Annual Report on Technology Transfer:

Approach and Plans, Fiscal Year 2024 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

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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) 2024, and provides statistical information from FY 2020 through FY 2024. 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 reporting requirements of this section.

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, other federal agencies and their laboratories, 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), and convener of the Interagency Working Group for Technology Transfer (IAWGTT) and 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). 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 other groups such as the FLC, IAWGTT, IAWGBD, and Small Business Innovation Research (SBIR) Policy Committee.

DOC coordinates the IAWGTT through quarterly NIST-hosted interagency meetings and through facilitating ongoing discussions on policy, new approaches to technology transfer, and lessons learned from agency technology transfer programs.[1] The IAWGTT was established in 1987 by

[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.

Executive Order 12591, Section 7, to "convene an interagency task force comprised of the heads of representative agencies and the 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, a nationwide network of over 300 federal laboratories and research centers, which provides a network 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 by statute (15 U.S.C. § 3710), that shares technology transfer best practices, develops promotional materials, facilitates partnerships, and organizes networking events. The mission of the FLC is "to increase the impact of federal laboratories' technology transfer for the benefit of the U.S. economy, national security and society."[2]

As the agency tasked with promulgating the Bayh-Dole regulations, DOC, through NIST, also coordinates the IAWGBD.[3] The IAWGBD reviews and discusses policy and implementation issues related to the Bayh-Dole Act and the associated Bayh-Dole regulations and facilitates aligning of agency policies. Additionally, the IAWGBD focuses heavily on the implementation of improvements to the iEdison reporting system. iEdison is a NIST-managed interagency system used by dozens of agencies and bureaus to facilitate the reporting and utilization of inventions and patents that were conceived or first actually reduced to practice by awardees using extramural federal research and development funding, 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 (IP) protection and licensing, 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 laboratories or conducts activities under 35 U.S.C. §§ 207 and 209 to report annually to the

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[2] https://federallabs.org/about/who-we-are/mission-vision

[3] The IAWGBD was formed to facilitate consistency in the development of agency policies related to the Bayh-Dole Act and its implementing regulations. It includes representatives from across the federal government including individuals from 16 Departments and independent federal agencies.

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	FY 2020	FY2021	FY2022	FY 2023	FY 2024
Invention Disclosures Received	70	67	72	62	104
Total Patent Applications Filed	36	41	27	31	27
U.S.	36	41	27	31	27
Foreign	0	0	0	0	0
Total Patent Cooperation Treaty (PCT) Applications Filed	3	3	8	8	11
Total Patents Issued	25	34	26	25	27
U.S.	25	34	26	25	27
Foreign	0	0	0	0	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 tables presenting statutorily required metrics report data from FY 2020 to FY 2023 data, in addition to FY 2024 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 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Licenses, Total Active	52	44	42	41	41
New Invention Licenses	15	9	11	9	6
New Invention Licenses Granted to Small Businesses	12	2	8	5	4
Income Bearing Licenses, Total Active	34	33	33	36	35
New Income Bearing Licenses	6	3	0	3	2
Exclusive, Total Active	19	17	15	17	18
Partially Exclusive, Total Active	0	0	0	0	0
Non-Exclusive, Total Active	15	16	18	19	17
Other Licenses, Total Active	0	0	0	0	0
New Other Licenses	0	0	0	0	0
New Other Licenses Granted to Small Businesses	0	0	0	0	0
Elapsed Amount of Time for Granting Invention Licenses	n/a	n/a	n/a	n/a	n/a
Average (months)	n/a	n/a	n/a	n/a	n/a
Minimum (months)	n/a	n/a	n/a	n/a	n/a
Maximum (months)	n/a	n/a	n/a	n/a	n/a
Licenses Terminated for Cause	0	0	0	0	0

Table 3: DOC Income from Licensing[5]

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention License Income	$191,178	$105,571	$210,610	$46,400	$74,310
Other License Income	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)	$187,578	$105,571	$210,610	$46,400	$74,310
ERI from Top 1% of Licenses	n/a	n/a	n/a	n/a	n/a
ERI from Top 5% of Licenses	n/a	n/a	n/a	n/a	n/a
ERI from Top 20% of Licenses	n/a	n/a	n/a	n/a	n/a
Minimum ERI	n/a	n/a	n/a	n/a	n/a
Maximum ERI	n/a	n/a	n/a	n/a	n/a
Median ERI	n/a	n/a	n/a	n/a	n/a
Disposition of ERI					
Average Percentage Distributed to Inventors	n/a	n/a	n/a	n/a	n/a
Average Percentage Distributed to Lab/Agency	n/a	n/a	n/a	n/a	n/a

Table 4: DOC Collaborative Relationships[6]

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Total Active CRADAs	2,014	2,238	2,240	2,362	2,689
New CRADAs	1,647	1,813	1,814	1,870	1,236
New CRADAs Involving Small Businesses	977	921	929	850	804
Other Collaborative Agreements	2,952	2,739	2,739	2,848	3,746

[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.

[6] CRADAs include bilateral agreements, consortia agreements, industry-led agreements, NVLAP accreditations, and calibrations. The duration and frequency of these agreement types influence the proportion of New CRADAs relative to Total Active CRADAs. Other Collaborative Agreements include material transfer agreements and guest researcher agreements.

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 promote the dissemination of the results of fundamental research and measurements sciences, and to promote standards-related programs 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.[7]

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.

[7] 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.

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 5: NIST Invention Disclosures and Patenting

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Disclosures Received	64	55	69	55	77
Total Patent Applications Filed	35	41	27	29	20
U.S.	35	41	27	29	20
Foreign	0	0	0	0	0
Total Patent Cooperation Treaty (PCT) Applications Filed	3	3	8	8	11
Total Patents Issued	25	32	25	25	27
U.S.	25	32	25	25	27
Foreign	0	0	0	0	0

Table 6: NIST Licensing[8]

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Licenses, Total Active	46	38	36	35	35
New Invention Licenses	12	7	11	9	6
New Invention Licenses Granted to Small Businesses	12	n/a	8	5	4
Income Bearing Licenses, Total Active	28	27	27	30	29
New Income Bearing Licenses	6	1	0	3	2
Exclusive, Total Active	15	14	14	16	15
Partially Exclusive, Total Active	0	0	0	0	0
Non-Exclusive, Total Active	14	13	13	14	14
Other Licenses, Total Active	0	0	0	0	0
New Other Licenses	0	0	0	0	0
New Other Licenses Granted to Small Businesses	0	0	0	0	0
Elapsed Amount of Time for Granting Invention Licenses					
Average (months)	18	2	11	9	4
Minimum (months)	1	2	1	2	4
Maximum (months)	25	2	29	14	4
Licenses Terminated for Cause	0	0	0	0	0

[8] "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 7: NIST Income from Licensing

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention License Income	$79,344	$36,399	$98,022	$27,418	$66,596
Other License Income	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)	$79,344	$36,399	$98,022	$27,418	$66,596
ERI from Top 1% of Licenses	$45,000	$10,000	$22,029	$6,000	$28,125
ERI from Top 5% of Licenses	$45,000	$10,000	$22,029	$6,000	$28,125
ERI from Top 20% of Licenses	$45,000	$10,000	$22,029	$6,000	$28,125
Minimum ERI	$1,250	$1,250	$173	$400	$536
Maximum ERI	$45,000	$10,000	$22,029	$6,000	$28,125
Median ERI	$5,000	$3,859	$6,250	$2,470	$2,038
Disposition of ERI					
Percentage Distributed to Inventors	42%	56%	43%	67%	47%
Percentage Distributed to Lab/Agency	58%	44%	57%	33%	53%

Table 8: NIST Collaborative Relationships[9]

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Total Active CRADAs	1,968	2,135	2,181	2,300	2,620
New CRADAs	1,633	1,789	1,795	1,853	1,212
New CRADAs Involving Small Businesses	973	956	917	838	791
Other Collaborative Agreements	2,952	2,618	2,738	2,848	3,746

2.3 Other Important NIST Performance Measures

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

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

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.

NIST authors published 985 manuscripts in fiscal year (FY) 2024 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) 2024, NIST-authored manuscripts that were published in peer-reviewed journals during the past five years (CY 2020–2024) garnered 29,837 citations.[10]

Table 9: NIST Publishing Activities – Papers[11]

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Number of NIST Papers	1,509	1,419	1,160	1,046	985
Number of NIST Paper Citations (CY)	n/a	36,882	28,621	26,404	29,837

NIST is the self-publisher of over 20 Technical Series publications (TechPubs) consisting of technical reports, recommendations, practice guides and standards, industry handbooks, and other documents. NIST produced 349 TechPubs in FY 2024. The number of times that a publication is downloaded serves as an indicator of technology transfer. In FY 2024, NIST TechPubs that were published during the past five years (CY 2019–2023) were downloaded over 6.8 million times.[12] Of these publications, those with the subject area of computer and information security standards and guidelines were downloaded thousands of times each day.[13]

[10] NIST peer-reviewed publication data were retrieved from queries of the Web of Science (WoS) database. 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.

