Annual Report on Technology Transfer:
Approach and Plans, Fiscal Year 2020 Activities and Achievements

U.S. Department of Commerce

Report prepared by:

National Institute of Standards and Technology

National Oceanic and Atmospheric Administration

National Telecommunications and Information Administration

Institute for Telecommunication Sciences

Pursuant to the

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

September 2021

This page is intentionally left blank.

FOREWORD

This report summarizes technology transfer activities and achievements of the Department of Commerce's (DOC) federal laboratories for fiscal year (FY) 2020. At DOC, technology transfer is a significant part of the mission and programmatic activities of the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA), and the National Telecommunications and Information Administration's (NTIA) Institute for Telecommunication Sciences (ITS). Accordingly, this report focuses on the activities of these agencies.

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

DOC's overall and laboratory-specific approaches and its plans for technology transfer are summarized in this report. The report focuses on current year activities and accomplishments, and provides statistical information from FY 2016 through FY 2020.

NIST, NOAA, and NTIA's ITS technology transfer offices have contributed to the organization and preparation of the material reported. An electronic version of this report and versions from previous fiscal years are available online.

This page is intentionally left blank.

TABLE OF CONTENTS

This page is intentionally left blank.

1 DEPARTMENT OF COMMERCE OVERVIEW

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

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

DOC is also responsible for organizing technology transfer activities across federal agencies. DOC coordinates the Interagency Work Group for Technology Transfer (IAWGTT) through NIST interagency discussion on policy, new approaches to technology transfer, and lessons learned from agency transfer programs.[1] NIST also serves as the host agency for the Federal Laboratory Consortium for Technology Transfer (FLC), which provides a forum for federal labs to develop strategies and opportunities for linking technologies and expertise with the marketplace, as well as serving as a Co-Chair and the Executive Secretariat for the National Science and Technology Council's Lab-to-Market subcommittee.

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

NIST | NOAA | ITS

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

Section 10 of the Technology Transfer Commercialization Act of 2000 (P.L. 106-404, codified at 15 U.S.C. § 3710(f)) requires each federal agency that operates or directs one or more federal laboratories or conducts activities under 35 U.S.C. §§ 207 and 209 to report annually to the

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

Office of Management and Budget (OMB) on the agency's technology transfer activities. The OMB's Circular A-11 also requires this information. The tables in the following sections present the required data.[2]

1.1 STATUTORILY REQUIRED COMBINED METRIC TABLES

Table 1: DOC Invention Disclosures and Patenting

Metric	FY 2020
Invention Disclosures Received	70
Total Patent Applications Filed	36
U.S.	36
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	3
Total Patents Issued	25
U.S.	25
Foreign	0

[2] In April 2020, the Interagency Working Group on Technology Transfer released the document, Guidance for Preparing Annual Agency Technology Transfer Reports Under the Technology Transfer Commercialization Act. Agencies independently decided whether to implement the new guidance in their FY 2020 for FY 2021 reports. DOC decided to implement the new guidance in its FY 2020 report. In this report, the statutorily required metrics only report FY 2020 data due to the new guidance's metrics and redefinitions. The additional metrics still display 5 years' worth of data because their definitions did not change. Technology transfer data is typically adjusted over time to account for new information resulting from changes in reporting procedures, patent decisions, programmatic changes, etc. With the new metrics and definitions, previous years' data will not be added or updated. The metrics outside the statutory requirements were adjusted, where necessary, to reflect the most accurate estimates for each year reported.

Table 2: DOC Licensing

Metric	FY 2020
Invention Licenses, Total Active	52
New Invention Licenses	15
New Invention Licenses Granted to Small Businesses	12
Income Bearing Licenses, Total Active	34
New Income Bearing Licenses	6
Exclusive, Total Active	19
Partially Exclusive, Total Active	0
Non-Exclusive, Total Active	15
Other Licenses, Total Active	0
New Other Licenses	0
New Other Licenses Granted to Small Businesses	0
Elapsed Amount of Time for Granting Invention Licenses	
Average (months)	18
Minimum (months)	1
Maximum (months)	25
Licenses Terminated for Cause	0

Table 3: DOC Income from Licensing[3]

[3] Aggregate DOC-level data on Earned Royalty Income (ERI) are not available due to aggregate values reported by DOC bureaus. Bureau-level data are available within each bureau's chapter of this report.

Metric	FY 2020
Invention License Income	$191,178
Other License Income	0
Total Earned Royalty Income (ERI)	$187,578
ERI from Top 1% of Licenses	n/a
ERI from Top 5% of Licenses	n/a
ERI from Top 20% of Licenses	n/a
Minimum ERI	n/a
Maximum ERI	n/a
Median ERI	n/a
Disposition of ERI	
Average Percentage Distributed to Inventors	n/a
Average Percentage Distributed to Lab/Agency	n/a

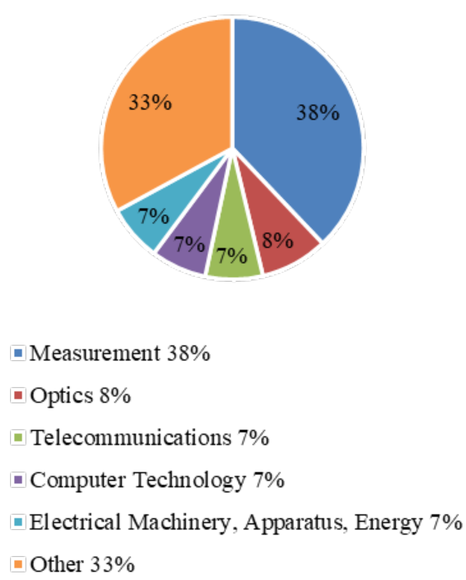
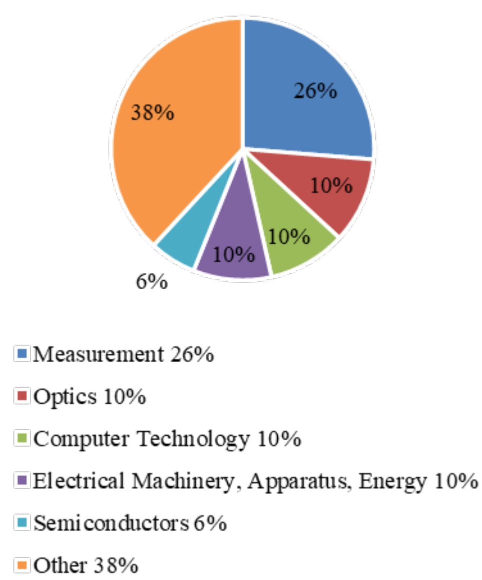
Table 4: DOC Collaborative Relationships

Metric	FY 2020
Total Active CRADAs	2,014
New CRADAs	1,647
New CRADAs Involving Small Businesses	977
Other Collaborative Agreements	2,952

1.2 Other Performance Measures Deemed Important

1.2.1 U.S. Patents Granted to DOC, by Technology Area

Figure 1 and 2 show the most common specific technical areas covered by DOC patents for FY 2019 and FY 2020. In FY 2019, the top three specific technical areas covered by DOC patents were Measurement (38%), Optics (8%), and Telecommunications (7%).[4] In FY 2020, the top three specific technical areas covered by DOC patents were Measurement (26%), Optics (10%), and Computer Technology (10%).[5]

Figure 1: Percent of U.S. Patents Granted to DOC, by Technology Area in FY 2019[6]	*Figure 2: Percent of U.S. Patents Granted to DOC, by Technology Area in FY 2020*[7]
	

[4] In FY 2019, the Other category included the technical areas of: Materials, Metallurgy, Analysis of Biological Materials, Micro-Structural and Nano-Technology, Medical Technology, Digital Communication, Semiconductors, Biotechnology, Chemical Engineering, Pharmaceuticals, Other Consumer Goods, Thermal Processes and Apparatus, Environmental Technology, and Organic Fine Chemistry.

[5] In FY2020, the Other category included the technical areas of: Telecommunications, Surface Technology, Coating, Biotechnology, Environmental Technology, Handling, Analysis of Biological Materials, Materials, Metallurgy, Chemical Engineering, Audio-Visual Technology, Control, Digital Communication, Micro-Structural and Nano-Technology, and Other Consumer Goods.

[6] Prepared by Science-Metrix using USPTO data indexed in PatentsView accessed in September 2020. Used with permission.

[7] A new data delivery schedule allowed for FY 2020 data to be included in this report. Prepared by Science-Metrix using USPTO data indexed in PatentsView accessed in March 2021. Used with permission.

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 International Patent Classification (IPC) codes to ensure that the sum of patents across technology areas—World Intellectual Property Organization (WIPO) technology classification—is equal to the total number of patents as each patent can be assigned to more than one technology area. Technology areas are identified in Appendix A.

1.2.2 Scientific and Technical Publications

Technology transfer mechanisms include more than just counting CRADAs, patents, and licenses. Scientific and technical publications are also technology transfer. In FY 2020, NIST, NOAA, and ITS researchers published 3,114 scientific and technical papers in peer-reviewed journals.

Table 5: DOC Scientific and Technical Publications

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NIST	1,355	1,433	1,415	1,396	1,345
NOAA	1,697	1,678	1,794	1,895	1,755
ITS	4	10	11	11	14
Department Total	3,056	3,121	3,220	3,302	3,114

1.2.2.1 Percent of Articles by Science and Engineering Fields Authored by DOC Staff

Figures 3 and 4 show the most frequent science and engineering fields of DOC publications for calendar year (CY) 2019 and CY 2020. Data are presented by calendar year as months of publication are not always available in Scopus. Taxonomy of Discipline (TOD) fields are used to classify articles. The TOD is a classification scheme developed by the National Science Foundation to suit its need for a unified scheme. Science-Metrix developed an alignment of its own classification scheme with the TOD and this alignment replaces the WebCaspar classification which was used in the past to produce bibliometric data for the Science & Engineering Indicators (SEI) reports. Journals are assigned to a unique TOD except for generalist journals, such as Science and Nature, for which articles are instead reclassified individually in TOD fields using an automated procedure based on machine-learning techniques. Articles are credited on a whole-count basis (i.e., each participating federal agency receives one count). Appendix B identifies science and engineering fields.

In CY 2019, the most frequent technology areas covered by DOC publications are Geosciences, Atmospheric, and Ocean Sciences (32%), followed by Physics (18%) and Engineering (16%).[8]

[8] In CY 2019, the Other category included the technology areas of: computer and information sciences, chemistry, materials science, health sciences, social sciences, mathematics and statistics, astronomy and astrophysics, psychology, and agricultural sciences.

In CY 2020, the most frequent technology areas covered by DOC publications are Geosciences, Atmospheric, and Ocean Sciences (32%), Physics (18%), and Engineering (16%).[9]

Figure 3: Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2019[10]

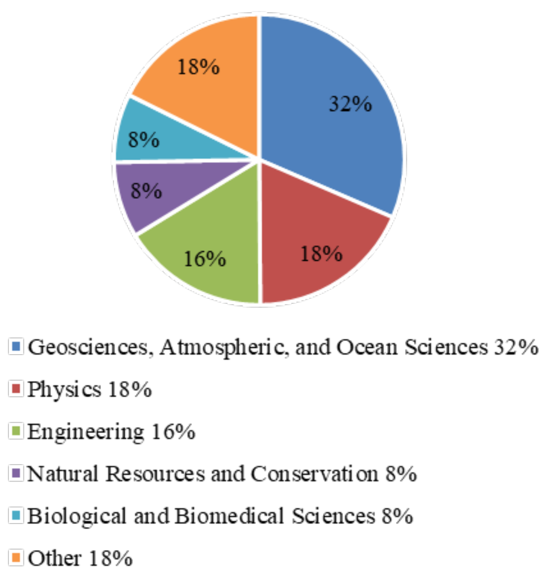
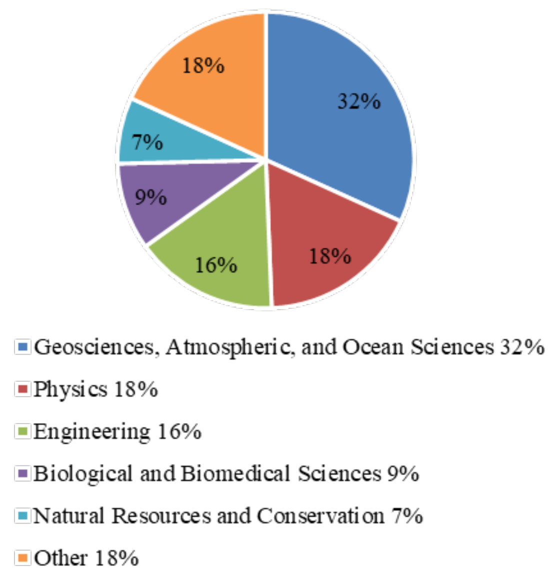


Figure 4: Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2020[11]



1.2.2.2 Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents

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 2019 cite 1,357 publications authored by DOC researchers. As shown in Figure 5, the largest technology areas citing DOC publications include Physics (32%), followed by Engineering (24%) and Chemistry (14%).[12]

---

[9] In CY 2020, the Other category included the technology areas of: chemistry, computer and information sciences, health sciences, materials science, social sciences, astronomy and astrophysics, mathematics and statistics, agricultural sciences, and psychology.

