Annual Report on Technology Transfer: Approach and Plans, Fiscal Year 2016 Activities and Achievements

U.S. Department of Commerce

Report prepared by:

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

Pursuant to the
Technology Transfer 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's) Federal laboratories for fiscal year (FY) 2016. 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's) 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. Pursuant to the Presidential Memorandum – Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses (October, 2011), this report contains significantly expanded metrics on technology transfer from previous editions.

DOC's overall and laboratory-specific approaches and its plans for technology transfer are summarized within this report. The report focuses on current year activities and accomplishments and provides statistical information from FY 2012 through FY 2016.

NIST, NOAA, and 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.

The Presidential Memorandum (PM) – *Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses* of October 21, 2011 further expanded DOC's role in coordinating technology transfer activities across Federal agencies.[2] The purpose of this PM is to foster innovation by increasing the rate of technology transfer leading to a greater economic and societal impact from Federal investments in R&D.

The PM directs agencies with Federal laboratories to establish goals to measure performance, streamline administrative processes, and facilitate local and regional partnerships in order to accelerate technology transfer and support private sector commercialization. The aim is to increase significantly the successful agency technology transfer and commercialization activities, while simultaneously achieving excellence in each agency's research activities. Section 2 of the PM specifically requires that "[t]he Secretary of Commerce, in consultation with other agencies, including the National Center for Science and Engineering Statistics, shall improve and expand,

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[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 Interior, Department of Transportation, Department of Veterans Affairs, Environmental Protection Agency, and National Aeronautics and Space Administration.

[2] http://www.whitehouse.gov/the-press-office/2011/10/28/presidential-memorandum-accelerating-technology-transfer-and-commerciali

where appropriate, its collection of metrics in the Department of Commerce's annual technology transfer summary report, submitted pursuant to 15 U.S.C. Section 3710(g)(2)." [3]

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.

[3] For a list of available reports see http://www.nist.gov/tpo/publications/doc-annual-reports-techtransfer.cfm

Summary of Technology Transfer Activities FY 2012 – FY 2016

This annual report provides comprehensive statistics on the technology transfer activities of DOC laboratories, including information regarding invention disclosures, intellectual property (patents/licenses), collaborative research and development agreements (CRADAs), and other technology transfer mechanisms. Examples of successful downstream results (e.g., 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 to Congress the results of its technology transfer activities. Office of Management and Budget Circular A-11 also requires this information. The tables in the following sections present the required data.[4]

Invention Disclosures and Patenting

In FY 2016, DOC researchers disclosed 55 new inventions. Of these, 46 invention disclosures were from NIST researchers and 9 were from NOAA researchers. There were 25 patent applications filed (21 for NIST and 4 for NOAA) and 12 patents issued (11 for NIST and 1 for NOAA).[5]

Table 1 – Invention Disclosure and Patenting

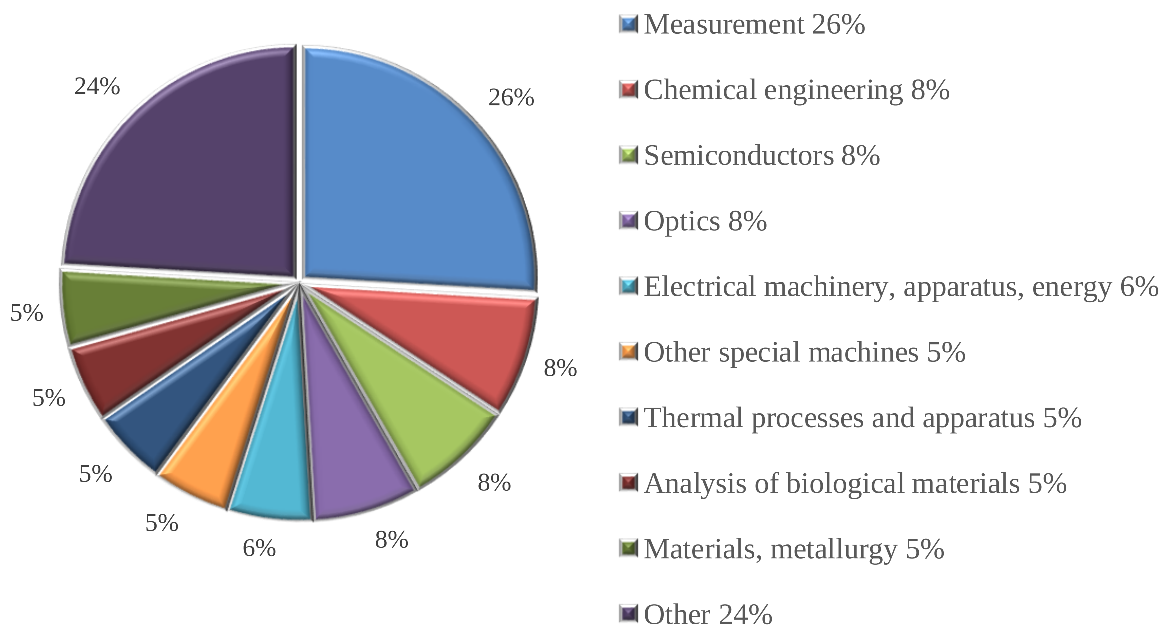
	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Invention Disclosures					
NIST	52	33	41	46	46
NOAA	8	8	6	15	9
ITS	0	0	0	0	0
Department Total	60	41	47	61	55
Patent Applications Filed					
NIST	24	23	21	26	21
NOAA	3	3	4	6	4
ITS	0	0	0	0	0
Department Total	27	26	25	32	25
Patents Issued					
NIST	12	20	19	19	11
NOAA	1	1	0	1	1
ITS	0	0	0	0	0
Department Total	13	21	19	20	12

[4] 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 2016 has been adjusted, where necessary, to reflect the most accurate estimates for each year reported.**

[5] Note that the time required for a patent to be granted may take two years or more. Patents issued in FY 2016 were filed in prior years.

In addition to reporting on the number of patents issued, the National Science Foundation (NSF) provides additional insight into the technology areas addressed by DOC patents.[6] In FY 2015 (the latest year available), 26% of the patents issued to DOC were in the technical area of Measurement Techniques and Instruments. This includes techniques and use of instrumentation that measures, tests, inspects or analyzes a wide variety of materials or processes.[7]

Figure 1 – Percent of USPTO Patents Granted to DOC, by Technology Area – FY 2015



[6] NSF routinely researches a wide range of data for its publication "Science and Engineering Indicators" http://www.nsf.gov/statistics/. NIST requested that NSF provide the data in Figure 1 and this complies with NSF's goal of supporting agencies in their tasks of enhancing the measurement of technology transfer activities.

[7] 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. Source: Prepared by Science-Metrix using USPTO data indexed in PATSTAT Spring 2016 edition (European Patent Office). Used with permission.

Licensing

In FY 2016, DOC reported 57 active patent licenses, the largest number in the last five fiscal years. Of these, NIST had 50 active patent licenses and NOAA had seven active patent licenses.

Table 2 – Profile of Active Licenses

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Active Patent Licenses[(a)]					
NIST	36	33	33	40	50
NOAA	5	5	5	6	7
ITS	0	0	0	0	0
Department Total	41	38	38	46	57

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

Of the 57 active patent licenses, 33 were income-bearing licenses. Of these income-bearing licenses, 20 were exclusive licenses and 13 were non-exclusive.

Table 3 – Characteristics of Income-Bearing Licenses

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total Income-Bearing Licenses					
NIST	20	21	21	25	26
NOAA	3	5	5	6	7
ITS	0	0	0	0	0
Department Total	23	26	26	31	33
Patent Licenses					
NIST	20	21	21	25	26
NOAA	3	5	5	4	7
ITS	0	0	0	0	0
Department Total	23	26	26	29	33
License Types					
Exclusive					
NIST	10	13	14	15	16
NOAA	0	0	0	1	4
ITS	0	0	0	0	0
Department Total	10	13	14	16	20
Partially Exclusive					
Department Total	0	0	0	0	0
Non-Exclusive					
NIST	8	7	7	10	10
NOAA	3	5	5	3	3
ITS	0	0	0	0	0
Department Total	11	12	12	13	13

In FY 2016, DOC's income-bearing licenses provided $148,662 in income. Of this amount, $137,662 came from NIST licenses and $11,000 came from NOAA licenses.

Table 4 – Income from Licensing

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total Licensing Income					
NIST	$146,796	$102,532	$150,995	$124,823	$137,662
NOAA	$100,867	$48,798	$69,151	$39,633	$11,000
ITS	$0	$0	$0	$0	$0
Department Total	$247,663	$151,330	$220,146	$164,456	$148,662

Collaborative Relationships for Research and Development (CRADAs)
In 2016, there were 2,994 CRADAs involving DOC researchers, the largest number in the last five fiscal years. There were 389 traditional CRADAs[8] and 2,605 non-traditional CRADAs.[9] Of the 389 traditional CRADAs, NIST was involved in 294, NOAA was involved in 33, and ITS was involved in 62. These traditional CRADAs included 54 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 2012	FY 2013	FY 2014	FY 2015	FY 2016
CRADAs					
Department Total	2,411	2,437	2,307	2,752	2,940
Traditional CRADAs					
NIST	140	179	206	329	294
NOAA	10	15	19	28	33
ITS	61	91	87	136	62
Department Total[(a)]	154	206	233	365	335
Joint CRADA Agreements (NIST and ITS)	57	79	79	128	54
Non-Traditional CRADAs					
NIST	2,255	2,231	2,074	2,387	2,605
NOAA	0	0	0	0	0
ITS	2	0	0	0	0
Department Total	2,257	2,231	2,074	2,387	2,605

(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.

[8] Traditional CRADAs involve collaborative research and development projects by a Federal laboratory and non-Federal partners.
[9] 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 2012. 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 2013, we divide the number of patents issued in FY 2013 by the number of patents issued in the base year (FY 2012) and then multiply by 100. Using data from the table on page 3 of this report, the index value for patents issued in FY 2012 is 162.

$$Index\ Value_{FY2012} = \frac{21}{13}\ x\ 100 = 162$$

Because the index value of 162 is greater than 100, we can interpret this as a 62% increase in the number of patents issued between FY 2012 and FY 2013. In FY 2014, the index value for patents issued is 146 which we can interpret as a 46% increase between FY 2012 and FY 2014.

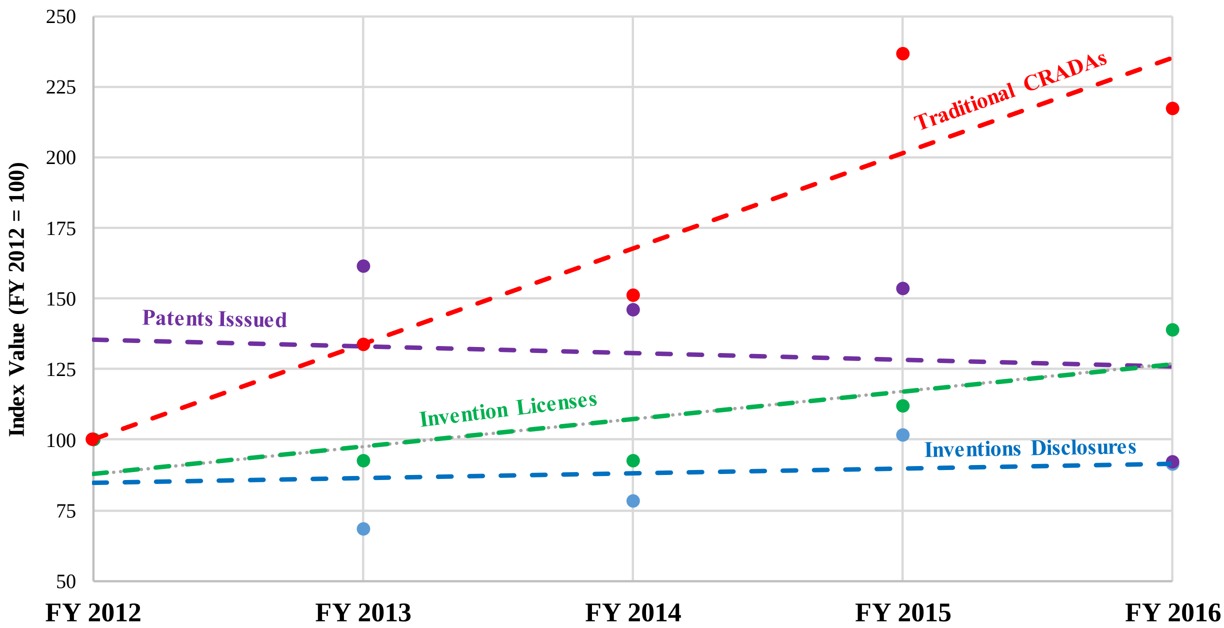
We calculate index values for key metrics (e.g., invention disclosures, patents issued, invention licenses, and CRADAs) and plot the values in the chart below. To show the trend for a given metric, a straight line is plotted in the middle of the plotted values for that metric.[10] In the chart below, 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 over this time

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

period there has been a slight increase in the trend for invention disclosures, a more significant increase in the trends for invention licenses and traditional CRADAs and a decrease in the trend for patents issued.