[11] Data as of December 18, 2024.

[12] Download statistics of NIST Technical Series Publications consist of the number of unique visitors ("downloads") for each publication, i.e., 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.

[13] 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.

Table 10: NIST Publishing Activities - Technical Report Series[14]

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Number of NIST TechPubs Published	232	225	290	283	349
Number of NIST TechPubs Downloads	n/a	2,840,058	3,114,035	4,188,584	6,883,293

NIST researchers published 183 data products in FY 2024, including datasets and software. The volume of downloaded data products serves as an indicator of technology transfer. In CY 2024, there were 172.5 terabytes[15] (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 an indicator of technology transfer. In FY 2024, 130 repositories[16] 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 11: NIST Publishing Activities – Data and Software[17]

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Number of NIST Datasets & Software Published	132	128	123	161	183
Quantity of NIST Data (direct download) from NIST Data Portal (CY)	n/a	14 TB	36 TB	190 TB	172.5 TB
Number of Repositories added to the NIST Open-Source Code Portal	143	68	95	94	130

[14] The number of NIST TechPubs published for FY 2022 through FY 2024 reflect the number of digital object identifiers (DOIs) registered. Downloads were reported by calendar year for FY 2021 through FY 2023. Download numbers are reported by fiscal year for FY 2024.

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

[16] 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.

[17] Data collection method from January 2024 through December 12, 2024 more accurately reflects downloads across repository holdings.

2.3.2 Participation in Documentary Standards Committees

Documentary standards are shared sets of rules developed by experts that specify agreed upon ways to carry out a technical process. For example, a standard could specify a test method or a measurement method or standard practices, or even specify a material's properties or product's properties. Econometric studies have reported that standards contribute significantly to economic growth and technological advancement. A significant study concluded that the 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.[18]

During FY 2024, 435 members of the NIST staff were involved with 333 standards organizations. Such participation helps NIST respond to the needs of the private sector and enables its scientists and engineers to bring NIST technology and know-how directly into standards-setting bodies.

Table 12: NIST Participation in Documentary Standards[19]

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Number of Participating NIST Staff	400	547	579	442	435
Number of Standard Organizations with NIST Participants	112	350	328	331	333

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 and develops them from measurements conducted at its laboratories that are carefully evaluated for accuracy and reliability. NIST currently maintains 75 SRD databases that

[18] 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.

[19] Starting in FY 2021, the data for the reported number of participating NIST staff and number of standard organizations with NIST participants come from a new database platform.

cover many areas of science, including analytical chemistry, atomic and molecular physics, biotechnology, and materials sciences.

In FY 2024, the NIST SRD Program distributed 1,496 e-commerce orders, 6,852 units sold via distributor, 142 active distributor agreements, 14 active site licenses, 60 active internet subscriptions, 49 units shipped to the user, and 2,923 products downloaded from the NIST website (1,647 free downloads, 1,276 paid downloads).

Table 13: NIST Standard Reference Data Program

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Products Available (Databases)	74	74	65	75	75
E-Commerce Orders	2,908	3,200	2,842	1,933	1,496
Units Sold via Distributor	7,905	8,499	7,999	7,831	6,852
Active Distributor Agreements	115	118	124	174	142
Active Site Licenses	15	19	17	10	14
Active Internet Subscriptions	140	69	81	60	60
Units Shipped via UPS	57	50	20	57	49
Products Downloaded from the NIST Website	4,578	4,449	3,805	3,542	2,923
Free Downloads	1,484	1,369	1,618	1,679	1,647
Paid Downloads	3,094	3,080	2,187	1,863	1,276

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 2024, NIST made available 1,076 SRMs and from these, sold 28,713 units.

Table 14: NIST Standard Reference Materials

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Units Available	1,114	1,116	1,121	1,103	1,076
Units Sold	27,319	28,065	28,777	27,400	28,713

2.3.5 User Facilities – Research Participants

NIST operates two unique and valuable laboratory user 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 conduct research and to solve problems.[20]

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.[21] In FY 2024, there were 246 distinct facility users at CNST and 1,142 research participants at NCNR.

Table 15: NIST Research Participants

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
CNST	230	184	198	200	246
NCNR	3,068	2,576	1,857	1,407	1,142

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 2024, NIST hosted 134 postdocs. Of these, 81 were based at the NIST Gaithersburg, Maryland campus; 53 were located in the NIST Boulder, Colorado campus; and 3 were located at the Joint Institute for Laboratory Astrophysics (JILA), also in Boulder, Colorado.

[20] The NCNR was temporarily shut down on February 3, 2021, in response to an incident where a single fuel element overheated and was damaged. On March 10, 2023, the Nuclear Regulatory Commission concluded that NIST had satisfied the safety requirements to restart the reactor and authorized NIST to restart the NCNR research reactor.

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

Table 16: NIST Postdoctoral Researchers

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
NIST Postdocs, Total (NRC)	154	132	120	118	134
Gaithersburg campus	103	94	71	93	81
Boulder campus	40	33	44	25	53
Joint Institute for Laboratory Astrophysics (JILA) [(a)]	7	5	4	4	3
Hollings Marine Laboratory [(b)]	4	0	1	0	0

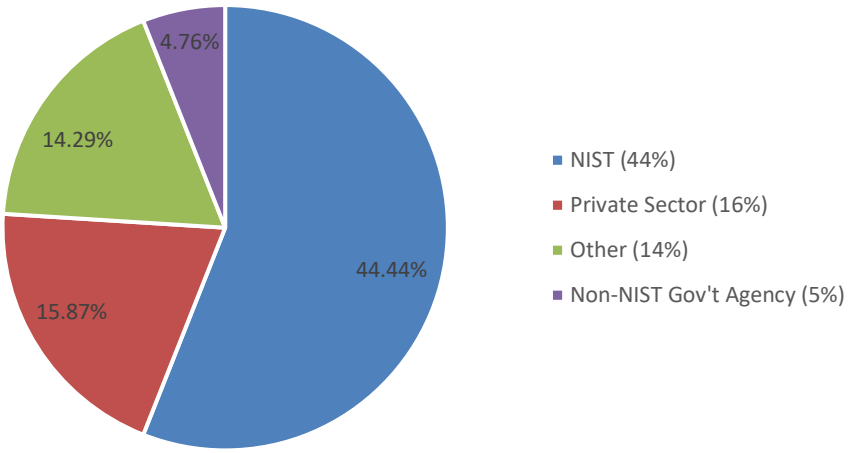
(a) JILA was founded in 1962 as a joint institute of CU-Boulder and NIST. JILA is located at the base of the Rocky Mountains on the CU-Boulder campus in the Duane Physics complex.

(b) The 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.

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 63 FY 2024 NIST National Research Council (NRC) program postdocs. Of these, 44% continued research careers with NIST,[22] approximately 16% percent moved to the private sector, 14% pursued other opportunities such as becoming independent researchers, and 5% moved to non-NIST government agencies.

[22] 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).

Figure 1: Tracking NIST Researchers after Initial Postdoc Tenure at NIST (FY 2024)



2.3.7 Guest Researchers

In addition to postdocs, each year thousands of guest 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 2024 there were 2,898 guest scientists and engineers working at NIST.

Table 17: NIST Guest Researchers

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Guest Scientists and Engineers	2,701	2,371	2,498	2,724	2,898

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 2024, NVLAP accredited 597 laboratories.

Table 18: NIST Accreditation Services

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
NVLAP Accreditations	644	650	623	627	597

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 2024, NIST performed 8,264 calibration tests.

Table 19: NIST Calibration Services

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Number of Calibration Tests Performed	9,225	13,568	14,013	8,701	8,264

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 NIST Summer Institute for Middle School Science Teachers; and
- the Professional Research Experience Program (PREP).

In FY 2024, 151 students participated in the SURF program, 51 students participated in SHIP, 23 individuals participated in the Summer Institute for Middle School Science Teachers, and 460 students participated in PREP.

Table 20: NIST STEM Education Participation

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
SURF[(a)]	0	146	156	172	151
SHIP	0	54	44	52	51
Summer Institute for Middle School Science Teachers	23	24	23	26	23
PREP	174	425	531	547	460

(a) NIST did not hold the SURF or SHIP programs in FY 2020.

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 and promote the transfer of technology and sharing of technical information.

In FY 2024, the NIST Conference Program arranged 69 conferences, both in person and virtual, that attracted 18,251 researchers to NIST's facilities in Gaithersburg, Maryland, and Boulder, Colorado. NIST's Office of Weights and Measures, which promotes uniformity in U.S. weights and measures laws, regulations, and standards, trained 1,559 weights and measures administrators, laboratory metrologists, and field enforcement officials. 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 21: NIST Conferences, Seminars, and Workshops[23]

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
NIST Conference Center					
Conferences and Workshops	74	40	35	44	69
Attendance	7,747	17,943	23,706	17,394	18,251
Office of Weights and Measures - Metrology Training					
Total Students	2,057	2,084	1,294	1,153	1,559
Seminar Attendance	101	0	125	171	289
Webinar Attendance	1,948	1,954	1,134	982	421
Info Hours Attendance	-	-	-	-	378
Workshop Attendance	8	130	35	0	471

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 2024, 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 642 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 61 days.