[10] Prepared by Science-Metrix using Scopus (Elsevier) accessed in September 2020. Used with permission.

[11] A new data delivery schedule allowed for FY 2020 data to be included in this report. Prepared by Science-Metrix using Scopus (Elsevier) accessed in February 2021. Used with permission.

[12] In FY 2019, the Other category included the technology areas of: Geosciences, Atmospheric, and Ocean Sciences, Health Sciences, Materials Science, Natural Resources and Conservation, Mathematics and Statistics, Social Sciences, Astronomy and Astrophysics, Psychology, and Agricultural Sciences.

U.S. patents issued in FY 2020 cite 1,537 publications authored by DOC researchers. As shown in Figure 6, the largest technology areas citing DOC publications include Physics (35%), followed by Engineering (18%) and Chemistry (12%).[13]

Figure 5: Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2019[14]

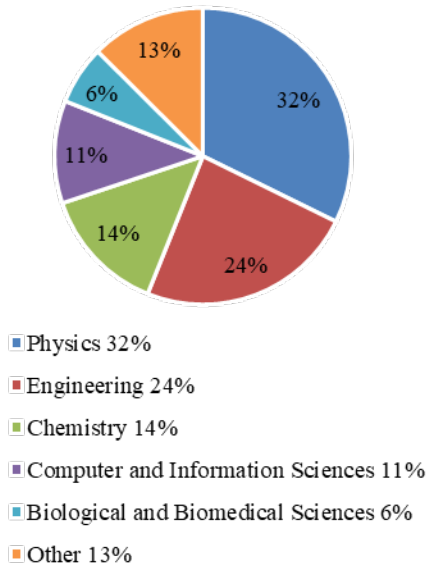
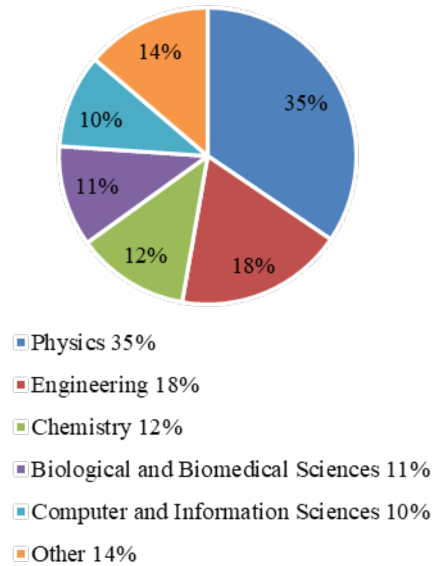


Figure 6: Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2020[15]



TOD fields are used to classify articles. Citations are classified on a whole count basis (i.e., each participating federal agency on a cited article receives one count). Citation counts are based on an 11-year window with a 5-year lag (e.g., citations for 2012 are references in USPTO patents issued in FY 2012 to articles published in 1997–2007). Appendix B identifies science and engineering fields.

---

13 In FY 2019, the Other category included the technology areas of: Geosciences, Atmospheric, and Ocean Sciences, Health Sciences, Materials Science, Natural Resources and Conservation, Mathematics and Statistics, Social Sciences, Astronomy and Astrophysics, Psychology, and Agricultural Sciences.

14 Prepared by Science-Metrix using Scopus (Elsevier) accessed in September 2020 and PatentsView accessed in September 2020. Used with permission.

15 A new data delivery schedule allowed for FY 2020 data to be included in this report. Prepared by Science-Metrix using Scopus (Elsevier) accessed in February 2021 and PatentsView accessed in March 2021. Used with permission.

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.

2.1 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.

NIST broadly defines technology transfer as:

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

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

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

2.2 STATUTORILY REQUIRED METRIC TABLES

Table 6: NIST Invention Disclosures and Patenting

Metric	FY 2020
Invention Disclosures Received	64
Total Patent Applications Filed	35
U.S.	35
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	3
Total Patents Issued	25
U.S.	25
Foreign	0

Table 7: NIST Licensing[16]

Metric	FY 2020
Invention Licenses, Total Active	46
New Invention Licenses	15
New Invention Licenses Granted to Small Businesses	12
Income Bearing Licenses, Total Active	28
New Income Bearing Licenses	6
Exclusive, Total Active	15
Partially Exclusive, Total Active	0
Non-Exclusive, Total Active	13
Other Licenses, Total Active	0
New Other Licenses	0
New Other Licenses Granted to Small Businesses	0
Elapsed Amount of Time for Granting Invention Licenses	
Average (months)	18
Minimum (months)	1
Maximum (months)	25
Licenses Terminated for Cause	0

[16] "Active" means an agreement in force at any time during the fiscal year. Invention licenses include licenses to pending patent applications. Elapsed Amount of Time for Granting Invention Licenses 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.

Table 8: NIST Income from Licensing

Metric	FY 2020
Invention License Income	$79,344
Other License Income	$0
Total Earned Royalty Income (ERI)	$79,344
ERI from Top 1% of Licenses	$45,000
ERI from Top 5% of Licenses	$45,000
ERI from Top 20% of Licenses	$45,000
Minimum ERI	$1,250
Maximum ERI	$45,000
Median ERI	$5,000
Disposition of ERI	
Percentage Distributed to Inventors	42%
Percentage Distributed to Lab/Agency	58%

Table 9: NIST Collaborative Relationships[17]

Metric	FY 2020
Total Active CRADAs	1,952
New CRADAs	1,624
New CRADAs Involving Small Businesses	970
Other Collaborative Agreements	2,952

2.3 Other Important NIST Performance Measures

2.3.1 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 2020, NIST staff published 1,345 papers in peer-reviewed journals, including 360 papers (27%) published in "top tier" journals. A top tier publication is a journal with a Clarivate Analytics Impact Factor (IF) in the top 10th percentile of its *Web of Science* Subject Category.

[17] CRADAs include: bilateral agreements, consortia agreements, industry-led agreements, NVLAP accreditations, and calibrations. Other Collaborative Agreements include: material transfer agreements and guest researcher agreements.

NIST researchers collaborated and co-authored with researchers world-wide, authoring papers with 6,505 unique non-NIST authors representing 1,310 institutions in 69 countries.[18]

Table 10: NIST Scientific and Technical Publications

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Number of NIST Papers	1,355	1,433	1,415	1,396	1,345
Number of NIST Papers in Top-Tier Journals	329	406	367	392	360
Percentage of NIST Papers in Top-Tier Journals	24%	28%	26%	28%	27%
Number of Unique Non-NIST Co-Authors	5,116	5,464	5,277	5,247	6,505
Number of Unique Institutions	1,037	1,334	1,283	1,142	1,310
Number of Countries	46	67	59	54	69

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

In addition to the primary methods of transferring technology i.e., patents, licenses, and CRADAs, NIST researchers routinely transfer technological innovations through the following mechanisms.

2.3.2 Participation in Documentary Standards Committees

Documentary standards are shared sets of rules that specify, for example, a test method or measurement method, a product's properties, or standard practices. Econometric studies proport that standards contribute significantly to economic growth, and a significant study concluded, "development of standards is integral to innovation; documentary standards contribute to economic growth at least as much as do patents; and the macroeconomic benefits of the development of standards extend beyond the benefits to the companies that use the standards."[19]

During FY 2020, 400 members of the NIST staff were involved with 112 standards organizations. Such participation helps NIST respond to the needs of the private sector and enables its scientists and engineers to bring NIST technology and know-how directly into standards-setting bodies.

---

[18] 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.

[19] 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.

Table 11: NIST Participation in Documentary Standards

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Number of Participating NIST Staff	445	440	423	440	400
Number of Standard Organizations with NIST Participants	120	119	116	112	112

The NIST Standards Coordination Office (SCO) maintains the Standards Committee Participation Database for employees to report their participation, including leadership positions within standards organizations.

2.3.3 Standard Reference Data

NIST's Standard Reference Data (SRD) Program provides critically evaluated numeric data to scientists and engineers for use in technical problem solving, research, and development. Many types of reference data are extremely important in engineering structures, optimizing chemical processes, and other industrial applications. NIST extracts SRD from scientific and technical literature or develops them from measurements conducted at its laboratories that are carefully evaluated for accuracy and reliability. NIST currently maintains 74 SRD databases that cover many areas of science, including analytical chemistry, atomic and molecular physics, biotechnology, and materials sciences.

In FY 2020, the NIST SRD Program distributed 2,908 e-commerce orders, 7,905 units sold via distributor, 115 active distributor agreements, 15 active site licenses, 140 active internet subscriptions, 57 units shipped to the user, and 4,578 products downloaded from the NIST website (1,484 free downloads, 3,094 paid downloads). The number of active internet subscriptions increased from 41 in FY19 to 140 in FY20 due to new online subscription for SRD 3.

Table 12: NIST Standard Reference Data Program

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Products Available (Databases)	102	97	92	90	74
E-Commerce Orders	2,689	2,229	2,670	2,613	2,908
Units Sold via Distributor	10,573	7,995	8,413	9,880	7,905
Active Distributor Agreements	124	154	157	125	115
Active Site Licenses	59	36	17	30	15
Active Internet Subscriptions	49	40	50	41	140
Units Shipped via UPS	311	328	146	82	57
Products Downloaded from the NIST Website	6,208	3,119	3,910	3,812	4,578
Free Downloads	4,083	1,225	1,099	1,100	1,484
Paid Downloads	2,125	1,894	2,811	2,712	3,094

2.3.4 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. In FY 2020, NIST made available 1,114 SRMs and from these, sold 27,319 units. The downward trend of units available is, in part, due to labor charges and limited availability of products.

Table 13: NIST Standard Reference Materials

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Units Available	1,194	1,182	1,140	1,130	1,114
Units Sold	31,938	32,348	31,503	29,955	27,319

2.3.5 User Facilities – Research Participants

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

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

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 2019, CNST began reporting the number of distinct facility users versus the previously reported number of research participants.[20] In FY 2020, there were 230 distinct facility users at CNST and 3,068 research participants at NCNR.

Table 14: NIST Research Participants

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
CNST	2,917	3,215	3,415	314	230
NCNR	2,536	2,769	2,742	2,923	3,068

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

2.3.6 Postdoctoral Researchers

Technology transfer includes the people who perform the actual research and development. NIST Postdoctoral researchers, or "postdocs," play an important role in transferring NIST technology and expertise. NIST adheres to the National Science Foundation's Proposal and Award Policies and Procedures Guide's standard of a postdoctoral researcher. In FY 2020, NIST hosted 154 postdocs. Of these, 103 were based at the NIST Gaithersburg, Maryland campus; 40 were located in Boulder, Colorado; and the remainder were located at five other locations.

Table 15: NIST Postdoctoral Researchers

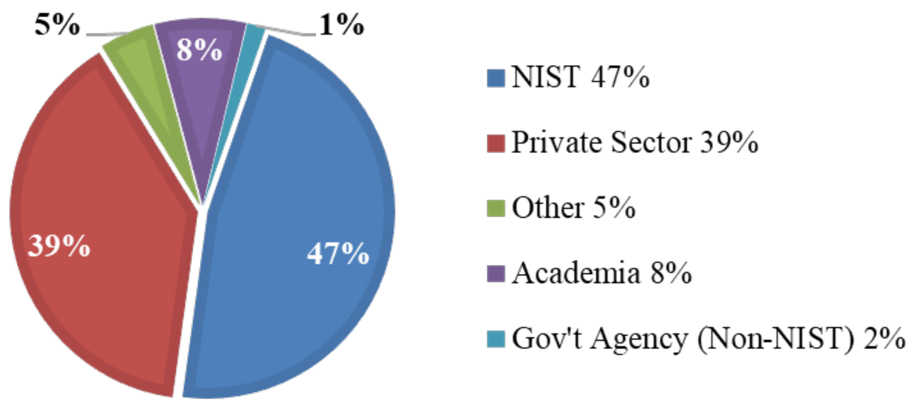
	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NIST Postdocs, Total (NCR)	167	159	153	165	154
Gaithersburg campus	104	87	91	110	103
Boulder campus	43	47	44	35	40
Joint Institute for Laboratory Astrophysics [a]	9	12	10	13	7
Joint Quantum Institute [b]	2	3	3	1	0
Hollings Marine Laboratory [c]	2	2	1	3	4
Institute for Bioscience and Biotechnology Research [d]	3	3	3	2	0
Brookhaven National Laboratory[e]	0	2	0	0	0
Joint Initiative for Metrology in Biology[f]	4	3	1	1	0

(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.
(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.
(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.
(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.
(e) The Brookhaven National Laboratory's National Synchrotron Light Source (NSLS) facility is co-led by DOE and NIST's Material Measurement Laboratory (MML). MML's Synchrotron Science Group develops and disseminates synchrotron measurement science and technology needed by U.S. industry to measure nanoscale electronic, chemical, and spatial structure of advanced materials.
(f) The Joint Initiative for Metrology in Biology (JIMB) is co-led by Stanford University and NIST and is designed to enable significant improvements in the accuracy and comparability of vital data used to make important research, regulatory, clinical, and manufacturing quality control decisions.