Figure 2 – Trends in DOC's Technology Transfer Activities (FY 2012 – FY 2016)



Scientific and Technical Publications

Technology transfer mechanisms include more than just counting CRADAs, patents, and licenses. [11] Scientific and technical publications also can lead to technology transfer. In FY 2016, NIST, NOAA, and ITS researchers published 3,056 scientific and technical papers in peer-reviewed journals.

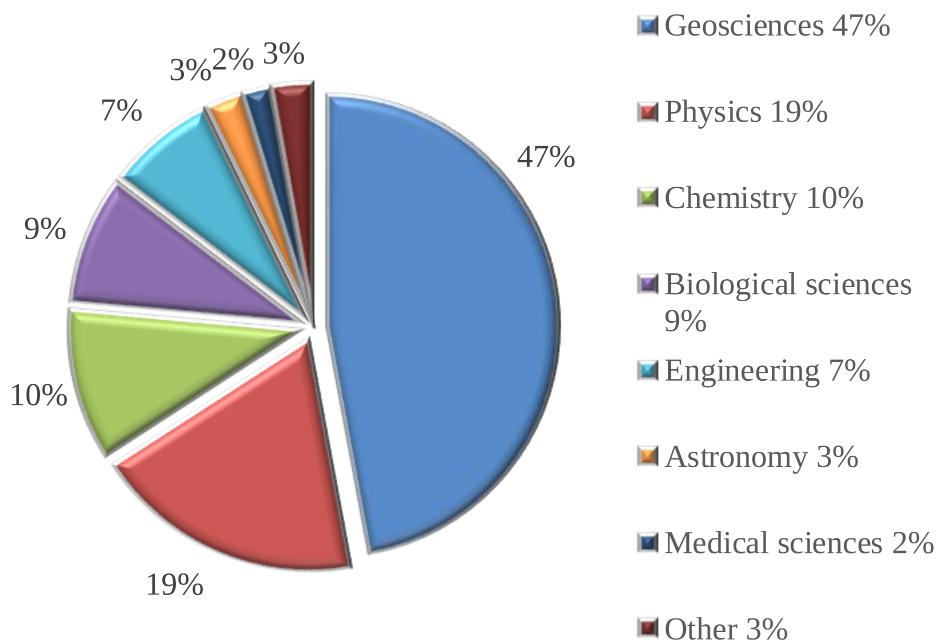
Table 6 – Scientific and Technical Publications

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Technical Publications					
NIST	1,335	1,393	1,359	1,323	1,355
NOAA	1,769	1,781	1,759	1,860	1,697
ITS	13	24	18	22	4
Department Total	3,117	3,198	3,136	3,205	3,056

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

In addition to the number of publications reported by each agency, NSF provides insight into the technology areas addressed by each Federal agency in its publications. Using data from Thomson Reuters' Science Citation Information (SCI)[12] and Social Sciences Citation Index (SSCI)[13] databases, NSF finds that, for FY 2015, the most recent year available, the largest technology areas shown in Figure 3 covered by DOC publications are Geosciences (47%), followed by Physics (19%) and Chemistry (10%).

Figure 3 – Percent of Articles by Technology Area Authored by DOC Staff in FY 2015[14]



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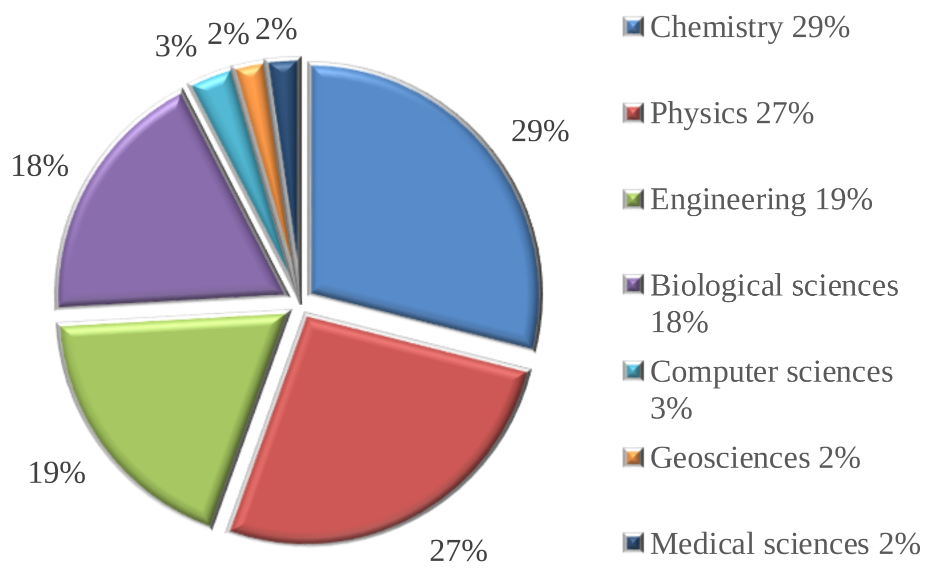
[12] http://ip-science.thomsonreuters.com/cgi-bin/jrnlst/jloptions.cgi?PC=K
[13] http://thomsonreuters.com/social-sciences-citation-index/
14 Data are presented by calendar year as month of publication is not always available in the Web of Science. Article counts are from the set of journals covered 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 2015 cite 826 publications authored by DOC researchers. As shown in Figure 4, the largest technology areas citing DOC publications include Chemistry (29%), followed by Physics (27%), Engineering (19%), and Biological Sciences (18%).

Figure 4 – Percent of Articles by Technology Area Authored by DOC Staff and Cited in U.S. Patents in 2015[15]



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

[15] 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. Source: Prepared by Science-Metrix using the Web of Science (Thomson Reuters), PATSTAT Spring 2016 edition (European Patent Office) and PatentsView (Accessed in December 2016) databases. 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.[16]

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

[16] 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/climate, information technology, manufacturing, materials science, nanotechnology, public safety and security, and transportation.

In FY 2016, there were 50 active NIST patent licenses of which 12 of these licenses were issued in FY 2016. Of these active licenses, 14 licenses were issued to small companies (i.e., companies with less than 500 employees).

Table 7 – Profile of NIST's Active NIST Licenses

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total Number of Active Licenses[(a)]	36	33	33	40	50
New Licenses Executed	6	7	7	11	12
Total Invention Licenses Active	36	33	33	40	50
New Invention Licenses Executed	6	7	7	11	12
Total Patent Licenses Active[(b)]	36	33	33	40	50
New Patent Licenses Executed	6	7	7	11	12
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	2	7	7	4	14

(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 2016, the average time to negotiate a patent license was 5 months. The minimum time to negotiate a license was less than 1 month (6 days) and the maximum time was 14 months.

Table 8 – Licensing Management

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
License Negotiation Time (Patent Licenses) [(a)(b)]					
Average (months)	2.9	6.0	4.0	7.0	5.0
Minimum (months)	2.4	2.3	0.2	0.2	1.0
Maximum (months)	5.5	13.5	17.3	38.7	14.0
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 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total Income Bearing Licenses	20	21	21	25	26
Exclusive	10	13	14	15	16
Partially Exclusive	0	0	0	0	0
Non-Exclusive	6	5	5	8	8
Total Other Income Bearing IP Licenses[(a)]					
Assignment	2	1	1	1	1
Custody Transfer	2	2	1	1	1
Total Income Bearing Invention Licenses	20	21	21	25	26
Exclusive	10	13	14	15	16
Partially Exclusive	0	0	0	0	0
Non-Exclusive	6	5	5	8	8
Total Other Income Bearing IP Licenses					
Assignment	2	1	1	1	1
Custody Transfer	2	2	1	1	1
Total Royalty Bearing Licenses	20	21	21	25	26
Total Royalty Bearing Invention Licenses	20	21	21	25	26
Royalty Bearing Patent Licenses	20	21	21	25	26
Other Royalty Bearing IP Licenses	0	0	0	0	0

(a) Includes licenses to pending patent applications.

In FY 2016, NIST received $137,662 from all active licenses. The median amount received was $5,295. The minimum amount received was $62 and maximum was $40,000.

Table 10 – Income from Licenses

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total Income, All Active Licenses[a]	$146,796	$102,532	$150,995	$124,823	$137,662
Invention Licenses (Patent Licenses)[b]	$146,796	$102,532	$150,995	$124,823	$137,662
Other IP Licenses, Total Active	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)[c]	$146,796	$102,532	$150,995	$124,823	$137,662
Median ERI	$9,971	$10,000	$6,250	$1,600	$5,295
Minimum ERI	$1,500	$640	$640	$640	$62
Maximum ERI	$64,185	$58,642	$74,575	$62,833	$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)	$146,796	$102,532	$150,995	$124,823	$137,662
Median ERI	$9,971	$10,000	$6,250	$1,600	$5,296
Minimum ERI	$1,500	$640	$640	$640	$62
Maximum ERI	$64,185	$58,642	$74,575	$62,833	$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, 33% ($45,148) was distributed to the NIST inventor and the remaining 67% ($92,514) was retained by the NIST inventor's Operating Unit.

Table 11 – Disposition of Invention License Income

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total Income Received[a]	$146,796	$102,532	$150,995	$124,823	$137,662
Invention Licenses (Patent Licenses)[b]					
Licensing Income to Inventor(s)	$61,300	$38,732	$54,602	$44,936	$45,148
	42%	38%	36%	36%	33%
Licensing Income to NIST	$85,497	$63,799	$96,393	$79,887	$92,514
	58%	62%	64%	64%	67%

(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).[17]

In FY 2016, NIST was involved in a total of 2,899 active CRADAs; 294 were traditional CRADAs[18] and 2,605 were non-traditional CRADAs.[19] There were 2,586 new NIST CRADAs. Of these, 89 were traditional and 2,497 were non-traditional.

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

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

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

Table 12 – NIST Collaborative Relationships for Research and Development

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NIST CRADAs					
Total Active CRADAs	2,916	2,410	2,280	2,716	2,899
New CRADAs Executed	2,810	2,252	2,092	2,481	2,586
Total Active Traditional CRADAs	140	179	206	329	294
New Traditional CRADAs Executed	53	48	50	143	89
Total Active Non-Traditional CRADAs	2,255	2,231	2,074	2,387	2,605
New Non-Traditional CRADAs Executed	2,236	2,204	2,042	2,338	2,497

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 2016, NIST staff authored 1,355 publications in peer-reviewed journals,[20] including 329 papers (24.0%) 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 10 percentile in its *Web of Science* Subject Category.[21] NIST researchers collaborated and co-authored with researchers from around the world. NIST researchers co-authored papers with 5,116 unique non-NIST authors from 1,037 unique institutions in 46 countries.[22]

[20] http://nvl.nist.gov
[21] For additional information see http://wokinfo.com/essays/journal-selection-process
[22] 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.

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

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Number of NIST Papers	1,335	1,393	1,359	1,323	1,355
Number of NIST Papers in Top-Tier Journals	369	436	444	384	329
Percentage of NIST Papers in Top-Tier Journals	28%	31%	33%	29%	24%
Number of Unique Non-NIST Co-Authors	n.a.	3,920	4,086	4,585	5,116
Number of Unique Institutions	n.a.	922	965	1,003	1,037
Number of Countries	n.a.	53	62	63	46

n.a. = not available.

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.[23]

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 at least one study concluded the following: 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.[24]

One mechanism used to transfer NIST measurement-science research and other technologies for market use is through participation in the development of consensus documentary standards.

