. Patent Applications Filed	3	4	6	4	3
U.S. Patents Received	1	0	1	1	3
Foreign Patent Applications Filed	0	1	0	0	0
Foreign Patents Received	0	0	0	1	0

Table 27 – Licenses

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Licenses					
Total Active Licenses	5	5	6	7	7
Total New Licenses	0	0	2	3	0
Income Bearing Licenses					
Total Active Income Bearing Licenses	5	5	4	5	7
New Income Bearing Licenses	0	0	3	3	2
Total Active Invention Licenses	5	5	4	7	7
New Invention Licenses	0	0	0	3	1
Exclusive Licenses	0	0	1	4	4
Partially Exclusive Licenses	0	0	0	0	0
Non-Exclusive License	5	5	3	3	3
Elapsed time for Granting Licenses					
Average (months)	0	0	3	9	3
Minimum (months)	0	0	0	5	1
Maximum (months)	0	0	0	14	5

Table 28 – License Income

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
License Income					
Total License Income	$48,798	$69,151	$39,633	$11,000	$65,810
Total Invention License Income	$48,798	$69,151	$39,633	$11,000	$65,810
Earned Royalty Income (ERI)					
ERI top 1%	$36,798	$50,000	$39,633	$7,000	$60,000
ERI top 5%	$36,798	$50,000	$39,633	$7,000	$60,000
ERI top 20%	$36,798	$50,000	$39,633	$7,000	$60,000
Minimum ERI	$1,000	$1,000	$39,633	$1,000	$210
Maximum ERI	$36,798	$50,000	$39,633	$7,000	$60,000
Median ERI	$11,000	$13,830	$39,633	$5,000	$2,800
Disposition of Earned Royalty Income					
Total amount of ERI received	$48,798	$69,151	$39,633	$11,000	$5,600
Percent of ERI distributed to inventors	$16,740	$22,845	$12,588	4000	$1,736
	34%	33%	32%	36%	31%
Percent of ERI distributed to agency or lab	$32,058	$46,306	$27,045	7000	$3,864
	66%	67%	68%	64%	69%
Licenses terminated for cause	0	0	0	0	0

Cooperative Research and Development Agreements

NOAA’s Labs, Centers and Programs executed 15 new Cooperative Research and Development Agreements (CRADAs) in 2017. Eight of these agreements were with small businesses. Factoring in the new and expiring agreements, the total NOAA CRADA portfolio is now 37 active agreements.

Table 29 – Cooperative Research and Development Agreements

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
CRADAs					
Active CRADAs	15	19	28	33	37
Newly Executed CRADAs	7	8	14	9	15
Active CRADAs with small businesses	0	0	0	18	26
Small Businesses in Active CRADAs	0	0	0	18	26
Traditional CRADAs					
Active Traditional CRADAs	15	19	28	33	36
Newly Executed Traditional CRADAs	7	8	14	9	14
Non-traditional CRADAs					
Active Non-traditional CRADAs	0	0	0	0	0
Newly Executed Non-traditional CRADAs	0	0	0	0	0

Table 30 – Small Businesses, Startups, and Young Companies.

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Small businesses supported					
Total Number of Small Businesses Supported	0	0	0	23	30
Total Number of Startup and Young Companies Supported	0	1	1	2	1

Note: Small business numbers were not tracked prior to FY16

Publications[45]

In FY 2017, peer-reviewed publications by NOAA scientists totaled 1,678. The following charts show the breakdown of publications by subject, NOAA Line Office, R&D Unit, as well as co-authorship by institution and country.

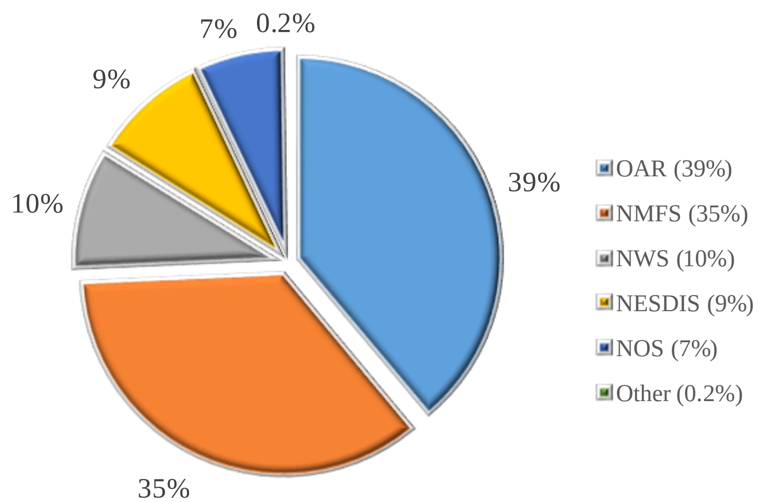
[45] NOAA publications data for 2017 were derived on October 5, 2017, using queries through the Web of Science database. As a result of variations in titles and nomenclature, these data do not provide a comprehensive measure of all NOAA publications. This reporting includes only those publications by NOAA scientists that were captured by the search queries. Extramural publications funded by NOAA either directly or indirectly are likewise not included.

Table 31 – Publications per Subject

Subject	Authored Publications
Meteorology Atmospheric Sciences	551
Marine Freshwater Biology	221
Oceanography	216
Environmental Sciences	202
Ecology	160
Fisheries	157
Geosciences Multidisciplinary	153
Multidisciplinary Sciences	130
Remote Sensing	60
Zoology	59

Figure 6 illustrates the number of publications per Line Office as a percentage of all NOAA-authored publications in FY2017. A single publication with authors from one or more-line office is counted as a publication for each line office.