Table 22: NIST Activity Trends

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Average Number of Days to File a Non-Provisional Patent Application[(a)]	450	488	612	632	642
Average Number of Days to Approve a CRADA[(b)]	109	92	76	86	61

[23] This report revises the number of Total Students and Workshop Attendance reported for FY 2021. The number of Total Students in FY 2021 was previously reported as 2,083 and is now revised to 2,084. The value of Workshop Attendance in FY 2021 was previously reported as 129 but is revised to 130.

(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 2024, NIST awarded 12 Phase I SBIR awards and 5 Phase II SBIR awards.

Table 23: NIST SBIR Award Count

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Phase I SBIR Awards	12	11	12	10	12
Phase II SBIR Awards	8	6	7	5	5

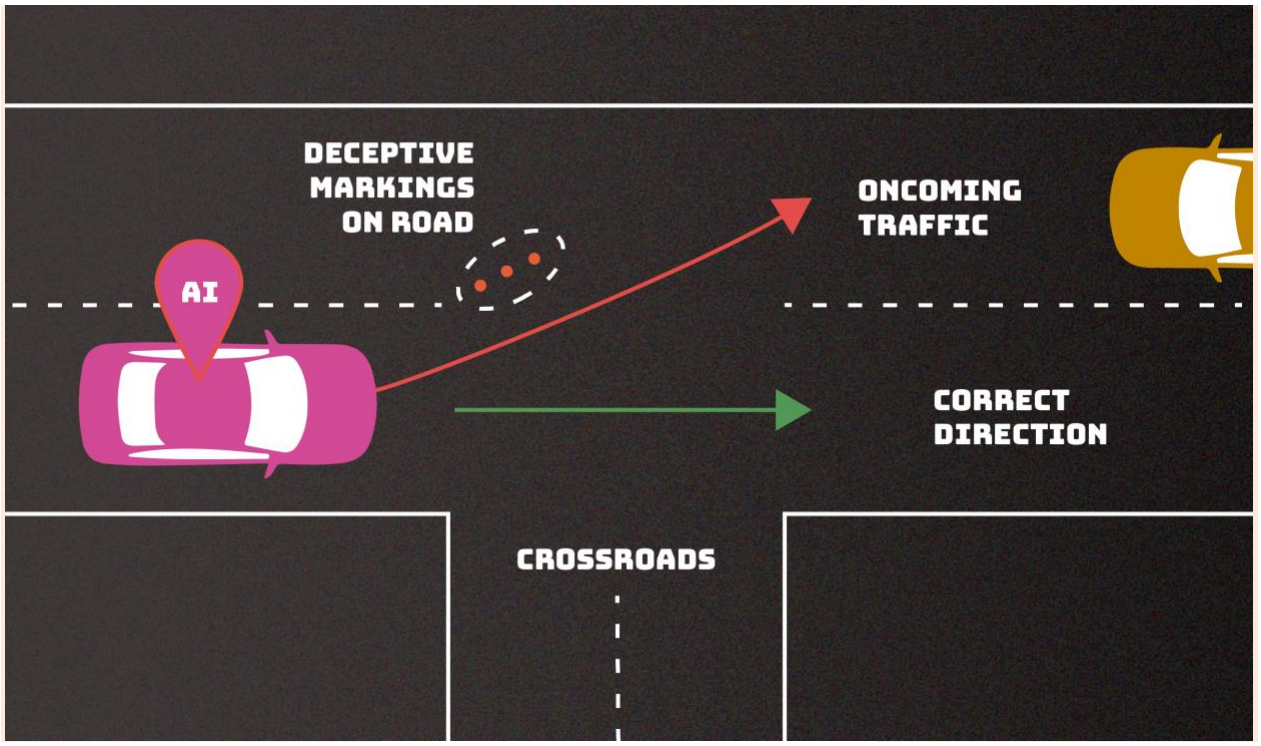
2.4 Success Stories Demonstrating Downstream Outcomes From NIST Technology Transfer Activities

2.4.1 NIST Identifies Types of Cyberattacks That Manipulate Behavior of AI Systems

- Publication co-authored by scientists at NIST, academia, and industry lays out "adversarial machine learning" threats, describing mitigation strategies and their limitations.
- AI systems can malfunction when exposed to untrustworthy data, and attackers are exploiting this issue.
- New guidance documents the types of these attacks, along with mitigation approaches.
- No foolproof method exists as yet for protecting AI from misdirection, and AI developers and users should be wary of any who claim otherwise.

An AI system can malfunction if an adversary finds a way to confuse its decision making. In the example shown in Figure 2, errant markings on the road mislead a driverless car, potentially making it veer into oncoming traffic. This "evasion" attack is one of numerous adversarial tactics described in a NIST publication intended to help outline the types of attacks we might expect along with approaches to mitigate them.

Figure 2: Illustration of Adversarial Attack on an AI System



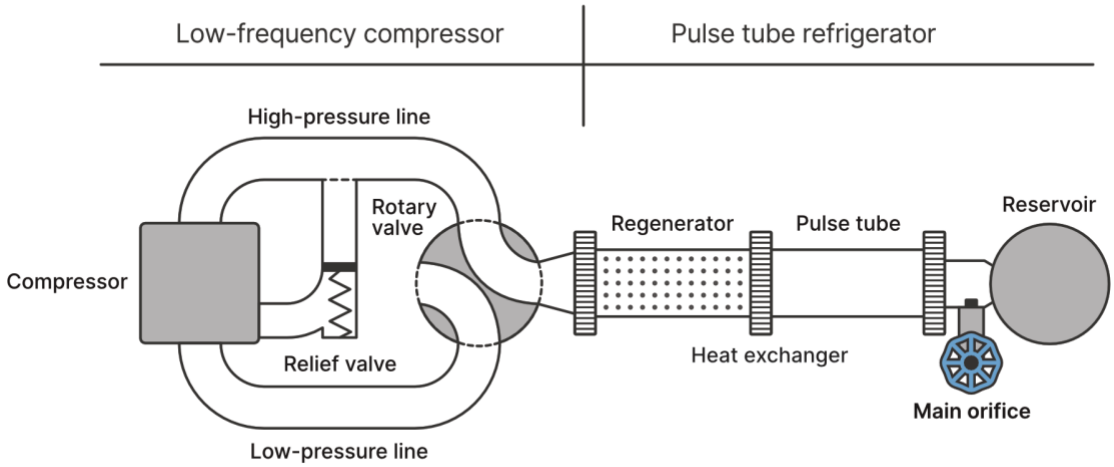
Credit: N. Hanacek/NIST

2.4.2 The Big Quantum Chill: NIST Scientists Modify Common Lab Refrigerator to Cool Faster with Less Energy

- Enhanced fridge will benefit quantum computing, astronomy, superconductors and other applications.
- Scientists have dramatically reduced the time and energy required to chill materials to temperatures near absolute zero.
- Their prototype refrigerator could prove a boon for the burgeoning quantum industry, which widely uses ultracold materials.
- NIST is now working with an industrial partner to commercialize the refrigerator.

Figure 3 shows a simplified version of a pulse tube refrigerator (PTR), commonly used to cool materials to a few degrees above absolute zero by compressing and expanding helium gas held under high pressure. NIST researchers optimized the efficiency of the PTR, dramatically reducing the amount of time and energy required to reach ultracold temperatures, by continuously adjusting the valve connecting the pulse tube to a reservoir of helium gas.

Figure 3: Pulse Tube Refrigerator



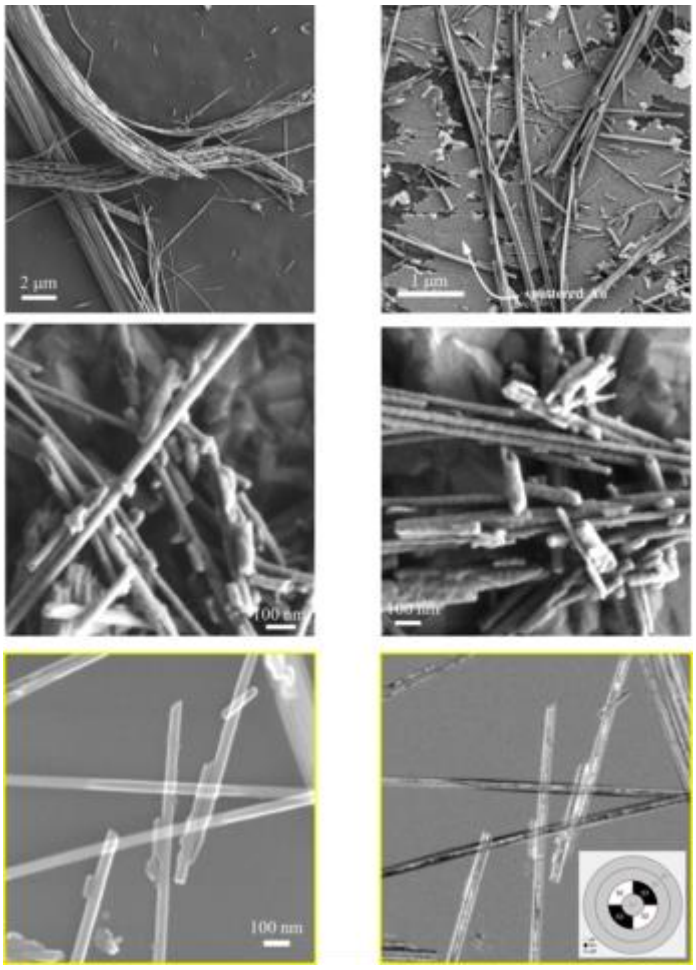
Credit: S. Kelley/NIST

2.4.3 [NIST Researchers Identify a Cheaper, More Convenient Method to Detect Asbestos]

- Researchers have verified that scanning electron microscopy (SEM) can be a highly accurate way to test air samples for the presence of asbestos.
- SEM offers a less expensive, easier-to-use alternative to transmission electron microscopy (TEM) and phase contrast microscopy, which have been used for decades.