The number of postdocs is a significant measure of technology transfer; at the conclusion of their tenure, they take what they have learned and apply it to their next employment. NIST surveyed 64 FY 2020 NIST National Research Council (NRC) program postdocs. Of these, 47%

continued research careers with NIST[21] and 52% transferred NIST technology to public venues. Thirty-nine percent moved to the private sector, 5% pursued other opportunities such as becoming independent researchers, 8% moved to academia, and 2% moved to non-NIST government agencies.

Figure 7: Tracking NIST Researchers after Initial Postdoc Tenure at NIST (FY 2020)



2.3.7 Guest Researchers

In addition to postdocs, each year, thousands of researchers visit NIST to participate in collaborative projects. NIST hosts many term appointment researchers and non-NIST employees working as guest researchers, collaborators, and student fellows. Similar to 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' NIST projects may result in inventions, all guest researchers leave NIST with technical and research skills that place them on the cutting edge of their disciplines. Each researcher takes the skills and knowledge and aspires to apply them in innovative ways in their careers. Paramount among these skills is the knowledge requirements and processes needed to collaborate with federal laboratories and the federal resources available to assist companies in creating and developing new and improved technologies.

In FY 2020 there were 2,701 guest scientists and engineers working at NIST. Fewer Guest Researchers visited NIST due to the COVID-19 pandemic and travel restrictions.

Table 16: NIST Guest Researchers

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Guest Scientists and Engineers	3,273	3,181	3,221	3,180	2,701

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

2.3.8 Accreditation Services

The NIST National Voluntary Laboratory Accreditation Program (NVLAP) is a voluntary, fee-supported program to accredit private sector laboratories competency to perform measurement tests or calibrations. In FY 2020, NVLAP accredited 644 laboratories.

Table 17: NIST Accreditation Services

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NVLAP Accreditations	735	723	674	674	644

2.3.9 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. The NIST on a Chip project established in 2018 aims to streamline a host of calibration services by making chip-scale calibration technologies available to end-users, with the goal of reducing the need for traditional calibration services provided on-site at NIST. In FY 2020, NIST performed 9,225 calibration tests.

Table 18: NIST Calibration Services

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Number of Calibration Tests Performed	12,971	13,802	11,771	11,519	9,225

2.3.10 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 educational outreach programs and partnerships that enrich basic research programs such as:

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

The Department of Commerce Women in Science Technology Engineering and Mathematics (DOC WSTEM) was formed in October 2018. To date there are 331 members representing all of the DOC bureaus. The group was formed for (1) information sharing (2) mentoring (3) conducting community out-reach (4) addressing diversity and inclusion and (5) networking .

DOC WSTEM hosts numerous events and maintains a sought after database for information sharing across the bureaus. In FY 2020, cross-pollination in science and technology transfer occurred across the bureaus when the group sponsored DOC-wide monthly "Lunch and Learn Webinars" where one bureau presented their bureau's mission, vision, and research efforts of the speaker. NIST provided a "Technology Transfer 101" webinar. The intention and results of these monthly webinars is a deeper understanding of the bureaus and opportunities for collaboration between bureaus and promote technology transfer.

In FY 2020, 77 students participated in the Pathways Program, 23 individuals participated in the Summer Institute for Middle School Science Teachers, and 174 students participated in the PREP program.

Table 19: NIST STEM Education Participation

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
SURF[(a)]	213	212	212	173	0
SHIP	70	70	64	55	0
Pathways Program	85	111	85	71	77
Summer Institute for Middle School Science Teachers[(b)]	20	21	0	24	23
PREP	204	36	200	360	174

(a) NIST did not hold the SURF or SHIP programs in FY 2020
(b) NIST did not hold the Summer Institute for Middle School Science Teachers in FY 2018.

2.3.11 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 2020, the NIST Conference Program arranged 74 conferences, both in person and virtually, that attracted 7,747 researchers to NIST's facilities in Gaithersburg, Maryland, and Boulder, Colorado. NIST's Office of Weights and Measures, which promotes uniformity in U.S. weights and measures laws, regulations, and standards, trained 2,057 weights and measures administrators, laboratory metrologists, and field enforcement officials which is more than three times the number trained in FY 2019. This is primarily due to the increase in webinar attendance. In addition to formal trainings, NIST staff respond to email, telephone, and mail inquiries from researchers requesting information and details about NIST technical developments and research results.

Table 20: NIST Conferences, Seminars, and Workshops

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NIST Conference Center					
Conferences and Workshops	102	108	101	78	74
Attendance	10,370	10,588	8,772	8,596	7,747
Office of Weights and Measures - Metrology Training					
Total Students	754	987	902	666	2,057
Seminar Attendance	357	537	523	441	101
Webinar Attendance	397	414	379	225	1,948
Workshop Attendance	0	36	0	0	8

2.3.12 Trends in Technology Transfer Office Activity

To better understand the year-over-year activity of its technology transfer office, NIST tracks the average number of days to both file a patent application and approve a CRADA. In FY 2020, 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 450 days. The average CRADA approval time was 109 days.

Table 21: NIST Activity Trends

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Average Number of Days to File a Patent Application[(a)]	442	396	337	408	450
Average Number of Days to Approve a CRADA[(b)]	104	108	91	129	109

(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.

2.3.13 Small Business Innovation Research (SBIR)

NIST's SBIR program funds science and technology based small businesses in the United States. The program offers qualified small businesses the opportunity to propose innovative ideas that align with NIST research and development and have the potential for commercialization. NIST took the following steps to improve its SBIR program:

1. Continued to streamline practices to reduce the administrative burden on small businesses and time needed to process and issue awards. NIST eliminated one of the review steps by combining the evaluation criteria used in the former process.

2. Eliminated subtopics to open the program to a greater number of small businesses. NIST Priority Areas in the NIST Three Year Programmatic Plan serve as topics to align SBIR priorities to NIST's mission.

3. Implemented a Technical and Business Assistance (TABA) program to assist NIST SBIR awardees with commercialization needs.

Table 22: NIST SBIR Award Count

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Phase I SBIR Awards	12	12	12	12	12
Phase II SBIR Awards	7	9	10	7	8

2.3.14 Economic Assessment

Economists at NIST completed two studies in FY 2020:

1. NIST Interactions: Fiscal Year 2015 through Fiscal Year 2018

   Abstract: This study analyzes data from fiscal years 2015 through 2018 of eighteen interaction types in which NIST participates annually. To describe the volume of direct relationships NIST has with the U.S. economy, it calculates the average number of interactions and the average number of partners per fiscal year, as well as the geographic location of those partners.

2. An Initial Look at Federal Offices of Research and Technology Applications

   Abstract: In Science the Endless Frontier, Vannevar Bush wrote that reaping the potential benefits of science conducted at federal laboratories requires the discoveries made in the labs be transferred to society. In federal laboratories, Offices of Research and Technology Applications (ORTAs) are tasked with transferring lab-developed technologies to the market, facilitating society's reaping the benefits provided by scientific investments. In fiscal year 2016, the Technology Partnerships Office of the National Institute of Standards and Technology conducted a first-of-its-kind survey of the ORTAs of more than fifty federal laboratories to obtain information on their organization and operation. We present descriptive analyses of the responses to this survey in two topical areas: organizational characteristics and technology transfer characteristics. We disaggregate the data across the dimension of budget size, and find similarities and differences across the budget categories. Among the relationships we observe, we find that ORTAs with larger technology transfer budgets report higher frequencies of conducting internal technology transfer activities, such as patent prosecution and market analysis. Additionally, we provide context to the data by overviewing the relevant research on ORTAs at universities and present potential inferences that may be drawn from that body of research and applied to the data on ORTAs at federal laboratories.

2.3.15 N-STEP Program

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

In FY 2020, ten companies completed N-STEP projects, two companies are involved in ongoing projects, and one company has a contingent award awaiting final approval. N-STEP is funded by NIST and administered by Maryland TEDCO but is a nationwide opportunity.

2.3.16 Challenge and Prize Competitions

Challenge.gov is a listing of challenge and prize competitions run by more than 102 agencies across the federal government. NIST offers cash prizes to the public participants for their help in solving perplexing mission-centric problems. In FY 2020, NIST either launched or continued the following challenges:

1. 2020 Agile Robotics for Industrial Automation Competition
2. Automated Streams Analysis for Public Safety (ASAPS) Prize Challenge: Contest 1
3. CHARIoT Challenge: Advancing First Responder Communications
4. Enhancing Computer Vision for Public Safety Challenge
5. Haptic Interfaces for Public Safety Challenge
6. Expanding the SIM Card Use for Public Safety Challenge
7. Tech to Protect Challenge, Coding for Emergency Responders
8. First Responder UAS Endurance Challenge

In addition to the challenges above that are executed under the COMPETES Prize Competition Authority, NIST launched and completed two, non-cash prize challenges related to COVID-19:

1. Too Close for Too Long
2. TREC-COVID

2.3.17 Awards

In addition to the NIST and DOC awards, NIST staff received the following prestigious awards during FY 2020:

2020 Health Level Seven (HL7) Fellow
Robert Snelick

2020 Highly Cited Researcher in Physics
Jun Ye

2020 IAPP Vanguard Award
Naomi Lefkovitz

2020 Vannevar Bush Faculty Fellows
Konrad W. Lehner

2020 Women in Biometrics Award
Mei Ngan

AAAS Fellow
Konrad W. Lehnert

ASPE College of Fellows
Jon Pratt

ASTM International James A. Thomas President's Leadership Award
Bala Muralikrishnan

American Physical Society Fellow
Alexey V. Gorshkov
Daniel S. Hussey
Sae-Woo Nam
Jacob Taylor

American Society of Mechanical Engineers (ASME) Fellow
John Wright

Annual Computer Security Applications Conference (ACSAC) – Test of Time Award
Dave Ferraiolo

Association for Computing Machinery Fellow
Ronald Boisvert

Association for Women in Mathematics Fellow
Fern Y. Hunt
B. Stephen Carpenter
Yoshi Ohno

CO-LABS Governor's Award for High Impact Research
Kuldeep Prasad

Dimensional Metrology Standards Consortium Special Recognition
John Horst

DOE/NREL Photovoltaic Module Reliability Workshop Best Poster Awards
Stephanie Moffitt
Xiaohong Gu

Earthquake Engineering Research Institute (EERI) Housner Fellowship
Siamak Sattar

Edsger W. Dijkstra Prize in Distributed Computing
Rene Peralta

FCW Government Innovation Awards – 2020 Rising Star
Katie Boeckl

Federal 100 Award
Naomi Lefkovitz

FedID 2020 Best Educational Effort
Patrick Grother
Mei Ngan
Kayee Hanaoka

HotSoS '20 Best Paper Award, 7th Symposium on Hot Topics in the Science of Security (HotSoS), Association for Computing Machinery (ACM)
Himanshu Neema
Bradley Potteiger
Xenofon Koutsoukos
Chee Tang
Keith Stouffer

IOP Trusted Reviewer
Zachary Levine

Innovation Research Interchange Medal
David J. Wineland

Micius Quantum Prize
Jun Ye

NIST/UL Workshop on PV Materials Durability Best Poster Awards
Debbie Jacobs
Xiaohong Gu
LaKesha Perry

National Academy of Construction
H.S. Lew

Object Management Group (OMG) 25-Year Service Award
Conrad Bock

Office of Naval Research Young Investigator Award
Adam Kaufman

Optical Society of America – Fellow
John H. Lehman
Alan Migdall
Sergey V. Polyakov

Optical Society of America – Optics and Photonics News Annual Photo Contest – 2nd Place
Alexandra Artusio-Glimpse
Optical Society of America – Paul F. Forman Team Engineering Excellence Award
Scott Diddams

Matthew T. Hummon
B. Robert Ilic
John Kitching
Scott Papp
Kartik Srinivasan
Daron Westly

PLM20 Best Paper Award, IFIP 17th International Conference on Product Lifecycle Management
Rick Candell
Yongkang Liu
Mohamed Hany
Karl Montgomery
Sebti Foufou

Rising Stars of Light – 2nd Place
Amit Agrawal

Society of Fire Protection Engineers (SFPE) Arthur B. Guise Medal, Distinguished Fire Protection Engineering Career
Erica Kuligowski

Society of Fire Protection Engineers (SFPE) Educational and Scientific Foundation Jack Bono Award
Matthew Hoehler
Solid Modeling Association 2020 Fellow
Ram Sriram

Top-Coder Public Sector Innovation Award
Terese Manley
Christine Task

Washington Academy of Sciences Award – 2020 Excellence in Research in Applied Mathematics Award
Michael Donahue

Washington Academy of Sciences Award – 2020 Excellence in Research in Computer Science
Elham Tabassi

Washington Academy of Sciences Award – 2020 Excellence in Research in Physical Science
John Villarrubia

Washington Academy of Sciences 2020 Fellow
Jeff Voas

Washington Academy of Sciences Award – 2020 Leadership in IT Standards for Industry Award
Lisa Carnahan

2.4 Success Stories Demonstrating Downstream Outcomes From NIST Technology Transfer Activities

2.4.1 A Better Alternative to Phthalates?

Detergents, shampoos, soaps and other everyday items sometimes contain a group of chemicals called phthalates, which are often used to enhance products and add flexibility to plastics. However, mounting research has shown a link between phthalates and effects on hormones in humans, laboratory animals and wildlife, which is why phthalates are increasingly being replaced with other chemicals, such as a compound called DINCH.