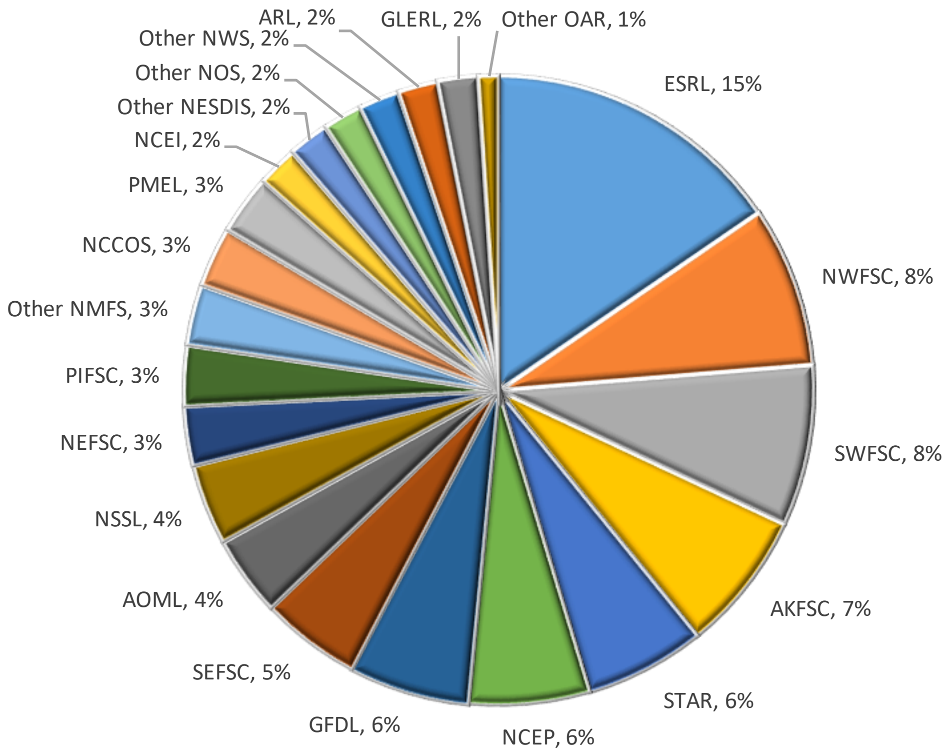
Figure 6 – NOAA-Authored Publications per Line Office



OAR	Oceanic and Atmospheric Research
NMFS	National Marine Fisheries Service
NWS	National Weather Service
NESDIS	National Environmental Satellite Data and Information Service
NOS	National Ocean Service

Figure 7 illustrates the number of publications per research unit as a percentage of all NOAA-authored publications in FY2017. A single publication with authors from one or more research unit is counted as a publication for each research unit.

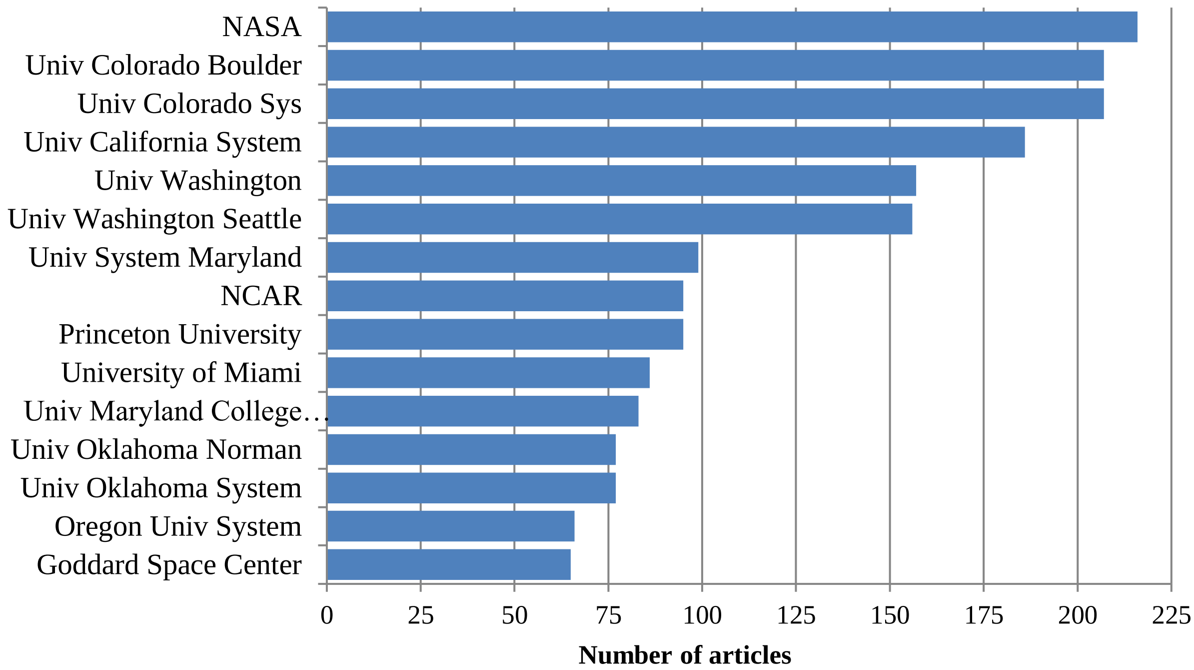
Figure 7 – Publications per Research Unit