Figure 4 shows images of asbestos fibers taken by scanning electron microscopy (SEM).

Figure 4: Scanning Electron Microscopy Images of Asbestos



Credit: J. Holm/NIST

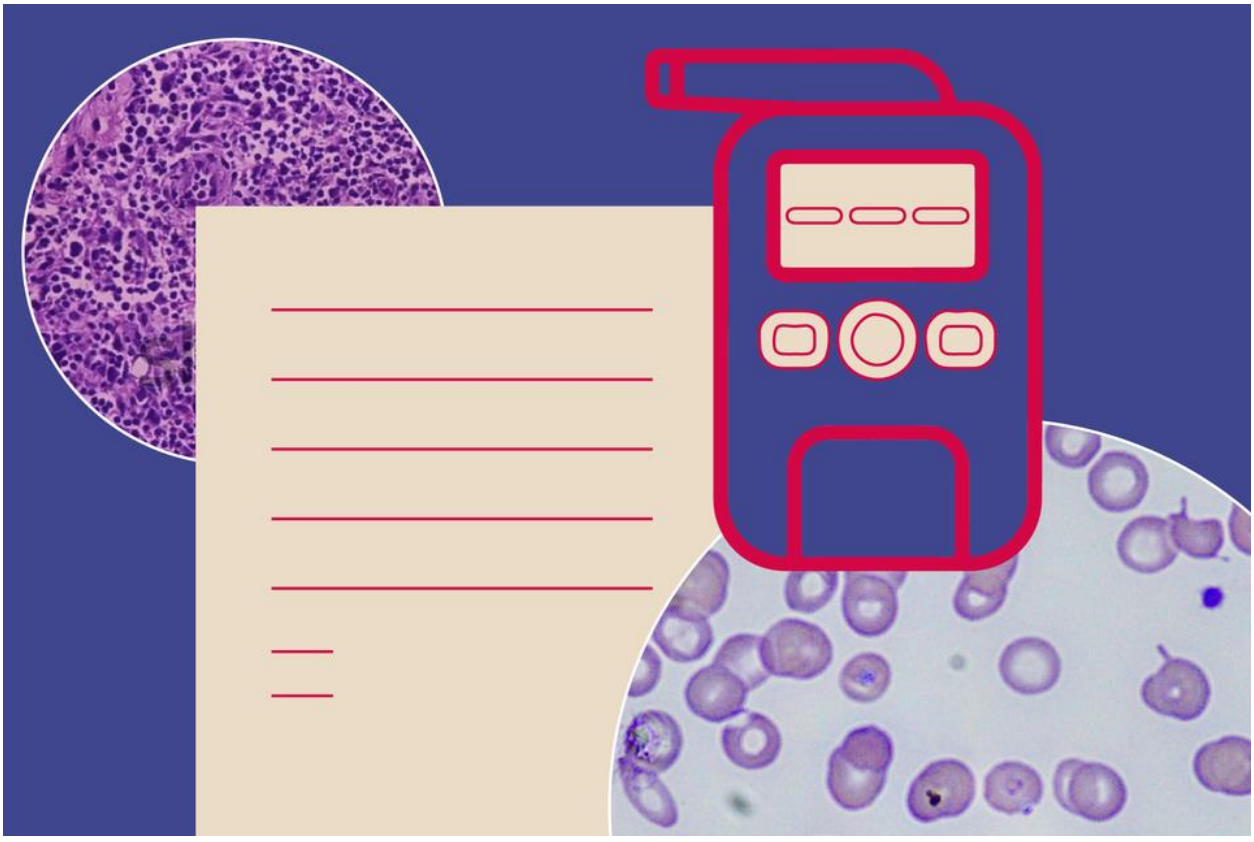
2.4.4 NIST Partners With the Gates Foundation to Develop Breathalyzers for Malaria and Tuberculosis

- Researchers are developing breathalyzers for malaria and TB.
- NIST will create the standards and tools needed to ensure that the breathalyzers produce accurate and reliable results.
- A new generation of breathalyzers for a wide range of diseases may soon be available.

Under a two-year, $2 million CRADA with the Gates Foundation, NIST's Fluid Characterization and Gas Sensing Metrology groups will focus on two long-term goals:

- Specially designed testing equipment to benchmark the breathalyzers' performance and ensure measurement accuracy.
- Gas mixtures for testing the accuracy of the breathalyzers. Some will model the breath of someone who has either malaria or TB; others will replicate the breath of an infection-free individual.

Figure 5: Breathalyzer Graphic



Credit: N. Hanacek/NIST

2.4.5 Now Live: Living Cells Can Be Seen with Infrared Light

- NIST researchers use new method to measure biomolecules in live cells.
- Scientists captured clear images of biomolecules in single live cells in water for the first time using infrared (IR) transmission imaging.
- The IR technique enables researchers to measure the mass of biomolecules such as proteins in a cell.
- Using simple components, the method has the potential to speed up advances in biomanufacturing, cell therapy development, and drug development.

2.4.6 AI Can 'Hear' When a Lithium Battery Is About to Catch Fire

- When a lithium-ion battery is about to catch fire, it makes a unique click-hiss as gases escape.
- NIST researchers have trained AI to detect this sound even in noisy environments.

If a lithium-ion battery gets too hot or is damaged, it may undergo a chemical reaction called thermal runaway. The experiment shown in Figure 6, performed at Xi'an University of Science and Technology in collaboration with NIST, was designed to record the sounds a lithium-ion battery makes before and during thermal runaway.

Figure 6: Lithium Battery Explosion Experiment

Credit: NIST

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.

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

Research across NOAA's laboratories is primarily aimed at improving the ability of the operational components to accomplish their respective missions. Recent examples demonstrating the direction of NOAA's research are severe storm (hurricane, tornado, derecho winds) and drought forecasting; 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 16 Cooperative Institutes at 80 universities and research institutions across 33 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 (TPO) works closely with the technology transfer offices from the Institutes to jointly manage intellectual property and seek out licensing partners.

Source: NOAA

3.1 Approach and Plans for Technology Transfer

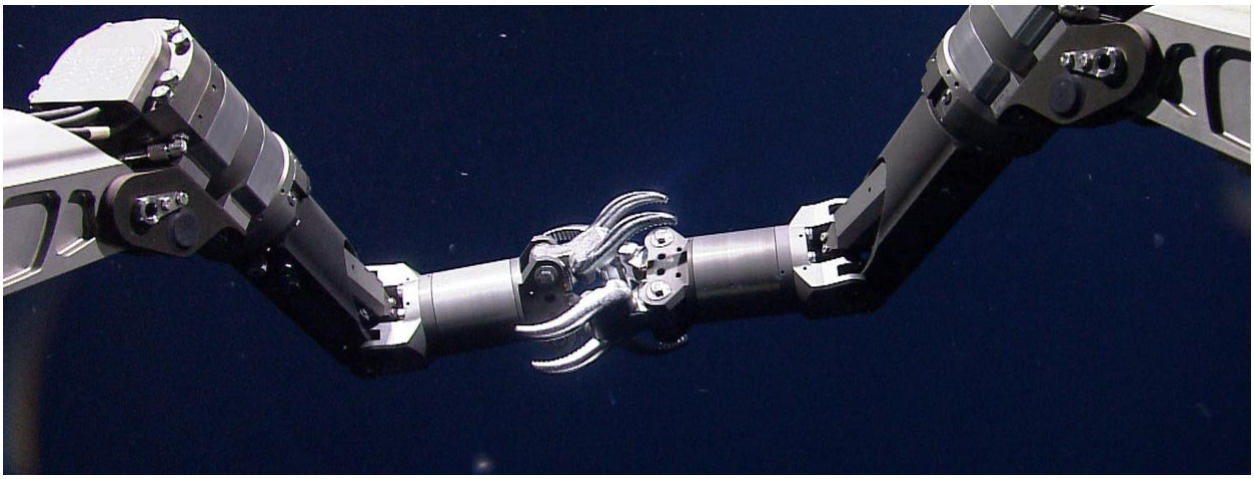
Specific roles and responsibilities for NOAA's technology transfer program include the execution and management of authorized and delegated technology transfer authorities, communicating and representing NOAA's technology transfer to NOAA's Line Offices, laboratories, programs and to the public, encouraging participation and promoting results of NOAA technology transfer activities, maintaining comprehensive records of all NOAA technology transfer agreements, cultivating of collaboration opportunities and partnerships between NOAA science and technology communities, industry and academia and providing continuous education on technology transfer to these populations.

