Annual Report on Technology Transfer:
Approach and Plans, Fiscal Year 2021 Activities and Achievements

U.S. Department of Commerce

Report prepared by:

National Institute of Standards and Technology

National Oceanic and Atmospheric Administration

National Telecommunications and Information Administration

Institute for Telecommunication Sciences

Pursuant to the

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

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FOREWORD

This report summarizes technology transfer activities and achievements of the Department of Commerce's (DOC) federal laboratories for fiscal year (FY) 2021. 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 2017 through FY 2021.

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.

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1 DEPARTMENT OF COMMERCE OVERVIEW

Technology transfer plays an important role in the Department of Commerce's (DOC) 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 U.S. economy.

DOC is also responsible for organizing technology transfer activities across federal agencies. DOC through NIST supports the interagency technology transfer community by serving as Co-Chair of the National Science and Technology Council's Lab-to-Market Subcommittee (L2M), host agency for the Federal Laboratory Consortium (FLC), convener of the Interagency Working Group for Technology Transfer (IAWGTT), and also coordinates the Interagency Working Group on Bayh-Dole (IAWGBD).

DOC through NIST serves as a Co-Chair and the Executive Secretariat for the National Science and Technology Council's Lab-to-Market subcommittee. L2M sets the high-level strategy for increasing the efficiency at which federally-funded technologies move out of the laboratories and into the market. Strategies currently include identifying administrative and regulatory impediments, increasing engagement with innovation ecosystems, sponsoring innovative technology transfer tools and services, and finding gaps in the R&D continuum. Implementing these strategies is accomplished through the work of several subgroups such as the FLC, IAWGTT, and the IAWG.

DOC coordinates the IAWGTT through NIST-hosted interagency discussion on policy, new approaches to technology transfer, and lessons learned from agency technology transfer programs.[1] The IAWGTT was established in 1987 by Executive Order 12591, Section 7, to "convene an interagency task force comprised of the heads of representative agencies and the

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

directors of representative Federal laboratories, or their designees, in order to identify and disseminate creative approaches to technology transfer from Federal laboratories."

NIST also serves as the host agency for the FLC, which provides a forum for federal labs to develop strategies and opportunities for linking technologies and expertise with the marketplace. The FLC operates as a quasi-governmental body, founded in statute (15 U.S. Code § 3710), that shares technology transfer best practices, develops promotional materials, facilitates partnerships, and organizes networking events. The mission of the FLC is "to promote, educate and facilitate federal T2 among its member labs and institutions so they can easily reach their commercialization goals, and create social and economic impacts with new innovative technologies. Through the various resources, education and training, tools, and services the FLC creates and provides its members, federal labs are better able to create partnerships, navigate the commercialization process, and achieve market success."[2]

As the agency tasked with promulgating the Bayh-Dole regulations, DOC through NIST also coordinates the IAWGBD.[3] The IAWGBD reviews and discusses issues related to Bayh-Dole, including potential amendments to the Bayh-Dole regulations and aligning agency policies. Recently, the IAWGBD has been reviewing the implementation of changes to the iEdison reporting system to ensure the system adheres to regulatory requirements as well as agency needs. iEdison is an interagency system used by over 30 agencies and bureaus to facilitate the reporting of inventions and patents that were conceived or first actually reduced to practice using extramural federal research funding. Over the last two years, NIST has been redesigning and modernizing the iEdison system in preparation for transfer of the management and maintenance of the system from NIH to NIST in 2022. NIST's improvements to iEdison are expected to bring increased reporting compliance and improved tracking of the utilization of these federally funded inventions including information on where resulting products are being manufactured.

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), cooperative 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

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[2] https://federallabs.org/about-the-flc

[3] The IAWGBD was formed to facilitate a response to 35 U.SC. 206 and included representatives from across the federal government including individuals from 14 federal agencies, the Executive Office of the President, and the White House Office of Science and Technology Policy.

laboratories or conducts activities under 35 U.S.C. §§ 207 and 209 to report annually to the Office of Management and Budget (OMB) on the agency's technology transfer activities. The OMB's Circular A-11 also requires this information. The tables in the following sections present the required data.[4]

1.1 Statutorily Required Combined Metric Tables

Table 1: DOC Invention Disclosures and Patenting

Metric	FY2021
Invention Disclosures Received	67
Total Patent Applications Filed	80
U.S.	41
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	3
Total Patents Issued	34
U.S.	34
Foreign	0

[4] 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 and 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,and the like. 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 2021
Invention Licenses, Total Active	44
New Invention Licenses	9
New Invention Licenses Granted to Small Businesses	2
Income Bearing Licenses, Total Active	33
New Income Bearing Licenses	3
Exclusive, Total Active	17
Partially Exclusive, Total Active	0
Non-Exclusive, Total Active	16
Other Licenses, Total Active	0
New Other Licenses	0
New Other Licenses Granted to Small	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 3: DOC Income from Licensing[5]

Metric	FY 2021
Invention License Income	$105,571
Other License Income	0
Total Earned Royalty Income (ERI)	$105,571
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 2021
Total Active CRADAs	2,192
New CRADAs	1,807
New CRADAs Involving Small Businesses	960
Other Collaborative Agreements	2,619

[5] 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.

1.2 Other Performance Measures Deemed Important

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

Figures 1 and 2 show the most common specific technical areas covered by DOC patents for FY 2020 and FY 2021. In FY 2020, the top three specific technical areas covered by DOC patents were Measurement (26%), Optics (10%), and Computer Technology (10%).[6] In FY 2021, the top three specific technical areas covered by DOC patents were Measurement (37%), Optics (16%), and Computer Technology (10%).[7]

Figure 1: Percent of U.S. Patents Granted to DOC, by Technology Area in FY 2020[8]

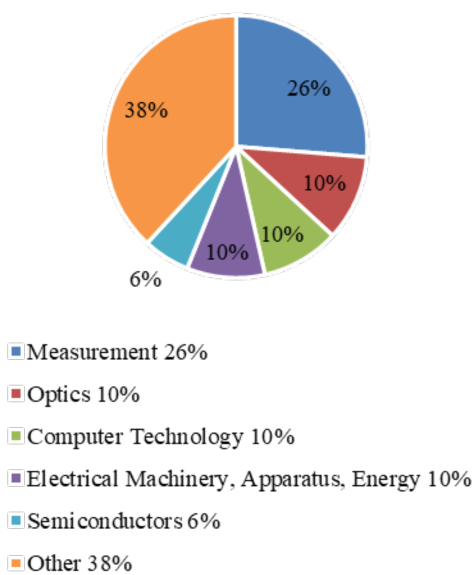
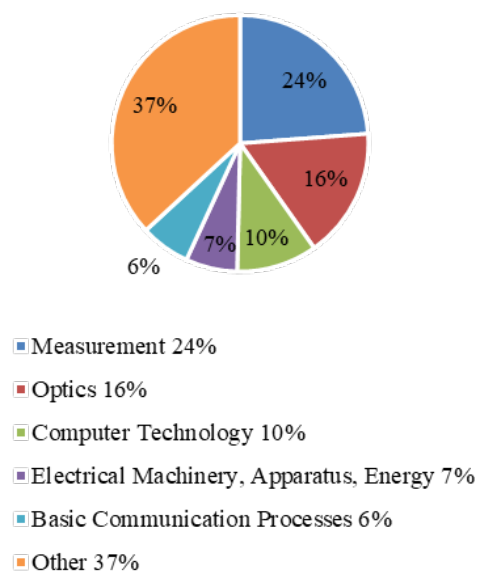


Figure 2: Percent of U.S. Patents Granted to DOC, by Technology Area in FY 2021[9]



[6] In FY 2020, the Other category included the following technical areas: 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.

[7] In FY 2021, the Other category included the technical areas of: Other Special Machines, Telecommunications; Surface Technology, Coating; Analysis of Biological Materials; Biotechnology; Control; Semiconductors; Materials, Metallurgy; Micro-structural and Nano-technology; Digital Communication; Pharmaceuticals; Environmental Technology; Medical Technology; Audio-visual Technology; and Textile and Paper Machines

[8] Prepared by Science-Metrix using USPTO data indexed in PatentsView accessed in March 2021. Used with permission.

[9] Prepared by Science-Metrix using USPTO data indexed in PatentsView accessed in January 2022. 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 included and counted as technology transfer. In FY 2021, NIST, NOAA, and ITS researchers published 3,323 scientific and technical papers in peer-reviewed journals.