In collaboration with the Medical University of South Carolina (MUSC), NIST researchers analyzed urine samples from pregnant women to look for the presence of DINCH, which is short for di(isononyl)cyclohexane-1,2-dicarboxylate. They found concentrations of DINCH in most of the urine samples but no evidence of effects in lab assays on two hormones, progesterone and estrogen. The researchers have published their findings in the journal *Chemosphere.*

2.4.2 NIST Expands Database That Helps Identify Unknown Compounds in Milk

Got milk? Most people have seen the famous ads featuring celebrities that highlight the importance of drinking milk for building strong bones. Research shows that milk has other benefits, especially for babies, such as helping them grow and strengthening their immune systems. But scientists still don't understand exactly how milk does these things.

Connie Remoroza operates a mass spectrometer, a laboratory instrument used to identify chemical compounds. "We want to find out as many details as we can about milk because it is so important, but so little is known about its chemistry," Remoroza said. Credit: R. Press/NIST

Solving that mystery starts with identifying the compounds in milk. To support that effort, NIST researchers have recently doubled the size of a reference library that includes examples of a certain type of carbohydrate found in milk from humans and several other animals. The expansion of the library will help scientists identify the unknown compounds in their own milk samples. The researchers published their new findings in *Analytical Chemistry*.

2.4.3 NIST Develops Benchmark for Accurately Detecting Large Genetic Mutations Linked to Major Diseases

The "book analogy" is a popular way of explaining genome changes. If the human genome is considered a book, a new NIST-developed benchmark will help scientists better detect large chapters that are missing (deleted chapters) or not in the original (inserted chapters). Credit: N. Hanacek/NIST

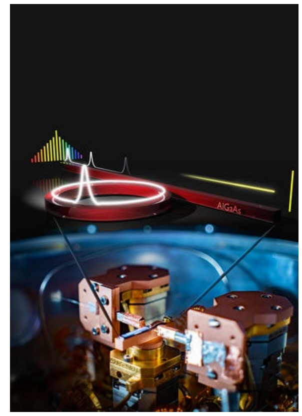
Many serious diseases, including autism, schizophrenia and numerous cardiac disorders, are believed to result from mutation of an individual's DNA. But some large mutations, which still make up only a small fraction of the total human genome, have been surprisingly challenging to detect.

Now, NIST researchers have developed a way for laboratories to determine how accurately they can detect these mutations, which take the form of large insertions and deletions in the human genome. The new method and the benchmark material enable researchers, clinical labs and commercial technology developers to better identify large genome changes they now miss and will help them reduce false detections of genome changes.

The researchers presented their new benchmark in *Nature Biotechnology*.

2.4.4 Comb on a Chip

As part of the NIST on a Chip program, NIST scientists and their University of California at Santa Barbra collaborators have demonstrated that microcombs—a device with hundreds of evenly spaced, sharply defined frequencies, that can be used to measure the colors of light waves with great precision—created from the semiconductor aluminum gallium arsenide have two essential properties that make them especially promising. The new combs operate at such low power that they do not need an amplifier, and they can be manipulated to produce an extraordinarily steady set of frequencies—exactly what is needed to use the microchip comb as a sensitive tool for measuring frequencies with extraordinary precision.



Experimental setup to generate a set of stable frequencies in a cryogenically cooled laser microresonator frequency comb.

Credit: NIST

Small enough to fit on a chip, miniature versions of these combs are making possible a new generation of atomic clocks, a great increase in the number of signals traveling through optical fibers, and the ability to discern tiny frequency shifts in starlight that hint at the presence of unseen planets. "The newly developed microcomb technology can help enable engineers and scientists to make precision optical frequency measurements outside the laboratory," said NIST scientist Gregory Moille. In addition, the microcomb can be mass-produced through nanofabrication techniques similar to the ones already used to manufacture microelectronics.

The researcher published their findings in *Laser and Photonic Reviews*.

2.4.5 Spotlight on N-STEP Graduates

N-STEP provides commercial opportunities for motivated researchers to build upon the experience they gained, while working at NIST, as they explore entrepreneurial careers. For National Entrepreneruship Week, the Technology Partnerships Office interviewed N-STEP graduates about their experiences.

Javier Atencia, a graduate of the N-STEP program said, "I spent several years at NIST developing new technology to leverage micro-scale phenomena." They continued, "This resulted in a significant number of disclousres and eight issued patents. The company I founded is commercializing one of those inventions." Regarding the outcome of the N-STEP program, Javier said, "The program allowed us to move to an incubator at the university of Maryland in College Park where we purchased critical tools and machines to move the technology to the next level. The project was a total success. Not only did we meet the milestones set forward in the proposal, but we went well beyond them. The N-STEP program allowed us to de-risk the technology and move substantially forward in the path of commercialization."

2.4.6 [SRM in Space]

NIST's thermal insulation standard reference materials are used to evaluate commonly used insulation materials such as cellular plastics, fiberglass, or mineral wool for buildings. But, NIST's thermal insulation also SRM played a role in helping the European Space Agency and Japanese Aerospace Exploration Agency test their BepiColombo probe that is headed to Mercury. To keep cool around all the radiation in space, the craft needs to collect heat with solar panels, transfer it through the panel's supporting structures, and push it back out into the stellar beyond.

How it works: Researchers check the SRM and our printout of its properties against their own guaraded hotplate (like the NIST one shown here).
Credit: NIST
Credit NIST

The NIST SRM allowed the agencies to determine if their probe's materials were up to the task of cooling the craft. The researchers use NIST's SRMs to make sure their own test methods were accurate. This helped the agencies scientists ensure that the supporting structures were doing what they were designed to do.

2.4.7 [NIST Adds New 'Fingerprints' to Chemical Identification Database]

NIST has updated its database of chemical fingerprints, called mass spectra, that are used to identify unknown chemical compounds. The NIST Spectral Library and its new version, called [NIST20] is used in health care, drug discovery, foods and fragrances, oil and natural gas, environmental protection, foresinsic science, and almost every other industry that manufactures or measures physical stuff. "If you have a mysterious substance—you have no idea what it is—you generate its fingerprints then run those prints through our library," said NIST biostatistican Tyuts Mak. "If you find a match, you know what the substance is."

NIST research chemist Kelly Telu injects a sample into a mass spectrometer, a laboratory instrument that scientists use to identify unknown chemical compounds.
Credit: M. Delorme/NIST
Credit NIST

This update includes more than 14,000 human and plant metabolites. Those are the substances formed when living things break down food, drugs or their own tissue, such as when you burn fat by exercising. Medical tests often involve identifying metabolites in blood or urine. Plant metabolites make up an even larger univerise of chemical compounds. They are in everything we eat and are important in the agricultural sector. The update also includes pesticides and environmental contaminants, chemicals used in manufacturing such as lubricants and surfactants, pharmecutical drugs and illicit drugs such as new varieties of fentanyl, the drug that is driving a nationwide overdose epidemic.

2.4.8 [NIST and OSTP Launch Effort to Improve Search Engines for COVID-19 Research]

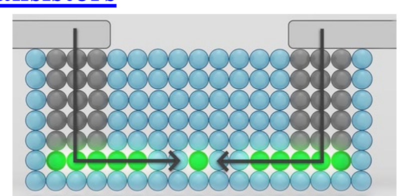
Researchers, clinicians, and policy makers involved with the response to COVID-19 are constantly searching for reliable information on the virus and its impact. NIST and the White

House Office of Science and Technology Policy (OSTP) launched a joint effort to support the development of search engines for research that will help in the fight against COVID-19. The result of this effort was TREC-COVID, a collaboration among the Allen Institute for Artificial Intelligence (AI2), the National Institute of Standards and Technology (NIST), the National Library of Medicine (NLM), Oregon Health & Science University (OHSU), and the University of Texas Health Science Center at Houston (UTHealth).

Based on the Text Retreieval Conference (TREC) model, TREC-COVID built a set of Information Retrieval (IR) test collections based on the CORD-19 data sets. The results of the TREC-COVID Challenge identify answers for some of today's questions and create infrastructure to improve tomorrow's search systems. The final document and topic sets together with the cumulative relevance judgments comprise a COVID test collection called TREC-COVID Complete. The incremental nature of the collection as viewed through the successive rounds supports research on search systems for dynamic environments.

2.4.9 NIST Scientists Create New Recipe for Single-Atom Transistors

Once unimaginable, transistors consisting only of several-atom clusters or even single atoms promise to become the building blocks of a new generation of computers with unparalleled memory and processing power. But to realize the full potential of these tiny transistors — miniature electrical on-off switches — researchers must find a way to make many copies of these notoriously difficult-to-fabricate components. Researchers at NIST and their University of Maryland colleagues have developed a step-by-step recipe to produce the atomic-scale devices.



Artist's illustration of part of the method developed by NIST to make single-atom transistors.
Credit: S. Kelley/NIST
Credit: NIST

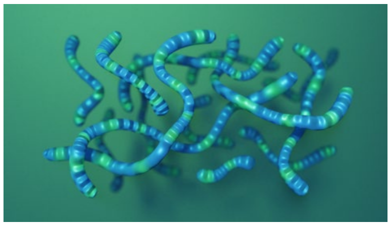
Fabricating single-atom transistors "is a difficult and complicated process that maybe everyone has to cut their teeth on, but we've laid out the steps so that other teams don't have to proceed by trial and error," said NIST scientist Curt Richter.

2.4.10 NIST Helps Build Accurate Measurement Infrastructure for 5G Communications

As fifth-generation (5G) devices and networks begin to roll out, NIST is helping to build the crucial measurement infrastructure for emerging wireless systems by developing new measurement methods and analysis tools and by facilitating the sharing of 5G performance data. These resources can help industry optimize designs for many applications, including cellphones, the internet of things, virtual reality, smart manufacturing and autonomous vehicles.

The 5G mmWave Channel Model Alliance, organized by NIST to address the need for accurate channel measurements and models, now has more than 175 participants representing 80 academic, government and industry research organizations worldwide. The Alliance has produced dozens of datasets and complex models for 5G communications scenarios ranging from offices to shopping malls to outdoor areas. These resources are publicly available and used by many companies and some organizations that set telecommunications standards. The group has also developed best-practice measurement guidelines for instrumentation used at these frequencies.

2.4.11 Roll-Up TVs and Benadable Smartphones: Toward More Choices for Flexible Electronic Materials



One way to visualize strands of PCDTPT, the conductive plastic material researchers studied in this work, is a collection of gummy worms.
Credit: Sean Kelley/NIST
Credit: NIST

A future with foldable, bendable, flexible and ultrathin electronics is fast becoming our present. The materials responsible for these consumer goods are typically polymers—plastics—that conduct electricity. To better understand this promising class of substances, scientists at NIST developed a technique that uses light to quickly and accurately test materials' conductivity—and potentially reveal behavior that other methods could not. Now, the NIST team has demonstrated the further usefulness of this light-based method by using it to uncover behavior in one polymer that no one had seen before.

The scientists report their results today in The Journal of Physical Chemistry C. The work is NIST's latest contribution to the quest to develop measurement tools to study novel materials for use in all different kinds of electronic transmission, from bendable biosensors to mobile phones and solar cells.

"There is a growing market for flexible displays and smartphones, and keeping things smaller, more flexible and easier to mass produce," said Tim Magnanelli, NIST research chemist and National Research Council postdoctoral fellow. "Streamlining the conductivity testing process could be very valuable to industry researchers who just want to know, 'Are we going in the right direction with a particular modification? Does this make the material better?'"

3 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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

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

Research across NOAA's laboratories is primarily aimed at improving the ability of the operational components to accomplish their respective missions. Recent examples demonstrating the direction of NOAA's research are:

- severe storm (hurricane, tornado, derecho winds) and drought forecasting
- physical forecasts for renewable energy siting
- predicting freshwater resources
- tsunami warnings
- air quality measurement
- solar emission forecasting
- monitoring and estimating of fish stocks and species health
- coastal habitat monitoring and pollution
- invasive species monitoring
- coral reef health
- ocean acidification
- coastal/ocean disaster response and restoration
- charting ocean bottom topography
- a wide variety of climate research and the impacts of a changing climate on human health, coastal zone management, and oceans.

Research results are routinely transitioned to NOAA's operational components to improve prediction, management, and other mission activities.

3.1 APPROACH AND PLANS FOR TECHNOLOGY TRANSFER

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

The following is an overview of NOAA's technology transfer activity, both formal and informal, during FY 2020.

3.1.1 Program and Portfolio Management

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

In 2017, the NOAA TPO developed a revised five-year strategic plan to ensure the program is effectively serving its customers and management. The Plan was refined in 2018 to more closely align with the Department of Commerce Strategic Plan and was included in our annual report. The NOAA TPO will likely update this strategic plan again in 2020 to better align with NOAA goals.