AKFSC	Alaska Fisheries Science Center	NMFS	National Marine Fisheries Service
AOML	Atlantic Oceanographic Meteorological Laboratory	NOS	National Ocean Service
ARL	Air Resources Laboratory	NSSL	National Severe Storms Laboratory
ESRL	Earth Systems Research Laboratory	NWFSC	Northwest Fisheries Science Center
GFDL	Geophysical Fluid Dynamics Laboratory	NWS	National Weather Service
GLERL	Great Lakes Ecosystems Research Laboratory	PIFSC	Pacific Islands Fisheries Science Center
NCCOS	National Center for Coastal Ocean Sciences	PMEL	Pacific Marine Environmental Laboratory
NCEI	National Centers for Environmental Information	SEFSC	Southeast Fisheries Science Center
NCEP	National Centers for Environmental Prediction	STAR	Center for Satellite Applications and Research
NESDIS	National Environmental, Satellite, Data and Information Service	SWFSC	Southwest Fisheries Science Center

Figure 8 illustrates the top 15 extramural collaborators as measured by the number of publications co-authored by authors from NOAA and each institution.[46]

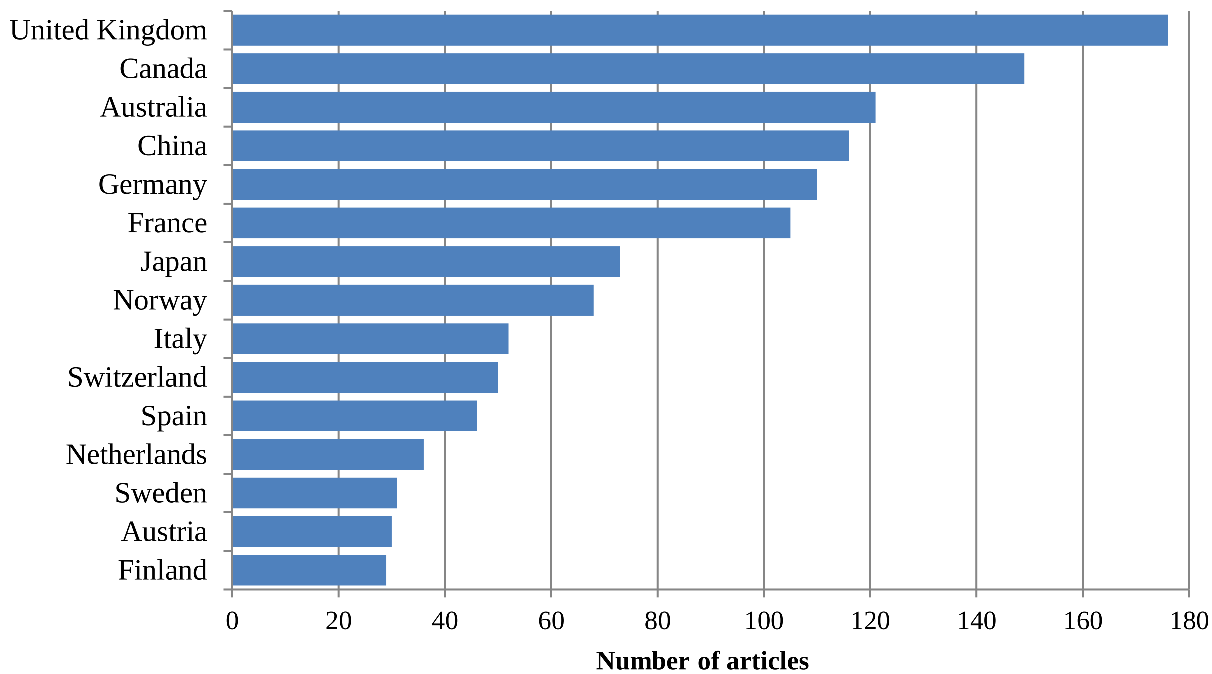
Figure 8 - Co-Authored Publications per Institution (top 15)



[46] Source: Web of Science as of October 23, 2017.

Figure 9 illustrates the top 15 international collaborators as measured by the number of publications co-authored by authors from NOAA and each nation.[47]

Figure 9 - Co-Authored Publications per Country (top 15)



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 No. 6,937,210) that uses computers and video projectors to display planetary data onto a six-foot diameter sphere, comparable to a giant animated globe. Researchers at NOAA developed SOS as an educational tool to help illustrate earth system science to people of all ages. Animated images of atmospheric storms 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.

Table 32 – SOS Installations

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total Number in Operation	101	110	126	135	144
New Domestic	7	4	6	3	6
New International	6	5	10	6	3
Total New Installs	13	9	16	9	9

Downstream Outcomes from NOAA Technology Transfer Activities

[47] Source: Web of Science as of October 23, 2017.

NOAA Big Data Project (BDP) Turns Two
NOAA's BDP was established in 2015 under a set of Cooperative Research and Development Agreements (CRADAs) between NOAA and five major commercial cloud service providers: Amazon Web Services, Google, IBM, Microsoft and the Open Commons Consortium. The goal of the project is to investigate how providing large NOAA data sets through modern cloud computing platforms can increase their utilization and value to U.S. businesses.

NOAA's Next Generation Weather Radar (NEXRAD) weather data were among the first to be delivered through these CRADAs. The National Centers for Environmental Information (NCEI) transferred the complete NEXRAD Level II historical archive to four of the five BDP collaborators. Amazon Web Services (AWS) was the first to make freely available the complete archived Level-II data through its AWS platform, with The Climate Corporation as a business partner and data consumer. AWS also collaborated with Unidata/University Corporation for Atmospheric Research (UCAR) to establish a real-time NEXRAD data feed, thereby providing on-demand dissemination of both archived and current data seamlessly through the same access mechanism.

Through this cloud platform alone, the utilization of the NEXRAD data by volume has increased by 130% over the past usage patterns observed at NCEI, while the load on NCEI systems has decreased by 50%. Additional NOAA datasets including fisheries catch data, numerical weather prediction model output, advanced weather radar products, and geostationary satellite data are at various stages of discussion and development.