Table 5: DOC Scientific and Technical Publications

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
NIST	1,433	1,415	1,396	1,345	1,509
NOAA	1,678	1,794	1,895	1,755	1,804
ITS	10	11	11	14	10
Department Total	3,121	3,220	3,302	3,114	3,323

1.2.2.1 Percentage 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) 2020 and CY 2021. 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 NSF Science & Engineering Indicators (SEI) reports. Journals are assigned to a unique TOD except for the 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 2020, the most frequent technology areas covered by DOC publications are Geosciences, Atmospheric, and Ocean Sciences (32%), Physics (18%), and Engineering.[10] In CY 2021, the

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

most frequent technology areas covered by DOC publications are Geosciences, Atmospheric, and Ocean Sciences (33%), Engineering (16%), and Physics (14%).[11]

Figure 3: Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2020[12]

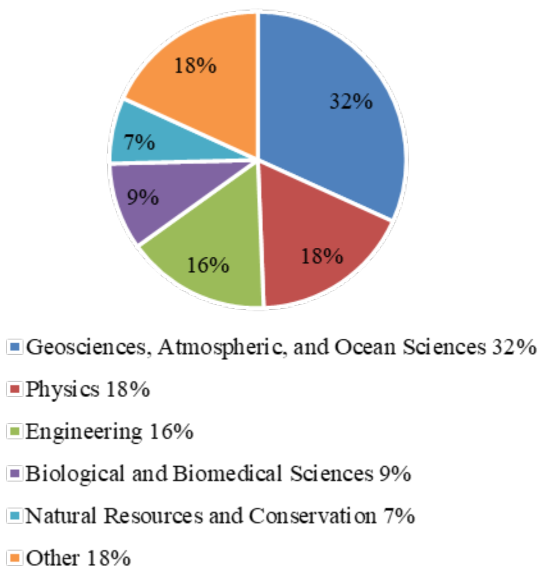
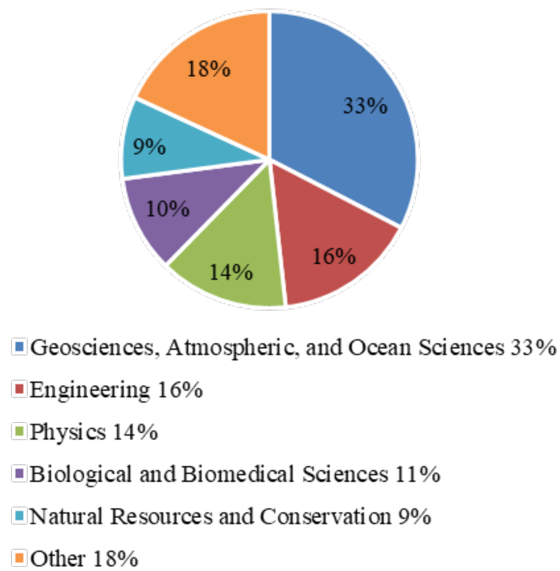


Figure 4: Percent of Articles by Science and Engineering Fields Authored by DOC Staff in CY 2021[13]



1.2.2.2 Percentage 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 2020 cite 1,516 publications authored by DOC researchers. As shown in Figure 5, the technology areas with the most numerous patents citing DOC publications include Physics (35%), followed by Engineering (18%) and Chemistry (12%).[14]

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[11] In CY 2021, the Other category included the following technology areas : Chemistry, Computer and Information Sciences, Health Sciences, Materials Science, Social Sciences, Astronomy and Astrophysics, Mathematics and Statistics, Agricultural Sciences, and Psychology.

[12] Prepared by Science-Metrix using Scopus (Elsevier) accessed in February 2021. Used with permission.

[13] Prepared by Science-Metrix using Scopus (Elsevier) accessed in February 2022. Used with permission.

[14] In FY 2020, the Other category included the following technology areas: Health Sciences; Geosciences, Atmospheric, and Ocean Sciences; Materials Science; Natural Resources and Conservation; Mathematics and Statistics; Psychology; Astronomy and Astrophysics; Agricultural Sciences; and Social Sciences.

U.S. patents issued in FY 2021 cite 1,610 publications authored by DOC researchers. As shown in Figure 6, the technology areas with the most numerous patents citing DOC publications include Physics (35%), followed by Engineering (20%) and Chemistry (15%).[15]

Figure 5: Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2020[16]

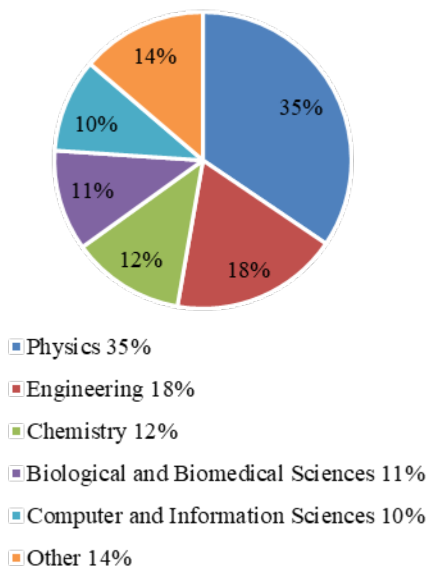
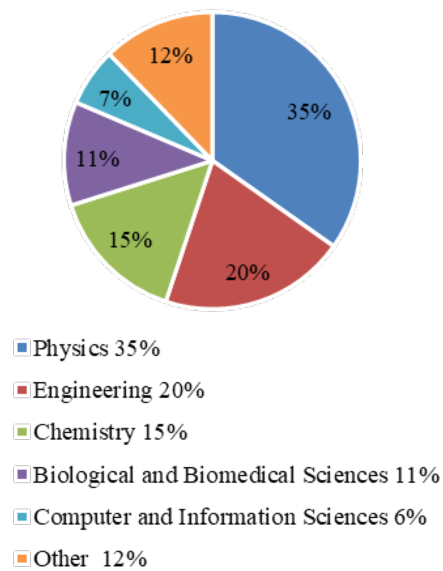


Figure 6: Percent of Articles by Science and Engineering Fields Authored by DOC Staff and Cited in U.S. Patents in FY 2021[17]



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.

[15] In FY 2021, the Other category included the following technology: Geosciences, Atmospheric, and Ocean Sciences; Health Sciences; Materials Science; Natural Resources and Conservation; Mathematics and Statistics; and Social Sciences.

[16] Prepared by Science-Metrix using Scopus (Elsevier) accessed in February 2021 and PatentsView accessed in March 2021. Used with permission.

[17] Prepared by Science-Metrix using Scopus (Elsevier) accessed in February 2022 and PatentsView accessed in January 2022. 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."*[18]

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.

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[18] https://www.nist.gov/director/congressional-and-legislative-affairs/fy-2019-presidential-budget-request-summary-1

NIST designed its technology transfer program to improve processes and work products directly through collaborations.

The mission of NIST's Technology Partnerships Office (TPO) is to serve its NIST customers by leading technology transfer processes that NIST researchers use to develop innovations from concept to practical application. TPO structures collaborative relationships between NIST researchers and regional, national, and global partners, fosters entrepreneurship and small business growth, and provides economic analysis to support the process. TPO serves its interagency customers by leading collaborative and consensus-building efforts for developing frameworks and best practices that enable all federal technology transfer offices to succeed in advancing their missions through partnerships and transferring technologies from lab to market.

TPO's vision is to facilitate the best possible outcome for each NIST research innovation and provide dynamic interagency leadership for technology transfer policy and analysis.

TPO went though a strategic planning process which resulted in a reorganization of the office to better accomplish its mission and better align with its vision.

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 2021
Invention Disclosures Received	55
Total Patent Applications Filed	80
U.S.	41
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	3
Total Patents Issued	32
U.S.	32
Foreign	0

Table 7: NIST Licensing[19]

Metric	FY 2021
Invention Licenses, Total Active	38
New Invention Licenses	7
New Invention Licenses Granted to Small Businesses	n.a.
Income Bearing Licenses, Total Active	27
New Income Bearing Licenses	1
Exclusive, Total Active	14
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)	2
Minimum (months)	2
Maximum (months)	2
Licenses Terminated for Cause	0

[19] "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 2021
Invention License Income	$36,399
Other License Income	$0
Total Earned Royalty Income (ERI)	$36,399
ERI from Top 1% of Licenses	$10,000
ERI from Top 5% of Licenses	$10,000
ERI from Top 20% of Licenses	$10,000
Minimum ERI	$1,250
Maximum ERI	$10,000
Median ERI	$3,859
Disposition of ERI	
Percentage Distributed to Inventors	56%
Percentage Distributed to Lab/Agency	44%

Table 9: NIST Collaborative Relationships[20]

Metric	FY 2021
Total Active CRADAs	2,135
New CRADAs	1,789
New CRADAs Involving Small Businesses	956
Other Collaborative Agreements	2,618

2.3 Other Important NIST Performance Measures

In addition to the previously discussed methods of transferring technology (i.e., patents, licenses, and CRADAs), NIST researchers routinely transfer technological innovations through the mechanisms discussed below.

2.3.1 Scientific and Technical Publications

NIST research results are published in a variety of formats including technical papers and reports, data, and software. These research outputs are made available to industry, academia, other agencies, and the public through various repositories and websites.

[20] 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 authors published 1,419 manuscripts in fiscal year (FY) 2021 in peer-reviewed journals. The number of times that a manuscript is cited by other authors serves as an indicator of technology transfer. In calendar year (CY) 2020, NIST-authored manuscripts that were published in peer-reviewed journals during the past five years (CY 2016–2020) garnered 36,882 citations.[21]

Table 10: NIST Publishing Activities – Papers

	FY 2020	FY 2021
Number of NIST Papers	1,509	1,419
Number of NIST Paper Citations (CY)	n/a	36,882

NIST is the self-publisher of over 15 Technical Series publications (TechPubs) consisting of technical reports, recommendations, practice guides and standards, industry handbooks, and other documents. NIST produced 225 TechPubs in FY 2021. The number of times that a publication is downloaded serves as an indicator of technology transfer. In CY 2020, NIST TechPubs that were published during the past five years (CY 2016–2020) were downloaded over 2.8 million times.[22] Of these publications, those with the subject area of computer and information security standards and guidelines were downloaded thousands of times every day.[23]

Table 11: NIST Publishing Activities - Technical Report Series

	FY 2020	FY 2021
Number of NIST TechPubs Published	232	225
Number of NIST TechPubs Downloads (CY)	n/a	2,840,058

NIST researchers published 128 data products in FY 2021, including datasets and software. The volume of downloaded data products serves as an indicator of technology transfer. In CY 2020, there were 14 terabytes[24] (TB) of data downloaded from NIST datasets located in the NIST Data Portal. The number of repositories added to the NIST Open-Source Code Portal, where public users search and explore open-source software developed by NIST and collaborators, serves as

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[21] NIST peer-reviewed publication data were retrieved from queries of the Web of Science (WoS) database on October 28, 2021. These data do not represent a comprehensive count of all NIST publications. This reporting includes only NIST-authored publications that are captured by the WoS search queries. Publications that are not indexed in the WoS database are not included in this reporting.

[22] Download statistics of NIST Technical Series Publications consist of the number of unique visitors ("downloads") for each publication, for instance, a count of requests to display PDF content from a unique IP address. Requests from spiders and web crawlers are not used to determine visitors.