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. NOAAs technology transfer program consists of three persons, a program manager, an agreements specialist and a commercialization and IP management specialist.

The NOAA TPO has acquired its first technology transfer management software package and began customization efforts for the software in FY24. This software allows for development, tracking, reporting, and management of all of NOAA's agreements and inventions as well as management of financial information such as incoming funds for CRADAs and patent license agreements.

Management of NOAA's intellectual property patent filing is achieved with a partnership between NOAA and NIST, having one NIST intellectual property attorney support drafting of patent applications, office actions, and other relevant USPTO activities.



Source: NOAA

3.2 STATUTORILY REQUIRED METRIC TABLES

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 and cooperative research and development agreements.

NOAA was awarded zero (0) issued patents. One (1) patent application, and six (6) provisional patent applications were filed in FY24.

NOAA researchers disclosed 27 inventions in FY24.

The licensing portfolio consists of six (6) active invention licenses. The NOAA-issued invention licenses include three (3) exclusive licenses, and three (3) non-exclusive licenses. NOAA now maintains an active portfolio of 12 patented technologies.

In FY24 NOAA entered into 24 new CRADAs which support a variety of NOAA laboratories across five Line Offices. NOAA's CRADA activity is with entities that reside within ten (10) states CA, WA, MD, CO, MA, NJ, NC, TX, VA, and OH.

Table 24: NOAA Invention Disclosures and Patenting

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Disclosures Received	6	12	3	7	27
Total Patent Applications Filed	1	0	0	2	7
U.S.	1	0	0	2	7
Foreign	0	0	0	0	0
Total Patent Cooperation Treaty (PCT) Applications Filed	0	0	0	0	0
Total Patents Issued	0	2	1	0	0
U.S.	0	2	1	0	0
Foreign	0	0	0	0	0

Table 25: NOAA Licensing

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Licenses, Total Active	6	6	6	6	6
New Invention Licenses	0	2	0	0	0
New Invention Licenses Granted to Small Businesses	0	2	0	0	0
Income Bearing Licenses, Total Active	6	6	6	6	6
New Income Bearing Licenses	0	2	0	0	0
Exclusive, Total Active	0	3	1	1	3
Partially Exclusive, Total Active	0	0	0	0	0
Non-Exclusive, Total Active	0	3	5	5	3
Other Licenses, Total Active	0	0	0	0	0
New Other Licenses	0	0	0	0	0
New Other Licenses Granted to Small Businesses	0	0	0	0	0
Elapsed Amount of Time for Granting Invention Licenses					
Average (months)	n/a	n/a	n/a	n/a	n/a
Minimum (months)	n/a	n/a	n/a	n/a	n/a
Maximum (months)	n/a	n/a	n/a	n/a	n/a
Licenses Terminated for Cause	0	0	0	0	0

Table 26: NOAA Income from Licensing

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention License Income	$111,834	$69,173	$112,588	$18,982	$7,715
Other License Income	$0	$0	$0	$0	$0
Total Earned Royalty Income (ERI)	$108,234	$69,173	$112,588	$18,982	$7,715
ERI from Top 1% of Licenses	$102,734	$69,173	$102,388	$13,500	$5,715
ERI from Top 5% of Licenses	$102,734	$69,173	$102,388	$13,500	$386
ERI from Top 20% of Licenses	$102,734	$69,173	$102,388	$13,500	$1,543
Minimum ERI	$500	$69,173	$10,200	$2,000	$200
Maximum ERI	$102,734	$69,173	$102,388	$13,500	$5,715
Median ERI	$27,959	$69,173	$56,294	$3,482	$3,857
Disposition of ERI					
Percentage Distributed to Inventors	34%	32%	31%	52%	79%
Percentage Distributed to Lab/Agency	66%	68%	69%	48%	21%

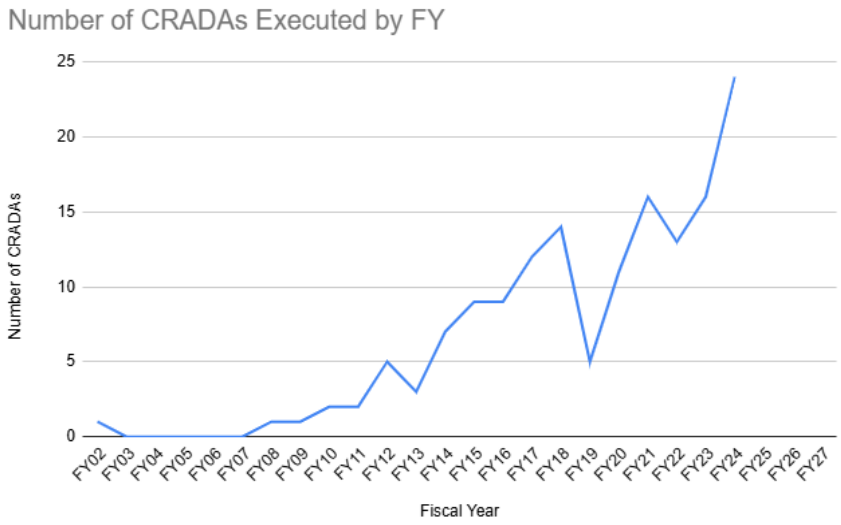
Table 27: NOAA Collaborative Agreements

	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Total Active CRADAs	46	57	51	57	64
New CRADAs	14	18	17	17	24
New CRADAs Involving Small Businesses	4	4	12	12	13
Other Collaborative Agreements	0	1	1	0	0

3.3 Other Important NOAA Performance Measures

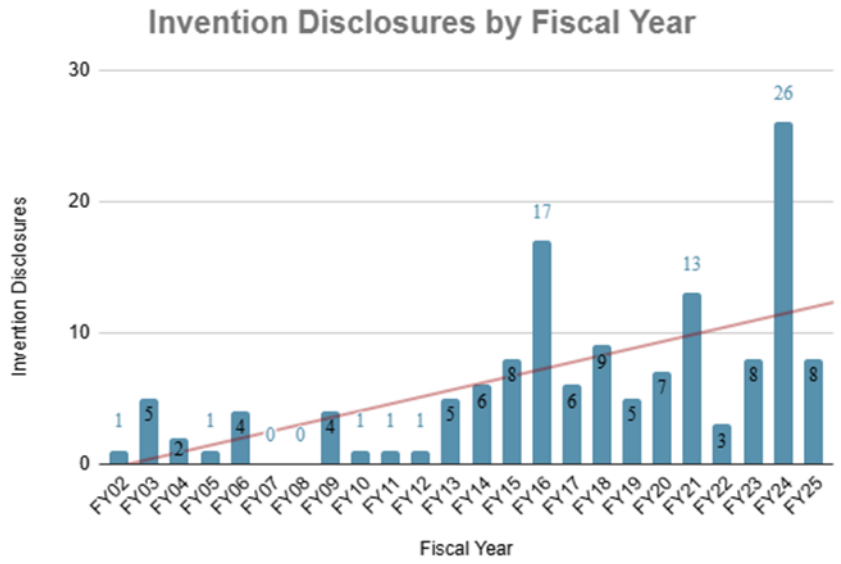
In reach and education to NOAA scientists and engineers is increasing the NOAA technology transfer portfolio. We signed 24 new CRADAs in FY 2024 which is a 41% increase over FY 2023. NOAAs average number of CRADAs over the last 5 years is 15.

Figure 7: Number of NOAA CRADAs Executed by FY



Our invention disclosures also saw a significant increase of 225% in FY 2024. These are the direct results of activities that began in FY23 and our intentional outreach and in reach with the strong understanding that technology transfer is a contact sport.

Figure 8: NOAA Invention Disclosures by Fiscal Year



3.4 Success Stories Demonstrating Downstream Outcomes from NOAA technology Transfer Activities

Here is a small sample of success stories sharing NOAA's technology transfer activity during Fiscal Year 2024.