NOAA and its collaborators are beginning to realize the potential of this collective effort among federal government, private industry, and academia, including stimulating new business opportunities and novel applications—all at no net cost to the U.S. taxpayer.

New marine channels forecast in Tampa gives ships a better navigation guide
On August 1, 2017, NOAA's National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) launched the Tampa Bay Marine Channels Forecast, an integrated suite of oceanographic and meteorological forecast products focused along the navigation channels of Tampa Bay. The product, initially developed by the National Weather Service (NWS) Tampa Bay Weather Forecast Office (TBWFO) at the behest of local pilots, includes a critical visibility forecast for the region. As a result of this new product, ship pilots no longer have to check multiple sources for information as they navigate the marine channels. The map-interface tool integrates forecasted water levels and tidal currents from CO-OPS with 24-hour weather forecasts, including winds, wind gust, visibility, rain chance, and marine hazard alerts from the TBWFO. The Tampa Bay Marine Channels Forecast provides information that is critical for the economy and safety of coastal communities. Vessel operators rely on accurate forecasts and observations to prevent costly maritime accidents and improve freight efficiency in an increasingly busy seaport. Source:
https://tidesandcurrents.noaa.gov/news/tampa-bay-marine-channels-forecast_article.html

Sister Sanctuary Agreement Protects Whales from New England to the Caribbean

A new "sister sanctuary" agreement signed this spring between NOAA and the government of The Netherlands adds to a network of marine protected areas stretching from New England to the Caribbean Sea, and now provides refuge for North Atlantic humpback whales at both ends of their 3,000-mile annual migration.

Humpback Whale in Stellwagen Bank National Marine Sanctuary Photo: NOAA

The agreement between NOAA's Stellwagen Bank National Marine Sanctuary, off the coast of Massachusetts, and the Yarari Marine Mammal and Shark Sanctuary of the Caribbean Netherlands in the Dutch Lesser Antilles, provides for joint whale research, monitoring, education and conservation.

From April through December, humpback whales feed in Stellwagen Bank, and migrate to lower latitudes in the Caribbean Sea during the winter to mate and calve. Yarari sanctuary is a breeding and calving ground for the humpback whale population of around 1,000 whales, which are shared by both nations.

"Cooperation is central to our goals of and to the implementation of the regional Marine Mammal Action Plan for the Caribbean," said Monica Borobia-Hill, UNEP program officer. "We welcome this agreement. It will open new opportunities for collaboration in activities of mutual interest on humpback whales and other marine mammals, as appropriate, as well as their respective habitats." Source: http://www.noaa.gov/media-release/new-sister-sanctuary-agreement-protects-whales-from-new-england-to-caribbean

Ongoing CRADA: Saildrones Return from Successful Arctic Cruise

On September 29, after three months of collecting data in the U.S. Arctic, three sailing drones provided under CRADA by Saildrone, Inc., safely returned to Dutch Harbor, AK.

The saildrones collectively traveled over 7775 nautical miles in under 90 days throughout the Bering and Chukchi Seas. Data from the tested technologies for fish and marine mammal acoustics are expected mid-October with preliminary analysis completed in the New Year.

Sailing drones return dockside in Dutch Harbor, AK Photo: Saildrone, Inc.

In mid-July, scientists sent off the unmanned sailing vehicles from Dutch Harbor, Alaska, with two sailing north through the Bering Strait into the Arctic Ocean and another transiting the Bering Sea. Traversing Alaska's inhospitable waters, the remotely-operated vehicles tracked melting ice, measured the ocean's levels of carbon dioxide, and monitored for the presence of fish, seals, and whales to better understand their behavior and population.

One vehicle surveyed the Bering Sea for walleye pollock, Northern fur seals that prey on them and the elusive North Pacific right whale. This work builds on research conducted during 2016, including a study of fur seal feeding rates. Carey Kuhn, ecologist with NOAA Fisheries' Alaska Fisheries Science Center, and her team also used, for the first time, video cameras on Northern fur seals to record feeding and verify the species and sizes of fish that fur seals are eating.

This was a collaborative mission led by NOAA including NOAA's Office of Oceanic and Atmospheric Research and NOAA Fisheries with partners Saildrone, Inc., Simrad AS/Kongsberg Maritime, Greeneridge Sciences, Inc, and Wildlife Computers. Source: https://www.pmel.noaa.gov/itae/follow-saildrone-2017

Daniel Murphy from NOAA's Earth System Research Laboratory Awarded Two U.S. Patents in 2017

This year, Dr. Murphy, who is a Program Lead for the Chemical Science Division (CSD) of the Earth System Research Laboratory, has twice accomplished what many of us only dream of doing in our lifetimes: he has been awarded a U.S. Patent for his innovative technology designs.

Dr. Murphy's first patent was awarded earlier this year for his Open Path Optical Cell design. The instrument uses lasers and mirrors to measure the absorption and scattering of light by aerosols in an air sample, which is central to CSD's mission to improve understanding of climate processes.

Dr. Murphy's second invention is an S-Shaped Time of Flight (ToF) instrument. ToF instruments measure the time it takes for a laser pulse to travel a specific distance. When compared to the known speed of light, the result provides useful information about the particles in the sample being analyzed. Dr. Murphy's design took the previous straight-line design and added two bends to achieve an S-shape which made the device more compact and consequently more useful for applications where the traditional ToF design was too large and cumbersome. The NOAA TPO is already exploring a number of possible licensing partners for this new design.