[23] NIST is responsible for developing information security standards and guidelines, including minimum requirements for federal information systems per statutory responsibilities under the Federal Information Security Modernization Act (FISMA), 44 U.S.C. § 3551 et seq., Public Law (P.L.) 113-283.

[24] Download statistics of NIST datasets are derived directly from usage metrics generated on the NIST Data Portal.

an indicator of technology transfer. In FY 2021, 68 repositories[25] were added to the NIST Open-Source Code Portal. These data products are generated as part of the NIST mission, spanning multiple disciplines of scientific, engineering and technology research.

Table 12: NIST Publishing Activities – Data and Software

	FY 2020	FY 2021
Number of NIST Datasets & Software Published	132	128
Quantity of NIST Data (direct download) from NIST Data Portal (CY)	n/a	14 TB
Number of Repositories added to the NIST Open-Source Code Portal	143	68

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*.

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."[26]

During FY 2021, 547 members of the NIST staff were involved with 350 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.

[25] NIST Open-Source Code Portal Repository data were retrieved from the Repo Creation History chart. These data do not represent a comprehensive count of all NIST data repositories. These data refer to the number of repositories added to the portal in the reporting fiscal year; it is not a cumulative number.

[26] 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 13: NIST Participation in Documentary Standards[27]

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Number of Participating NIST Staff	440	423	440	400	547
Number of Standard Organizations with NIST Participants	119	116	112	112	350

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 2021, the NIST SRD Program distributed 3,200 e-commerce orders, 8,499 units sold via distributor, 118 active distributor agreements, 19 active site licenses, 69 active internet subscriptions, 50 units shipped to the user, and 4,449 products downloaded from the NIST website (1,369 free downloads, 3,080 paid downloads).

Table 14: NIST Standard Reference Data Program

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Products Available (Databases)	97	92	90	74	74
E-Commerce Orders	2,229	2,670	2,613	2,908	3,200
Units Sold via Distributor	7,995	8,413	9,880	7,905	8,499
Active Distributor Agreements	154	157	125	115	118
Active Site Licenses	36	17	30	15	19
Active Internet Subscriptions	40	50	41	140	69
Units Shipped via UPS	328	146	82	57	50
Products Downloaded from the NIST Website	3,119	3,910	3,812	4,578	4,449
Free Downloads	1,225	1,099	1,100	1,484	1,369
Paid Downloads	1,894	2,811	2,712	3,094	3,080

[27] The FY 2021 data for the reported number of participianting NIST staff and number of standard organization with NIST participants come from a new database platform.

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 2021, NIST made available 1,116 SRMs and from these, sold 28,065 units.

Table 15: NIST Standard Reference Materials

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Units Available	1,182	1,140	1,130	1,114	1,116
Units Sold	32,348	31,503	29,955	27,319	28,065

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.[28] In FY 2021, there were 184 distinct facility users at CNST and 2,576 research participants at NCNR.

Table 16: NIST Research Participants

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
CNST	3,215	3,415	314	230	184
NCNR	2,769	2,742	2,923	3,068	2,576

[28] 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 2021, NIST hosted 132 postdocs. Of these, 94 were based at the NIST Gaithersburg, Maryland campus; 33 were located in Boulder, Colorado; and the remainder were located at the Joint Institute for Laboratory Astrophyics (JILA).

Table 17: NIST Postdoctoral Researchers

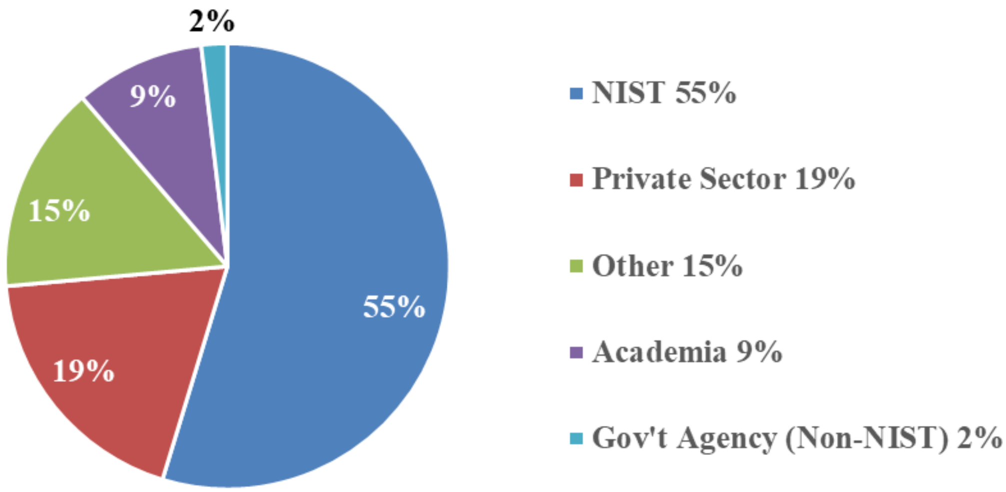
	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
NIST Postdocs, Total (NRC)	159	153	165	154	132
Gaithersburg campus	87	91	110	103	94
Boulder campus	47	44	35	40	33
Joint Institute for Laboratory Astrophysics [a]	12	10	13	7	5
Joint Quantum Institute [b]	3	3	1	0	0
Hollings Marine Laboratory [c]	2	1	3	4	0
Institute for Bioscience and Biotechnology Research [d]	3	3	2	0	0
Brookhaven National Laboratory[e]	2	0	0	0	0
Joint Initiative for Metrology in Biology[f]	3	1	1	0	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

53 FY 2021 NIST National Research Council (NRC) program postdocs. Of these, 55% continued research careers with NIST,[29] 19% percent moved to the private sector, 15% pursued other opportunities such as becoming independent researchers, 9% moved to academia, and 2% moved to non-NIST government agencies.

Figure 7: Tracking NIST Researchers after Initial Postdoc Tenure at NIST (FY 2021)



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 are 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 2021 there were 2,371 guest scientists and engineers working at NIST. Fewer guest researchers visited NIST due to the COVID-19 pandemic and travel restrictions.

[29] 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).

Table 18: NIST Guest Researchers

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Guest Scientists and Engineers	3,181	3,221	3,180	2,701	2,371

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 2021, NVLAP accredited 650 laboratories.

Table 19: NIST Accreditation Services

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
NVLAP Accreditations	723	674	674	644	650

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 2021, NIST performed 13,568 calibration tests.

Table 20: NIST Calibration Services

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Number of Calibration Tests Performed	13,802	11,771	11,519	9,225	13,568

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 324 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 2021, WSTEM efforts included the creation of groups within the organization to engage in a range of activities including the following: community connection, equity and representation, information sharing, mentoring, networking, and recruitment.

In FY 2021, 48 students participated in the Pathways Program, 24 individuals participated in the Summer Institute for Middle School Science Teachers, and 425 students participated in the PREP program.

Table 21: NIST STEM Education Participation

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
SURF[(a)]	212	212	173	0	146
SHIP	70	64	55	0	54
Pathways Program	111	85	71	77	48
Summer Institute for Middle School Science Teachers[(b)]	21	0	24	23	24
PREP	36	200	360	174	425

(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 2021, the NIST Conference Program arranged 40 conferences, both in person and virtual, that attracted 17,943 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 2,083 weights and measures administrators, laboratory metrologists, and field enforcement officials. 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 22: NIST Conferences, Seminars, and Workshops

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
NIST Conference Center					
Conferences and Workshops	108	101	78	74	40
Attendance	10,588	8,772	8,596	7,747	17,943
Office of Weights and Measures - Metrology Training					
Total Students	987	902	666	2,057	2,083
Seminar Attendance	537	523	441	101	0
Webinar Attendance	414	379	225	1,948	1,954
Workshop Attendance	36	0	0	8	129

2.3.12 Trends in Technology Transfer Office Activity

To better understand the year-to-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 2021, 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 488 days. In most cases, NIST files a provisional patent application before a non-provisional filing. Therefore, the duration reported here reflects a time period that starts with an invention disclosure, includes the filing of a provisional patent application, and ends with the filing of a non-provisional patent application, which usually occurs close to 365 days after the provisional application filing date. The average CRADA approval time was 92 days.

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Average Number of Days to File a Non-Provisional Patent Application[a]	396	337	408	450	488
Average Number of Days to Approve a CRADA[b]	108	91	129	109	92

(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. In FY 2021, NIST awarded 11 Phase I SBIR awards and 6 Phase II SBIR awards.

Table 24: NIST SBIR Award Count

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Phase I SBIR Awards	12	12	12	12	11
Phase II SBIR Awards	9	10	7	8	6

2.3.14 Economic Assessment

Economists at NIST completed two studies in FY 2021:

1. The Geographic Footprint of NIST Coopertive Research and Development Agreements and Licenses: Fiscal Year 2019

   Key findings: In this paper, the authors show the geographic distribution of active NIST cooperative research and development agreements (CRADAs) and invention licenses in fiscal year 2019. The authors show that NIST had 388 CRADAs in 34 states and the District of Columbia with a national rate of 1.17 CRADAs per million population. The authors show that NIST has 69 invention licenses in 20 states and the District of Columbia with a national rate of 0.21 licenses per million population. Of the six Federal Laboratory Consortium regions, the Mid-Atlantic region had the highest rates of CRADAs per million population with 3.27 and of invention licenses per million population with 0.78.