The following are selected reports of progress planned for 2020:

Goal 1: Enhance Innovation within NOAA and the Nation

Activity 1.2: Increase the number of CRADAs with U.S. Private Sector

Progress Update:

NOAA CRADA activity rebounded in 2020, up from a lower 2019 level of activity, despite the COVID 19 lockdowns. Active CRADA numbers have remained steady. The NOAA TPO continues to educate staff internally and to engage with the U.S. private sector at selected events. The NOAA TPO has also been directly engaged in the development of NOAA's new Science and Technology Focus Area Strategies to ensure public-private partnerships are encouraged.

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

Activity 2.2: Increase adoption rate for NOAA technologies

Progress Update:

The NOAA TPO has been a key driver in the internal effort to standardize NOAA's approach to licensing of software and data products. The NOAA TPO has submitted a revised draft of its NOAA Administrative Order for approval. This new Order outlines the general principles NOAA will follow for technology dissemination.

The NOAA TPO has also been directly engaged in the development of the NOAA guidance for software licensing and public distribution. This guidance is now being transitioned to a formal NOAA Administrative Order, which will increase awareness and adoption of the processes.

Both documents will lead to a more coherent and coordinated approach to releasing NOAA's software and data products to industry and to the public.

Goal 3: Enhance Resilience and Security

Task 3.2: Increase public private partnerships in Aquaculture

Progress Update:

Currently, nine of NOAA's 46 active CRADAs (19.5%) are in Aquaculture, with three additional aquaculture CRADAs under development.

In FY 20 NOAA entered into multiple facilities-use partnerships in aquaculture. These partnerships, enabled under the CRADA authority, have ensured full exploitation of taxpayer funded facilities, while allowing fledgling U.S. entities the opportunity to grow.

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

Task 2: Increase NOAA TPO input to Intra and Interagency Groups

Progress Update:

As mentioned above, the NOAA TPO is an active member in the development of NOAA's Science and Technology Focus Area Strategies and will be involved in the implementation plans for many of these efforts. In addition, the TPO is an active member on the NOAA Blue Economy Executive Committee, which aims to develop a 5-year Blue Economy Strategic Plan.

3.2 STATUTORILY REQUIRED METRIC TABLES

NOAA filed two (2) provisional patent applications and one (1) non-provisional application in 2020.

NOAA researchers disclosed three software innovations, two hardware inventions, and one method invention. The rights for the software inventions were consolidated and the products were released under a Creative Commons Zero public domain designation. NOAA now maintains an active portfolio of 15 technologies, four of which are being marketed for licensees or are being actively commercialized.

The licensing portfolio consists of six (6) active invention licenses, two of which have been executed through university partners, and three (3) research and development licenses. The NOAA-issued invention licenses include three exclusive licenses, and one non-exclusive license, all of which are income-bearing.

NOAA's Labs, Centers, and Programs executed 14 new Cooperative Research and Development Agreements (CRADAs) in FY 2020. One of these agreements was with small businesses.

Factoring in the new and expiring agreements, the total NOAA CRADA portfolio is 46 active CRADAs.

Table 23: NOAA Invention Disclosures and Patenting

Metric	FY 2020
Invention Disclosures Received	6
Total Patent Applications Filed	1
U.S.	1
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	0
Total Patents Issued	0
U.S.	0
Foreign	0

Table 24: NOAA Licensing

	FY 2020
Invention Licenses, Total Active	6
New Invention Licenses	0
New Invention Licenses Granted to Small Businesses	0
Income Bearing Licenses, Total Active	6
New Income Bearing Licenses	0
Exclusive, Total Active	4
Partially Exclusive, Total Active	0
Non-Exclusive, Total Active	2
Other Licenses, Total Active	0
New Other Licenses	0
New Other Licenses Granted to Small Businesses	0
Elapsed Amount of Time for Granting Invention Licenses	
Average (months)	n/a
Minimum (months)	n/a
Maximum (months)	n/a
Licenses Terminated for Cause	0

Table 24: NOAA Income from Licensing

	FY 2020
Invention License Income	$111,834
Other License Income	$0
Total Earned Royalty Income (ERI)	$108,234
ERI from Top 1% of Licenses	$102,734
ERI from Top 5% of Licenses	$102,734
ERI from Top 20% of Licenses	$102,734
Minimum ERI	$500
Maximum ERI	$102,734
Median ERI	$27,959
Disposition of ERI	
Percentage Distributed to Inventors	34%
Percentage Distributed to Lab/Agency	66%

Table 26: NOAA Collaborative Agreements

	FY 2020
Total Active CRADAs	46
New CRADAs	14
New CRADAs Involving Small Businesses	4
Other Collaborative Agreements	0

3.3 Other Important NOAA Performance Measures

3.3.1 Data Products and Services

NOAA data support a wide range of multi-billion dollar economic sectors in the U.S. and the global economy and is possibly the most impactful example of technology transfer NOAA provides. Express couriers, rail systems, retailers, and third-party weather forecasts rely on this free and publicly available information to determine routes, weather risks, seasonal merchandising, and scheduling. Ocean and coastal data give the fishing industry tools to determine prime fishing locations through private forecasters who build fishing reports using archived data. NOAA continues to improve and expand public access to its data. NOAA's Big Data Program is an ongoing example of these efforts, which is starting to show some commercial success.

3.3.2 Decision Support Tools

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

3.3.3 Cooperative Institutes

NOAA supports a network of 20 Cooperative Institutes at 69 universities and research institutions across 27 states and the District of Columbia. Some Cooperative Institutes are located near NOAA laboratories or science centers, creating a strong, long-term collaboration between federal and university scientists. The work done through the Cooperative Institutes directly supports NOAA's mission activities and results in similar technology transfer opportunities. NOAA's Technology Partnerships Office works closely with the technology transfer offices from the Institutes to jointly manage intellectual property and seek out licensing partners.

3.3.4 Publications[22]

In FY 2020, peer-reviewed publications by NOAA federal scientists totaled 1,755. The following charts show the breakdown of publications, including publications from NOAA and NOAA-funded sources.

Table 25: NOAA Publication Count by Quarter[23]

Quarter (FY 2020)	Authored Articles	Funded Articles (including authored pubs)	Funded Articles (without authored pubs)	Total NOAA-Authored and Funded Articles
Q1	525	760	482	1,007
Q2	519	739	461	980
Q3	410	595	383	793
Q4	301	431	285	583
Total FY 2020	1,755	2,525	1,611	3,363

3.3.5 Science on a Sphere®

Science on a Sphere® (SOS) is a room-sized, global display system (U.S. 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.

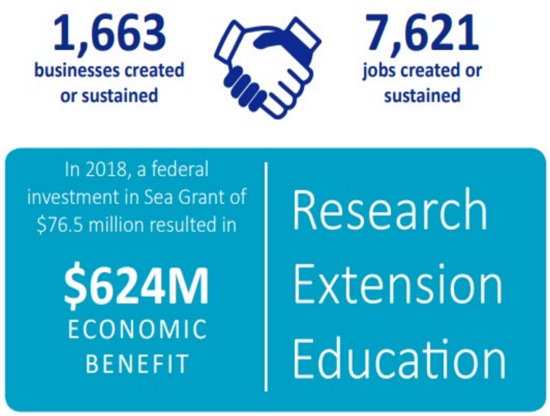
Table 28: SOS Installations

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
SOS Installations					
Total Number in Operation	135	144	155	165	169
New Domestic	3	6	3	7	5
New International	6	3	8	8	3
Total New Installs	9	9	11	15	8

[22] NOAA publications data for 2020 were derived on October 9, 2020, 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. Due to a lag in indexing of articles in Web of Science this report does not reflect all articles published in FY2020 Q4.

3.3.6 NOAA-Funded (Extramural) R&D

3.3.6.1 NOAA Sea Grant



The National Sea Grant College Program was established by the U.S. Congress in 1966 and works to create and maintain a healthy coastal environment and economy. The Sea Grant network consists of a federal/university partnership between the National Oceanic and Atmospheric Administration (NOAA) and 34 university-based programs in every coastal and Great Lakes state, Puerto Rico, and Guam. The network draws on the expertise of more than 3,000 scientists, engineers, public outreach experts, educators, and students to help citizens better understand, conserve and utilize America's coastal resources.

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

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

3.3.6.2.1 Ocean Technology Transition (OTT) Program

The OTT looks for developing ocean, coastal, and Great Lakes observing, product development, and data management technologies for which there is a known need and steps in to accelerate its transition to operations. These technologies include hardware and software platforms, sensors, and data management aimed at improving available ocean information to support decision making for the coastal ocean, and Great Lakes' environments.

For 2020, IOOS, in conjunction with the National Oceanographic Partnership Program (NOPP), sought projects focused on regional coastal ocean observing systems and advancing data management and cyberinfrastructure for observations. The Program supported six projects with the high opportunity for successful transition.

3.3.6.3 Climate Program Office

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

3.3.6.3.1 [Fire Influence on Regional and Global Environments Experiment (FIREX)]

The Fire Influence on Regional and Global Environments Experiment (FIREX) is a field campaign designed to understand and predict the impact of North American fires on the atmosphere and to support better land management to help prevent them from occurring.

The Chiwaukum Fire in Washington State in 2014. (Washington Department of Natural Resources)

Fires in the Western U.S. are regular seasonal events that greatly affect air quality and climate through the production and direct release into the atmosphere of trace gases and particulates, and their subsequent chemical evolution and transport. A number of field campaigns and laboratory studies have been undertaken in recent years that have provided data on various aspects of emission products resulting from biomass burning, their chemical composition, chemical and physical transformation, and their eventual impact on air quality and climate.

Over the next 5 years, NOAA's Chemical Science Division (CSD) of the Earth System Research Laboratory is planning to add to the available knowledge of atmospheric composition resulting from biomass burning by focusing on fires in the Western U.S. FIREX will span a variety of ground, mobile, and aircraft measurements, in addition to chamber and Fire Science Laboratory experiments.

3.3.7 Education and Outreach

3.3.7.1 Environmental Literacy for a Blue Planet

Environmental Education BLUE or eeBLUE is a five-year partnership between NOAA Office of Education and the North American Association for Environmental Literacy (NAAEE) to help create a more environmentally literate society that has the knowledge, skills, and motivation to conserve our natural resources and build more resilient communities across the country. Partnership activities strengthen professional networks, support high-quality STEM education, and provide education and outreach for educators and other audiences.

3.3.8 NOAA Technology Transfer Awards

NOAA selected three projects to receive the Agency's Technology Transfer Award in 2020. These projects exemplified the highest standard for developing new technology in cooperation with private sector partners in the service of NOAA's mission.

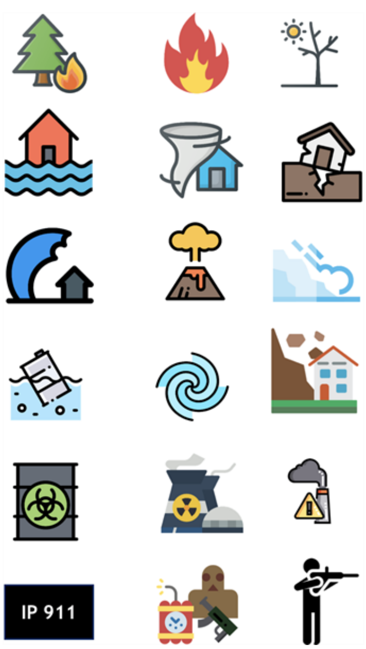
- **Richard Stumpf, Michelle C. Tomlinson, D. Rance Hardison, William C. Holland, Wayne R. Litaker:** For development and transition to citizen scientists, technology that gives beachgoers in Florida forecast of respiratory irritation from red tides.

- **Benjamin Johnson:** For innovative development of an inexpensive, automated river gage and transfer of that technology to the private sector through a CRADA.

- **RuShan Gao, Steven J. Ciciora:** For creating a unique instrument to measure atmospheric particles and helping a small company successfully commercialize it to yield $1M+ in sales.