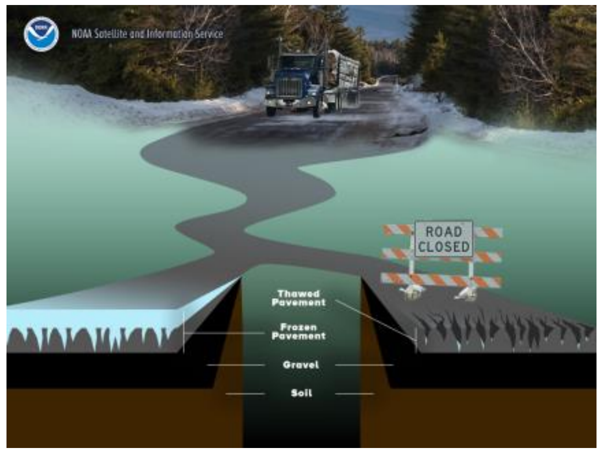
Agencies Team Up to Accelerate Earth System Prediction

Protecting the Nation's security and economic well-being will increasingly rely on improved skill in forecasting weather, weather-driven events like floods and droughts, and long-term shifts in weather, ocean and sea-ice patterns. A new partnership called the National Earth System Prediction Capability, or National ESPC, is underway to coordinate and accelerate America's environmental prediction capability. The partnership, which is a collaboration between the NOAA, NASA, the Department of Energy, the National Science Foundation, the U.S. Navy, and U.S. Air Force, has the goals of coordinating a national predictive capability with common requirements and standards and developing a national research agenda. Source: http://research.noaa.gov/LabsPrograms/OARPrograms/OfficeofWeatherAirQuality/OWAQPrograms/ESPC.aspx

Improved Shoreline Mapping Data Transitioned to Coast Guard, Other Stakeholders

NOAA's Integrated Ocean and Coastal Mapping Initiative supports the U.S. Ocean Action Plan that calls for the coordination of ocean and coastal mapping activities. This approach includes the coordination of NOAA's National Geodetic Survey (NGS) with multiple parties interested in using the topographic-bathymetric (topo-bathy) LIDAR data. Topo-bathy LIDAR is a method for determining water depth and allows ships to operate safely in areas with rugged shorelines, such as Alaska, the North Atlantic Coast, and the Caribbean. For example, NGS updated NOAA Nautical Charts for Key West and the Florida Keys Outer Reef directly supporting navigational safety and U.S. Coast Guard operations. Many of these areas are in dire need of a new survey; some areas in particular have not had surveys conducted since the 1900s to 1930s. NGS has completed processing and delivering 258 square nautical miles of topo-bathy LIDAR data for Key West and the Keys outer reef area for application to NOAA nautical chart products. NGS's LIDAR sensor was capable of reaching depths up to 18 meters (60 feet) along the outer reef, and for the first time we were able to resolve some imprecisely-positioned charted dangers. NGS has the unique capability of being able to help survey nearshore areas where it is either inefficient or dangerous for NOAA hydrographic vessels to survey.

NOAA Helping Department of Transportation in Northeast Conserve Low Volume Roads



In many northern states, state departments of transportation (DOTs) adjust allowable weight limits of trucks transporting goods on rural, "low volume" roads depending on air temperature. DOT's use "seasonal load restrictions" in order to reduce potential damage to the structural integrity of these roads due to "freeze-thaw" conditions. The NOAA Northeast Regional Climate Center, working with the Infrastructure Climate Network at the University of New Hampshire, created a Roadway Freezing-Thawing interface that allows road managers in the northeast to better assess when load restriction should be applied or suspended. Using the latest temperature data from the NOAA National Centers of Environmental Information and borrowing an approach developed by the Minnesota DOT, real-time, color contour maps of air-freezing and thawing indices for Maine, New Hampshire, and the Northeast are generated. These maps help state DOTs balance the needs of the industry with conservation of the roads, as well as the environmental impacts associated with seasonal load restrictions. Source: https://www.nesdis.noaa.gov/content/ncei%E2%80%99s-data-helps-dots-northeast-conserve-low-volume-roads

NOAA Engineers and More Reliable, Cost Efficient Current Sensor for Mariners

Navigating into seaports is now safer and more efficient for mariners thanks to improved NOAA technology that ships rely on to give them information about currents. The Center for Operational Oceanographic Products and Services (CO-OPS) developed a more reliable, cost-saving version of a current sensor system that can now be placed at more remote locations along navigation channels.

Max Ivanov and Scott Mowery with NOAA's Center for Operational Oceanographic Products and Services install an improved current sensor system on a navigation buoy in Chesapeake Bay. The system transmits real-time current speed and direction observations via satellite to help mariners more safely navigate busy shipping channels. (Photo: NOAA)

The updated Acoustic Doppler Current Profiler (ADCP) system provides real-time current speed and direction observations where many mariners need it most—at U.S. Coast Guard Aids-to-Navigation (ATON) buoys along major shipping channels. Accurate information about ocean conditions helps ship operators protect their cargo and the environment as they navigate narrow channels with increasingly larger vessels. Source: https://oceanservice.noaa.gov/news/aug16/current-sensor.html

New Experimental Coral Reef Laboratory

In partnership with the University of Miami's Rosenstiel School, NOAA's Atlantic Oceanographic and Meteorological Laboratory recently completed work on a state-of-the-art Experimental Reef Laboratory. For the first time, scientists will be able to precisely regulate CO2 levels and temperature, providing insight on how corals, such as the threatened staghorn coral Acropora cervicornis, respond to two of the major threats to coral reefs: thermal stress and ocean acidification. Thermal stress from elevated sea surface temperatures cause corals to expel their symbiotic algae resulting in coral bleaching, while ocean acidification obstructs coral's ability to build their skeletons. Using sixteen identical aquaria, researchers can now program CO2 conditions at coral reefs in the Florida Keys or simulate future CO2 levels and ocean temperatures. This ability to mimic real world conditions as well as predicted scenarios, provides NOAA with a versatile tool for observing how corals respond to an array of stress factors. By exploring coral resiliency mechanisms, researchers are hopeful they can discover the molecular underpinnings that will enable some corals to adapt and, ultimately, survive a marine environment in transition. Source: http://www.aoml.noaa.gov/keynotes/PDF-Files/Jan-Feb2017.pdf