Table 28: FY2024 CRADA Success: Facilities Use CRADA (FUSA)

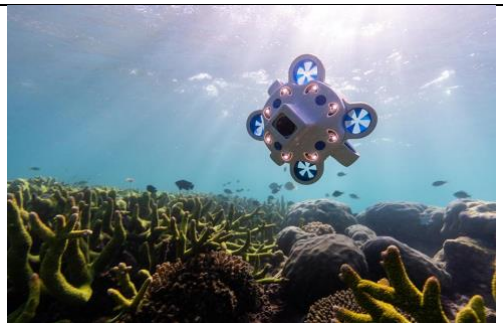
NOAA has unique facilities that NOAA makes available to partners through Facilities Use CRADAs (FUSA).	 *Autonomous Hydrus underwater vehicle. Source: NOAA*
NOAA's Southwest Fisheries Science Center provided access to Advanced Navigation to a specialized saltwater tank to test their autonomous Hydrus underwater vehicle to verify the system's capabilities and advance its technology readiness level.	NOAAs TPO was able to get the FUSA Agreement in place within four days. The Southwest Fisheries Science Center allowed for the Navy, Coast Guard, and a Hollywood filming company to observe the test and demo to support efficient use of the company's time and broaden the impact of the test.

Table 29: FY24 Technology Transfer Outreach Success: Contact Sport Connecting with NOAA PIs & External Partners

A three day packed agenda allowed NOAA's Office of Research and Technology Applications (ORTA) and TPO to connect with both internal NOAA offices and external partners.	 *Source: NOAA*
ORTA & TPO engaged with the following external partners: Ocean Aero, Inc. Mississippi Enterprise for Technology (MSET) Northern Gulf Institute (NGI) Naval Meteorology and Oceanography Command (CNMOC) Naval Research Laboratories	NOAA's TPO provided briefings on how it manages two unique and varied programs that include the Small Business Innovation Research (SBIR) Program and Technology Transfer Program in support of a strong and resilient U.S. economy. The visit has supported outcomes such as a new type of partnership agreement NOAA TPO will put into use in FY25.

4 NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION: INSTITUTE FOR TELECOMMUNICATION SCIENCES

The Institute for Telecommunication Sciences (ITS) manages the telecommunications technology research and engineering programs of the National Telecommunications and Information Administration (NTIA), the Executive Branch agency principally responsible by law for advising the President on telecommunications and information policy issues. ITS basic research in radio science provides a technical foundation for NTIA's policy development and spectrum management activities and enhances scientific knowledge and understanding in cutting-edge areas of telecommunications technology. ITS also serves as a principal federal resource for solving telecommunications concerns of other federal agencies, state and local governments, private corporations and associations, and international organizations through Interagency Agreements (IAAs) and cooperative research and development agreements (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

Over the past several years, ITS has adopted a multimodal approach to transferring proven technical methods into widespread use within the wider spectrum community. "Technical publications" under this approach include traditional peer-reviewed manuscripts published as Technical Reports, journal articles, or conference papers; peer-reviewed video journal articles and NTIA technical videos; validated and verified software implementations of spectrum-related models and tools; and carefully curated datasets to support further research in telecommunications.

For 20 of the past 24 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.

4.2 STATUTORILY REQUIRED METRIC TABLES

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 30: NTIA ITS Invention Disclosures and Patenting

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Disclosures Received	0	0	0	0	0
Total Patent Applications Filed	0	0	0	0	0
U.S.	0	0	0	0	0
Foreign	0	0	0	0	0
Total Patent Cooperation Treaty (PCT) Applications Filed	0	0	0	0	0
Total Patents Issued	0	0	0	0	0
U.S.	0	0	0	0	0
Foreign	0	0	0	0	0

Table 31: NTIA ITS Licensing[24]

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention Licenses, Total Active	0	0	0	0	0
New Invention Licenses	0	0	0	0	0
New Invention Licenses Granted to Small Businesses	n/a	n/a	n/a	n/a	n/a
Income Bearing Licenses, Total Active	0	0	0	0	0
New Income Bearing Licenses	0	0	0	0	0
Exclusive, Total Active	0	0	0	0	0
Partially Exclusive, Total Active	0	0	0	0	0
Non-Exclusive, Total Active	0	0	0	0	0
Other Licenses, Total Active	0	0	0	0	0
New Other Licenses	0	0	0	0	0
New Other Licenses Granted to Small Businesses	n/a	n/a	n/a	n/a	n/a
Elapsed Amount of Time for Granting Invention Licenses					
Average (months)	n/a	n/a	n/a	n/a	n/a
Minimum (months)	n/a	n/a	n/a	n/a	n/a
Maximum (months)	n/a	n/a	n/a	n/a	n/a
Licenses Terminated for Cause	n/a	n/a	n/a	n/a	n/a

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

Table 32: NTIA ITS Income from Licensing

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Invention License Income	n/a	n/a	n/a	n/a	n/a
Other License Income	n/a	n/a	n/a	n/a	n/a
Total Earned Royalty Income (ERI)	n/a	n/a	n/a	n/a	n/a
ERI from Top 1% of Licenses	n/a	n/a	n/a	n/a	n/a
ERI from Top 5% of Licenses	n/a	n/a	n/a	n/a	n/a
ERI from Top 20% of Licenses	n/a	n/a	n/a	n/a	n/a
Minimum ERI	n/a	n/a	n/a	n/a	n/a
Maximum ERI	n/a	n/a	n/a	n/a	n/a
Median ERI	n/a	n/a	n/a	n/a	n/a
Disposition of ERI					
Percentage Distributed to Inventors	n/a	n/a	n/a	n/a	n/a
Percentage Distributed to Lab/Agency	n/a	n/a	n/a	n/a	n/a

4.3 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 2024, 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.

Table 33: NTIA ITS Collaborative Agreements

Metric	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Total Active CRADAs	0	6	8	5	5
New CRADAs	0	0	2	0	0
New CRADAs Involving Small Businesses	0	0	0	0	0
Other Collaborative Agreements	0	0	0	0	0

4.4 Other Important NTIA ITS Performance Measures

4.4.1 Technical Publications

Publication of scientific reports and articles has historically been the means through which ITS has transferred research results to other researchers, the commercial sector, and government agencies. ITS technical reports 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, but "publication" has come to encompass multiple media. ITS has released peer-reviewed video journal articles and NTIA technical videos, software packages, and datasets for download. Downloads of traditional manuscripts have fluctuated as downloads in other categories increase.

Technical publications are released after an internal peer review process; manuscript release is managed by the ITS Editorial Review Board (ERB). In FY 2024, ITS published 5 NTIA reports and 11 journals articles or conference papers. 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.

Led by the ERB, ITS has drafted procedures for documenting technical peer review of technical publications in non-traditional media as well.

4.4.1.1 Technical Publications Downloaded or Viewed

ITS makes all its publications available to the public through its website 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 traditional manuscript PDFs rather than pageviews of the bibliographic summaries. Video publications not published in peer-reviewed scientific video journals are published on the NTIA YouTube channel. Software and datasets are made available either through the ITS website or the NTIA GitHub repositories. In FY 2024, ITS technical publications of all kinds in all media were downloaded 17,847 times.

4.4.1.2 Multimodal Transfer of Technical Methods

High-precision radio frequency measurements are key to creating and validating radio propagation models, and ITS and its predecessor laboratories have been collecting measurement data for more than a century. This has resulted in a unique expertise in measurement science and electromagnetic compatibility analysis that has been leveraged by other agencies seeking data needed to coordinate with commercial entrants into spectrum bands being opened for federal-nonfederal sharing. Using a multimodal approach to technical publication allows ITS to target audiences of differing scientific literacy, to amplify the reach of best practices messaging and expand message penetration.

Workforce development to support the demands of the rapidly expanding telecommunications industry has been identified as a priority at all levels of the Administration and the Department. However, for the most part, university curricula have been slow to adapt to the needs of industry. ITS is currently participating in curriculum development initiatives with the National Science Foundation (NSF) as well as SpectrumX, the NSF-funded national academic hub for spectrum stakeholders, to enable the development of a technical workforce that is aware of spectrum technology and policy issues and well prepared to support the industry. Beyond academic preparation, best practices in areas such as radio frequency emissions and spectrum measurements must be disseminated in order that data collected by multiple parties can be considered comparable and reliable.

In FY 2024 the various episodes of the video series NTIA Special Publication SP-09-460 "Seminar Series on Spectrum Measurement Theory and Techniques" received a total of 13,868 views. The Institute originally distributed this multi-episode video publication, produced in FY 2009 and aimed at dissemination of measurement best practices, on DVD. Briefly hosted on the ITS website, the series is now available on the NTIA YouTube channel. Each of the 20 one-hour episodes in this series combines a tutorial on a particular aspect of radio spectrum measurement technique or theory with a hands-on demonstration using actual measurement hardware and radio signals. ITS still receives occasional requests for the DVDs for use in training events that take place behind military firewalls.

4.4.2 Software and Data Downloads

Increasingly, technology transfer also occurs through the publication of software. ITS makes several software and data tools available via open source download as executable packages, and those downloads increased 40% between FY 2023 and FY 2024. About a decade ago ITS began moving from offering software tools as .zip files from the ITS public website to using the NTIA GitHub open source code hosting platform, and now offers 39 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. Thus, as there is presently no generally accepted impact metric for GitHub repositories, ITS has added a count of the number of public repositories and a count of

packages downloaded as proxy metrics until a more generally accepted impact metric is defined.