3.4 Success Stories Demonstrating Downstream Outcomes From NOAA Technology Transfer Activities

3.4.1 Mayday.ai Applies Artificial Intelligence to NOAA Satellite Imagery to Detect Natural Disasters, Starting with Wildfires

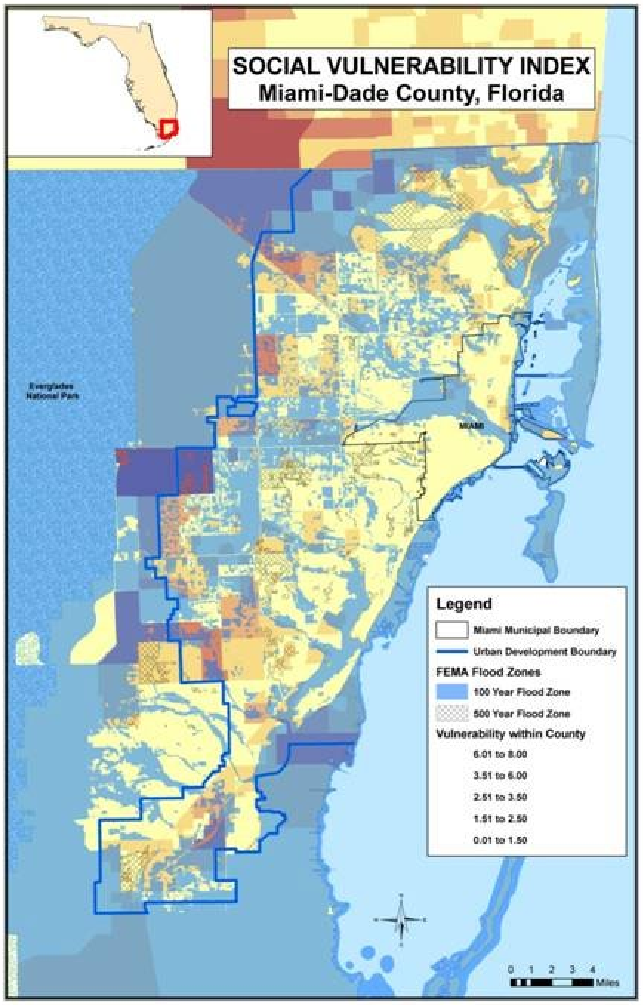


NOAA's Big Data Program, which was launched in 2016, provided the general public the ability to access and analyze near real-time data feeds from NOAA satellites and other NOAA data sources via the major U.S. Cloud Service Platforms. This access eliminated the need for a satellite dish and a supercomputer to analyze and develop products and services from these data. This low-cost access to near real-time data, together with the powerful computing resources and advanced AI technology available on the Cloud Service Providers' platforms, has opened the doors for small startups and innovators, such as California-based startup Mayday.ai.

Mayday.ai was founded in May 2018 with the mission to help save lives, reduce costs and impacts of disasters, and protect the environment. Using multiple resources, including satellites, traffic cameras and social media, Mayday.ai has developed a cloud-based platform which can provide centralized early warning and dispatch for first responders and emergency managers combating high-impact events, such as wildfires.

The 2020 fire season was unprecedented in California, Oregon, and beyond, which put Mayday.ai's concept quickly to the test and provided multiple opportunities to evaluate and fine tune this early-warning technology. Mayday.ai has been training its analysis engine using Machine Learning to see through partial clouds, which has enabled Mayday.ai to detect a high proportion of wildfire events up to 15 minutes after starting and well in advance of 911 calls reporting the incidents.

3.4.2 NOAA Digital Coast



Examining flood zones with societal information helps county employees think about how increased flooding from sea level rise will impact their work. Credit: NOAA

The Digital Coast was developed to meet the unique needs of the coastal management community. The website provides not only coastal data, but also the tools, training, and information needed to make these data truly useful. Content comes from many sources, all of which are vetted by NOAA.

Data sets range from economic data to satellite imagery. The site contains visualization tools, predictive tools, and tools that make data easier to find and use. Training courses are available online or can be held at the user's location. Information is also organized by focus area or topic.

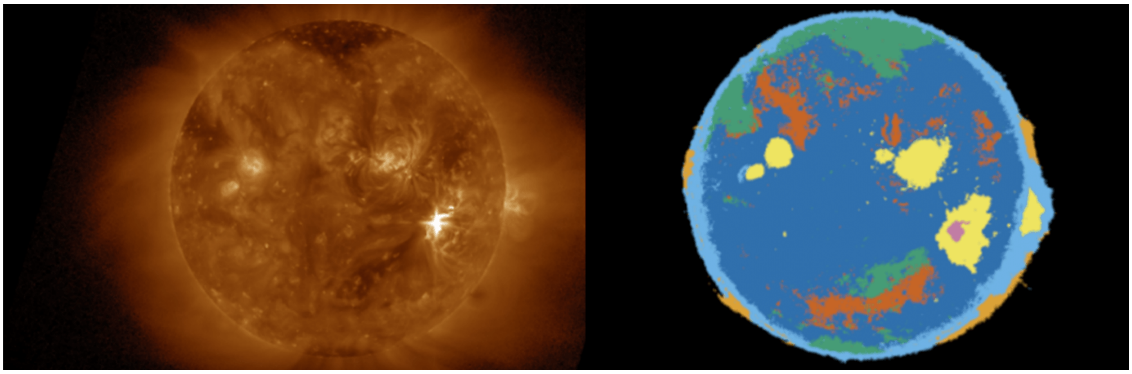
Technology Application:

Miami-Dade County recognized the need for a cohesive plan for adapting to climate change. Their Office of Sustainability worked with the NOAA Office for Coastal Management to host a workshop.

At the workshop, county department representatives learned how sea level rise could affect their county and generated ideas for adaptation strategies. To help participants fully understand local sea level rise predictions, maps were developed showing sea level rise and saltwater intrusion, and impacts to land cover and land use, zoning, emergency facilities, human infrastructure, and important natural features.

3.4.3 [Machine-Learning Tool May Improve Space Weather Forecasts]

Changing conditions on the Sun and in space—broadly called "space weather"—can affect various technologies on Earth, blocking radio communications, damaging power grids and diminishing navigation system accuracy. So Cooperative Institute for Research in Environmental Sciences (CIRES) scientists at NOAA's National Centers for Environmental Information and CU Boulder developed a machine-learning technique to search massive amounts of satellite data and pick out features significant for space weather.



Credit: University of Colorado, Boulder

"Being able to process solar data in real time is important because flares erupting on the Sun impact Earth over the course of minutes," said Rob Steenburgh, a forecaster in the NOAA Space Weather Prediction Center in Boulder, Colorado.

To predict incoming space weather, forecasters summarize current conditions on the Sun twice daily. They use hand-drawn maps labeled with various solar features, including active regions, filaments and coronal hole boundaries. But solar imagers produce a new set of observations every few minutes: the Solar Ultraviolet Imager (SUVI) on NOAA's GOES-R Series satellites runs on a 4-minute cycle, collecting data in six different wavelengths every cycle. Keeping up with all that data would take up a lot of a forecaster's time.

The algorithm's skill at finding patterns assists short-term forecasting and also scientists evaluating long-term solar data. "Because the algorithm can look at 20 years' worth of images and find patterns in the data, we'll be able to answer questions and solve problems that have been intractable," Seaton said.

3.4.4 [NOAA Teams Up with Viking to Conduct and Share Science Aboard New Great Lakes Expedition Voyages]

NOAA plans to expand its research in the Great Lakes region as the agency teams up with the travel company Viking to carry scientists aboard new expedition voyages planned to begin in 2022.

As part of the Cooperative Research and Development Agreement, NOAA scientists will join Viking expeditions in the Great Lakes to conduct research focused on changes in the region's weather, climate, ecosystems and maritime heritage resources. NOAA scientists will also serve on the Viking Scientific Advisory Committee.

"We are very excited about the ways that our scientists can expand their research in the Great Lakes with sensors and testing aboard the new ship," said Deborah Lee, Director of NOAA's Great Lakes Environmental Research Laboratory. "We also welcome the chance to help people learn about the richness and maritime heritage of the Great Lakes as well as the environmental challenges it faces."

This rendering shows what the new Viking expedition ships will look like, including the hangar for launching small vessels. Credit: Viking

Viking's arrival in the Great Lakes in 2022 will bring a new vessel with advanced research capabilities to explore this region of North America and will mark a major commitment to local tourism and economic development for the states of Michigan, Minnesota and Wisconsin, as well as the Canadian province of Ontario.

Viking's new expedition voyages will be hands-on learning experiences; guests will explore their destinations while also having the opportunity to engage with working scientists in the ship's laboratory or participate directly in citizen science programs.

This public-private collaboration will draw global attention to NOAA's research, laboratories and programs in the Great Lakes region. The new Great Lakes itineraries will include opportunities for guests to visit NOAA Thunder Bay National Marine Sanctuary on Lake Huron in Alpena, Michigan, and the Lake Superior National Estuarine Research Reserve (NERR) in Superior, Wisconsin, among many other locations. NOAA Great Lakes scientists and program leaders will be on board and engage with guests as they advance Great Lakes ecosystems research.

The new Polar Class 6 Viking Octantis will debut in 2022 in the Great Lakes. This ship and a second ship, Viking Polaris, which will be used in the Arctic and Antarctica, are small enough to navigate remote polar regions and the St. Lawrence River, while large enough to provide superior handling and stability in the roughest seas.

Science onboard

The new ships, while hosting guests, will also be research vessels with an onboard team of Viking resident scientists working on a variety of studies. Each ship is equipped with a FerryBox, a set of instruments continuously collecting and displaying data on water quality, oxygen content, plankton composition, and more. A key attribute of the venture is the continuous, simultaneous collection of these Great Lakes vital signs along the repetitive ship routes, which allows scientists to monitor changes on scales of season, years, and even decades. The laboratory on each ship is also designed to support a broad range of research activities and is equipped with wet and dry laboratory facilities, a sample processing area, fume cupboard, freezer and cool storage, comprehensive microscope optics, and extensive bench space for analysis-specific instruments.

NOAA has collaborated with commercial vessels for scientific purposes before. In 2019, for instance, NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) installed and tested autonomous carbon-dioxide-measuring instruments aboard the Celebrity cruise ship Flora. Each time the Flora sails to the Galapagos Islands, the instruments will measure CO2 levels in the surface waters around the ship, providing insights into the health of this part of the ocean. NOAA's Ships of Opportunity (SOPs) or Volunteer Observing Ships (VOSs) are another example of non-research ships such as, commercial cargo ships or ferries, that provide unique and valuable opportunities to collect ocean surface data for use in NOAA science.

The new collaboration with Viking also supports NOAA's goals to embrace transformative advances in science and technology through public-private partnerships, which were announced at the November 2019 White House Summit on Partnerships in Ocean Science and Technology.

3.4.5 NOAA Printed Optical Spectrometer (POPS) Delivered to the International Space Station

A miniaturized aerosol spectrometer developed by scientists in the NOAA Chemical Sciences Laboratory (CSL) reached new heights on Monday, October 5 when it was delivered by a cargo capsule to the International Space Station (ISS) orbiting more than 250 miles above Earth's surface. The Portable Optical Particle Spectrometer (POPS) will help monitor air quality in the main living area of the space station.

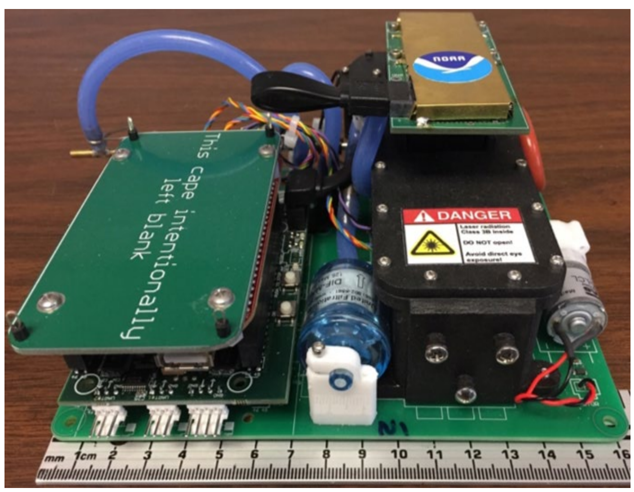
Developed by NOAA physicist Ru-Shan Gao, POPS uses an on-board laser to measure and count aerosol particles between 140 nanometers to 2.5 micrometers in diameter. A micrometer is 1/1000th of a millimeter. A nanometer is 1,000 times smaller than that. At six inches long and 1.3 pounds, POPS is about one tenth the size and one fifth the cost of comparable instruments.

The instrument was integrated into Aerosol Dynamics Inc's Ambient Particle Monitor, and ferried to the space station along with four tons of science experiments, crew supplies and station hardware on the Cygnus resupply capsule carried on an Antares rocket launched from NASA's Wallops Flight Facility on Wallops Island, Virginia.

In a spacecraft cabin environment, the size range of indoor aerosols is much larger, and they persist longer than on Earth because they are not removed by gravitational settling. High concentrations of inhalable particles on the space station may be responsible for crew complaints of respiratory and eye irritation and comments about 'dusty' air reported to NASA. POPS will participate in a flight experiment which will provide data on floating particulate matter in the air inside the space station. Samples will be returned to Earth for chemical and microscopic analyses and will provide the first look at aerosol composition in the spacecraft.

<u>POPS instrument</u>

NOAA CSL's Portable Optical Particle Spectrometer (POPS) uses an on-board laser to measure tiny suspended particles that influence stratospheric chemistry and reflect incoming sunlight. The miniaturized instrument, designed by CSL researchers in Boulder, Colorado, weighs 1.3 pounds and is about the size of a lunch box.



NOAA CSL's Portable Optical Particle Spectrometer (POPS) uses an on-board laser to measure tiny suspended particles that influence stratospheric chemistry and reflect incoming sunlight. The miniaturized instrument, designed by CSL researchers in Boulder, Colorado, weighs 1.3 pounds and is about the size of a lunch box. (Credit: NOAA)

The small size and light weight have earned POPS another high-flying mission in 2021. The instrument will be incorporated as a science payload launched by the Arizona company World View, for a series of high-altitude, long-duration flights aboard the company's "Stratollite" balloons for a uniquely detailed look at the composition of Earth's stratosphere.