NOAA Offers Tools and Expertise to Help U.S. Aquaculture Industry Expand

Offshore aquaculture is a promising new frontier for U.S seafood production. However, the growth of this industry has been constrained by the complexity of determining the best sites for farms while also minimizing any environmental impacts. In response to these concerns, NOAA's National Centers for Coastal Ocean Science (NCCOS) and NOAA's Office of Coastal Management partnered to develop a new offshore aquaculture planning tool, CanVis

Aquaculture. This seascape visualization tool contains an image library of aquaculture gear, vessels, buoys, and other infrastructure that can be used to simulate the changes that result from aquaculture development. Coastal managers and developers in Hawaii, California, and Washington are currently using this tool to visualize and plan offshore aquaculture projects. Through this effort, NOAA is supporting economic growth while balancing environmental and societal impacts of a burgeoning U.S. industry. Source: https://coast.noaa.gov/digitalcoast/tools/canvis

Using Behavioral Science to Improve Severe Weather Warnings

The NOAA National Weather Service (NWS) watch and warning process has not fundamentally changed in more than 50 years. However, society, technology, and science have made great advances. The Forecasting a Continuum of Environmental Threats (FACETs) paradigm modernizes the high-impact weather forecasting and communication process by adapting to evolving technology. At the core of this paradigm shift is a change to the current deterministic approach for hazardous weather warnings to one based upon Probabilistic Hazard Information (PHI). This framework will enable decision-makers who require more advanced notice, such as hospitals, schools, and large venues, to set their own threat thresholds based on their specific needs. It will also enable new science advances, such as Warn-on-Forecast and Phased Array Radar, to be fully leveraged into better warnings and forecasts for society.

Since hazardous weather forecasting is a physical science done by humans for humans, social and behavioral science is fully integrated into FACETs research and development. Collaborative research projects between OAR, NWS, and academic partners are beginning to move us toward the FACETs paradigm. In the spring of 2017, several experiments were conducted in the NOAA Hazardous Weather Testbed bringing together NWS forecasters, researchers, and partners such as emergency managers and broadcasters to evaluate early prototypes of forecast and warning technology based on the FACETs approach.
Source: http://www.nssl.noaa.gov/projects/facets/)

Fisheries and Biomedical Researchers Collaborate to Look for Cancer Cures in the Ocean

A little over ten years ago, a NOAA Alaska Fisheries Science Center scientist discovered a small green sponge, the Latrunculia austini. No one could have predicted the attention this unassuming sponge would receive in the years following its discovery.

A golf ball-size sponge discovered in the deepest, darkest ocean areas off Alaska holds promise in developing new treatments for pancreatic cancer, according to biomedical researchers. (Photo: NOAA)

This golf-ball sized sponge contains unique chemical compounds that may hold the key for developing life-saving cancer treatments. Biomedical researchers at the Hollings Cancer Center in South Carolina and at the Henry Ford Cancer Institute in Detroit have demonstrated that several of this green sponges' molecules selectively target and kill pancreatic tumor cells in lab tests. Although many challenges still need to be addressed, this discovery holds great potential for developing new medicines. Continued public-private partnerships along

these lines will enable NOAA to learn more about the ocean while advancing valuable research that may have life-saving benefits.
Source: http://www.noaa.gov/news/noaa-discovery-of-green-deep-sea-sponge-shows-promise-for-cancer-research

NOAA Launches Mobile App for Popular Emergency Operations Software
Introduced in 1986, the Computer-Aided Management of Emergency Operations (CAMEO®) software suite is the most widely used chemical response software in the world. It includes several desktop programs, as well as the CAMEO Chemicals website that provides emergency responders and planners with information about thousands of hazardous chemicals. The CAMEO suite programs are routinely used nationwide for chemical incidents initiated by extreme weather (such as hurricanes, tornadoes, and wildfires) as well as human error. In 2017, NOAA launched a mobile app version of CAMEO Chemicals for iOS and Android. The app does not require an internet connection, uses responsive design to adjust to tablets and phones, and includes the full CAMEO Chemicals hazardous chemical database as well as a tool to predict whether an explosion, toxic fumes, or other safety hazard could occur if a group of chemicals were mixed during an incident. Source: https://cameochemicals.noaa.gov/

Autonomous Aircraft Support Search and Rescue Under CRADA
The NOAA Unmanned Aircraft Systems (UAS) Program Office, working together with representatives of AeroVironment Inc., conducted a search and rescue exercise, called Arctic Shield, in the waters north of Alaska in order to test the utility of integrating unmanned aircraft into a simulated response incident.


Launch of the PUMA AE UAS from U.S. Coast Guard Cutter HEALY. Photo: NOAA

Working from the deck of the U.S. Coast Guard Cutter HEALY, the research team launched a small unmanned aircraft, the AeroVironment Puma, to search for a simulated missing person stranded in icy waters.

Following the launch, the Puma used both its electro-optical and infrared cameras to locate the simulated victim floating in a survival raft on the water approximately one nautical mile away from the ship. The Puma was able to relay the coordinates to the test control center on board the HEALY, which then directed a Coast Guard H-60 and Era Helicopter to the scene. Both helicopters deployed rescue swimmers to simulate recovery and then returned safely to shore. The exercise concluded with a successful net capture of the Puma UAS and a recovery of the survival raft by the HEALY. Much of this mission was conducted under the auspices of a Cooperative Research and Development Agreement (CRADA) between NOAA and AeroVironment. The results from this and other tests will be analyzed by both NOAA and AeroVironment to improve NOAA's operational capabilities and AeroVironment's products for real-life mission-based scenarios.