During FY 2016, 445 members of NIST staff were involved with more than 120 standards organizations. Such participation helps NIST respond programmatically 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).[25]

[23] http://www.nist.gov/public_affairs/tech-beat/index.cfm
[24] 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
[25] http://gsi.nist.gov/global/index.cfm/L1-1

Table 14 – Participation in Documentary Standards

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Number of Participating NIST Staff	n.a.	400	464	469	445
Number of Standard Organizations with NIST Participants	n.a.	100	121	165	120

The NIST Standards Coordination Office (SCO) maintains the Standards Committee Participation Database for employees to self-report their involvement, 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

The 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.[26]

NIST laboratories conducted data evaluations and supplied the results to NIST customers through the Standard Reference Data Program. In FY 2016, NIST SRD distributions included 2,689 e-commerce orders, 10,573 units sold via distributor, 124 active distributor agreements, 59 active site licenses, 49 active internet subscriptions, 311 units shipped to the user, and 6,208 products downloaded from the NIST website (4,083 free downloads, 2,125 paid downloads).

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

Table 15 – Standard Reference Data Program

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Standard Reference Data					
Products available (databases)	111	120	111	111	102
E-Commerce Orders	2,628	2,658	3,111	2,596	2,689
Units Sold via Distributor	4,446	5,495	5,142	9,807	10,573
Active Distributor Agreements	52	62	101	123	124
Active Site Licenses	15	30	58	57	59
Active Internet Subscriptions	59	50	42	38	49
Units Shipped via UPS	547	430	595	418	311
Products Downloaded from the NIST Website	1,951	2,055	3,435	5,751	6,208
Free Downloads	1,137	1,399	1,352	3,615	4,083
Paid Downloads	1,951	2,055	2,083	2,136	2,125

(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.[27] In FY 2016, NIST made available 1,194 SRMs and from these, sold 31,938 units.

Table 16 – Standard Reference Materials

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Standard Reference Materials					
Units Available	1,298	1,299	1,281	1,240	1,194
Units Sold	33,441	32,267	32,636	33,490	31,938

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 are a vibrant means by which NIST customers can 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 nanotechnology. The NCNR is a national center for research using thermal and cold neutrons.

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

Many of its instruments rely on intense beams of cold neutrons emanating from an advanced liquid hydrogen moderator.[28]

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 2016, there were 2,856 research participants at CNST and 2,536 at NCNR.

Table 17 – NIST Research Participants

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NIST Research Participants					
CNST [(a)]	1,669	1,885	2,147	2,434	2,856
NCNR	1,976	2,148	2,271	2,436	2,536

(a) The FY 2016 Research Participant totals for CNST are preliminary.

[28] http://www.nist.gov/user-facilities.cfm

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.[29] For the purpose of this report, NIST uses the NSF's description of a postdoctoral researcher[30] 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 2016, there were 167 NIST postdocs. Of these, 104 were located on the NIST campus in Gaithersburg, Maryland, 43 were located in Boulder, Colorado, and the remainder were located at five other NIST locations.

Table 18 – Postdoctoral Researchers

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NIST Postdocs, Total (NCR)	130	140	172	174	167
Gaithersburg campus	84	88	115	113	104
Boulder campus	28	32	35	49	43
Joint Institute for Laboratory Astrophysics (a)	12	11	9	5	9
Joint Quantum Institute (b)	2	4	3	2	2
Hollings Marine Laboratory (c)	1	2	1	2	2
Institute for Bioscience and Biotechnology Research (d)	2	1	4	3	3
Advances in Biological and Measurement Science program (e)	1	2	5	5	4

(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 Advances in Biomedical Measurement Science program (ABMS) 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. https://sites.stanford.edu/abms/

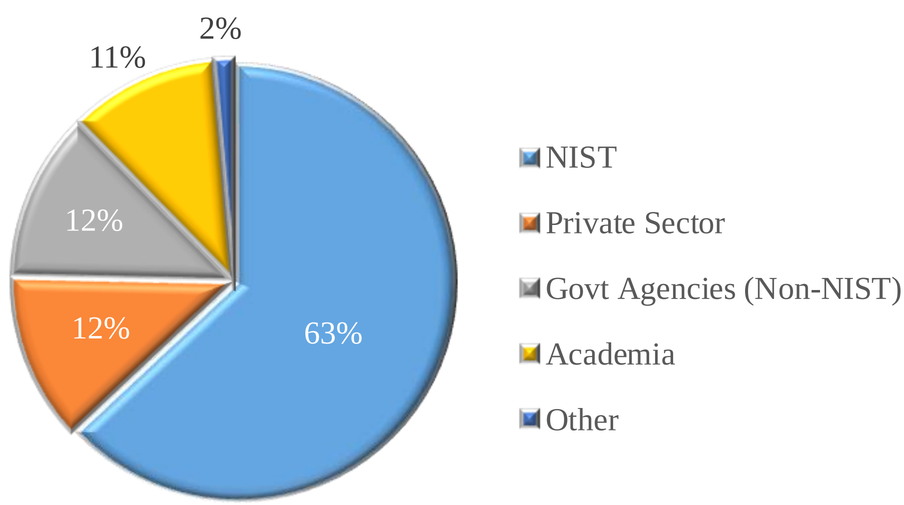
The number of postdocs is a measure of technology transfer because once their tenure at NIST ends they can take what they have learned and apply it to other projects outside of NIST. This is

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

[30] http://www.nsf.gov/statistics/seind12

supported by efforts NIST has begun to track postdocs after their initial tenure at NIST. NIST surveyed 73 researchers who were postdocs with the NIST National Research Council (NRC) program in FY 2016. More than half of these postdocs (63%) continued research careers with NIST,[31] 12% moved to the private sector, 12% moved to other government agencies, 11% moved to academia and 2% either became independent researchers or were unemployed. As more data becomes available, NIST will employ advanced research tools, such as those utilized in the National Institute of Health's (NIH) Star Metrics Program,[32] to track and evaluate the post tenure work of postdocs from NIST.

Figure 5 – Tracking Researchers after Initial Postdoc Tenure at NIST (FY 2016)



Guest Researchers

In addition to postdocs, each year, thousands of researchers visit NIST to participate in collaborative projects.[33] 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.

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[31] Researchers who left their postdoc positions and stayed at NIST became career conditional / term employees (85%) or became non-career conditional or term employees, i.e. contractors or guest researchers (15%).

[32] https://www.starmetrics.nih.gov

[33] http://www.nist.gov/tpo/collaborations/guestresearchers.cfm

In FY 2016, there were 3,273 guest scientists and engineers working at NIST.

Table 19 – Guest Researchers

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NIST Guest Researchers					
Number of Guest Scientists and Engineers	2,782	2,963	2,981	3,125	3,273

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.[34] In FY 2016, NVLAP accredited 735 laboratories.

Table 20 – Accreditation Services

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NVLAP Accreditations					
Number of NVLAP Accreditations	732	743	774	726	735

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.[35] In FY 2016, there were 12,971 calibration tests performed by NIST.

Table 21 – Calibration Services

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Calibrations					
Number of Calibration Tests Performed	17,206	14,974	15,401	13,906	12,971

[34] http://www.nist.gov/nvlap/
[35] http://www.nist.gov/calibrations/index.cfm

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

- the Summer Undergraduate Research Fellowship (SURF) program;[36]
- the Summer High School Internship (SHIP) program;[37]
- the Pathways Program;[38]
- the NIST Summer Institute for Middle School Science Teachers;[39] and
- the Professional Research Experience Program (PREP).[40]

In FY 2016, there were 213 students enrolled in the SURF program, 70 students enrolled in the SHIP program, 85 students enrolled in the Pathways program, 20 students enrolled in the NIST Summer Institute for Middle School Science Teachers, and 204 students enrolled in the PREP program.

Table 22 – STEM Education

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
SURF	196	205	203	206	213
SHIP	47	55	60	48	70
Pathways Program	130	98	78	97	85
Summer Institute for Middle School Teachers	n.a.	n.a.	22	22	20
PREP	n.a.	n.a.	134	164	204

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 2016, the NIST Conference Program arranged for 102 conferences that attracted 10,370 researchers to NIST's facilities in Gaithersburg, Maryland and Boulder, Colorado. NIST's

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36 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
37 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
38 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
39 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
40 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. http://www.boulder.nist.gov/bdprepo.htm

Office of Weights and Measures, which promotes uniformity in U.S. weights and measures laws, regulations, and standards, trained 1,223 weights and measures administrators, laboratory metrologists, and field enforcement officials during FY 2016.

Table 23 – Conferences, Seminars, and Workshops

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NIST Conference Center					
Conferences and Workshops	80	86	80	118	102
Attendance	9,104	8,579	9,208	11,490	10,370
Office of Weights and Measures - Metrology Training					
Seminar Attendance	167	446	355	457	342
Webinar Attendance	448	110	133	266	156
Workshop Attendance	n.a.	55	30	27	0
Students	615	633	518	750	725
Total	1,230	1,244	1,036	1,500	1,223

n.a. = not available.

NIST is continuing to collect and retain current information on metrology training and is expanding its efforts in this area to include additional information on training activities NIST conducts for 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 by 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. In FY 2016 our times increased rather than decreased and NIST is taking efforts to address this issue. 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 442 days. The average CRADA approval time was 104 days.

Table 24 – Streamlining

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Streamlining Efforts					
Average Number of Days to Prepare a Patent Application(a)	348	401	456	410	442
Average CRADA Approval Time(b)	145	91	110	65	104

(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 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 2016, NIST issued patent licenses to 14 small businesses. There were 58 small businesses involved in traditional CRADAs and 823 small businesses were involved in non-traditional CRADAs. NIST's non-traditional CRADAs involved 823 small businesses including 12 small businesses involved with material transfer agreements, 223 involved in calibration services and 588 receiving NVLAP certifications. There were also 12 small businesses who received Phase I SBIR awards and 7 small businesses who received Phase II SBIR awards.

Small Business Innovation Research (SBIR)
NIST's Small Business Innovation Research (SBIR) program funds science and technology based small businesses in the U.S. 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.[41] 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%;

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

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. During FY 2016, the Phase I-time period was reduced to 82 days.

Table 25 - Number of Small Businesses Interacting with NIST

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
NIST Licenses	2	7	7	4	14
Number of Small Businesses involved in Traditional NIST CRADAs	20	31	37	68	58
Number of Small Businesses involved in Non-Traditional NIST CRADAs	n.a.	n.a.	733	794	823
Number of Small Businesses involved in Phase I SBIR Awards	8	9	12	14	12
Number of Small Businesses involved in Phase II SBIR Awards	4	5	4	6	7

n.a. = not available.

In addition, NIST reports that 19 other small businesses were engaged in collaborative research activities with NIST. NIST has also identified 49 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 2016.

Technology Transfer Metrics and Impact Studies

In 2012, NIST expanded the reporting of activity metrics and is currently developing tools and techniques to enhance the measurement of technology transfer impacts.

Activity metrics measure the activities or outcomes of a program, i.e., efforts made by a Federal agency to transfer technologies outside of the agency. In this report, activity metrics are basic counts of the number of times an agency uses different transfer mechanisms during a fiscal year, such as the number of patents, licenses, CRADAs, etc. The function of an activity metric is to characterize a technology transfer operation and to show how various processes are functioning over time.[42]

Impact metrics measure things that happen outside of an agency because of the technologies the agency transferred. They are used to assess the performance of technologies and technology transfer operations by quantifying the resulting benefits or net benefits. Impact metrics are

[42] It is important to note that because each Federal agency has a different mission, addresses the needs of different stakeholders, customers and consumers, and pursues the development of different technologies, activity metrics are not effective measures to use when comparing the performance of agencies.

derived from careful studies of a transferred technology's use and demand environment. The demand environment is the environment where the need for the transferred technology is formed, where the technology is utilized, and where economic and societal impacts are generated. It can refer to any number of consumers or end-users, research laboratories, institutes, companies, markets, industries, economic regions, etc.

Impact studies and impact metrics are important tools that are used to evaluate and monitor the efficiency of programs that develop technologies as well as the programs that transfer technologies. There are many different types of impact studies and the appropriate study to use depends on the objective of the study and the nature of the transfer mechanisms and impacts being assessed. Federal technologies that are transferred to commercial enterprises via patent licenses or CRADAs are often assessed with economic impact studies. These studies focus on the net benefits that accrue to commercial developers and consumers of goods or services enabled by the technologies. Economic impact studies can provide an array of different metrics; some measure the return on the government's investment in developing the technologies (e.g., measures of benefit to cost ratios, net present value, internal rate of return, etc.) while others measure the change in economic activity brought about by the technologies (e.g., changes in revenues, costs, employment, tax revenues, etc.).