Stratospheric particles, or aerosols, play a key role in moderating Earth's climate system by scattering or reflecting sunlight as it nears the surface and by modifying the formation of clouds. The stratosphere also holds the Earth's protective ozone layer, which absorbs ultraviolet radiation that can damage cellular structure, increase the risk of skin cancer and cataracts, and suppress the human immune system. Aerosols in the stratosphere act as surfaces for chemical reactions to occur, such as those that lead to depletion of the ozone layer.

The size range of particles that POPS can detect is particularly important for understanding the climate since they are both small enough to accumulate in the atmosphere instead of settling out, and large enough to efficiently reflect sunlight. The data will play a role in helping NOAA to understand baseline conditions in the stratosphere.

POPS has also been successfully transitioned to the commercial sector. In 2015, Dr. Gao disclosed the POPS to the NOAA Technology Partnerships Office (TPO), which filed a provisional patent application on the technology in June 2015. Later that year, TPO signed a non-exclusive license to commercialize the device with Handix Scientific of Boulder, Colorado.

4 NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION: INSTITUTE FOR TELECOMMUNICATION SCIENCES

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

4.1 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, open data, and software tools
- Leadership and technical contributions in the development of telecommunications standards

For 18 of the past 22 years, ITS has also hosted the International Symposium on Advanced Radio Technologies (ISART), a U.S. government-sponsored conference that brings together government, academia, and industry leaders for the purpose of collaborating on groundbreaking developments and applications of advanced radio technologies. In FY 2020, the virtual symposium drew over 200 attendees and 50 panelists on the topic of *5G Spectrum and a Zero-Trust Network.* Presentations, video archives, and proceedings are available online.

4.2 STATUTORILY REQUIRED METRIC TABLES

Table 26: NTIA ITS Invention Disclosures and Patenting

Metric	FY 2020
Invention Disclosures Received	0
Total Patent Applications Filed	0
U.S.	0
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	0
Total Patents Issued	0
U.S.	0
Foreign	0

Table 27: NTIA ITS Licensing[24]

	FY 2020
Invention Licenses, Total Active	0
New Invention Licenses	0
New Invention Licenses Granted to Small Businesses	n/a
Income Bearing Licenses, Total Active	0
New Income Bearing Licenses	0
Exclusive, Total Active	0
Partially Exclusive, Total Active	0
Non-Exclusive, Total Active	0
Other Licenses, Total Active	0
New Other Licenses	0
New Other Licenses Granted to Small Businesses	n/a
Elapsed Amount of Time for Granting Invention Licenses	
Average (months)	n/a
Minimum (months)	n/a
Maximum (months)	n/a
Licenses Terminated for Cause	n/a

[24] Since FY 2008, ITS no longer licenses software technology. Instead, software is made available via open-source download. ITS reports zero licensing and income from licensing activity.

Table 28: NTIA ITS Income from Licensing

	FY 2020
Invention License Income	n/a
Other License Income	n/a
Total Earned Royalty Income (ERI)	n/a
ERI from Top 1% of Licenses	n/a
ERI from Top 5% of Licenses	n/a
ERI from Top 20% of Licenses	n/a
Minimum ERI	n/a
Maximum ERI	n/a
Median ERI	n/a
Disposition of ERI	
Percentage Distributed to Inventors	n/a
Percentage Distributed to Lab/Agency	n/a

4.2.1 Collaborative Relationships for 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 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 2020, as it has for decades, ITS participated in CRADAs with private-sector organizations to design, develop, test, and evaluate advanced telecommunication concepts. CRADAs provide ITS with insights into industry's needs for productivity growth and competitiveness. This enables ITS to adjust the focus and direction of its programs for effectiveness and value. The private industry partner benefits by gaining access to the results of research in commercially important areas that it would not otherwise be able to undertake.

To date, major contributions to citizens broadband commercial radio service (CBRS) (including testing and evaluation of spectrum access systems (SAS) and environmental sensing capability (ESC) sensors), spectrum monitoring, personal communication services (PCS), local multipoint distribution service (LMDS), ultra-wideband (UWB), objective audio and video Quality of Experience (QoE) metrics, advanced antennas for wireless systems, remote sensing and global position (GPS) technologies, high resolution laser radar (LADAR), autonomous networks for unmanned aerial vehicles (UAVs), and broadband air-interface and core network capabilities for Long Term Evolution (LTE) mobile communications have been achieved through CRADAs. These have aided U.S. efforts to rapidly introduce new socially constructive communications technologies.

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

Table 29: NTIA ITS Collaborative Agreements

	FY 2020
Total Active CRADAs	16
New CRADAs	9
New CRADAs Involving Small Businesses	3
Other Collaborative Agreements	0

4.3 Other Important NTIA ITS Performance Measures

4.3.1 Technical Publications

Publication has historically been the means through which ITS has transferred research results to other researchers, the commercial sector, and government agencies. Many ITS technical publications—both reports and monographs published by NTIA and peer-reviewed articles in scientific journals—have become standard references in several telecommunications areas. Technical publication remains a principal means for ITS technology transfer; software releases are becoming increasingly important and publication downloads have been decreasing as software downloads increase. Technical publications are released after an internal peer review process managed by the ITS Editorial Review Board (ERB). In FY 2020, 57% of manuscripts released through the ERB process were published in scientific journals or conference proceedings and 43% were published as NTIA reports. While official NTIA publications allow greater in-depth analysis of research results, journal articles and conference papers often have greater reach in transferring new tools and discoveries.

4.3.2 Technical Publications Downloaded

ITS makes all of its publications available to the public through its web site and provides online users with advanced search capabilities to locate relevant publications by keyword. To ensure a meaningful and realistic metric, ITS counts actual downloads of publication PDFs rather than pageviews of the bibliographic summaries. In FY 2020, ITS technical publications were downloaded 5,691 times.

4.3.3 Transfer of Technical Methods

High-precision measurements are key to creating and validating radio propagation models. ITS and its predecessors have been collecting measurement data for more than a century, creating a unique expertise in measurement science and techniques which has been leveraged by other agencies seeking data needed to coordinate with commercial entrants into spectrum bands being opened for federal-nonfederal sharing. In FY 2020, ITS published in a peer-reviewed video journal the first of a planned series of video-illustrated articles that delve deeply and in detail into specific radiofrequency measurement techniques. The video article was viewed 1,784 times in its first year of publication, and it represents a continuation of a multimodal approach to transferring these techniques into broadspread use within the wider spectrum community. Theoretical context for this video article was set in a 2018 NTIA Technical Memorandum on "Best Practices for Radio Propagation Measurements," which was adopted by the Defense Spectrum Organization's (DSO) Spectrum Sharing Test & Demonstration (SST&D) program as a required resource to reduce the uncertainties of propagation measurement campaigns by commercial entrants seeking to coordinate sharing with DOD. The original Technical Memorandum, the series of 20 videos on Spectrum Measurement Theory and Techniques that combine theory and hands-on demonstration published on YouTube in 2019, and the 2020 peer-reviewed video journal article target audiences of differing scientific literacy through different media to amplify the reach of the best-practices message and expand message penetration.

4.3.4 Software and Data Downloads

Increasingly, technology transfer occurs through the publication of software rather than traditional technical reports. ITS makes several software and data tools available via open-source download. Reliable and robust methods of counting downloads of these tools took some time to develop; earlier, simpler software tools were offered as .zip files from the ITS public website, but over the past five years ITS increased its use of the GitHub open source code hosting platform, and by FY 2020 ITS had published 21 public repositories. While this allows more interaction with potential users of the software and can perhaps be said to broaden the audience, the open source paradigm also makes it more difficult to understand the impact of the software. As there is presently no generally accepted impact metric for GitHub repositories, ITS has added a count of the number of public repositories as a proxy until a more meaningful impact metric is determined. ITS continues to explore the development of metrics for GitHub-posted code in collaboration with other federal research institutions.

4.3.4.1 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 downloads of ITS software/data are for propagation prediction tools. Open-sourcing trusted and authoritative propagation models meets a critical need for spectrum sharing. The C++ implementation of the Extended Hata (eHata) Urban Propagation Model was used to inform regulation, and the repository was forked by the Wireless Innovation Forum™ (WInnForum), which redistributed it to industry members for use in developing the Spectrum Access Systems (SAS) that enabled spectrum sharing using the three-tier architecture in 3.5 GHz (CBRS Band).

4.3.4.2 Audio Quality Testing

ITS has developed a family of no-reference speech quality and intelligibility estimators and is providing software implementations to industry, researchers, and other agencies via GitHub. These estimators (called WAWEnets) leverage convolutional neural networks, which are a specialized and very efficient type of deep neural network. This allows accurate speech quality and intelligibility estimates without access to any reference signal, thus expanding the utility of the tool to include real-time endpoint monitoring in the field.

Two earlier ITS-developed objective estimators of speech intelligibility are freely available for download from the ITS web site. These tools follow the paradigm of the Modified Rhyme Test (MRT) but consume a tiny fraction of the resources required by the conventional MRT. The Articulation Band Correlation MRT (ABC-MRT) provides excellent estimates of MRT intelligibility results (Pearson correlations of .95–.99) for narrowband speech transmissions. ABC-MRT16, released in FY 2017, not only updated the audition model, but also extended the estimator to cover wideband, superwideband, and fullband speech systems. The ITS web site also offers a large variety of audio recordings that support the use of these tools.

4.3.4.3 Video Quality Measurement Software

ITS began researching objective video quality models in FY 1988, to address the needs of U.S. industry to understand the complex relationship between digital video technologies, networks, and video quality. Rapid advances in video and network technologies make this a moving goal. ITS video quality research produces improved methods for human testing as well as objective metrics that provide users an inexpensive alternative to human testing. ITS distributes software for various tasks related to subjective testing (including subject screening, subjective test control, image filtering, color calibration, statistical analyses, and merging multiple subjective datasets onto a single scale) as well as software implementing objective metrics.

Objective metrics that predict human perception of video quality would allow broadcasters to optimize the tradeoff between bandwidth and quality in real time. Early ITS research focused on objective metrics that compare the current video to a pristine original, culminating in a series of objective video quality metrics (VQM) that are included in ATIS and ITU standards. The VQM software was downloaded 249 times and forked three times from GitHub in FY 2020. Downloads of the VQM software have been steadily decreasing as its age and changes in technology make it less relevant.

Most contemporary video distribution technologies only have access to the current video signal (e.g., a pristine original never existed) and this presents a difficult challenge. Despite decades of research, existing no reference (NR) metrics remain too inaccurate for U.S. industry applications. ITS has intensified research on NR objective metrics over the past five years, but international experts agree that widespread collaboration is needed to build reliable NR metrics. In FY 2020, ITS made available a framework on GitHub that supports collaborative R&D into NR metrics for image and video quality. The repository was released to the public domain to stimulate an open exchange of ideas, information, and research to accelerate development of the robust and trusted NR metrics industry needs to more efficiently use increasingly crowded bandwidth. The NRMetricFramework repository contains all of the tools, information, and statistical methods needed to begin research on this difficult problem. This repository has been forked twice and downloaded 32 times.

4.3.4.4 Consumer Digital Video Library Users Downloading Clips

The Consumer Digital Video Library (CDVL), a web site hosted and maintained by ITS, provides researchers access to high quality, uncompressed video clips royalty-free for use in video processing and video quality product development and testing. CDVL enables an open data solution that protects content owners' rights, hosts large records (up to 0.5 GB), and provides generous terms for users. The technical committee for this collaborative project includes industry and academic representatives as well as ITS staff. ITS launched the site in 2010 with 1000 clips and clips continue to be added by ITS and other collaborators. The CDVL website software was replaced in Q1 of FY 2020 to comply with new security policies and to accommodate an increasing volume of data as the site has become increasingly important to the wider research community. The updated website allows researchers to share entire experiments as open data. Significant recent additions include six experiments from ITS plus experiments contributed by the University of Brasília (UnB), the Delft University of Technology (TUD), Dolby, AGH University of Science and Technology, and the Video Quality Experts Group (VQEG).

In FY 2020, 601 unique records were downloaded from the new website, by a total of 120 users. Self-reported demographics indicate 35% of users were from the United States, 21% China, 7% United Kingdom, 5% Canada, 5% India, and 3% or less from 16 other countries. The applications were 42% academic, 38% industry, 5% government, and 12% personal, with the remainder unreported. 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.

Table 30: NTIA ITS Software and Data Downloads

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Technical Publications Released	4	10	11	11	14
Technical Publications Downloaded	8,748	6,214	5,513	5,980	8,476
Consumer Digital Video Library Users Downloading	*	*	*	*	120*
Video Quality Metric Software Users Downloading	496	372	332	194	248
Propagation Modeling Software Downloads	781	1,160	1,325	1,352	1,213
Other Software/Data Downloads	591	819	661	714	875
Public GitHub Repositories	4	8	17	21	21

* CDVL download statistics are not compared to prior years, due to suspected flaws in the prior website's statistics.

4.3.5 Development of Telecommunication Standards

ITS works with industry to apply research results to the development of telecommunication performance standards and guidelines. For several decades, ITS has provided leadership and technical contributions to organizations, both national and international, responsible for developing telecommunication standards. ITS's technical inputs are relied upon as technically advanced and sound, and as unbiased by commercial interests.