4.4.2.1 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 datasets 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. Releasing trusted and authoritative propagation models under an open-source license meets a critical need for evidence-driven spectrum sharing proposals.

4.4.2.2 Spectrum Monitoring Software

The NTIA Spectrum Monitoring program is creating a new paradigm to enable distributed, persistent, and automated monitoring with heterogeneous and lower-cost sensors; standardized interfaces; open source software implementations; common metadata; automated provisioning, deployment, and maintenance; and data analytics that can be incorporated into artificial intelligence and machine learning routines. ITS tests and integrates new sensing architectures and algorithms in the lab, transitions the sensing platforms to the field, and collaborates with other research and development groups 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, scos-actions, scos-usrp, scos-tekrsa, tekrsa-api-wrap, and preselector). This ecosystem of software and platforms allows other researchers to take measurements using the same interfaces with the same data format, allowing for far easier aggregation of data across multiple projects. In this way, the value of each individual project can extend beyond the original scope and further benefit spectrum research.

4.4.2.3 Audio Quality Testing

ITS has developed a family of no-reference speech quality and intelligibility estimators and is providing software implementations available to industry, researchers, and other agencies via GitHub. These estimators (called WAWEnets) leverage convolutional neural networks, allowing accurate speech quality and intelligibility estimates without access to the originally recorded signal, thus expanding the utility of the tool to include real-time endpoint monitoring in the field. Staff continue to enhance and extend the ITS no-reference tools and made key updates to the WAWEnets software repository in FY 2022 and FY 2023. In FY 2024, a new research effort

produced a new ITS method for advantageously combining contradictory datasets to produce larger, consistent, more powerful datasets. This work is shared with stakeholders via the ITS AlignNet repository on GitHub

Two earlier ITS-developed objective estimators of speech intelligibility are freely available for download from the ITS website 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 website also offers a large variety of audio recordings that support the use of these tools.

4.4.2.4 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 in real time would allow live video streams to optimize the trade-off between bandwidth and quality. This would impact in-service use cases like broadcast video, video surveillance, video conferencing, video analytics, telehealth, and online gaming. Early ITS research focused on objective metrics that compare the current video to a reference, typically the pristine original video, culminating in a series of objective video quality metrics (VQM) that are included in Alliance for Telecommunications Industry Solutions (ATIS) and ITU standards. All VQMs that rely on a reference can be tracked back to ITS's open research, open data, open software, and leadership in international standards development processes. The ITS VQM compiled software was downloaded 91 times and the repository uniquely cloned 66 times from GitHub in FY 2024.

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 2024, ITS expanded the NRMetricFramework public GitHub repository that was released to the public domain in FY 2020 to support collaborative R&D into NR metrics for image and video quality and stimulate an open exchange of ideas, information, and research. This repository was published with the goal of accelerating development of the robust and trusted NR metrics industry needs to more efficiently use increasingly crowded bandwidth. It contains all the tools, information, and statistical methods needed to begin research on this difficult problem. In FY 2024, this repository was cloned 71 times and downloaded 16 times.

4.4.2.5 Consumer Digital Video Library Users Downloading Clips

The Consumer Digital Video Library (CDVL), a website 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 available to industry, academic, and government researchers.

The CDVL website was re-architected in FY 2021 to comply with new security policies and improve download robustness to accommodate an increasing volume of data as the site has become ever more important to the wider research community. The updated website allows researchers to share entire experiments as open data and by the end of FY 2024 offered 13 TB of data to researchers worldwide. Included in the data are ANSI T1.801.01 (American National Standards Institute) and ITU-R Rec. BT.802 standard video sequences that are no longer available from ATIS or the ITU. In FY 2024, 460 unique records were downloaded from the new website, by a total of 151 users.

The total number of media files downloaded by each user is difficult to calculate, because 52% of the downloaded records were datasets with hundreds of images or videos, most of which also contain subjective ratings and other metadata. Individual sequences that are frequently downloaded are those that pose particular problems for codecs, such as a professionally produced sports sequence in UHD HDR that was donated to CDVL by Sky. Just as complete datasets have become more desirable to researchers, so have higher resolution clips become more desirable. While standard definition video is still of limited interest, demand is rapidly growing for UHD clips and lower resolutions (e.g., CIF, QCIF) are no longer of interest.

In FY 2024, ITS published a set of American Sign Language (ASL) videos with English translations. These ASL videos were filmed and distributed to enable research into the use of modern video systems for ASL communication. The videos are distributed with translations. The videos depict Deaf signers and one teacher at a school for the Deaf. These people are conversing at a natural pace. The goal during filming was to characterize various signing behaviors by seeking a large variety of ages, genders, skin tones, health conditions, and places of origin (e.g., vocabulary). The University of Texas at Austin partnered with ITS to use these ASL videos in an experiment that explores the impact of modern video systems on ASL communications. In FY 2024, ITS published this ASL dataset and subjective ratings on CDVL.

CDVL users must register for each download or upload session. Self-reported demographics from FY 2024 indicate users were 48% academic, 49% industry, 3% government. The number of registrants who perform downloads each year was selected as the most significant measure of the impact of this resource.

Table 34: NTIA ITS Software and Data Downloads

Metric	FY 2024
Technical Publications Released	16
Technical Publications Downloaded	17,847
Consumer Digital Video Library Users Downloading	123
Video Quality Metric Software Users Downloading	66
Propagation Modeling Software Downloads	588
Other Software/Data Downloads	746
Public GitHub Repositories	39

4.4.3 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.

Various offices of NTIA work collaboratively with the International Telecommunication Union (ITU), U.S. National Committee for the International Union of Radio Science (USNC-URSI), 3rd Generation Partnership Project (3GPP), Wireless Innovation Forum (WInnForum), Institute of Electrical and Electronics Engineers Standards Association (IEEE), O-RAN ALLIANCE, Telecom Infra Project (TIP), Telecommunications Industry Association (TIA), Internet Engineering Task Force (IETF), and Inter-American Telecommunications Commission (CITEL) to develop, interpret, analyze, and implement standards, specifications, and regulations.

ITS in particular participates most intensely at the Working Group or Working Party level, both directly providing technical contributions and engaging in collaborative assessment and validation of others' technical contributions. For example, a plurality of the technical recommendations of the International Telecommunication Union Radiocommunication Sector (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. This method of technology transfer directly addresses improvement and protection of U.S. competitiveness in telecommunications.

ITS also actively contributes to ITU efforts around best practices for video quality assessment. In FY 2024, 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 (ITU-R SG6 and ITU-T SG12). This allows more technical experts to follow and contribute to ITU recommendations.

In FY 2024, staff from 6 separate offices of NTIA held 144 positions in 15 standards bodies, including 20 Chair/Co-Chair/Vice-Chair/Chair-Elect positions. NTIA staff filled key leadership positions in the ITU-R, ITU-T, USNC-URSI, and CITEL. NTIA also significantly increased involvement in the O-RAN ALLIANCE with several engagements, notably in the Testing and Integration Focus Group (TIFG), to facilitate and promote standardized testing procedures that produce repeatable testing results with consistency around the world when used by network operators. The U.S. delegation advanced spectrum policy for such critical federal missions as aviation safety, weather, and—looking to the future—lunar communication; and for the private sector the delegation advanced spectrum policy in support of both licensed and unlicensed services, and in expanding space and satellite services.

4.5 Success Stories Demonstrating Downstream Outcomes from NTIA ITS Technology Transfer Activities

To date, major contributions to the Citizens Broadband Radio Service (CBRS), including testing and evaluation of Spectrum Access Systems (SAS) and Environmental Sensing Capability (ESC) sensors; spectrum monitoring; objective audio and video Quality of Experience (QoE) metrics. Broadband air-interface and core network capabilities for Long Term Evolution (LTE) and 5G mobile communications have been achieved through CRADAs. These have aided U.S. efforts to rapidly introduce new socially constructive communications technologies.

4.5.1 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. Radio 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 radio 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 Federal Advanced Communications Test Site (FACTS) within the radio quiet zone supports fundamental research, engineering studies, and experiments into the nature, interaction, and evaluation of telecommunication devices, systems, and services. These studies are critical to ensuring full utilization of the limited radio spectrum for new and emerging telecommunications technologies. They provide real world, over-the-air measurement data to validate models and simulations that support technical feasibility studies for spectrum sharing between and among disparate spectrum-dependent systems.

A unique feature of the FACTS is an automated system for performing emission measurements on both commercial communications base stations and 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 promote efficient spectrum use by ensuring an acceptable degree of electromagnetic compatibility among radar systems, and between such systems and those of other radio services sharing the radio frequency spectrum. Interference-free spectrum sharing between radars and commercial communications systems continues to pose a serious technical challenge to expanding commercial use of the radio spectrum.

All U.S. government 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 NTIA TR-05-420 "Measurement procedures for the radar spectrum engineering criteria (RSEC)" describes the required method for certifying compliance.