To provide an effective economic impact study, the impacts being studied must be easily identifiable and measurable. Unfortunately, this is not the case for all impacts resulting from transferred technologies. Impacts resulting from a complex integration of multiple technologies (both federal and non-federal) are not easily assessed because it is not possible to identify and isolate the contribution(s) made by any one technology. Other impacts are hard to measure because technologies are transferred to non-commercial applications, or the impact may be dispersed in an open access manner (e.g. via publications). For these technologies, an alternative approach is to assess impacts in terms of the changes in technical or physical performance. For example, impact studies can be used to measure improvements in fuel efficiency, drug delivery or manufacturing efficiency, enhancements in cyber security or highway safety and navigation, improvements in food production and safety, or efforts to control pollution, traffic congestion, pests or disease. Other technologies may be more suitable to societal impact studies where measures of impact focus on improvements in behavior, training, crime enforcement, safety, security, and quality of life.

It is also important to note that many impacts are dynamic, i.e., they change over time. Because of this, impact metrics are often reported as a range of values over time rather than a single value. And, for any given study, the resulting impact metrics are highly dependent on 1) the nature of the study, 2) the methodology used to assess the impact, 3) the quantity and quality of data, 4) the assumptions used to perform the analysis, and 5) the timing of the study, both in terms of when the impact occurred or is expected to have occurred and when the assessment was made. This means that when an impact is observed and assessed at two different times it is possible to get two different (but appropriate) measures of the size and nature of the impact.

To illustrate this point, consider two impact studies, a forward-looking study performed in 2002 and a retrospective study performed in 2013, that were performed on the same set of technologies transferred from NIST. In 2002, NIST contracted with RTI International[43] to provide an *ex ante* study of the potential economic impacts of a set of international standards. These standards addressed interoperability problems encountered in the exchange of digital product information in the transportation equipment industries and were based on the Standard for Exchange of Product model data (STEP) that provided a suite of standards used by a variety of industries.

Along with other institutions, companies, and academic researchers, NIST made significant contributions to the development of the STEP model, the STEP standard, the integration of STEP functionality into applications, and the adoption of STEP functionality by end users. NIST also participated in several public-private partnerships involving demonstrations and development projects with software developers, industry, and other federal agencies.

The RTI study found that STEP's benefits would accrue to end users through increased interoperability of computer-aided design, engineering, and manufacturing and product data management systems used in the product design supply chain. Using data collected from industry surveys and case studies, RTI prepared an *ex ante* study of STEP's impact as well as NIST's contribution. The 2002 study estimated that the present value of benefits that would accrue to the development and use of STEP between the years 2002 and 2010 would be $1,186 million and the present value of costs would be $104 million. The net present value was therefore estimated to be $1,082 million and the benefit-to-cost ratio would be 11.4 to 1. This indicated that each dollar invested in STEP would likely yield $11.40 in return. For NIST's involvement, the RTI study estimated that in 2002, the present value of benefits would therefore be $206 million and the present value of costs would be $26 million. The net present value would therefore be $180 million and the benefit-to-cost ratio would be 7.9 to 1. So, for each dollar invested in STEP, NIST could expect $7.10 in return.

In 2013, NIST revisited this assessment by contracting with Robert D. Neihus, Inc. (RDN), to reassess the economic impact of the STEP standard.[44] This study provided an *ex post* assessment of STEP's benefits to the U.S. as well as NIST's contribution. This study estimated that the present value of benefits that had accrued due to the development and use of STEP between 2002 and 2010 was $901 million and the present value of costs was $83 million. The net present value was therefore estimated to be $812 million and the benefit-to-cost ratio was estimated to be 10.9 to 1. This means that each dollar invested in STEP yielded $10.90 in return. For NIST's involvement, the RDN study estimated the present value of benefits was $89 million and the present value of costs was $15 million. The net present value was therefore estimated to be $74 million and the benefit-to-cost ratio was estimated to be 5.9 to 1. So, for each dollar invested in STEP, NIST received $5.90 in return.

[43] NIST Planning Report 02-5 Economic Impact Assessment of the International Standard for the Exchange of Product Model Data (STEP) in Transportation Equipment Industries. Prepared by RTI International. December 2002. https://www.nist.gov/sites/default/files/documents/director/planning/report02-5.pdf

[44] Reassessing the Economic Impacts of the International Standard for the Exchange of Product Model Data (STEP) on the U.S. Transportation Equipment Manufacturing Industry. Prepared by: Robert D. Niehaus, Inc. November 2014. http://www.rdniehaus.com/rdn/wp-content/uploads/2015/07/Economic-Impact-of-STEP-on-the-Transportation-Industry.pdf

To compare the results from the RTI and RDN studies, it is necessary to convert the dollar values to reflect the same purchasing power. This is done by adjusting the dollar estimates from the 2001 RTI study to 2013 dollars using the Consumer Price Index[45] so that estimates from both studies are expressed in terms of 2013 dollars. As shown in the table below, the earlier, *ex ante* RTI study estimated net benefits for the overall development and use of STEP to be $1,432 million in 2013 dollars. The later, *ex post* RDN study estimated net benefits were $818 for a difference of $614 million. The benefit to cost ratio for each study was very close with the RTI study forecasting 11.4 to 1 and the RDN study estimating 10.9 to 1.

Economic Returns to STEP ($ million)

	RTI Study (2001)	RDN Study (2013)	Difference
Present Value of Benefits (2013 Dollars)	$1,560	$901	($659)
Present Value of Costs (2013 Dollars)	$137	$83	($54)
Net Present Value (2013 Dollars)	$1,432	$818	($614)
Benefit-to-Cost Ratio	11.4	10.9	(0.5)

The two studies also differed in their estimate of the economic returns from NIST's investment in STEP. The earlier RTI study forecasted a net present value of $237 million when converted into 2013 dollars. The later RDN study estimated the net present value was $74 million for a difference of $163 million. The benefit to cost ratios also differed with the earlier RTI study forecasting a 7.9 to 1 ratio and the later RDN study estimating a 5.9 to 1 ratio.

Economic Returns to NIST from STEP ($ million)

	RTI Study (2001)	RDN Study (2013)	Difference
Present Value of Benefits (2013 Dollars)	$271	$89	($182)
Present Value of Costs (2013 Dollars)	$34	$15	($19)
Net Present Value (2013 Dollars)	$237	$74	($163)
Benefit-to-Cost Ratio	7.9	5.9	(2.0)

The most significant finding from both studies is that the development and deployment of STEP and NIST's involvement overwhelmingly provided significant returns for the U.S. The difference in the estimated impacts can be attributed to several factors, including:

- The difference in the methodology use (i.e., *ex ante* vs. *ex post*).
- The RTI study's projection of a higher adoption rate of STEP, up to 75 percent by 2010 for the aerospace, automotive, and shipbuilding industries. The RDN study used adoption rates that were based on surveys of STEP end-users that showed variable adoption rates (in 2010 of adoption rates were 20.0 percent in the aerospace sector, 6.0 percent in the shipbuilding sector, and 17.4 percent in the automotive sector).

[45] See https://www.bls.gov/data/inflation_calculator.htm

- The difference in some cost estimates including: avoidance costs, mitigation costs, and delay costs.
- The 2008 recession which significantly impacted STEP's development and deployment.

Despite the difference in results, it is clear that at the time the studies were made, both provided appropriate, best estimates for measuring the impact for STEP's development and deployment. From this comparison, it should be clear that unlike activity metrics that are simple counts of transfer activities, impact metrics are far more complex. In order to correctly interpret, compare, and aggregate impact metrics it is important to have an understanding of how the metrics were derived, what assumptions were used in their production, and when they were made.

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.

EIRs offer NIST employees seminars that cover such topics as business formation, funding, protection of intellectual property, and conflict-of-interest issues. EIRs also counsel NIST Post-Doctoral Fellows (postdocs) and other temporary employees on identifying and exploring career opportunities in small and start-up technology-oriented businesses. Additional one-on-one sessions are provided to staff members who have an interest in pursuing efforts to develop a company that will spin out a NIST technology. Over the past two years, more than 20 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 Counsel and from the Department of Commerce Ethics Counsel before undertaking their initiative which is being pursued on their own time.

N-STEP Program

The NIST Science and Technology Entrepreneurship Program (N-STEP)[46] was launched in November 2015 with the goal of providing 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.

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.

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

As of December 2016, TEDCO made a total number of 6 awards.

Challenges

NIST has been increasing its efforts to offer Challenge competitions.[47] In FY 2016, NIST's involvement included the following Challenges:

- NIST, partnering with the National Football League, Under Armour, and General Electric, launched the **Head Health Challenge III** in February 2015 to catalyze the development of advanced materials with improved impact resistance. This multi-phased Challenge is ongoing with the grand prize winner to be announced early 2017.
- In September, 2016, NIST's Technology Partnerships Office launched the **Federal Impact Assessment Challenge** in collaboration with the Journal of Technology Transfer to stimulate new impact assessments of technology transferred from the Federal government.
- NIST's Information Technology Laboratory launched the **Post-Quantum Crypto Challenge** in support of the computer security division's mission.
- The Reference Data Challenge occurred in summer 2015 to spur the development of mobile applications using NIST scientific reference data as part of its ongoing effort to modernize availability and use of NIST data. The prizes were awarded in the early FY 2016.
- NIST's Public Safety Communications Research (PSCR) division of CTL launched an **Innovation Accelerator** in FY 2016 with a mission to advance broadband communication technologies for use by the public safety responders. In February 2012, Congress enacted the middle-class tax reform and job creation act. The legislation contains landmark visions for the development and build out of the new nationwide public safety broadband network ("the Network"), a dedicated interoperable network for emergency responders. The Public Safety trust fund was established to support the design implementation of the network. The PSCR has been given the lead at NIST to plan and execute the $300 million Public Safety trust fund allocations to establish a research and development program to support the development and deployment of the network. A significant portion of the funds will go toward prize and challenge competitions starting in the fiscal year 2017 through 2022.

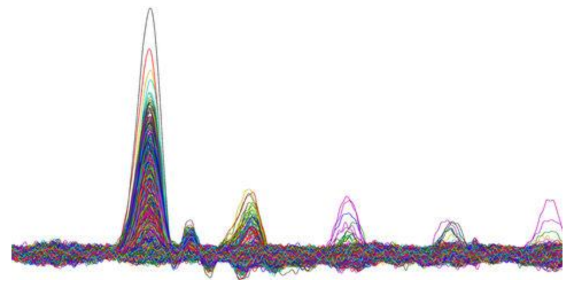
  PSCR also entered into an agreement with NASA Center for Excellence in Collaborative Innovation (CoECI) to leverage their contract vehicle to engage crowdsourcing vendors and processes to achieve innovation goals. PSCR will focus on key areas for technology acceleration true prize competitions including: location-based services, mission-critical voice, enhance user interfaces and experiences, and data analytics.

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

Downstream Outcomes from NIST Technology Transfer Activities

NIST Patents Single-Photon Detector for Potential Encryption and Sensing Apps

Individual photons of light now can be detected far more efficiently using a device patented by NIST scientists who have overcome longstanding limitations with one of the most commonly used type of single-photon detectors. Their invention could allow higher rates of transmission of encrypted electronic information and improved detection of greenhouse gases in the atmosphere.

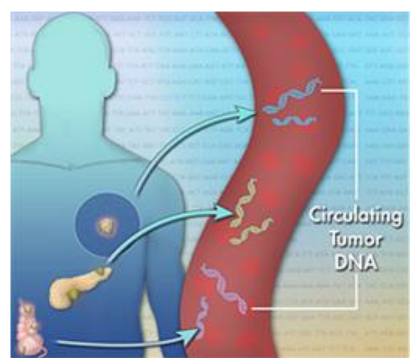


The team, which also includes scientists working at the California Institute of Technology and the University of Maryland, has patented a method to detect the photons that arrive when the gates are either open or closed. The NIST team had developed a highly sensitive way to read tiny signals from the detector, a method that is based on electronic interferometry, or the combining of waves such that they cancel each other out.

The new detector can count individual photons at a very high maximum rate—several hundred million per second—and at higher than normal efficiency, while maintaining low noise. Its efficiency is at least 50 percent for photons in the near infrared, the standard wavelength range used in telecommunications. Commercial detectors operate with only 20 to 30 percent efficiency.

NIST Supports Precision Medicine Diagnostics

NIST efforts to support accurate diagnostic testing so that cancer treatments can be tailored to the tumor DNA and other characteristics particular to individual patients continue to gain momentum, as the agency mounts a multi-laboratory study to evaluate candidate reference materials for benchmarking measurements of circulating tumor DNA, so-called liquid biopsies.