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

In FY 2020, ITS staff held 28 positions in eight standards bodies, including 10 Chair/Co-chair/Vice-chair positions. ITS staff filled key leadership positions in the ITU-R, including Head of the U.S. Delegation to Study Group (SG) 3 (Radiowave Propagation), International Chair and U.S. Chair of SG3 Working Parties 3K and 3L (Point-to-area and ionospheric propagation), and U.S. Chair of Working Party 3J (Propagation fundamentals). ITS staff also filled key leadership positions in the ITU-T, including Head of U.S. Delegation to Study Group 13 (Future Networks) and Study Group 11 (Protocols and Test Specifications). ITS staff hold the Co-Chair position for the ATIS 5G Supply Chain Working Group. ITS also continued its technical leadership and contributions to communications standards for emerging 5G technologies through participation in 3GPP and in that capacity, and at the behest of the National Security Council, is responsible for driving collaboration between U.S. Departments/Agencies participating in 3GPP. Finally, ITS provided technical leadership and contributions to IEEE standards for local/personal/ metropolitan area networks (LAN/PAN/MAN) through participation in IEEE 802.

4.4 SUCCESS STORIES DEMONSTRATING DOWNSTREAM OUTCOMES FROM NTIA ITS TECHNOLOGY TRANSFER ACTIVITIES

4.4.1 Innovative Commercial Services

ITS research, technology transfer, and testing was critical to the successful commercial deployments of the new Citizens Broadband Radio Service (CBRS) and $4.6 billion auction of licenses within CBRS in 2020. When the FCC, in consultation with NTIA, created the innovative three-tiered access and authorization framework to accommodate shared federal and non-federal use of the 3.5 GHz band, no roadmap existed for creating and authorizing the new sharing system between high power federal radars and commercial mobile services. Broadly and openly disseminated ITS research and publications on electromagnetic compatibility between LTE and radars, LTE hotspot emission measurements, on-shore detections of off-shore radars, and effects of high-power radars on low noise amplifiers informed the development of technical requirements and commercial solutions.

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

ITS worked with the industry-led standards organization on applying those analyses in the development of technical standards for a technology-neutral commercial broadband service, including providing critical propagation software through publication of the C++ implementation of the eHata propagation model. At the request of the FCC, ITS developed a certification testing system for environmental sensing capability sensors (ESCs) critical for protection of federal radar systems, and conformance tests for the spectrum access systems (SAS) that leveraged the WInnForum SAS certification system. ITS published a technical memorandum detailing procedures and processes for ESC testing and published a SAS test software-based study guide via GitHub. Under CRADAs with industry partners, ITS conducted certification testing on ESCs and SASs. These test reports paved the way for the FCC, after consultation with the DoD and NTIA-OSM, to authorize initial commercial operations at 3.5 GHz on September 16, 2019. Subsequent real-world deployments proved the ITS testing regime successful, enabling the FCC to authorize full commercial service in 2020, and to conduct a $4.6 billion auction of priority access licenses within the CBRS band.

4.4.2 Telecommunication Standards

Models used to predict wireless propagation are fundamental to enabling spectrum sharing. The International Telecommunication Union – Radiocommunication Sector (ITU-R), an international treaty organization, has as its primary objective to ensure interference free operations of radiocommunications systems. The ITU-R publishes internationally standardized propagation prediction models that are used to harmonize spectrum assignments internationally and to manage space-related spectrum assignments. Increasing spectrum crowding demands increased accuracy and granularity of these models, which are developed through the participation of technical committees from all the treaty nations.

ITS leads efforts at ITU-R Study Group 3 (Radiowave Propagation) to ensure that U.S. interests and policy objectives are given due consideration by international technical experts and to promote informed decisions founded on physics and mathematics. ITS holds two of the four International Chairs of Study Group 3 and acts as Head of the U.S. Delegation to the Study Group 3 meetings. At the May 2019 meetings of SG3, ITS put forth a major revision of Recommendation P.528, *A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands*, along with a corresponding open source software implementation of the model—both of which were adopted by Study Group 3. ITS open-sourced the reference implementation source code, a compiled DLL, and a pre-built executable that launches a graphical front end for this software implementation. Throughout FY 2020, input was collected from the user community and minor updates released to GitHub, stimulating additional collaborative input that is expected to bear fruit as another major release after the July 2021 SG3 meetings.

During FY 2020, the International Civil Aviation Organization (ICAO) acknowledged the value of the ITS-contributed update by incorporating the updated revision of Recommendation P.528 into updates to their internal frequency assignment software. In addition, members of ICAO reach out to ITS for technical assistance with the model as well as requesting additional improvements in Recommendation P.528 to support the diversity of existing aeronautical systems—improvements that ITS proposed to Study Group 3 during the August 2020 meetings. Furthermore, one output of the 2019 World Radio Conference (WRC19) was a proposal for sharing studies between existing aeronautical systems and newly proposed commercial deployments at select millimeter wave (mmWave) frequencies. ITS is chairing the Correspondence Group that will be developing and proposing updated air-to-ground propagation prediction models for millimeter wave frequencies.

ITS leads efforts in the ITU Telecommunications Sector to defend U.S. interests in ensuring hostile regional agendas that are antithetical to U.S. policy on open standards development don't take root. In particular, ITS staff lead the effort to push back against Chinese attempts to use the ITU to promulgate policy through standards via attempts to modify fundamental aspects for how the Internet operates.

Direct participation by ITS in the 3rd Generation Partnership Project (3GPP), the dominant cellular communications standards development organization, allows NTIA to advance U.S. commercial, economic, and government interests by providing technical input to promote strong unbiased standards that support fair competition in next generation/5G cellular technologies. For a number of years, ITS has provided technical guidance to other government agencies in advocating for standardization of service features specific to public safety, emergency communications, and transportation. In particular, ITS represents the Department of

Transportation and the Department of Defense Undersecretary for Research and Engineering's interests in 5G within 3GPP. In FY 2020 ITS continued to provide U.S. Government stakeholders a comprehensive understanding of the 3GPP New Radio (5G NR—the global standard for the air interface of 5G networks) capabilities, the services 5G NR was built to deliver, and deployment scenarios in both licensed and unlicensed spectrum for the evolution to 5G.

Direct participation by ITS in IEEE 802.15.22.3 led to standardization of the Spectrum Characterization and Occupancy Sensing (SCOS) standard. The purpose of the SCOS system is to characterize and assess spectrum occupancy towards supporting its more efficient and effective use. SCOS establishes a high-level architecture to support different spectrum sensing technologies and deployments. It enables specialization, promotes broad adoption of sensing technologies and subsequent economies of scale. SCOS achieves broader availability and usage of sensing information from different sources.

SCOS applications include:

- policy and planning
- radio planning, management, and engineering
- regulatory enforcement to detect (RF incursion), locate (source), classify (by type and severity), and resolve/remediate
- research and technology development

4.4.3 Table Mountain Research

ITS manages the Table Mountain Radio Receiving Zone of the Research Laboratories of the Department of Commerce located in Boulder County, Colorado, an area designated by federal and state law as a Radio Quiet Zone. Quiet zones are protected by restrictions on radiofrequency radiation in the vicinity so as to minimize possible impact on the research operations that are highly sensitive to interference. This quiet zone managed by ITS is the only one presently available on a consistent basis for collaborative research across between government and industry and between different government agencies.

The Advanced Communications Test Site (ACTS) within the quiet zone supports fundamental research, engineering studies, and experiments into the nature, interaction, and evaluation of telecommunication devices, systems, and services. Annually NTIA, NOAA, NIST, universities, private companies, and other organizations conduct research at the ACTS under a variety of agreements (IAAs, Reimbursables, CRADAs). The work accomplished at the ACTS provides unique opportunities for cooperative learning and discovery, with the outcomes frequently becoming seeds of commercial and Government successes.

- In FY 2020, ITS continued its support of NOAA's Radio Frequency Interference Monitoring System (RFIMS) program at the ACTS. ITS continued to assist NOAA in understanding Meteorological Satellite (MetSat) radio frequency (RF) downlink technical performance in the face of new spectrum sharing requirements recently imposed on the MetSat RF downlink spectrum by the $41 billion auction of the AWS-3 frequency bands. To prepare for the eventual co-existence of MetSat downlinks and terrestrial cell phones (or equivalent), NOAA is developing a radio frequency interference monitoring system (RFIMS) to mitigate the risk of potential interference by commercial wireless carriers that were slated to begin sharing the spectrum with NOAA satellite operations in 2020. The ACTS was chosen to host a functionally equivalent MetSat Operations Center that mimics NOAA's two main operational MetSat sites. In FY 2020, the installation of a 6.5 m Geostationary Operational Environmental Satellite (GOES) receiver dish was completed and brought to an operational status. Additionally, ITS procured and installed a 3.7-meter Data Collection System (DCS) Direct Readout Ground Station (DRGS) and a 1.5 meter High Rate information System (HRIT).

These new systems complete the representative MetSat systems build-out began in 2018 with a 2.4 meter Polar Operational Environmental Satellite (POES) tracking and downlink earth station. The 2.4 meter system was the first MetSat system installed at the ACTS and has been the primary platform used to assess the degree to which terrestrial cellular interference can affect MetSat data downlink operations. The ACTS supports a test bed where commercial RFIMS systems can be tested for compliance with interference protection standards defined for the various federal MetSat assets, whether the commercial wireless systems seeking to share this spectrum are LTE (4G), 5G, 6G, or beyond. In concert with NOAA's development of a very robust RFIMS, a more modest Spectrum Survey System (SSS), created in FY2017, has been used over the past three years to prototype near-real time monitoring, data collecting, and reporting methods that might be used by the RFIMS. The SSS can also be used to analyze potential sharing concerns in other frequency bands. This foundational work is central to ITS's vanguard work and ability to assist government and industry in achieving peaceful and harmless standards-based coexistence in spectrum sharing situations.

- In FY 2020, several companies used the ACTS under CRADAs to safely test and demonstrate LIDAR 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. The ACTS was used to 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
    - sensing of hazardous liquids and gases

- For the past twelve years, the University of Colorado's Research and Engineering Center for Unmanned Vehicles has used the ACTS under a CRADA to safely and accurately test collective and autonomous sensing and communication technologies to facilitate 4D sight through a ground-to-space sensing column with unmanned aircraft systems (UAS) operating in the atmosphere integrated with ground-based and space-based observation systems. These capabilities are intended to be applied to a myriad of purposes ranging from improved climate and weather forecasting to better-informed government policymaking.

4.4.4 Video Quality Research

Both CDVL and the VQM tools are used by industry and academia for research into new techniques for transmitting video. Lack of access to appropriate video footage to test new video distribution technologies was a significant impediment to video processing R&D until the launch of CDVL. The clips may be used to test codecs, to evaluate new display technologies or validate testing of new standards. For example, ITU-T Study Group 12 has used CDVL clips for research into the development of parametric models and tools for multimedia quality assessment and the MPEG committee opened a conversation with ITS about using the CDVL video clips for validation testing of new video coding standards. Currently, 40% of CDVL’s content is simulated public safety content; real public safety content is nearly impossible to obtain for research due to litigation concerns. Since first responders use consumer grade electronics, promoting development and standardization of commercial video technologies that meet public safety requirements through access to this simulated content, has the potential to save lives as well as money.

ITS actively contributes to ITU efforts around best practices for video quality assessment. ITS leads and sponsors VQEG, an open venue where technical experts collaborate to develop subjective test methods for new video technologies. VQEG also independently validates objective video quality metrics, which is a necessary step in the standards development process. VQEG meetings are co-located with meetings of the Intersector Rapporteur Group (IRG) for Audiovisual Quality Assessment (IRG-AVQA) of the ITU. This allows more technical experts to follow and contribute to ITU Recommendations. ITS participation in VQEG facilitates knowledge sharing and enables research into difficult issues that can only be resolved through international collaborations. In FY 2020, ITS contributed to VQEG efforts to develop improved statistical methods, value-added experiment designs, and no reference (NR) metrics.

5 SUMMARY

This report details the results of the FY 2020 collaborative technology activities and technology transfer successes of the Department of Commerce agency laboratories at NIST, NOAA, and NTIA ITS. The report demonstrates that as technology advances and the economy changes, DOC federal laboratories play a critical role in providing America a competitive advantage and bolstering the U.S. economy through the transfer and commercialization of innovative technologies. Technology transfer is an essential DOC mission highlights and the report highlights how well the DOC labs position to be competitive the global markets.

6 APPENDIX A

Technology Area Classifications

Mapping of International Patent Classifications to Technology Area[25]

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

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

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

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

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

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

---

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

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

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

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

7 APPENDIX B

Fields and Subfields of S&E Publications Data[26]

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

Astronomy and Astrophysics: astronomy and astrophysics

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

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

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

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

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

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

---

[26] The fields are based on the Taxonomy of Disciplines (TOD) developed by the National Science Foundation (NSF). Science-Metrix used its own classification of 176 subfields developed more than a decade ago and worked with NSF to align its subfields to the TOD scheme.

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

Materials Science: materials

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

Natural Resources and Conservation: Environmental sciences; fisheries; forestry

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

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

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