ITS enters CRADAs with manufacturers of new radars to perform emission measurements and provides a report that can be used for system certification. 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.

Annually the National Oceanic and Atmospheric Administration (NOAA), National Institute of Standards and Technology (NIST), other federal agencies, universities, private companies, and other organizations conduct research at the Table Mountain Radio Quiet Zone under IAAs and CRADAs. The work provides unique opportunities for cooperative learning and discovery, with the outcomes frequently becoming seeds of commercial and government successes.

- In FY 2024, ITS used the Table Mountain Radio Quiet Zone to perform measurements to support electromagnetic compatibility analyses. One measurement campaign gauged the impact of 5G base stations on adjacent-band FAA ASR-9 radars. ITS coordinated with a mobile network operator which deployed a transportable base station to the site so its out-of-band emissions could be measured. These data were used to develop proposed solutions for mitigating interference reported by the FAA
- Another more complex measurement campaign involved live testing of the compatibility of the Army's TPQ-53 counterfire target acquisition radar with co-channel 5G base stations. Operating both systems in close proximity enabled the ITS researchers to catalogue the impact of the radar transmissions on 5G base station receivers, as well as the impact of the 5G transmissions on the radar's tracking capabilities.
- In FY 2024, ITS continued to expand its support of NOAA's Radio Frequency Interference Monitoring System (RFIMS) program at the Table Mountain Radio Quiet Zone to add capacity for 5G testing. ITS continued to assist NOAA in understanding Meteorological Satellite (MetSat) radio frequency (RF) downlink technical performance, in the face of spectrum sharing requirements with continually evolving commercial systems. Table Mountain hosts a functionally equivalent MetSat Operations Center that mimics NOAA's two main operational MetSat sites and serves as a testbed to assess the degree to which terrestrial cellular interference can affect MetSat data downlink operations. The testbed also allows testing of commercial RFIMS systems 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 FY 2024, several companies used the Table Mountain site under CRADAs to safely test and demonstrate lidar technologies under development in atmospheric conditions and at distances relevant to potential applications, and to fully test the functionality of new antenna designs during product development. Some CRADA partners conducted scaled demonstrations for missions relevant to U.S. government organizations.

4.5.2 Innovative Commercial Services

ITS research, development, testing, and evaluation (RDT&E) efforts enabled successful commercial deployment of the Citizens Broadband Radio Service (CBRS). A decade of ITS research, from initial technical feasibility studies of sharing between high power radars and commercial services through initial conformance testing of the Environmental Sensing

Capability (ESC) and Spectrum Access System (SAS) components of CBRS, laid the foundation for CBRS mid-band sharing and the $4.6 billion success of the 2020 auction of CBRS licenses.

ITS worked with the FCC (through interagency agreements), industry (through CRADAs), and the standards group WInnForum (through membership) to identify, address, and resolve technical issues of interference potentials, protection thresholds, and propagation predictions. After completing FCC Part 96 conformance testing on two waves of SAS candidate systems, ITS delivered the SAS conformance test toolset to the FCC and conducted several trainings on its use, to support testing and certification of future SAS systems.

In FY2024, ITS provided the SAS conformance test toolset and a walkthrough of the toolset to MITRE. MITRE modified and used the conformance test toolset to develop test configurations used by the SAS administrators for self-testing of the "CBRS 2.0" changes that expanded potential CBRS service coverage to 240 million people, or 91% of the U.S. population, up from 49%.

As part of the post-3.5 GHz Priority Access License (PAL) auction (FCC Auction 105) spectrum relocation fund programs approved by OMB and Congress, ITS is also participating in a multi-year program with DoD Defense Information Systems Agency (DISA) and others aimed at developing tools and capabilities to determine the effectiveness of the innovative CBRS sharing arrangements. As a member of the National Advanced Spectrum and Communications Test Network (NASCTN), ITS took a lead role in the Sharing Ecosystem Assessment (SEA) project by co-developing and deploying distributed sensors capable of measuring CBRS band spectrum behavior and assessing aggregate spectrum usage. The sensor control and data collection software was transferred to the public domain through GitHub and is freely available for use in other bands of interest for sharing.

NTIA's FY 2023 Technical Report TR-23-567, "An Analysis of Aggregate CBRS SAS Data from April 2021 to January 2023" was the first of several planned analyses of aggregate CBRS SAS data. These data provide valuable insights into the growth of CBRS, the impact of dynamic spectrum sharing, the role of General Authorized Access (GAA) spectrum usage, and CBRS's role in rural wireless connectivity. A second longitudinal study that extended the analysis to July 2024 underwent ITS peer review at the end of FY 2024.

Along with the expanded market access of CBRS 2.0, the evidence of steady growth in CBRS usage supports the optimism expressed by such industry groups as the OnGo Alliance and the Wireless Innovation Forum (WInnForum) that investment in private networks operating in the 3550–3700 MHz band will continue to expand. Indeed, Juniper Research predicts an additional 20% market growth in CBRS between 2024 and 2028.

In FY 2024, ITS executed multiple propagation measurement campaigns as part of a multi-year project with the DOD Chief Information Officer (CIO) to develop improved propagation models for mid-band spectrum management. The collected data is expected to be published in FY 2025,

along with several articles, reports, and tutorials summarizing the data and describing the novel measurement system used to collect it. This critically important research will continue through FY 2027 with proceeds from the Spectrum Relocation Fund 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's mid-band propagation improvement program includes significant inputs and information sharing with other federal agencies, academia, and the commercial sector through regular meetings of a multistakeholder group first convened in FY 2024.

Open source sharing of measurements, modeling, and code is an integral part of this program. The improved propagation models will in turn provide an opportunity to refine spectrum sharing scenarios. Just as refinements to the parameters used by the CBRS SASs to control on demand spectrum access through dynamic channel sharing expanded commercial access to a greatly expanded market for systems relying on highly desirable mid-band spectrum, improved propagation models will enable more precise and cost effective interference-protected deployments for both federal and non-federal services. Expanded availability of reference measurements, more accurate modeling, and easily applied software implementations are foundational to achieving the objectives of the National Spectrum Strategy and U.S. goals for resolution of 2027 World Radio Conference (WRC-27) agenda items.

4.5.3 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 leadership efforts at ITU-R Study Group 3 (Radiowave Propagation) ensure that U.S. interests and policy objectives are given due consideration by international technical experts and promote informed decisions founded on physics and mathematics. An ITS researcher acts as Head of the U.S. Delegation to the international Study Group 3 meetings, convening the preparatory meetings of U.S. Study Group 3. At these meetings, U.S. Government agencies, academia, and private industry prepare U.S. contributions and positions to be discussed during upcoming plenary meetings. Within Study Group 3, in addition to Head of Delegation, ITS researchers hold three U.S. Working Party Chairs, one International Working Party Chair, and six Correspondence Group chairs. In FY 2024, ITS hosted the May/June 2024 ITU-R Working

Party meetings in Denver, CO. A new CG for opening discussions on potential lunar propagation models was formed during these meetings.

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 Under Secretary for Research and Engineering's interests in 5G within 3GPP. In FY 2024, 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 2024, ITS attended TSG SA1 and SA3 working groups and provided briefings on agency-specific concerns with regard to standardization developments with respect to spectrum sharing, vehicle-to-everything communication, non-terrestrial networks, unmanned aerial vehicles, and cyber security topics relative to security vulnerabilities in 4G and 5G systems architecture.

4.5.4 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, evaluate new display technologies, or develop and evaluate 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.

The remainder of CDVL's content targets other use cases: 13% is standard test sequences and experiments from ITU, ATIS, or VQEG; 15% is academic experiments distributed as open data; and 18% is simulated public safety content. Due to litigation concerns, real public safety content is nearly impossible to obtain for research. Since first responders use consumer grade electronics, promoting development and standardization of commercial video technologies that meet public safety requirements through access to this simulated content has the potential to save lives as well as money.

ITS continues to support industry discussions within VQEG that pursue new or improved ITU Recommendations. In FY 2024, ITS worked within VQEG and ITU-T Study Group 12 to merge

ITU-T Recs. P.910, P.911, and P.912 into a single Recommendation. These three Recs. each separately addressed subjective testing methods for video quality assessment techniques for reasons that are no longer relevant. ITS identified new techniques developed by VQEG attendees over the past decade and led discussions on the best way to incorporate those techniques into the updated ITU-T Rec. P.910. These new methods will help U.S. industry and academia develop new technologies that rely on video streaming.

The impact of the updated Recommendation is difficult to measure, since industry rarely publishes techniques used during the product development cycle, but intense participation by industry in this standardization effort testifies to the perceived value of the updated ITU-T Rec. P.910. A literature search of relevant studies in IEEE publications located consistent references to P.910, which indicates that authors were aware of the merger. Most of the remaining studies focused on broadcast applications and referenced ITU-R Rec. BT. 500.

5 SUMMARY

This report details the results of the FY 2024 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 positioned to improve the nation's competitiveness in the global markets.