Awards and Recognition

James Ott of the National Weather Service Wins Commerce Ron Brown Award

Mr. James Ott is the recipient of the 2017 Department of Commerce Platinum Award, also known as the Ron Brown award. This award is the highest bestowed by the Secretary of Commerce each year. Mr. Ott is only the second recipient, and first NOAA employee, to receive the Ron Brown Award. Mr, Ott was recognized for developing a wind compression algorithm that provides Federal Aviation Administration decision-makers the information needed for safe and efficient air traffic management at major airports in the United States.

From left to right: Ellen Herbst, Chief Financial Officer/Assistant, James Ott, Meteorologist, NOAA's National Weather Service, and Benjamin Friedman, Deputy Under Secretary for Operations, NOAA

Science on a Sphere® Team Receives Honorable Mention at 2017 CO-Labs Governor's Award for High Impact Research

The NOAA Earth System Research Laboratory Global Systems (Division ESRL/GSD) and Cooperative Institute for Research in Environmental Sciences (CIRES) and Cooperative Institute for Research in the Atmosphere (CIRA) team was honored for Science on a Sphere® and SOS Explorer™ visualization systems that are used worldwide to educate the public about science. The CO-Labs event gathers scientists, researchers, entrepreneurs, business leaders and government officials to celebrate the exceptional and groundbreaking work of scientists and engineers from Colorado's federally funded research labs and institutions.

NOAA Technology Transfer Awards

NOAA selected nine projects to receive the Agency's Technology Transfer Award in 2017. These projects exemplified the highest standard for developing a new technology in cooperation with private sector partners in the service of NOAA's mission.

Scott Abbott, et al. (Oceanic and Atmospheric Research): For the design, implementation, and operation of a 21st-century observing network to address water resource and flood protection issues in the Western U.S.

Dave Eckberg (National Weather Service): For design and development of the Automated Surface Observing System Ice Free Wind Sensor New Style Bird Deterrent to eliminate ASOS wind data errors.

Quay Dortch, et al. (National Ocean Service): For leading development and successful transition to commercial application of an automated sensor that provides early warning of harmful algal blooms.

Melinda Marquis, et al. (Oceanic and Atmospheric Research): For improving forecasts of turbine-height winds and solar irradiance from their High-Resolution Rapid Refresh (HRRR) weather model to improve usage of renewable power by industry.

Richard Okulski, et al. (National Weather Service): For transfer of operational wave run-up forecast technology to domestic and international emergency response partners for the protection of life.

Glenn Rolph, et al. (Oceanic and Atmospheric Research): For exceptional work in transferring the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) dispersion model to first responders, emergency planners, academia, and other government agencies.

Ronald B. Johnson (National Marine Fisheries Service): For conducting scientific studies and gaining approval for use of taurine as an essential ingredient in fish feeds.

Steve Ruberg, et al. (Oceanic and Atmospheric Research): For delivering a buoy that provides water managers with the critical information necessary to more effectively process compromised drinking water.

Galen Scott, et al. (National Ocean Service): For transferring expertise and technical assistance needed to implement national protocols used to measure sea level rise impacts on estuaries.

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 Web site and GitHub; and
- Leadership and technical contributions in the development of telecommunications standards.

ITS Work Products and Collaborative Activities

Cooperative Research and Development

ITS is authorized under the Federal Technology Transfer Act of 1986 (FTTA) to enter into 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 2017, 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, and remote sensing and global position system (GPS) technologies have been achieved through CRADAs. These have aided U.S. efforts to rapidly introduce new socially constructive communications technologies.

More recently, CRADAs in the areas of 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 allowed ITS to contribute to the development of new products and services.

ITS is a partner in the 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 has been operating for about two decades on behalf of sponsors at the Department of Homeland Security and the Department of Justice. Since the First Responder Network Authority (FirstNet) began its work, PSCR's research scope has expanded to supporting FirstNet's work toward creation of a nationwide broadband wireless network dedicated to public safety agencies through RDT&E of equipment that may be used to both build the network and communicate over it.

The vast majority of CRADAs ITS has entered into in the past six years are the Public Safety 700 MHz Broadband Demonstration Agreements. These agreements allow 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 test bed and over-the-air (OTA) network (both hosted and managed by ITS) in order to test interoperability of public safety communications equipment under simulated field conditions, with the participation of public safety practitioners. At the close of FY 2017, 53 CRADAs were in place under this program. The CRADAs protect the intellectual property of vendors and manufacturers, encouraging participation in testing that simulates real multi-vendor environments in the field. This is the first government or independent facility in the U.S. capable of testing or demonstrating public-safety-specific LTE implementation requirements.

Table 33 – Collaborative Relationships for Research & Development

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
CRADAs					
Active CRADAs	81	60	56	62	59
Newly Executed CRADAs	30	11	53	12	8
Active CRADAs with Small Businesses Involvement	17	12	12	17	17
Number of Small Businesses Involved in Active CRADAs	17	12	12	17	59

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 publications are released after going through an internal peer review process managed by the ITS Editorial Review Board (ERB). In FY 2017, 60% or manuscripts released through the ERB process published in scientific journals or conference proceedings and 40% 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. To ensure a meaningful and realistic metric, ITS counts actual PDF downloads of publications rather than pageviews of the bibliographic summaries. In FY 2017, ITS technical publications were downloaded 6,214 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 and Public Safety Communications Research staff. ITS launched the site with 1,000 clips and ITS and collaborators continues to add clips. Significant recent additions include a collection of public safety video clips filmed during training exercises, and 4K sports content uploaded by Sky Broadcasting in the UK. Over 2,400 different video clips were downloaded from the library in FY 2017.