2. Filing Rate and Transfer Rate at NIST: An examination of invention disclosures, patent applications, and invention licenses

   Abstract: In this work, we apply new technology-transfer measures—filing rate (i.e., proportion of invention disclosures that result in a patent application) and transfer rate (i.e., proportion of patent applications that result in an invention license)—proposed in the academic literature on technology transfer, to data on invention disclosures, patents, and invention licenses from the National Institute of Standards and Technology (NIST). We calculate these measures for NIST and compare their calculated values to the measures reported for the Naval Medical Research and Development Enterprise (NMR&D) and for universities. For fiscal years 2010 through 2014, NIST had a filing rate of 67 % and a transfer rate of 15.3 % on reported inventions. During that same time period, NMR&D had an 84.5 % filing rate and 9.4 % transfer rate. Compared to the university mean filing rate of 60 % and transfer rate of 42 %, NIST and NMR&D invention disclosures appear to be prosecuted for patenting at a higher rate and result in licensing at a lower rate. We caveat analysis of these measures by noting that these values are influenced by many factors unobserved in this work, including the nature of research conducted, the organization's mission, and the organization's policies towards intellectual property.

2.3.15 Technology Maturation Accelerator Program (TMAP)

The Technology Maturation Accelerator Program (TMAP) was begun at NIST in 2019 to provide a platform for NIST scientists and engineers to help propel their lab-created innovations to the commercial market in an accelerated timeline. Each year, the labs at NIST submit proposals for their projects deemed the easiest to commercialize. The finalists are selected and are given a chance to pitch their innovations to a panel of venture capitalists and business experts. The judges select the winners based on the following: potential market opportunity, a unique and/or defensible component, and the ability to attract financial or venture investment to scale for their projects. Each winning team is granted a set amount of NIST funds to get their projects more market-ready in one year with the end goal of full commercialization. TMAP is a platform to help bridge the worlds of federal government and the private sector together in a collaborative effort to help drive the U.S. economy forward with the latest, cutting-edge technologies.

Four participating projects were funded for FY 2021:

- Gopman, Daniel (MML) – "Ultrahigh Density in Memory Compute Chips using Advanced Magnetic Memory Devices";
- Ferraiolo, David (ITL) – "Fine-grained Data Sharing Infrastructure";
- Marino, John (MML) – "RNA-based N-terminal Amino Acid Binding (rNAAB) Reagents for use in Next-Generation Protein Sequencing Devices"; and
- Douglass, Kevin (PML) – "Vacuum-Fixed Length Optical Cavity".

2.3.16 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 2021, ten companies completed N-STEP projects and three companies are involved in ongoing projects. N-STEP is funded by NIST and administered by Maryland TEDCO but is a nationwide opportunity.

2.3.17 Challenge and Prize Competitions

NIST's Communications Technology Laboratory (CTL) and Engineering Laboratory (EL) host prize competitions under the America COMPETES Act authority (15 U.S.C. § 3719) to spur ideation and innovation from public solvers. The laboratories use prize competitions to advance manufacturing robotics (EL) and public safety communications (CTL) research by engaging individuals, industry, academia, and organizations in a rapid, more collaborative means than traditional funding opportunities. In FY 2021, NIST awarded 122 cash prizes totaling $1,631,000 to 57 teams. NIST launched or completed the following eleven prize competitions in FY 2021.

1. Tech to Protect Challenge: Coding for Emergency Responders
2. CHARIoT Challenge - Advancing First Responder Communications

3. First Responder UAS Endurance Challenge
4. Automated Streams Analysis for Public Safety (ASAPS) Prize Challenge: Contest 1
5. Enhancing Computer Vision for Public Safety Challenge
6. Differential Privacy Temporal Map Challenge
7. The Mobile Fingerprinting Innovation Technology (mFIT) Challenge
8. First Responder UAS Triple Challenge: 3.1 FastFind - UAS Search Optimized
9. First Responder UAS Triple Challenge: 3.2 LifeLink - UAS Data Relay
10. First Responder UAS Triple Challenge: 3.3 Shields Up! Securing Public Safety UAS Navigation and Control
11. Agile Robotics for Industrial Automation Competition (ARIAC)

Several of the above prize challenges had culminating phases focused on contestants developing a business or commercialization strategy surrounding their prototypes. Some prize challenges provided additional awards to help finalists connect to commercialization resources and advance their early-phase innovations.

2.3.18 Commercialization Programs and Support for External Researchers

NIST's Communications Technology Laboratory (CTL) has piloted two commercialization programs to support the commercialization of external researchers' technology:

1. Federal Funding Opportunity Focused on Commercialization:

   Starting in March 2020, NIST also offered a unique federal funding opportunity - *2020-NIST-PSIAP-TABA-01, NIST Public Safety Innovation Accelerator Program (PSIAP) – Follow-on Funding for Technical and Business Assistance and Demonstration Projects with Public Safety Agencies*- focused on advancing early phase prototypes to more advanced technology readiness levels.

   Acknowledging the technology development and life cycle gap from early-stage research and prototypes to publicly available technology, NIST is providing this funding opportunity to entities with a previous federal award to advance awardees' research and prototypes further and accelerate needed improvements in communications technology for first responders. The funding opportunity provides additional funding to entities to either: (1) more rapidly advance their prototypes through needed technical and business assistance; or (2) conduct a demonstration project with a partnering public safety agency to provide additional testing and research. The federal funding opportunity is available for proposals until May 2022.

2. Virtual Accelerator for Public Safety Communications Technology

   NIST designed the Pulse Accelerator to help emerging communications technology companies accelerate growth and development that supports the public safety and first responder sectors. Working together in a collaborative program, selected participants engage directly with specialists and experts from business, technology, and public safety to develop a commercialization plan for their technology innovation. Eight to ten companies participated in each of the three rounds of the accelerator (FY21 and FY22).

2.3.19 Awards

In its simplest form, technology transfer is achieved through dissemination of research results via publication, participation in professional societies, and other activities. As part of these activities and in addition to the NIST and DOC awards, NIST staff received the following prestigious awards during FY 2021:

American Physical Society (APS) Fellow
Alexander Kramida

American Physical Society (APS) Fellow
David Leibrandt

American Vacuum Society (AVS) Fellow
B. Robert Ilic

Breakthrough Prize in Fundamental Physics
Jun Ye

European Frequency and Time (EFTF) Young Scientist Award
David Leibrandt

Francis M. Pipkin Award of the American Physical Society
Andrew Ludlow

IEEE Fellow
Sae-Woo Nam

Niels Bohr Institute Medal of Honor
Jun Ye

Optica Fellow
Tara Fortier

Optica Fellow
Sergey Polyakov

PEAR Technical Accolade
Benjamin Heacock

Physics World 2021 Breakthrough of the Year
Jose Aumentado
Katarina Cicak
Raymond Simmonds
John Teufel

Robert H. Goddard Exceptional Achievement Award in Science
Steven Brown
Steven Grantham
Thomas Larason
Stephen Maxwell
John Woodward

Scialog Advanced Bioimaging Fellow
Kathryn Keenan

2020 New Internet IPv6 Hall of Fame
Doug Montgomery

2020 IEEE TCCLD Outstanding Service Award
Irena Bojanova

Rising Star Award from Federal Computer Week
Katie Boeckl

Service to America Medal
Donna Dodson

2021 Distinguished Alumni Award from the Indian Institute of Technology, Madras
Ram D. Sriram

CITAC Best Paper Award
Young Ma

CITAC Best Paper Award
Blaza Towman

2021 Federal 100 Award
Elham Tabassi
Victoria Yan Pillitteri

Fellow of International Council on Systems Engineering (INCOSE)
Ram D. Sriram

ANSI Edward Lohse Information Technology Medal
Wo Chang

INCITS Exceptional International Leadership Award
Mary Theofanos

2021 INCITS Merit Award
Annie Sokol

2021 INCITS Service Award
John Messina

2021 InnovateIT Award
Robert Byers
Christopher Turner
David Waltermire

2021 Etta Zuber Falconer Lecturer by the Association for Women in Mathematics and the Mathematical Association of America
Bonita Saunders

Special Recognition Award from The American Bar Association's Section on Science & Technology Law
Ron Ross

Excellence in Research in Applied Mathematics Award by the Washington Academy of Sciences
Tony Kearsley

Career Achievement Award from Federal Identity Forum 2021 – AFCEA
P. Jonathon Phillips

Vice President of the Earthquake Engineering Research Institute
Judith Mitrani-Reiser

UC Berkeley Civil and Environmental Engineering (CEE) Academy of Distinguished Alumni
Judy Mitrani-Reiser

American Society of Civil Engineers (ASCE) Metropolitan Section Civil Engineer of the Year for 2020 – 2021
Sissy Nikolaou

2021 ASCE Walter P Moore, Jr. Award
Therese McAllister

Chemical Society of Washington Outreach Volunteer of the Year
LaKesha Perry

Best Poster Award, Energy Storage and Conversion Horizons Conference
Behrang Hamadani
Andrew Shore
Brianna Conrad

IBPSA-USA Emerging Contributor Award
Lisa Ng
ASTM D-22 on Air Quality, Award of Appreciation
Dustin Poppendieck

Alice Hamilton Award for Occupational Safety and Health
Wai Cheong Tam

Best Paper Award, 11th International Conference on Structures in Fire (SiF 2020)
Lisa Choe

Best Paper Award, 11th International Conference on Structures in Fire (SiF 2020)
Selvarajah Ramesh
Xu Dai
Matthew Hoehler
Matthew Bundy

German-American Frontiers of Engineering Symposium
Moneer Helu

SME 25 Leaders Transforming Manufacturing
Moneer Helu

SME Eli Whitney Productivity Award
Shaw Feng

2021 SME Geoffrey Boothroyd Outstanding Young Manufacturing Engineer
Michael Brundage

SME College of Fellows
KC Morris

ASTM Award of Merit, with accompanying title of ASTM Fellow
Kevin Jurrens

SME 30 women in robotics you need to know about – 2020
Elena Messina

2020 Homeland Security Today Award, Most Valuable Player for Drones
Adam Jacoff

SME Smart Manufacturing Magazine: Top 20 Women in Robotics & Automation
Elena Messina

2020 ASME Outstanding Paper Award
Soocheol Yoon
Roger Bostelman

2020 ASME Runner Up: Outstanding Paper Award
Omar Aboul-Enein
Roger Bostelman

Samuel J. Heyman Service to America Medal Finalist
Adam Jacoff and the Response Robotics Team