Credit: National Human Genome Research Institute

The comparative exercise, sometimes referred to as an inter-laboratory "round robin", benefits from a new three-year CRADA with SeraCare Life Sciences, Millford, Massachusetts. Under the agreement, SeraCare will supply its circulating DNA reference material technology to NIST to help further development and refinement of digital measurement methods. NIST will distribute these materials for testing at laboratories in the National Cancer Institute's Early Detection Research Network and to other research and testing organizations.

Reliably accurate measurements are critical to the successful introduction and adoption of liquid biopsies for clinical applications, which include monitoring therapeutic progress and detecting drug resistance mutations.

An Extraordinary Standard

NIST has issued one of the world's most intricate measurement standards: an exhaustively analyzed antibody protein that the biopharmaceutical industry will use to help ensure the quality of treatments across a widening range of health conditions, including cancers, autoimmune disorders and infectious diseases.

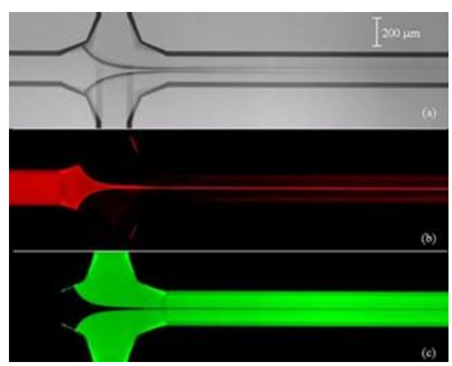
The standard is an antibody protein—consisting of more than 20,000 atoms—analyzed so thoroughly that the material can be used by organizations around the globe to verify and improve their analytical methods for quality control. The new reference material (NIST RM8671) is a monoclonal antibody, or mAb that is produced in the lab by living cells, usually from mouse or hamster cell lines. Uniform in composition and structure, mAbs account for five of the 10 top-selling drugs and over $75 billion in annual sales worldwide. According to one estimate, about 300 monoclonal-antibody-based therapeutics are being evaluated for safety and effectiveness in clinical trials.

Chosen for development in consultation with industry, NIST RM 8671 is an important addition to the toolkits of biological drug manufacturers and their suppliers and regulators. It serves as a representative molecule that can be used to determine that methods for assessing product quality are working properly and to evaluate new methods or technologies. It also provides an industry very mindful of intellectual property concerns with a standard benchmark for everyone, from aspiring startup to multinational firm to regulator.

Industry experts have indicated that the universally available "public" mAb, characterized and distributed by NIST, will allow better assessment of existing analytical methods and potentially faster adoption of new technologies. The utility of this reference material has already been demonstrated by more than 100 collaborators from companies, regulatory agencies and universities around the world.

Newly Patented NIST Technique Creates Precisely Sized Nanocontainers Useful for Drug Delivery

What if doctors could deliver anti-cancer drugs directly to tumors without making patients sick? Bringing this dream of targeted drug delivery closer to reality for pharmaceutical manufacturers, researchers at NIST have received a patent for a method to create precisely sized nanometer-scale capsules.



Credit: A. Jahn, W.N. Vreeland, M. Gaitan, L.E. Locascio/NIST

The NIST method employs microfluidics, the use of fluids at the microscopic level, to create precise nanoscale spherical capsules. Made of lipids, the kinds of biomolecules that also comprise fats, the spherical capsules are known as liposomes. The inside of a liposome could hold drugs, and the outside could be coated with receptors that bind to specific cancer cells. The method can produce liposomes with typical diameters of 100-400 nanometers, or billionths of a meter. This size range is useful for attaching to cells, whose size is typically 1 to 10 micrometers, or millionths of a meter.

Once this technique was developed researchers were able to create a variety of liposomes of many useful sizes and the potential drug-delivery applications became clear. “This research and the resulting patent also have implications for the on-demand formulation of drugs in a way that's applicable to personalized or precision medicine,” said Laurie Locascio, director of NIST's Material Measurement Laboratory.

NIST Expertise and Collaborations Lead to Portable Test Solution for Laser Trackers
A collaboration between NIST researchers and a private-sector firm has led to development of a commercial device to fill a critical need in industry: field verification of laser tracking systems.

Laser trackers are state-of-the-art instruments capable of measuring the dimensions of objects as large as 120 meters in length to high accuracy and with uncertainties as low as 60 micrometers – about half the width of a human hair. Laser-tracker measurements are responsible for ensuring the functionality of millions of dollars in products each day, and are used, for example, in precision measurement of the size, shape, and alignment of aircraft wings during assembly. Performance testing of the tracker systems, which can cost in the neighborhood of $200,000, is difficult because it requires long, high-accuracy, portable reference artifacts that retain their exact dimensions and characteristics over multiple sites and uses.
Thanks to a successful CRADA between NIST's Engineering Physics Division and Brunson Incorporated, a U.S. manufacturer of metrology equipment, such an artifact – the first of its kind – is now a reality. Brunson Incorporated provided the funding, product design, and manufacturing, and PML provided state-of-the-art measurement expertise.

NIST invented the first laser tracker in 1987, and since then has continued research in measurement applications, standardization, uncertainties, and testing. This commercialized product is the latest of many significant achievements in improving the understanding, and therefore the functionality, of laser trackers.

Awards

Consortium Names NIST's May Top Lab Director
The Federal Laboratory Consortium for Technology Transfer (FLC) has named Under Secretary of Commerce for Standards and Technology and National Institute of Standards and Technology (NIST) Director Willie E. May as its Laboratory Director of the Year for 2016. Also recognized by the FLC with a 2016 Excellence in Technology Transfer Award is a NIST engineering team for its development of a computer simulation program that predicts air and contaminant movement within buildings.

Both May and the research trio of engineer W. Stuart Dols, engineer Steven Emmerich and information technology specialist Brian Polidoro were honored at the 2016 FLC National Meeting in Chicago, Ill., during an awards ceremony on April 27, 2016. The FLC is "the formally chartered, nationwide network of over 300 federal laboratories, agencies and research centers that fosters commercialization best practice strategies and opportunities for accelerating federal technologies from out of the labs and into the marketplace."

In selecting May as the top director among all of its federal member organizations, the FLC noted that "technology transfer achievements have grown exponentially" during his service as associate director of laboratory programs, acting director and director of NIST. The FLC also stated that between fiscal year 2013 and fiscal year 2015 "over two-thirds of the nearly 1,000 active tech transfer activities were completed under Dr. May's oversight." Additionally, Dr. May was acknowledged for streamlining and enhancing the procedures by which NIST arranges and manages its Cooperative Research and Development Agreements (CRADAs) with external partners. According to the FLC award summary, May's efforts "have resulted in a tripling of new CRADAs per year from fiscal year 2010 to fiscal year 2014, while reducing the review time required to process each CRADA."

May also conceptualized a new partnership with the state of Maryland to provide up to 10 grants per year to former NIST postdoctoral fellows for commercializing technologies developed during their tenure at the agency.

Other NIST awardees include:

American Institute of Physics

- Jenny Lee: Science Communication Award, Broadcast/New Media Category (2016)

Colorado Governor's Award for High-Impact Research

- Konard Lehnert: Foundational Science and Technology Category (2016)

Institute of Electrical and Electronics Engineers (IEEE)

- Darine Haddad: Technical Award (2016)
- John Kitching: Frequency Control Rabi Award (2016) and Sensors Counsel Technical Achievement Award (2016)
- Ron Goldfarb: Distinguished Service Award (2016)

American Chemical Society

- Stephanie Watson: National Committee Service Award (2016)

Thomson Reuters

- Jun Ye and Deborah Jin: Highly Cited Researchers (2016)

Federal Laboratory Consortium

- Steve Emmerich, Stuart Dols, and Brian Polidoro: Award for Excellence in Technology Transfer (2016)

ASTM International

- Sudarsan Rachuri: President's Leadership Award (2016)
- Bob Chapman: Award for Excellence in Symposium and Publication Management (2016)
- Clarissa Ferraris: Award of Merit (2016)

AmericaMakes

- Shawn Moylan: Distinguished Collaborator Award

Washington Academy of Science

- Piotr Domanski: Engineering Science Award (2016)

CHAPTER 3
National Oceanic and Atmospheric Administration

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

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

NOAA dedicated $560 million, or approximately 10% of the agency's total budget, to R&D in Fiscal Year 2016, with R&D defined as all research and development activities outside of facilities and equipment purchases. This continues a five-year trend of increased R&D expenditures, highlighting NOAA's efforts to keep up with increased stakeholder demand for environmental intelligence and services in the face of a changing planet.

Almost 60 percent of NOAA's FY 2016 R&D budget went to internal R&D efforts, including those at NOAA labs and science centers within the line offices. The remaining 40 percent was set aside for extramural research, enabling partnerships and collaborations with non-NOAA entities. Over the past five years, NOAA has been dedicating an increasing percentage of its resources to extramural research, which shows the importance NOAA places on external partnerships in fulfilling its R&D mission.

Research across NOAA's laboratories is primarily aimed at improving the ability of the operational components to accomplish their respective missions. NOAA's research priorities are outlined each year in a Strategic Research Guidance Memorandum[48] issued by the Office of the NOAA Chief Scientist. Current priorities include:

- Improve and integrate earth system models and predictions
- Optimize observing systems and networks
- Advance data science, management and distribution
- Enhance risk assessment and communication to the public
- Integrate water prediction and decision support capabilities
- Improve understanding of the Arctic environmental system

[48] NOAA Strategic Guidance Memorandum, 2016: http://nrc.noaa.gov/LinkClick.aspx?fileticket=BPiCcAnn18s%3d&portalid=6

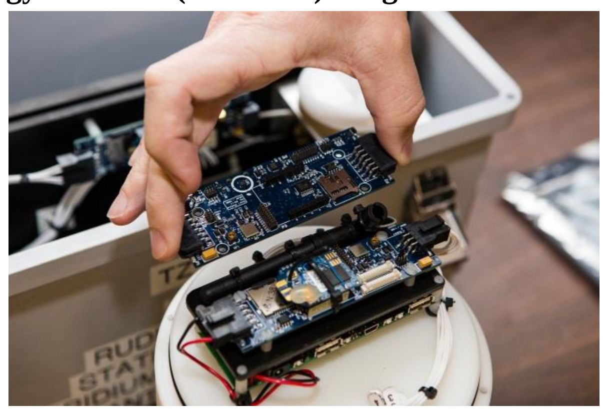
Approach and Plans for Technology Transfer

As required by 15 U.S. Code § 3710, the NOAA Technology Partnerships Office (TPO), housed under the NOAA Office of Oceanic and Atmospheric Research (OAR), serves as the central Office of Research and Technology Applications (ORTA) for all NOAA labs, centers, programs, and external partners. The TPO has the primary mission of facilitating the conduct of, and reporting the results of, NOAA's research to commercialization (R2C) activities.

In FY 2012, in response to President Obama's request to accelerate technology transfer out of federal labs, the TPO developed a 5-Year Plan to improve technology transfer, including R2C from NOAA. The TPO reported on the outcomes of these activities in the 2015 Report to Congress. The TPO is now developing a new technology transfer plan for NOAA, which will be ready for implementation in 2017-2018.

Small Business Innovation Research – Technology Transfer (SBIR-TT) Program

In FY 2016, the TPO began a pilot program to explore offering some of its patented technologies for commercial development through the Small Business Innovation Research (SBIR) Program. This pilot, called SBIR-TT, resulted in two Phase I proposals to develop commercial applications for NOAA's *Smart Module for Communications, Processing, and Interface* technology. TPO has awarded R&D licenses to two U.S. small businesses under this program.



Based on the initial success of this program, NOAA is planning to continue offering some of its patented technologies through this innovative vehicle to support the growth of small businesses in the United States.

2016 Research to Applications/Use (R2A/U) Overview

The majority of NOAA's R&D portfolio is transitioned as research to applications or other uses through various channels and processes including:

- Peer-reviewed publications
- MOUs and non-CRADA agreements
- Cooperative Institutes
- Data portals
- Computer models
- Decision-support tools

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, water conditions, 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 decision support software tools that bring data to the public in a user-friendly format to enable effective decision-support. In many cases these sites are developed in conjunction with academia and private sector partners.