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

ITS makes several software and data tools available via open-source download. In FY 2017, ITS increased its use of the GitHub open source code hosting platform. While GitHub allows more interaction with potential users of the software and may broaden the audience, it also makes it more difficult to understand the impact of the software without investing in additional tracking software. ITS is exploring the development and value 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. ITS has developed and shared software to predict propagation for planned communications systems through input of specific parameters, as well as data sets that companies can use to test and validate prediction models. The majority of software and data downloads from 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 members 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: In FY 2017, ITS released an updated objective estimator of speech intelligibility that follows the paradigm of the Modified Rhyme Test (MRT). 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. The new speech intelligibility estimation algorithm released in FY 2017, ABC-MRT16, not only updated the audition model, but also extended the estimator to wideband, superwideband, and fullband speech systems as well as narrowband. ABC-MRT and ABC-MRT16 tools and MRT databases are available for download through the ITS web site, 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 (VQM) method, which has been made a national standard by the American National Standards Institute (ANSI), to estimate the quality of video impairments, providing users an inexpensive alternative to viewer panels for testing new transmission technologies. In FY 2017, 372 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 web site and from a public GitHub repository, from where it has been forked several times.

Table 34 – Other Performance Measures Deemed Important by the Agency

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Technical Publications Released	24	18	22	4	10
Technical Publications Downloaded	7,174	7,707	9,048	8,748	6,214
Consumer Digital Video Library Users Downloading	418	184	212	169	202
Video Quality Metric Software Users Downloading	591	685	507	496	372
Propagation Modeling Software Downloads	n.a.	717	798	781	1,160
Other Software/Data Downloads	n.a.	489	493	591	995

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), and various federal public safety groups to interpret and analyze 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, 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, ATIS, and other telecommunication standards organizations, providing technical leadership that is trusted by the commercial-sector participants.

In FY 2017, ITS staff held 38 positions on 42 different bodies in eight standards bodies, including 13 Chair/Co-chair/Vice-chair positions. ITS staff filled key leadership positions in the ITU-R, including U.S. Chair of 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 staff members also held the position of International Vice-chair of the ITU Intersector Rapporteur Group on Audiovisual Quality Assessment. ITS also continued its technical leadership and contributions to communications standards for public safety, particularly for first responders.

Downstream Outcomes from ITS Technology Transfer Activities

Telecommunication Standards

ITU-R Study Group 3 held two international meetings in FY 2017. ITS provided technical leadership and guidance in the creation and approval of 12 consensus U.S. contributions to the first round of meetings and eight in the second round. These contributions targeted international standards for sharing spectrum measurement data and developing new and improved propagation models. Shared measurement data is critical to validating new and improved models, which in turn are critical to providing a technical foundation for potential U.S. rulemaking around spectrum sharing across diverse services and future spectrum auctions.

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 Department of 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, i.e. 5G cellular technologies.

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 2017, several companies used the Table Mountain site under a CRADA to safely test and demonstrate LADAR technologies under development in atmospheric conditions and at distances relevant to potential applications, to fully test the functionality of new antenna designs during product development, and to safely and accurately test an Adaptive Tactical Laser System (ATLAS) compensated beacon adaptive optics (CBAO) system under development. Applications for these technologies include detection and tracking of wind shear and wake vortices, remote wind measurements for the offshore wind energy industry, mission-critical communications, electronic warfare, direction finding/geolocation, and sensing of hazardous liquids and gases.

- For the past eleven years, the University of Colorado's Research and Engineering Center for Unmanned Vehicles safely and accurately tested collective and autonomous sensing and communication technologies for small unmanned aircraft used for atmospheric science applications such as the study of tornadogenesis.
- ITS also uses the Table Mountain test facility to perform independent CTA-2009-B surveillance testing for manufacturers wishing to obtain verification that their equipment meets the requirements to be certified as a NOAA Weather Radio All Hazards receiver. Two companies entered into CRADAs with ITS for this testing in FY 2017.

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.

Public Safety Broadband Demonstration Network

The PSCR Public Safety Broadband (PSBB) Demonstration Network facilitates accelerated development of testing for emerging LTE broadband equipment specific to public safety. The PSBB Demonstration Network was established in the ITS labs in FY 2010 by the Public Safety Communications Research program. This network provides a central and independent test bed and laboratory to help public safety understand 3GPP Band 14 LTE. Through CRADAs that protect their intellectual property, manufacturers and carriers test the deployment of 700 MHz systems under development in this multi-vendor environment and execute public-safety specific test cases to provide proof of concepts and improve the quality of future systems. This cooperative program provides ITS with guidance to develop technical contributions toward LTE standards to support public safety and First Responder Network Authority (FirstNet) requirements. This work advances the development of new public safety communications equipment that will eventually operate on the nationwide public safety broadband network.

SUMMARY

Technology transfer is an essential mission of the Department of Commerce, using 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[48]

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.

Me**asurement** – Includes but is not limited to: measuring linear dimensions, measuring distances, surveying, navigation, gyroscopic instruments, measuring volume, weighing, measurement of mechanical vibrations, measurement of intensity or velocity, measuring temperature or quantity of heat, measuring force, testing static or dynamic balance of machines or structures, sampling, investigating strength properties of solid materials by application of mechanical stress, investigating density or specific gravity of materials; investigating flow properties of materials, investigating or analyzing materials by use of optical or thermal means, and investigating or analyzing materials by the use of nuclear magnetic resonance, electron paramagnetic resonance or other spin effects.

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[48] 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 (http://web2.wipo.int/classifications/ipc/ipcpub/#refresh=page).

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[49]

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

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[49] 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.