Reviewer of the Year for the ASME Journal of Manufacturing Science and Engineering
Brandon Lane

ASME Best Organizer of Symposium & Sessions (BOSS) Award
Ho Yeung

ASME Outstanding Service Award
Shawn Moylan

2.4 Success Stories Demonstrating Downstream Outcomes From NIST Technology Transfer Activities

2.4.1 NIST Program Gives Protein-Sequencing Technology a Springboard from Lab to Market

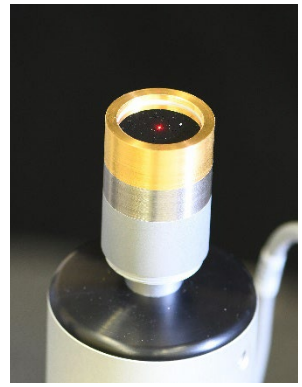
A protein-sequencing technology developed by researchers from the National Institute of Standards and Technology (NIST) is now being commercialized by a publicly traded company, less than two years after being part of NIST's first Technology Maturation Accelerator Program (TMAP). The inaugural TMAP cycle took place in November 2019 and attracted a wide selection of NIST scientists and engineers and their innovations with more than 60 proposals submitted. One of the winning teams was composed of John Marino (team leader), Zvi Kelman, and Jennifer Tullman-Arbogast of the Material Measurements Laboratory at NIST; their project was entitled, "N-terminal amino acid binding (NAAB) reagents for use in next-generation protein spread prevention." This research revolved around next-generation protein sequencing.

Following the team's TMAP award, as its members began to accelerate their protein-sequencing technology, the private sector began to take notice. A Connecticut-based startup company, Quantum-SI, whose mission is to develop a next-generation, single-molecule protein sequencing platform, expressed interest in the project. Quantum-SI seeks to promote an ecosystem that "includes the necessary tools to decode the molecules of life, including tools for sample preparation, sequencing, and data analysis." To achieve this vision, Quantum SI negotiated an exclusive commercial license with NIST in 2019 for the engineered protein reagents invented by the TMAP project team. These protein reagents are a key infrastructural technology that enables the approach Quantum SI wants to take with its existing cutting-edge platform.

In February 2021, after licensing the engineered protein reagent technology from NIST, Quantum-SI agreed to merge with HighCape Capital Acquisition Corp in a deal to take the company public. The company will receive $425 million in private investment from multiple institutional investors to help fund operations. The merging of Quantum-SI and HighCape Capital Acquisition Corp brings with it a valuation of $1.46 billion.

2.4.2 Testing 1-2: New Laser-Based Microphone Calibration Measures Up

Researchers at the National Institute of Standards and Technology (NIST) have conducted the first demonstration of a faster and more accurate way to calibrate certain kinds of microphones. The technique, which uses lasers to measure the velocity at which a microphone's diaphragm vibrates, performs well enough to overtake one of the main calibration methods used at NIST and throughout industry.



Close-up of a microphone, with the laser spot hitting the center of its diaphragm.
Credit: NIST

Traditional "comparison calibrations" involve comparing a customer's microphone to a laboratory standard microphone that has already been calibrated by other means. The new laser method demonstrated by NIST has lower uncertainties and is roughly 30% faster than the traditional comparison method currently used at NIST to calibrate customers' microphones. "People have been looking for a highly accurate calibration method that uses lasers, and they haven't found an approach that is competitive with the most accurate existing method," said NIST scientist Richard Allen. "But now we've found a comparison calibration that is better than the ones used in common practice."
NIST scientist Randall Wagner and Allen say that the laser comparison method saves "significant time" primarily because it is performed in open air. In contrast, the traditional NIST way of doing a comparison at higher frequencies requires connecting two microphones with an acoustic coupler and then filling the coupler with hydrogen, which takes up to 20 minutes per test.

Their work was published in *JASA Express Letters*. As of March, 2022, their article was viewed 1,376 times.

2.4.3 NIST Announces Top 4 Winners in the National First Responder UAS Endurance Challenge

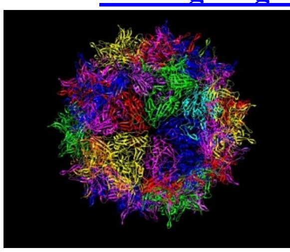
This drone from Advanced Aircraft Company took first place in NIST's UAS Endurance Challenge with 112 minutes of flight time with a heavy payload.
Credit: Advanced Aircraft Company

The U.S. Department of Commerce's National Institute of Standards and Technology (NIST) recently announced the four winners of the 2021 Public Safety Communications research (PSCR) First Responder unammed aircraft system (UAS) Endurance Challenge. In the four-stage challenge, participants designed, built and flew an UAS with the goal of flying for the longest time possible while carrying a 10-pound (4.5-kilogram) payload.

One of the barriers for the public safety community is not having access to a UAS that can fly for long periods of time, 90 minutes or longer, while carrying a heavy payload. For example, in a typical search-and-rescue mission, emergency responders may be dispatched to a location where broadband LTE communications are unavailable. To maintain communications, a UAS equipped with an LTE system can be deployed to extend coverage to the emergency location. PSCR is exploring ways to optimize drones for increased flight endurance while making them more efficient and flexible for use by public safety workers.

"Our grant programs and prize challenges help us make great leaps forward in solving public safety concerns by initiating collaboration with industry, academia and the public safety community," said Dereck Orr, chief of NIST's PSCR division, which managed the challenge. "The challenge has helped advance our mission and UAS technology, with the winning team surpassing 112 minutes of flight time for FAA Part 107 drone flights, which are systems weighing less than 55 pounds flown by certified drone pilots."

2.4.4 New Collaboration Aims to Improve Measurement of Viral Vectors Used in Cutting-Edge Gene Therapies



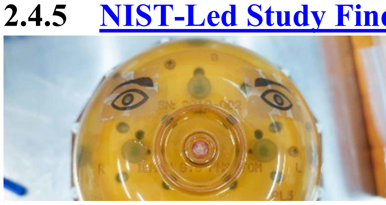
A ribbon diagram showing a portion of the protein shell of an adeno-associated virus used for delivering gene therapies. The colored ribbons represent different proteins.
Credit: Jazzlw, CC BY-SA 4.0

The U.S. Department of Commerce's National Institute of Standards and Technology (NIST), the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) and United States Pharmacopeia (USP) have announced a research collaboration to assess analytical methods and develop standards for adeno-associated virus (AAV), an important mechanism for delivering gene therapies.

"AAV is important because these are critical components to manufacture a variety of gene and cell therapy products," explained Kelvin Lee, NIIMBL institute director. "By addressing the quality attributes assessment of viral vectors, the field of gene therapies as a whole will benefit from access to high quality components to enable the development of a variety of products."

As part of this collaboration, USP and NIST will conduct an interlaboratory study in which multiple laboratories will measure these critical quality attributes and their results will be compared and analyzed. This will contribute to the standardization of measurement methods and the development of physical reference materials that will improve measurement consistency across the industry.

2.4.5 NIST-Led Study Finds Variations in Quantitative MRI Scanners' Measurements



NIST physicist Stephen Russek came up with the idea of giving MRI phantom Phreddie "eyes" to help technicians correctly position the device, as they would a human head, in an MRI machine.
Credit: R. Jacobson/NIST

Magnetic resonance imaging (MRI) is widely used in medicine to detect, diagnose and treat diseases such as cancer, while relying on experts' interpretation of images. Quantitative MRI, which obtains numerical measurements during the scans, can now potentially offer greater accuracy, repeatability and speed — but rigorous quality control is needed for it to reach its full potential, according to a new study.

The new study compared MRI scanner measurements of a value called T1, a property of water molecules that can depend on the surrounding tissue. T1 of the pixels in images is one of the parameters that could be measured by clinical MRI systems. By contrast, subjective interpretations of MRI images look at "T1-weighted" judgments, which are qualitative and nonnumerical.

The study found that T1 measurements can be subject to significant bias and variation. There was no consistent pattern of discrepancy between vendors, and as a result, a diagnostic threshold value determined on one MRI system can't be transferred to other MRI systems. In some cases, these variations could make a clinical difference in diagnosing a benign versus a malignant brain tumor, seriously affecting patient care, the study found.

As a remedy, the study recommended establishing rigorous quality control procedures for quantitative MRI measurements to promote confidence and stability in measurement techniques and to transfer measurement thresholds for diagnosis, disease progression, and treatment monitoring from research venues to the entire clinical community. The study results echo previous findings by other researchers.

This study was published online in *PLOS One*. As of March, 2022, their article was viewed 1,652 times and cited 2 times.

2.4.6 Bringing Atoms to a Standstill: NIST Miniaturizes Laser Cooling

Scientists at the National Institute of Standards and Technology (NIST) have miniaturized the optical components required to cool atoms down to a few thousandths of a degree Celsius above absolute zero, the first step in employing them on microchips to drive a new generation of super-accurate atomic clocks, enable navigation without GPS, and simulate quantum systems.

For more than two decades, scientists have cooled atoms by bombarding them with laser light, a feat for which NIST physicist Bill Phillips shared the 1997 Nobel Prize in physics. Now NIST researcher William McGehee and his colleagues have devised a compact optical platform, only about 15 centimeters (5.9 inches) long, that cools and traps gaseous atoms in a 1-centimeter-wide region. Although other miniature cooling systems have been built, this is the first one that relies solely on flat, or planar, optics, which are easy to mass produce.

The researchers described their apparatus online in the *New Journal of Physics*. As of March, 2022, their article was downloaded 4343 times and cited 8 times.