Tools and Expertise Help U.S. Aquaculture Industry Expand

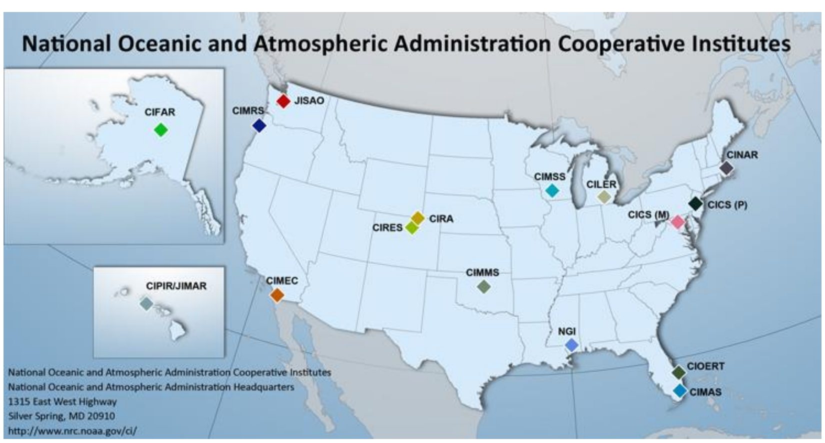
Offshore aquaculture is a promising new frontier for U.S seafood production. However, the growth of this industry has been constrained by concerns regarding negative environmental effects of improperly sited farms. In response to these concerns, NOAA's National Centers for Coastal Ocean Science (NCCOS) and NOAA's Office of Coastal Management partnered to develop a new offshore aquaculture planning tool, CanVis Aquaculture.[49]

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.

Cooperative Institutes

NOAA supports a network of 16 Cooperative Institutes at 42 universities and research institutions across 23 states and the District of Columbia.

Often these Cooperative Institutes are in the same state as a NOAA laboratory and Institute researchers are frequently co-located with NOAA scientists at NOAA labs. The work done through the Cooperative Institutes directly supports NOAA's mission activities and results in similar technology transfer opportunities. NOAA's Technology Partnerships Office works with the technology transfer offices from the Institutes to jointly manage intellectual property and seek out licensing partners.



49 https://coast.noaa.gov/digitalcoast/tools/canvis

Visiting Scientists - International Collaborations

In addition to NOAA's Cooperative Institutes, a number of NOAA labs transfer technology by hosting visiting scientists, both domestic and international. 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 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.

Facilities Use

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/suitability evaluation in operational proving grounds. NOAA maintains 12 individual testbeds related to weather, climate, Arctic 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 Work Products and Collaborative Activities

In FY 2016, NOAA researchers disclosed 18 new inventions bringing the total active NOAA intellectual property portfolio to 65 technologies.[50] NOAA also filed one provisional patent application, three non-provisional applications on technologies, and was awarded one U.S. patent and a patent in China.

Table 26 – Invention Disclosures and Patents

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Invention Disclosures					
Number of new inventions disclosed	8	8	6	15	18
Patents					
Number of U.S. patent applications filed	3	3	4	6	4
Number of U.S. patents received	1	1	0	1	1
Number of foreign patent applications filed	0	0	1	0	0
Number of foreign patents received	0	0	0	0	1

NOAA signed three Patent License Agreements and two Research and Development License Agreements in FY 2016. NOAA now maintains 7 technologies under patent licenses, two technologies under R&D license, and one technology with multiple installation/use licenses.[51] In addition, the TPO has assisted with the successful transfer of 10 technologies to industry through non-license agreements.

[50] Managed technology portfolio is for NOAA intramural research and does not include any technologies that may not have been disclosed to the NOAA Technology Partnerships Office.
[51] License totals do not include patent license agreements for joint inventions managed by third parties.

Table 27– Licenses

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Licenses					
Total Active Licenses	5	5	5	6	7
Total New Licenses	0	0	0	2	3
Income Bearing Licenses					
Total Active Income Bearing Licenses	3	5	5	4	5
New Income Bearing Licenses	0	0	0	3	3
Total Active Invention Licenses	3	5	5	4	7
New Invention Licenses	0	0	0	0	3
Exclusive Licenses	0	0	0	1	4
Partially Exclusive Licenses	0	0	0	0	0
Non-Exclusive License	3	5	5	3	3
Elapsed time for Granting Licenses					
Average (months)	0	0	0	3	9
Minimum (months)	0	0	0	0	5
Maximum (months)	0	0	0	0	14

Table 28 – License Income

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
License Income					
Total License Income	$100,867	$48,798	$69,151	$39,633	$11,000
Total Invention License Income	$100,867	$48,798	$69,151	$39,633	$11,000
Earned Royalty Income (ERI)					
ERI top 1%	$89,965	$36,798	$50,000	$39,633	$7,000
ERI top 5%	$89,965	$36,798	$50,000	$39,633	$7,000
ERI top 20%	$89,965	$36,798	$50,000	$39,633	$7,000
Minimum ERI	$1,000	$1,000	$1,000	$39,633	$1,000
Maximum ERI	$89,965	$36,798	$50,000	$39,633	$7,000
Median ERI	$9,902	$11,000	$13,830	$39,633	$5,000
Disposition of Earned Royalty Income					
Total amount of ERI received	$100,867	$48,798	$69,151	$39,633	$11,000
ERI distributed to inventors	$35,331	$16,740	$22,845	$12,588	$4,000
	35%	34%	33%	32%	36%
ERI distributed to agency or lab	$65,536	$32,058	$46,306	$27,045	$7,000
	65%	66%	67%	68%	64%
Licenses Terminated for Cause	0	0	0	0	0

Cooperative Research and Development Agreements

NOAA's labs, centers and programs executed 9 new CRADAs in FY 2016. Six of these agreements were with small businesses. Factoring in the new and expiring agreements, the total NOAA CRADA portfolio is now 33 active agreements.

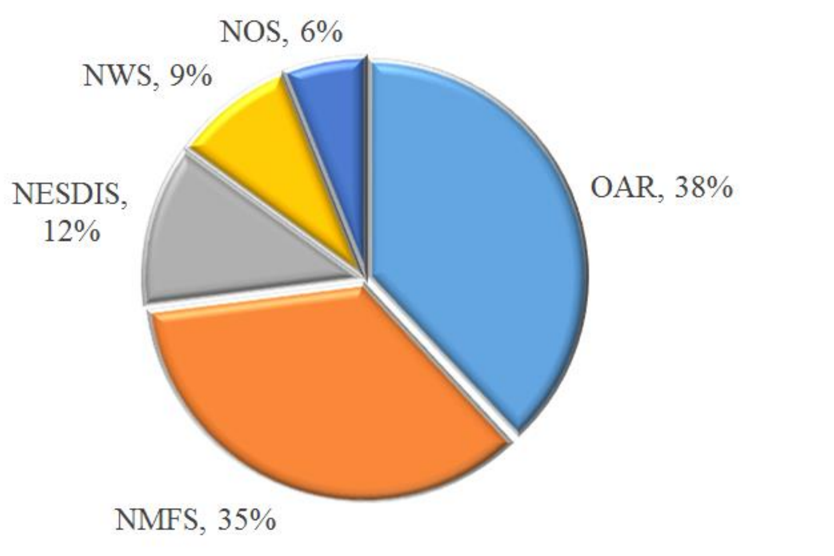
Table 29 – Cooperative Research and Development Agreements

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
CRADAs					
Number of active CRADAs	10	15	19	28	33
Number of newly executed CRADAs	4	7	8	14	9
Active CRADAs with small businesses	0	0	0	0	18
Number of small businesses in active	0	0	0	0	18
Traditional CRADAs					
Active traditional CRADAs	10	15	19	28	33
Newly executed traditional CRADAs	4	7	8	14	9
Non-traditional CRADAs					
Active non-traditional CRADAs	0	0	0	0	0
Newly executed non-traditional CRADAs	0	0	0	0	0

Publications[52]
In FY 2016, peer-reviewed publications by NOAA scientists totaled 1,697. 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.

Figure 6 shows the number of publications per Line Office as a percentage of all NOAA-authored publications in FY 2016. A single publication with authors from one or more Line Office is counted as a publication for each Line Office.

Figure 6 – NOAA Publications per Line Office

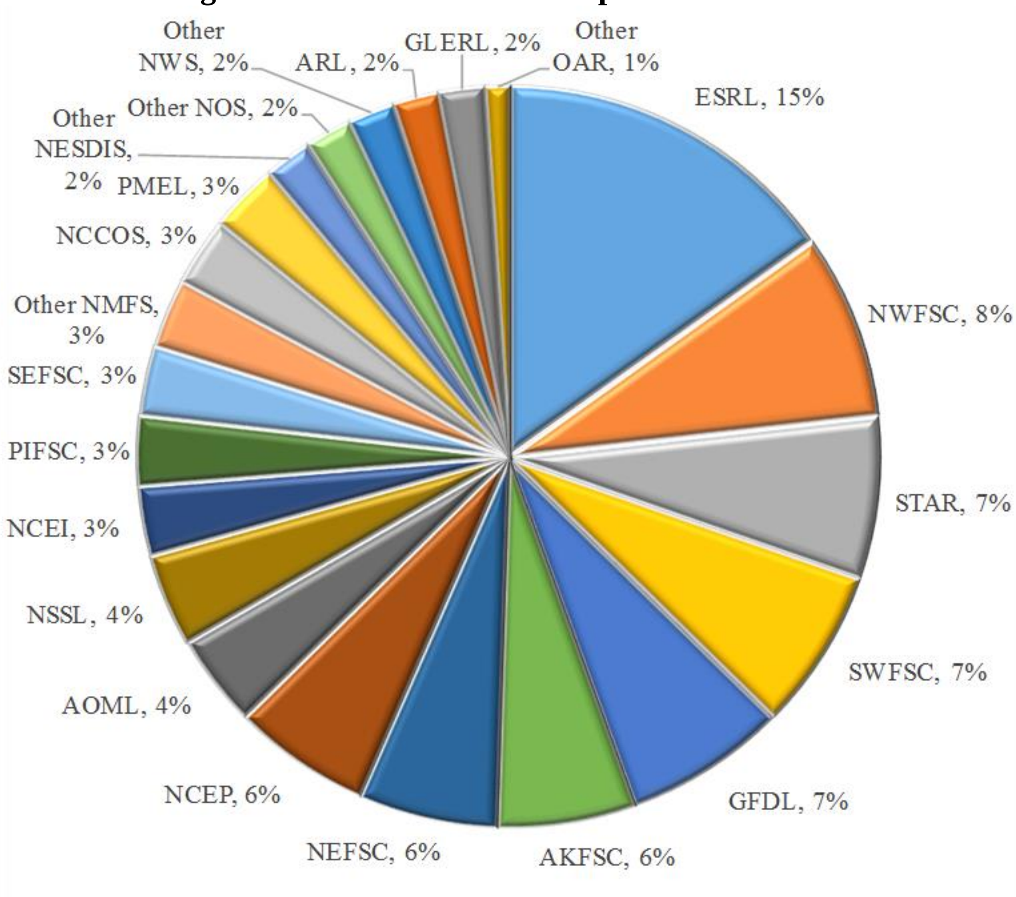


NESDIS	National Environmental Satellite Data and Information Service
NMFS	National Marine Fisheries Service
NOS	National Ocean Service
NWS	National Weather Service
OAR	Oceanic and Atmospheric Research

[52] NOAA publications data for FY 2016 were derived on November 3, 2016, 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 also not included.

Figure 7 shows the number of publications per Line Office as a percentage of all NOAA-authored publications in FY 2016. A single publication with authors from one or more Line Office is counted as a publication for each Line Office.