2.4.7 NIST on a Chip: A Better Way to Measure Acceleration

Addressing the increasing demand to accurately measure acceleration in smaller navigation systems and other devices, researchers at the National Institute of Standards and Technology (NIST) have developed an accelerometer—a sensor that detects sudden changes in velocity—a mere millimeter thick, that uses laser light instead of mechanical strain to produce a signal. This study is part of NIST on a Chip, a program that brings the institute's cutting-edge measurement-science technology and

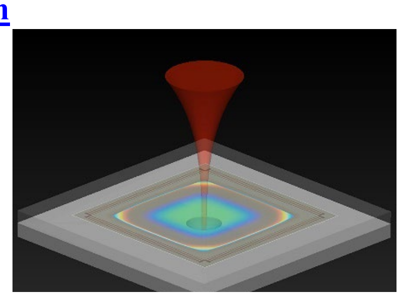


Illustration of an optomechanical accelerometer, which uses light to measure acceleration.
Credit: F. Zhou/NIST

expertise directly to users in commerce, medicine, defense, and academia.

Although a few other accelerometers also rely on light, the design of the NIST instrument makes the measuring process more straightforward, providing higher accuracy. It also operates over a greater range of frequencies and has been more rigorously tested than similar devices. The accelerometer also has the potential to improve inertial navigation in such critical systems as military aircraft, satellites and submarines, especially when a GPS signal is not available.

The researchers described their work in *Optica* and in *Optics Letters*. As of March, 2022 their article in *Optica* has been viewed 3,861 times and cited 7 times while their article in *Optics Letters* was viewed 464 times and cited 5 times.

2.4.8 NIST Scientists Explore the World of Tech Transfer

NIST scientists have taken part in FedTech's Startup Studio Program. FedTech, which is an organization that helps accelerate federal technologies to the commercial market, designed the Startup Studio Program to pair entrepreneurs with federal researchers to try and develop startup companies around technologies with commercial applications. Before transferring their technologies to market, though, federal researchers can enroll in the program and go through a small business boot camp of sorts. This program can provide NIST scientists and engineers with an opportunity to remove their lab coats and put on their business coats to better understand that world.

Two NIST researchers are taking part and have formed two different teams, made up of entrepreneurs, business coaches, and mentors to develop possible start-up companies and further their technologies toward the end goal of commercialization. Babak Nikoobakht, of the Nano Materials Research Group within the Material Measurement Laboratory, worked with his team on developing a novel, light-emitting diode that eliminates the issue of decline in efficiency as current LEDs cannot operate beyond one Ampere per one square millimeter.

Arvind Balijepalli, of the Biophysical and Biomedical Measurement Group within the Physical Measurement Laboratory, collaborated with his team to develop a modular electronic platform for measurements of biomarkers, which allows for a more comprehensive readout and more robust measurements. These two NIST scientists will continue to work with their teams, as they navigate through the Startup Studio Program, to gain a better understanding of building a company around a technology, discovering the appropriate target markets, and driving technologies to market.

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; 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. And this year, the first research to education operations transition with OAR/GSL's Science On a Sphere® program moving to the Office of Education. 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; forecasts for renewable energy siting; predicting freshwater resources; tsunami warnings; air quality measurement; solar emission forecasting; monitoring and estimating of fish stocks and species health; coastal habitat monitoring and pollution; invasive species monitoring; coral reef health; ocean acidification; coastal/ocean disaster response and restoration; charting ocean bottom topography; and a wide variety of climate research and the impacts of a changing climate on human health, coastal zone management, and oceans. Research results are routinely transitioned to NOAA's operational components to improve prediction, management, and other mission activities.

NOAA supports a network of 20 Cooperative Institutes at 70 universities and research institutions across 28 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.

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.

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 2021.

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 FY 2022 to better align with NOAA goals.

The following are selected reports of progress planned for FY 2022:

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 FY 2021 to pre-pandemic numbers, despite the COVID 19 lockdowns. Active CRADA numbers have increased as delayed projects have requested amendments. 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 execution of NOAA's new Science and Technology Focus Area Strategies to support public-private partnerships.

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 a new NOAA Administrative Order which provides guidance for software licensing and public distribution. The Order has been drafted and is in the review and approval phase.

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

<u>Task 3.2</u>: Increase public private partnerships in Aquaculture

<u>Progress Update:</u>

Currently, four of NOAA's 57 active CRADAs (7%) are in Aquaculture.

The current COVID-19 pandemic has slowed our efforts in this goal, but there is renewed effort to start again. We will continue to assist with the development of CRADAs and Facility Use Agreements to grow our public private partnerships in Aquaculture in our role of supporting partnerships across the NOAA Science and Technology focus areas.

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

<u>Task 2</u>: Increase NOAA TPO input to Intra and Interagency Groups

<u>Progress Update:</u>

As mentioned above, the NOAA TPO is an active member in the NOAA's Science and Technology Focus Area Strategies and continues to be involved in the implementation plans for many of these efforts.

3.2 Statutorily Required Metric Tables

NOAA was awarded two (2) patents and one (1) non-provisional application was filed in 2021.

NOAA researchers disclosed four software innovations, five hardware inventions, and three method inventions. The rights for the software inventions were consolidated and the products were released under a Creative Commons Zero public domain designation.

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 licensing portfolio consists of six (6) active invention licenses, two of which have been executed through university partners. The NOAA-issued invention licenses include three exclusive licenses, and three non-exclusive licenses, all of which are income-bearing. NOAA now maintains an active portfolio of 15 technologies, four of which are being marketed for licensees or are being actively commercialized.

Table 25: NOAA Invention Disclosures and Patenting

	FY 2021
Invention Disclosures Received	12
Total Patent Applications Filed	0
U.S.	0
Foreign	0
Total Patent Cooperation Treaty (PCT) Applications Filed	0
Total Patents Issued	2
U.S.	2
Foreign	0

Table 26: NOAA Licensing

	FY 2021
Invention Licenses, Total Active	6
New Invention Licenses	2
New Invention Licenses Granted to Small Businesses	2
Income Bearing Licenses, Total Active	6
New Income Bearing Licenses	2
Exclusive, Total Active	3
Partially Exclusive, Total Active	0
Non-Exclusive, Total Active	3
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 27: NOAA Income from Licensing

	FY 2021
Invention License Income	$69,173
Other License Income	$0
Total Earned Royalty Income (ERI)	$69,173
ERI from Top 1% of Licenses	$69,173
ERI from Top 5% of Licenses	$69,173
ERI from Top 20% of Licenses	$69,173
Minimum ERI	$69,173
Maximum ERI	$69,173
Median ERI	$69,173
Disposition of ERI	
Percentage Distributed to Inventors	32%
Percentage Distributed to Lab/Agency	68%

Table 28: NOAA Collaborative Agreements

	FY 2021
Total Active CRADAs	57
New CRADAs	18
New CRADAs Involving Small Businesses	4
Other Collaborative Agreements	1

3.3 Other Important NOAA Performance Measures

3.3.1 Publications:

In FY 2021, peer-reviewed publications by NOAA federal scientists totaled 1804.[30] The following charts show the breakdown of publications, including publications from NOAA and NOAA-funded sources. Table 29 shows the number of publications by research unit as a percentage of all NOAA-authored publications in FY 2021.[31] A single publication with authors from one or more line offices is counted as a publication for each line office.

Table 29: NOAA Publications

Quarter (FY 2021)	Authored Articles	Funded Articles (including authored pubs)	Funded Articles (without authored pubs)	Total NOAA-Authored and Funded Articles
Q1	541	811	507	1,859
Q2	571	756	465	1,792
Q3	438	622	364	1,424
Q4	254	376	216	846
Total FY 2021	1,804	2,565	1,552	5,921

3.3.2 Science on a Sphere®

Science On a Sphere® (SOS) is a room-sized, global display system (US Patent 6,937,210) that uses computers and video projectors to display planetary data onto a six-foot diameter sphere, analogous to a giant animated globe. Researchers at NOAA developed Science On a Sphere® as

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30 NOAA publications data for 2021 were derived on October 9, 2021, 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.

31 Due to a delay in indexing in Web of Science, not all Q4 articles are included in this report.

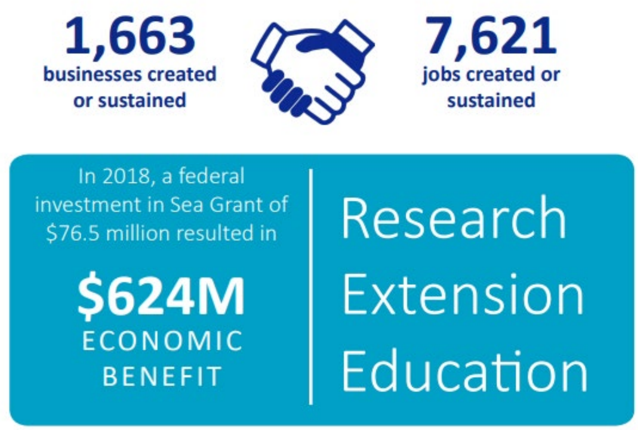
an educational tool to help illustrate Earth System science to people of all ages. Animated images of atmospheric storms, climate change, and ocean temperature can be shown on the sphere, which is used to explain complex environmental processes in a way that is simultaneously intuitive and captivating.

Table 30: SoS Installations

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
SOS Installations					
Total Number in Operation	144	155	165	169	177
New Domestic	6	3	7	5	4
New International	3	8	8	3	4
Total New Installs	9	11	15	8	8

3.3.3 NOAA-Funded (Extramural) R&D - NOAA Sea Grant

The National Sea Grant College Program was established by the U.S. Congress in 1966 and works to create and maintain a healthy coastal environment and economy. The Sea Grant network consists of a federal/university partnership between 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.