Figure 7 – NOAA 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 Services
GLERL	Great Lakes Ecosystems Research Laboratory	PIFSC	Pacific Islands Fisheries Science Center
NCCOS	National Center for Coastal Ocean Sciences	PMEL	Pacific Marine Environmental Laboratory
NCDC	National Climate Data Center	SEFSC	Southeast Fisheries Science Center
NCEP	National Centers for Environmental Prediction	STAR	Center for Satellite Applications and Research
NEFSC	Northeast Fisheries Science Center	SWFSC	Southwest Fisheries Science Center
NESDIS	National Environmental, Satellite, Data and Information Service		

Source: Web of Science as of November 3, 2016

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

Figure 8 – NOAA Co-Authored Publications per Institution (Top 15)

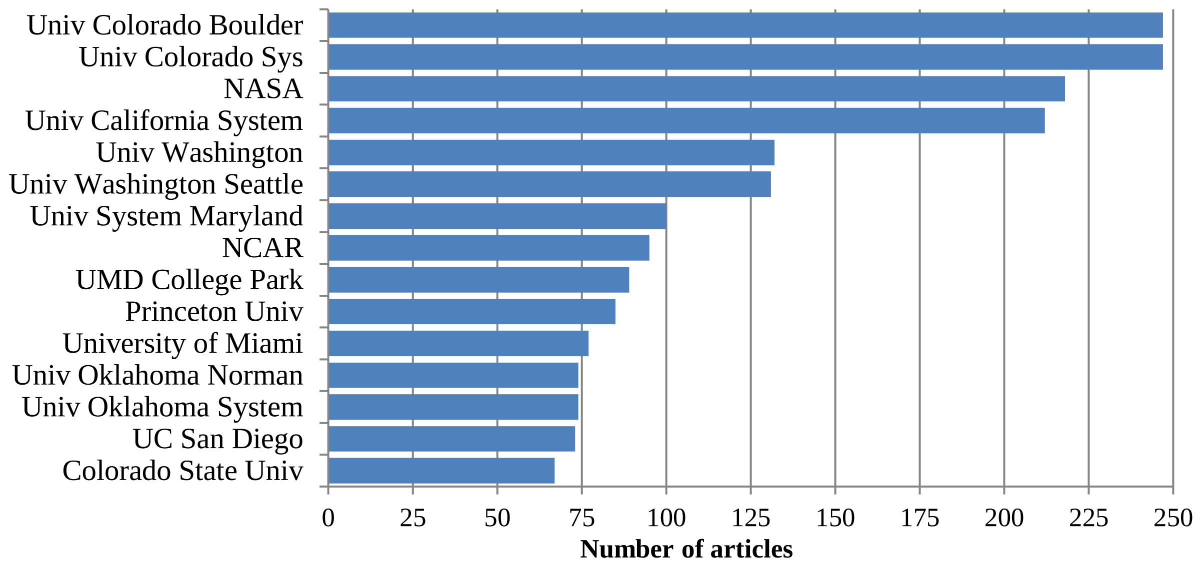


Figure 9 shows the top 15 international collaborators as measured by the number of publications co-authored by authors from NOAA and each nation.

Figure 9 – NOAA Co-Authored Publications per Country (Top 15)

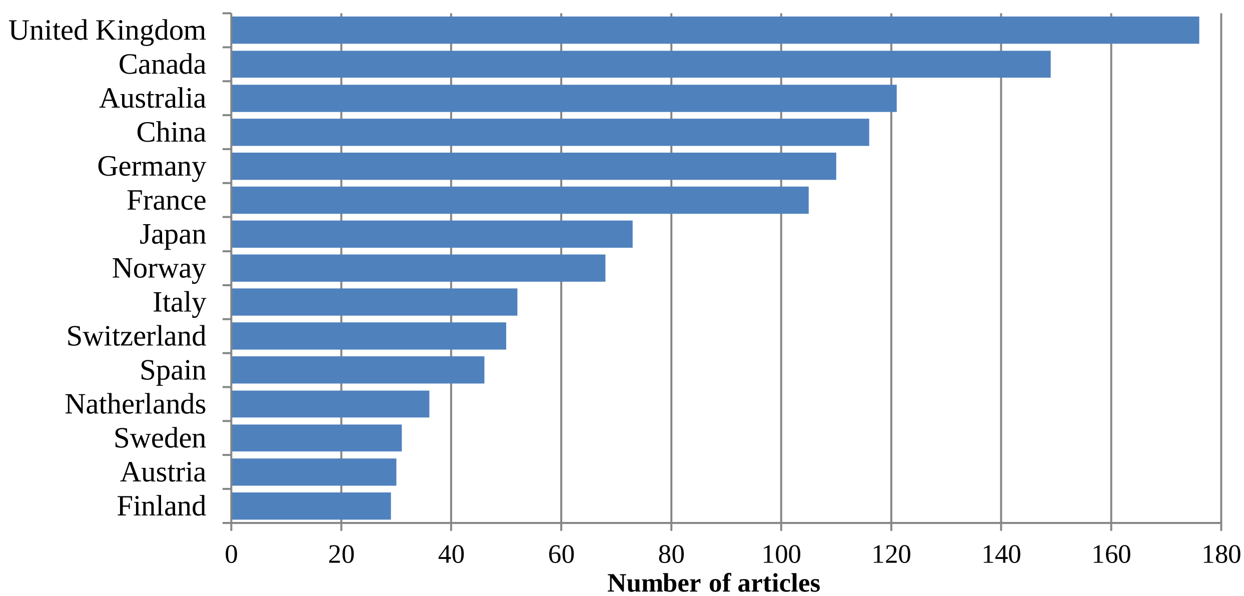


Table 30 -- Small Businesses, Startups, and Young Companies.

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Small businesses supported					
Total number of small businesses supported	n.a.	n.a.	n.a.	n.a.	23
Total number of startup and young companies supported	n.a.	n.a.	1	1	2

n.a. = not available.

Other Activities, Performance Measures Deemed Important by the Agency

Trademark and Copyright[53]

NOAA currently maintains 79 live registered Trademarks, seven of which were either registered or applied for in FY 2016, according to the USPTO Trademark Electronic Search System. NOAA's university partners may copyright portions of jointly developed work, but these instances are rarely reported to the TPO. In FY 2016, there were two reported cases where universities were enforcing their copyrights to jointly developed materials.

Software

In FY 2016, TPO noted an increase in the number of software-based inventions and tools being disclosed. As a result of recent USPTO rulings, TPO has limited the number of non-provisional patents filed on software-based products. At the same time, NOAA's corporate policies regarding software release and commercialization are somewhat fragmented, which may result in an ad hoc and less comprehensive adoption for some of NOAA's software products. TPO will continue to assist with the transfer of NOAA software technology with an eye towards developing a corporate solution for improving NOAA's software dissemination in the future.

Science on a Sphere®

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

[53] TPO began tracking this information in FY 2013 as a new metric. For FY 2016 and future years, we will only report this information in the text and not in the metrics tables.

Table 31 – Science on a Sphere (SOS) Installations

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
SoS Installations					
Total Number in Operation	88	101	110	126	135
New Domestic	4	7	4	6	3
New International	11	6	5	10	6
Total New Installs	15	13	9	16	9

Challenges/Prizes

Shell Ocean Discovery XPRIZE: NOAA Offers $1M Bonus Prize

The Shell Ocean Discovery XPRIZE is a global competition challenging teams to advance deep-sea technologies to allow for autonomous, high-speed, and high-resolution ocean exploration.

The $7 million Shell Ocean Discovery XPRIZE includes a $1 million bonus prize from NOAA for teams that demonstrate technology that can find a specified object in the ocean through biological and chemical signals and trace its source.

"The goal of the $1 million NOAA bonus prize is to aid NOAA's marine resource management responsibilities by identifying technologies capable of detecting and tracking sources of marine pollution, locating deep-ocean hydrothermal vents and methane seeps, and monitoring marine life for scientific research and conservation efforts," said Alan Leonardi, director of the NOAA Office of Ocean Exploration and Research.

A total of 32 teams from 22 countries entered the XPRIZE challenge that will take place in two rounds of testing over the next three years. Of these entries, 21 semi-finalists are moving forward to the first round of testing. These teams have accepted the challenge of mapping the ocean floor and are taking innovative approaches that run the gamut from gliders and drones, underwater robotic swarms to artificial intelligence. Information regarding each team is available at: http://oceandiscovery.xprize.org/teams.

Improving Nutrient Management and Reducing Pollution through Open Innovation Prizes

Launched in December 2014, the Nutrient Sensor Challenge is designed to accelerate the development, production, and use of affordable, reliable, and accurate nutrient sensors. These sensors will enable automated and high-resolution nutrient monitoring in aquatic environments ranging from freshwater lakes and streams to the coastal ocean. Nutrient pollution is one of the nation's most difficult environmental challenges. While nutrients are essential compounds for functioning ecosystems and the production of food, fiber, and livestock feed, excessive nutrient levels can dramatically alter aquatic environments and threaten economic and human health.

For the past two years, the Challenging Nutrients Coalition has been working to facilitate the development of nutrient sensors that will provide the data needed to inform decisions to reduce nutrient loads on land, in the air, and in waterways and to track progress. The Coalition is an extensive collaboration between government agencies (including EPA, NOAA, the United States Geological Survey, and NIST), non-profit research organizations, and academic institutions that deploy open innovation and incentive prize approaches to advance nutrient pollution management and reduction.

To stimulate these new innovations, the Coalition launched the Nutrient Sensor Challenge in collaboration with the Alliance for Coastal Technologies (ACT). The challenge goal was for new, more accurate, precise and reliable technologies to be commercially available by 2017 for a purchase price of less than $5,000 and with other significant savings in cost-of-ownership. After two years of development, and rigorous field and laboratory testing by ACT, the winners were selected by an independent panel of expert judges. Information on the nutrient pollution issue, the Nutrient Sensor Challenge, and the winners can be found at https://ioos.noaa.gov/news/act-nutrient-sensor-challenge-winners-announced/

Downstream Outcomes from NOAA Technology Transfer Activities

CRADA Success: NOAA and Saildrone Chart New Territory for Ocean Science
NOAA Research and NOAA Fisheries have teamed up with academic and private sector partners to test innovative technologies that, if successful, will enable researchers to gather information in areas of the ocean virtually off limits to standard research vessels.

Scientists will be using a novel research platform that resembles a windsurfer, called a Saildrone, developed by Saildrone, Inc. Scientists and engineers equipped two of these autonomous, wind- and solar-powered vessels with other newly designed technologies. Their goal is to collect needed oceanographic data and information for endangered and commercially important species living in remote areas of the Bering Sea.

The Saildrone research platform is equipped with technologies to collect oceanographic data. Photo credit: Saildrone Inc.

"We have high hopes for this mission – that it could mark a new chapter in ocean research," said Christopher Sabine, director, NOAA Research's Pacific Marine Environmental Laboratory. "Last year, we successfully implemented a 3-month testbed Saildrone mission in the Bering Sea to remotely collect data on physical oceanographic conditions via satellite in near real-time. This summer, we are testing other new technologies in the hopes of demonstrating their efficacy for remotely collecting critical biological data."

"As pioneers in this new research frontier we're seeking to discover more cost-effective ways to augment our existing research efforts and gather additional biological information in places that are difficult to navigate with a full-sized research vessel," said Douglas DeMaster, research and center director, NOAA Fisheries' Alaska Fisheries Science Center.

The mission unites scientists and engineers from NOAA, the University of Washington, the Joint Institute for the Study of the Atmosphere and the Ocean, Saildrone, Inc., Simrad AS/Kongsberg Maritime, and Greeneridge Sciences, Inc. The marine mammal related research is possible due to the generous support of the Marine Mammal Commission.

"This advance in technology and science is the result of a sustained partnership between the NOAA laboratories and the University of Washington and reflects the talent and quality of the engineers and scientists involved in the project. Understanding climate change in the Arctic requires new tools and innovative measurements and we are all pleased to be part of that effort. We look forward to the results of this summer's campaign, as well as future measurement campaigns in the Arctic," said Thomas Ackerman, director, Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington.

CRADA Success: Making Better Use of NOAA Data - The NOAA Big Data Project
NOAA's Big Data Partnership (BDP) was established in April 2015 through cooperative research and development agreements between NOAA and Amazon Web Services, Google, IBM, Microsoft and the Open Cloud Consortium. The BDP is investigating how the value inherent in NOAA's data may be leveraged to broaden their utilization and dissemination through the use of modern cloud platforms and associated technologies. The CRADA collaborators work with NOAA experts to identify and deliver those datasets of interest, around which they can build business cases to justify their investments

NOAA's Next Generation Weather Radar (NEXRAD) weather radar data were among the first data to be delivered. The National Centers for Environmental Information (NCEI) transferred the complete NEXRAD Level II historical archive to four interested 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 by October 2015. Through this cloud platform alone, the utilization of the NEXRAD data by volume has increased by 130% over the past usage patterns observed at the National Centers for Environmental Information (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.

SAIC Introduces New Generation of Commercial Tsunami Buoy Systems
Following 10 years of supporting the evolving tsunami buoy network, Science Applications International Corp. (SAIC), in collaboration with NOAA, will soon be deploying commercially available fourth generation (4G) buoy systems worldwide. As a leader in commercial tsunami

buoy systems manufacturing, SAIC is helping to provide the world's tsunami warning centers with access to affordable technology and critical data.

Working with NOAA, SAIC develops, tests, and implements commercial tsunami buoy systems under a NOAA-license agreement. Under this license, SAIC has produced more than 35 second-generation buoy systems based on the NOAA Deep-ocean Assessment and Reporting of Tsunamis II (DART® II) system, and two types of third-generation systems based on the Easy-to-Deploy (ETD) DART® technology.