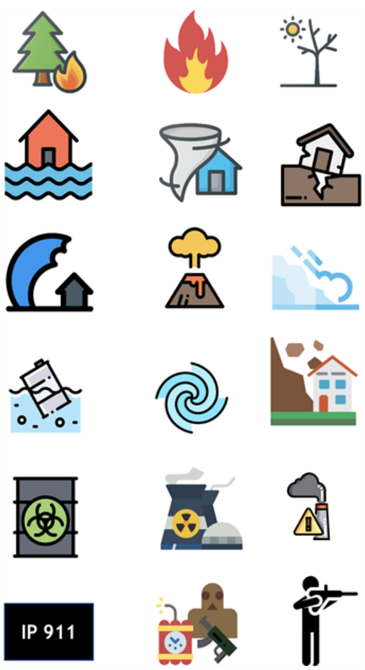
3.4 Success Stories Demonstrating Downstream Outcomes From NOAA Technology Transfer Activities

The following is an overview of NOAA's technology transfer activities, both formal and informal, during Fiscal Year 2021.

3.4.1 Data Products and Services:

NOAA data supports a wide range of multi-billion dollar economic sectors in the United States and the global economy, and is possibly the most impactful example of technology transfer we provide. Express couriers, rail systems, retailers, and third-party weather forecasts rely on this free and publicly available information to determine routes, weather risks, seasonal merchandising, and scheduling. Ocean and coastal data give the fishing industry tools to determine prime fishing locations through private forecasters who build fishing reports using archived data. NOAA has continued 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.

Mayday.ai applies artificial intelligence to NOAA satellite imagery to detect natural disasters, starting with wildfires



Credit: [NOAA]

NOAA's Big Data Program, which was launched in 2016, provides 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, the company has developed a cloud-based platform that 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 his 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 Hardware:

NOAA has patented several different types of hardware to enable its mission. Some of the successes from FY 2021 are listed below:

NOAA Portable 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, 2020, 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 onboard 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.

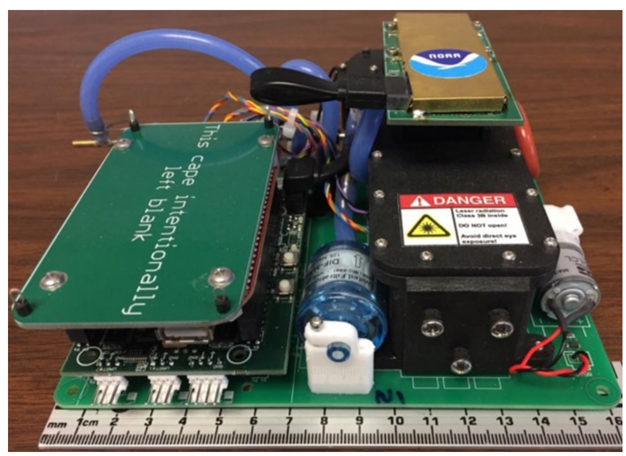
The instrument was integrated into Aerosol Dynamics Inc.'s Ambient Particle Monitor and ferried to the space station along with four tons of science experiments, crew supplies, and station hardware on the Cygnus resupply capsule, carried on an Antares rocket launched from NASA's Wallops Flight Facility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

POPS instrument

NOAA CSL's Portable Optical Particle Spectrometer (POPS) uses an onboard 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.

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.



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

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.

NOAA Lionfish Trap

Over the last 20 years, invasive lionfish populations have dramatically increased throughout the western Atlantic Ocean, Gulf of Mexico, and Caribbean Sea. Lionfish have already caused a decline in native species that have significant ecological, cultural, and commercial value. Further impacts on coral reefs and other important ecosystems are anticipated, but not yet fully understood. Fortunately, as the threat of lionfish has intensified, so too have the levels of awareness and concern among not just scientists and fishers, but among members of the public.

In recent years, state-sponsored lionfish fishing derbies have incentivized divers to remove lionfish from coastal waters, and the growing demand for this tasty and widely-promoted sustainable seafood has surpassed the supply. Although spearfishing has proven to be an effective approach for managing populations in shallow areas, lionfish remain uncontrolled in deeper waters, where they continue to threaten fragile ecosystems (and evade dinner plates). Therefore, there is a demonstrated need and resounding demand for effective, non-destructive ways to capture lionfish that linger beyond recreational scuba depths.

A lionfish trap undergoes scientific testing in the Gulf of Mexico.
Source: Webster, S., 2021: Innovative Lionfish Trap. Sea Tech., Vol. 60, No. 8, 27-30.

NOAA's recently-patented lionfish trap could be a solution that offers both ecological and commercial benefits. The trap is shaped like a change purse and is constructed primarily out of a hinged steel frame, attached netting, and a centrally-located vertical panel called a "fish attraction device". Once deployed from the surface, the lionfish trap descends vertically through the water until it hits the bottom, where two curved extensions cause the jaws to spring open and lay flat on the bottom. The fish attraction device is then revealed, drawing lionfish towards the center of the six-foot diameter net. Later, the trap can be recovered by pulling on a surface line, which closes the trap's hinged jaws and captures the fish within the ring of netting.

This innovative technology was designed with specific operational and conservation-related goals in mind, and as a result, has several benefits over conventional fish traps. For example, the lionfish trap's open non-containment design prevents "ghost fishing," which is when gear "continues to fish" after being lost or abandoned. The lack of bait in the trap minimizes by-catch, or the capture of unwanted fish. Furthermore, the trap causes minimal damage to the ocean floor, is easily transportable on fishing boats due to its flat design, and is relatively simple to construct, deploy, and retrieve.

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 (IAAs) 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 through CRADAs and IAAs;
- Technical publications, open data, and open source software tools; and
- Leadership and technical contributions in the development of telecommunications standards

For 19 of the past 23 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. Presentations, video archives, and proceedings are available online.

ITS received mixed feedback on the breadth of the topic chosen for ISART 2020. Accordingly, in FY 2021 an abbreviated ISART "2022 prequel" was held in conjunction with the annual NTIA Spectrum Policy Symposium to collect stakeholder feedback in preparation for a full ISART 2022 focusing on data-, science-, and technology-driven ways to evolve and expedite spectrum-sharing analyses and decision-making.

4.2 Statutorily Required Metric Tables

Table 31: NTIA ITS Invention Disclosures and Patenting

Metric	FY 2021
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 32: NTIA ITS Licensing[32]

Metric	FY 2021
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

[32] 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 33: NTIA ITS Income from Licensing

Metric	FY 2021
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	n/a
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 CRADAs 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 2021, as it has for decades, ITS participated in CRADAs with private-sector organizations to design, develop, test, and evaluate advanced telecommunication concepts. The 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, advanced antennas for wireless systems, remote sensing and global position (GPS) technologies, active holographic sensing with high resolution laser radar (lidar), autonomous networks for unmanned aerial vehicles (UAVs), objective audio and video Quality of Experience (QoE) metrics, 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.

Of increasing importance to the Nation are CRADAs that ITS enters into with manufacturers of advanced radar systems. NTIA administers the Radio Frequency Spectrum Standards applicable to federal radio stations and systems. This includes the Radar Spectrum Engineering Criteria (RSEC)—federal regulations that ensure an acceptable degree of electromagnetic compatibility among radar systems, and between such systems and those of other radio services sharing the radio frequency spectrum to promote efficient spectrum use. Interference free spectrum sharing between radars and commercial communications systems has emerged as a serious technical challenge to expanding the commercial use of spectrum.

All U.S. radar systems must meet emission limits imposed by the NTIA RSEC as described in the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management ("Redbook," incorporated by reference in 47 CFR 300). The ITS-published Technical Report "Measurement procedures for the radar spectrum engineering criteria (RSEC)" describes the required method for certifying compliance.

ITS enters into CRADAs with manufacturers of new radars to perform emission measurements and provide a report certifying compliance. This allows ITS to collect valuable information on newly emerging radar technologies and ensure that the RSEC are kept up to date. The RSEC CRADAs allow NTIA to retain anonymized waveform recordings that are used to automate RSEC compliance analysis. The RSEC were last revised in 2005 and are currently undergoing revision to incorporate new radar technologies characterized through ITS RSEC CRADAs.

Table 34: NTIA ITS Collaborative Agreements

Metric	FY 2021
Total Active CRADAs	6
New CRADAs	0
New CRADAs Involving Small Businesses	0
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 2021, 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 2021, 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 2021, ITS developed the second of a planned series of video-illustrated articles that delve deeply and in detail into specific radiofrequency measurement techniques, which was accepted for publication in a peer-reviewed video journal. The first video article was viewed 5,767 times in FY 2021.

Theoretical context for this video article series 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. In FY 2021, ITS also began preparing scripts for several new YouTube series as part of a planned expansion of this multimodal approach to transferring proven technical methods into widespread use within the wider spectrum community.

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 2021 ITS had published 26 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 Spectrum Monitoring Software

The NTIA Spectrum Monitoring program is creating a new spectrum monitoring paradigm to enable distributed, persistent, and automated monitoring with the following: heterogeneous and low cost sensors, standardized interfaces, open source software implementations, common metadata, automated provisioning/deployment/maintenance, and data analytics incorporating artificial intelligence and machine learning. ITS works to test and integrate new sensing technologies and algorithms in the lab and the field and collaborate via open-source code development. Code repositories released to the public include LTE measurement utilities (gr-ltetrigger), RF measurement metadata best practices (sigmf-ns-ntia), and NTIA software implementations associated with the IEEE 802.15.22.3 Spectrum Characterization and Occupancy (SCOS) standard (scos-sensor). In FY 2021, NTIA expanded by adding two additional spectrum-monitoring repositories (i.e., scos-actions, scos-usrp).

4.3.4.3 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 and from GitHub. 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. The 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.

4.3.4.4 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 2021. 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. Part of the problem is that NR metric researchers had not previously considered two key industry requirements. First, to be exploitable, NR metrics must provide root cause analysis (RCA). Most industry applications for NR metrics involve identifying and mitigating specific impairments. Second, the external validity (and thus reliability) of an NR metric depends on its ability to assess camera capture impairments.

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 2021, ITS expanded the NRMetricFramework public GitHub repository first made available in FY 2020 to provide additional support for NR metric research. The repository was released to the public domain—to support collaborative R&D into NR metrics for image and video quality and 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.