SAIC's second- and third-generation buoy systems are currently operational in maritime countries worldwide, including Australia, Chile, China, India, Japan, Russia, and Thailand, and are gathering actionable data for its users and NOAA. Recently, SAIC provided developmental 4G payloads and bottom pressure recorders to NOAA in support of a 4G research effort off the coast of Chile.

Now, as SAIC enters another decade of work with NOAA, the company is manufacturing more than 85 percent of the world's commercially deployed tsunami buoys, helping to make the concept of a globally interconnected, tsunami buoy network a reality.

Successful Completion of NE Fisheries Science Center/Envera CRADA
In 2016 NOAA's Milford Laboratory and Envera LLC completed research under their CRADA agreement to explore large-scale production trials of Milford Laboratory probiotic strain OY15 for potential commercialization.

Under the CRADA, Envera provided the Milford Laboratory with freeze-dried and spray-dried formulations of Milford Probiotic Strain OY15, which were analyzed in the lab to see if they stimulate immune functions as well as live OY15. In addition, larval bioassays comparing these two formulations to live OY15 have been run. Future adjustments to the concentrations of these formulations will aid in confirming their probiotic effects on survival of oyster larvae and ideally lead to the commercialization of the Milford Probiotic Strain OY15.

NOAA Tracks Bacterial Contamination to Gulls, Watershed Managers Deploy Falcons
A manuscript was recently published through NOAA's Atlantic Oceanographic Meteorological Laboratory (AOML) that documents a successful technology transfer and subsequent management decisions which were facilitated through a CRADA with Weston Solutions in Carlsbad, CA. The paper describes application of two detection tests, called "assays", which were developed by AOML to identify sources of bacterial contamination, primarily from animal feces.

The assays were applied to a site with chronic water quality failure, a $3B problem for the U.S. annually. Despite a $3M facility to UV-treat watershed flow, remediation was not achieved. In contrast, NOAA's tools aided management by identifying gulls as a key pollutant source. This allowed water quality managers to undertake the relatively inexpensive solution of employing falcons to harass and disburse the gulls from the site. The management action resulted in improved coastal water quality, despite the traditionally poor ability to model environmental bacteria dynamics.[54]

Better Toxin Detection for Harmful Algal Blooms
Toxins produced by harmful algal blooms (HABs) accumulate in marine resources and are a major cause of human seafood poisoning, which impacts subsistence harvests, economic development, and international trade. Tests, known as receptor binding assays, developed by NOAA scientists to measure levels of HAB toxins, have recently been accepted by the Interstate Shellfish Sanitation Conference. This standardized test for regulatory users helps secure the food supply against these potent algal-based toxins and are in various phases of implementation in testing laboratories worldwide.

In Alaska, NOAA scientists trained staff at the Sitka Tribe of Alaska Environmental Regulatory Laboratory on the extraction and detection of HAB-related paralytic shellfish toxins. Implementation of this NCCOS-developed technology by the Sitka tribe will mitigate the threat of toxic shellfish consumption from traditional subsistence shellfish harvesting to members of the Southeast Alaska Tribal Toxins partnership.

The development of HAB toxin detection methods, specifically receptor binding assays, also has a domestic and international component for their implementation. Domestically the use of this method is currently being evaluated by relevant public health agencies in Washington and California. Internationally, NOAA has an agreement with the International Atomic Energy Agency to support the use of this method worldwide.

Awards and Recognition

NOAA Researchers Honored with Federal Laboratory Consortium 2016 Interagency Partnership Award
NOAA researchers Michael Ek (NWS), James Verdin (OAR), Christopher Jackson (NESDIS), and Xiwu Zhan (NESDIS) were honored as part of a broad interagency team working on a USDA/NASA project to build broad user applications for NASA's Soil Moisture Active Passive (SMAP) satellite data. The result of this collaboration was an unprecedented transfer of SMAP technology to users and critical feedback from users to the mission to improve product specifications and distribution for post-launch applications. This was a first-time, one-of-a-kind program that has since been implemented in every NASA Earth Observation mission since SMAP.

NOAA Technology Transfer Awards
NOAA selected two projects to receive the Agency's Technology Transfer Award in 2016. These projects exemplified the highest standard for developing a new technology in cooperation with private sector partners in the service of NOAA's mission.

[54] Source: "Watershed assessment with beach microbial source tracking and outcomes of resulting gull management" K.D. Goodwin, et al. Environmental Science and Technology, http://dx.doi.org/10.1021/acs.est.6b02564, 2016.

Transfer of Geodetic Leveling Technology to Industry
Steve Breidenbach, John Ellingson, Kendall Francher, Charlie Geoghagen, Tim Hanson, Dave Zenk, Brian Ward, National Ocean Service.

For exceptional performance in the design and transfer of procedures and supporting equipment to complete geodetic leveling across wide rivers

NOAA's National Geodetic Survey (NGS) recently developed an alternate method for surveyors and geodesists to perform leveling surveys across rivers, valleys, and other barriers. The new method uses readily available commercial electronic theodolites, which are instruments commonly used for precise astronomical observations. This task previously required government equipment, so stakeholders could not complete the work independently.

The new method addresses sources of error, such as atmospheric refraction and Earth's curvature, that are often encountered during river and valley crossings, as well as instrument and observer errors. The team successfully developed, tested, and transferred procedures and equipment designs to stakeholders that were completing geodetic leveling across wide rivers. This transfer will save time and money for stakeholders.

Transfer of Floating Surface Collectors Technology to Industry
Edward Meyer, National Marine Fisheries Service

For innovative design of floating surface collectors, a major advancement in economical, safe, and effective fish passage for the hydropower industry.

Economical, safe, and effective fish passage has been a significant issue for the hydropower industry from its inception. Development of Baker River's Floating Surface Collectors provides the industry and regulators with design approaches and criteria to meet the challenge of passing fish downstream, past high-head dams. Mr. Meyer's advancements have been transferred to industry and consultants and have been the basis for successful juvenile collection systems at other projects in the Pacific Northwest, including the Cushman and Cowlitz collectors; Swift, River Mill, North Fork Clackamas, and Pelton Round Butte facilities; and the Cougar portable prototype floating collector. The system has attracted attention from resource groups not only along the entire West Coast, but throughout the country, and internationally in regions as diverse as Europe and China.

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. Three-quarters of ITS research programs are undertaken for and with other Federal agencies; state, local and tribal governments; private corporations and associations; or international organizations. 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
- 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 2016, 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, advanced antennas for wireless systems, and remote sensing and global position (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 (DHS) and the Department of Justice (DOJ). Since the First Responder Network Authority (FirstNet) became operational, 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 and are joint with NIST. 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 2016, 54 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 32 – Collaborative Relationships for Research & Development

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
CRADAs					
Number of active CRADAs	62	81	60	56	62
Number of newly executed CRADAs	30	30	11	53	12
Active CRADAs with small businesses involvement	n.a.	17	12	12	17
Number of small businesses involved in active CRADAs	n.a.	17	12	12	17
Traditional CRADAs					
Active traditional CRADAs	60	81	60	56	62
Newly executed traditional CRADAs	28	30	11	53	12
Non-traditional CRADAs[(a)]					
Active non-traditional CRADAs	2	0	0	0	0
Newly executed non-traditional CRADAs	2	0	0	0	0

(a) ITS Telecommunications Analysis Services (TA Services), discontinued in FY 2012, provided Web-based analysis support on a cost-reimbursable basis for wireless system design/evaluation and site selection to private industry and public agencies through on-demand electronic CRADAs. The programing language used for TA Services is too old to update. Other service applications may be developed in the future depending on funding.

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 of ITS technical publications—both internal reports and monographs and peer-reviewed articles in external scientific journals—have become standard references in several telecommunications areas. Technical publication remains a principal means for ITS technology transfer. Most of these technical publications are released only after going through an internal peer review process managed by the ITS Editorial Review Board (ERB). The majority of the publications released through the ERB process in FY 2016 were approved for external publication in scientific journals or conference proceedings; only 20% were published as NTIA reports. While official NTIA publications allow greater in-depth analysis of research results, journal articles and conference papers have equal, and sometimes greater, reach in transferring new tools and discoveries.

Technical Publications Downloaded

ITS makes all of its publications available to the public through its website, and provides online users with advanced search capabilities that will locate relevant publications by keyword. To ensure a meaningful and realistic metric, ITS counts actual PDF downloads of publications rather than page views of the bibliographic summaries. In FY 2016, ITS technical publications were downloaded 8,748 times.

Consumer Digital Video Library users downloading clips
In FY 2010, ITS began development of the Consumer Digital Video Library, a web site hosted and maintained by ITS that provides researchers access to high quality, uncompressed video clips royalty-free for use in video processing and video quality product development and testing. The technical committee for this collaborative project includes industry and academic representatives as well as ITS and Public Safety Communications Research staff. ITS launched the site with 1000 clips and clips continue to be added by ITS and other collaborators. Over 2,400 different video clips were downloaded from the library in FY 2016. Users must register for each download or upload session. The number of registrants who perform downloads each year was selected as the most significant measure of the impact of this resource, and collection began in FY 2011. This number experienced a significant spike in FY 2013, probably due to the publication of a number of journal articles describing CDVL; annual rates of between 150 and 200 users are consistent with the target audience for this library.

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. Reliable and robust methods of counting downloads of these tools took some time to develop. VQM downloads were reported for the first time in FY 2013 and other downloads were reported for the first time for FY 2014.

Propagation Prediction
ITS is, and has been for decades, a world leader in the development of models and methods for accurate prediction of radio propagation. Propagation prediction algorithms are freely shared through publication. In addition, software developed to predict propagation for planned communications systems through input of specific parameters to these algorithms has been developed and shared over the years, and some data sets that can be used to test and validate propagation prediction models are also available. The majority of software/data downloads on the ITS web site are for propagation prediction tools.

Audio Quality Testing
In FY 2013, ITS developed an objective estimator of speech intelligibility that follows the paradigm of the Modified Rhyme Test (MRT). The Articulation Band Correlation MRT (ABC-MRT) consumes a tiny fraction of the resources required by MRT testing and provides excellent estimates of MRT intelligibility results (Pearson correlations of .95–.99). ABC-MRT 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 method, which has been made a national standard by ANSI, to estimate the quality of video impairments, providing users an inexpensive alternative to viewer panels for testing new transmission technologies. In FY 2016, 496 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.

Table 33 – Other Performance Measures Deemed Important by the Agency

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Technical Publications Released	13	24	18	22	4
Technical Publications Downloaded	n.a.	7,174	7,707	9,048	8,748
Consumer Digital Video Library Users Downloading	187	418	184	212	169
Video Quality Metric Software Users Downloading	n.a.	591	685	507	496
Propagation Modeling Software Downloads	n.a.	n.a.	717	798	781
Other Software/Data Downloads	n.a.	n.a.	489	493	591

Development of Telecommunication Standards[55]

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 2016, ITS staff held 36 positions on 29 different bodies in six standards development organizations. ITS staff filled key leadership positions in the ITU-R, including U.S. Vice-chair of SG3 (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 and Vice-Chair of Working Party 3J (Propagation fundamentals). ITS staff members also hold the positions of U.S. Chair of ITU-T Study Group 9 (Broadcast cable and TV) and International Vice-chair of the ITU Intersector Rapporteur Group on Audiovisual Quality Assessment. ITS also continued its technical

[55] In 2004, ITS added a collaborative standards contributions measure for participation on standards committees. As standards bodies increasingly move towards digital collaboration methods using wikis, email threads, and discussion boards, it has become impossible to define what constitutes a single "contribution." This metric was discontinued in FY 2013.

leadership and contributions to communications standards for public safety, particularly for first responders.

Downstream Outcomes from ITS Technology Transfer Activities

Telecommunication Standards

The ITS chair of ITU-R Study Group 3 Working Party 3K led the examination of over 70 input documents into the final 25 technical documents that were considered by ITU-R Study Group 3 during 2016 meetings. ITS authored four of the 18 technical contributions submitted by the U.S. These addressed air-to-ground propagation, world refractivity mapping, and the effects of sunspot number recalculation.

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. These features are critical to ensuring that LTE can meet public safety's requirements and are a prerequisite to allowing FirstNet to offer mission-critical voice (MCV) on the new Band Class 14 nationwide interoperable public safety communications network when these capabilities become available.

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 2016, 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 ten 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 aircrafts used for atmospheric science applications such as the study of tornado genesis.

Video Quality Research

Both CDVL and the VQM tools are used by industry and academia for research into new techniques for transmitting video. 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.

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/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 DOC, 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 DOC'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 DOC's Federal laboratories. As knowledge advances and the needs of the economy change, DOC, 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.