The NRMetricFramework repository reports on the performance of 36 previously published NR metrics on modern camera systems using a robust corpus of 9,833 media files. These independent analyses address industry concern that NR metric developers publish exaggerated performance claims. The repository contains all of the code and information needed to reproduce these analyses. In addition, the repository contains NR metric *Sawatch*, which was developed by ITS as a baseline NR metric for future collaborative development. *Sawatch* adheres to industry specifications of providing RCA and being able to analyze camera capture impairments. Finally, the repository contains new statistical methods for analyzing the performance of subjective tests and NR metrics.

4.3.4.5 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 TB), 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; additions by ITS and other collaborators have increased the collection to tens of thousands of clips.

The CDVL website software was replaced in Q1 of FY 2021 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 four experiments from the *Enhancing Computer Vision for Public Safety Prize Challenge*, which was proposed by ITS and sponsored by NIST. This challenge enables a new line of research into NR metrics for computer vision applications. The goal is NR metrics that facilitate the productization of computer vision apps, by identifying camera capture impairments that hinder computer vision (e.g., camera noise, jerky motion, focus problems, motion blur, and lens flare). Currently, each product developer must study the complex interactions between their task and impairments caused by commercial cameras in non-pristine environments.

Another recent addition to CDVL is an experiment jointly conducted by Nokia, the Universidad Politécnica de Madrid, AGH University of Science and Technology, and ITS. This experiment proposed and validated a new subjective method that relies on four to six team members instead of the standard 15 or 24 naïve subjects. The new method enables quick analyses of new technologies by product developers during the pandemic. Distributing the experiment on CDVL allows U.S. industry to verify the new method (for increased trust) and academic researchers to investigate further improvements.

In FY 2021, 601 unique records were downloaded from the new website, by a total of 120 users. Because many of the downloads were entire experiment sets, this is equivalent to 37,128 individual files, an 18-fold increase over the prior year. Self-reported demographics indicate 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 35: NTIA ITS Software and Data Downloads

Metric	FY 2021
Technical Publications Released	10
Technical Publications Downloaded	13,358
Consumer Digital Video Library Users Downloading	250
Video Quality Metric Software Users Downloading	195
Propagation Modeling Software Downloads	1,479
Other Software/Data Downloads	746
Public GitHub Repositories	26

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 Wireless Innovation Forum (WInnForum), 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 International Communication Union Radiocommunication (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.

ITS actively contributes to ITU efforts around best practices for video quality assessment. In FY 2021, ITS continued to lead and participate in the Video Quality Experts Group (VQEG), an open venue where technical experts collaborate to develop subjective test methods for new video technologies. VQEG 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.

In FY 2021, ITS staff held 14 positions in 12 standards bodies, including 8 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 Party 3K (Point-to-area and ionospheric propagation), and U.S. Chair of Working Parties 3J and 3L (Propagation fundamentals). 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.

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

4.4.1 Innovative Commercial Services

In FY2021, ITS continued conducting critical research and development, and testing of the new Citizens Broadband Radio Service (CBRS). ITS research, technology transfer, and testing has been critical to the successful commercial deployments of CBRS in the highly desirable 3.5 GHz spectrum. A decade of ITS efforts cleared the way for the $4.6 billion auction of licenses within CBRS in 2020, from research on technical feasibility of sharing between high power radars and commercial services that began in 2010, through successfully demonstrating the capability to effectively test spectrum management and sensor detection software through conformance and compliance testing of the Spectrum Access System (SAS) and Environmental Sensing Capability (ESC) components of CBRS. This work to address and resolve technical issues of interference potentials, protection thresholds, and propagation predictions, widely published and freely transferred to Industry, laid the foundation for mid-band sharing and CBRS.

In FY 2021, ITS worked with the FCC and the standards group WInnForum to make improvements to the SAS certification test system, and developed CRADA relationships with the remaining Spectrum Access System administrators to complete testing of their software implementations of the spectrum management technical specifications, as additional entrants and competition within the spectrum access the system, in the greater ecosystem. As part of the post-3.5 GHz Priority Access License auction (FCC Auction 105) spectrum relocation fund programs approved by OMB and Congress, ITS began working in FY2021 with DoD Defense Information Systems Agency (DISA) and others on the Shared Spectrum Ecosystem Assessment (SEA) project, aimed at developing tools and capabilities to determine the effectiveness of the innovative CBRS sharing arrangements. ITS is taking a lead role in developing firmware and software for deployable sensor technology for that program. In addition, in FY 2021, ITS conducted research on mobile sensors capable of validating occupancy and assessing aggregate spectrum usage which will be refined for technology transfer and use in other bands of interest for sharing.

In FY21, ITS also began working with the DOD Chief Information Officer (CIO), using 3.45 GHz pre-auction spectrum relocation funds authorized by OMB and Congress, to develop plans for improving propagation models for mid-band spectrum. This critically important research will continue through FY 2025 with post-auction funds from the successful 3.45 GHz auction (FCC Auction 110). Improving the ability of propagation models to predict how mid-band radio signals propagate through various environments will increase the efficiency of spectrum use by both federal and commercial users. ITS' mid-band propagation improvement program will include significant inputs and information sharing with other federal agencies, academia, and the commercial sector, and open-source sharing of measurements, modeling, and code.

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. Growing 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 2021, ITS chaired a Study Group 3 Correspondence Group (CG-3K-3M-9) on aeronautical propagation, which looked at extending the upper frequency limit of ITU-R P.528 to include millimeter wave frequencies. This frequency extension was in support of WRC-23 agenda items 1.8[33] and 1.10[34], where sharing studies are being performed to examine the possibility of new sharing assignments and usage of existing frequency allocations involving aeronautical systems. This work culminated in an update to Recommendation ITU-R P.528, along with a major release of software products at the July 2021 Study Group 3 meeting. 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 2021, 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

[33] Resolution 171 (WRC-19) and Resolution 155 (Rev WRC-19), https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000D0027PDFE.pdf

[34] Resolution 430 (WRC-19), https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000D0010PDFE.pdf

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. The National Oceanic and Atmospheric Administration (NOAA) also adopted the ITS P.528 companion graphical user interface (GUI) software to support their work on frequency sharing between NOAA assets and possible future aeronautical commercial cellular systems, such as HIBS (High altitude IMT Base Stations). 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 at the next WRC.

ITS additionally led a Study Group 3 Correspondence Group (CG-3L-3) on radio noise. This culminated in a revision to Recommendation ITU-R P.372, *Radio Noise*, a Recommendation which is also cited by the Radio Regulations. Updates to P.372 include information on the background levels of radio noise in the frequency range from 0.1 Hz to 100 GHz, taking into account radio noise emitted by lightning, atmospheric gases, clouds, rain, the Earth's surface, the galaxy, and man-made sources; updated higher-resolution figures conveying the global levels of atmospheric radio noise for different months of the year and hours of the day; and ITS contributed software that allows researchers to programmatically obtain atmospheric radio noise values given primary location and time of year and day.

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 2021, 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. In addition, in FY 2021, ITS provided briefings on agency-specific concerns with regard to standardization developments with respect to spectrum sharing, vehicle-to-everything communication, non-terrestrial networks, and unmanned aerial vehicles.

Direct participation by ITS in IEEE 802.15.22.3 led to standardization of the Spectrum Characterization and Occupancy Sensing (SCOS) standard. SCOS will allow broader availability and usage of spectrum sensing information from different sources by establishing a high-level architecture to support different technologies and deployments. In FY 2021, ITS entered into research collaborations with the multi-agency Sharing Ecosystem Assessment (SEA) program funded by DoD/DISA and coordinated through the National Advanced Communications Test Network (NASCTN) and the National Science Foundation (NSF) Spectrum Innovation Initiative

(SII), to explore using widespread SCOS deployments to characterize and assess spectrum occupancy and make the data widely available to support more efficient and effective spectrum use.

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 their 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 among government, academia, and industry, and between the 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 2021, 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 2021, 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, which 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 2021, 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 the following:
    - detection and tracking of wind shear and wake vortices;
    - remote wind measurements for the offshore wind energy industry;
    - mission-critical communications;
    - electronic warfare;
    - direction finding/geolocation; and
    - sensing of hazardous liquids and gases.

- For the past 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. Approximately half of CDVL's content is contribution quality footage that characterizes the broadcast use case. This footage allows users 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.

The remainder of CDVL's content targets other use cases: 13% standard test sequences and experiments from ITU, ATIS, or VQEG; 15% academic experiments distributed as open data; and 18% 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.

In FY 2021, ITS supported industry discussions within VQEG that pursue new or improved ITU Recommendations. First, the ITU-T Rec. P.910 spatial information (SI) and temporal information (TI) metrics, developed by ITS in 1994, have become ambiguous due to rapid advances in video technology. U.S. industry wants to continue using SI and TI to categorize video content when analyzing the response of new video products and services. Second, VQEG vetted and agreed upon the validity of an improved method to screen human subjects during video quality testing. This method has been sent to the ITU for inclusion in international standards. Third, VQEG will use ITU-T Rec. T.35 to embed standard video quality metadata in video streams. These video quality assessments are available in most modern video equipment; the missing element is a mechanism to propagate this information through the video processing pipeline. Fourth, VQEG is gathering key performance requirements for new video services on 5G networks, to guide new product developers. ITS facilitates these U.S. industry led efforts by providing meeting venues, logistical support, and subject matter expertise on both video quality and ITU working methods.

5 SUMMARY

This report details the results of the FY 2021 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 the United States with a competitive advantage and bolstering the U.S. economy through the transfer and commercialization of innovative technologies. Technology transfer is an essential DOC mission, and the report highlights how well the DOC labs are in position to be competitive in the global markets.

6 APPENDIX A

Technology Area Classifications

Mapping of International Patent Classifications to Technology Area[35]

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

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

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[35] 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[36]

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;

[36] 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 science.

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.