U.S. Department of Transportation

Office of the Secretary of Transportation

Deputy Assistant Secretary
for Research and Technology

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Washington, DC 20590

December 16, 2021

TO: Dr. Michael Hall, Technology Partnerships Office
National Institute of Standards and Technology

FROM: Robert C. Hampshire, Ph.D. RCH
Deputy Assistant Secretary for Research and Technology
Chief Science Officer

SUBJECT: Fiscal Year 2020 Technology Transfer (T2) Annual Summary Report

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Every year, the Department of Commerce (DOC) submits a Federal Laboratory T2 Fiscal Year Summary Report to the President and the Congress in accordance with 15 U.S.C. 3710(g)(2). The report summarizes the implementation of technology transfer authorities established by the Technology Transfer Commercialization Act of 2000 (Pub. L. 106-404) and other legislation.

This report summarizes the United States Department of Transportation's (U.S. DOT) information for DOC's Fiscal Year 2020 Summary Report.

Please submit questions pertaining to this report to Aimee Flannery at Aimee.Flannery@dot.gov or (202) 366-7433.

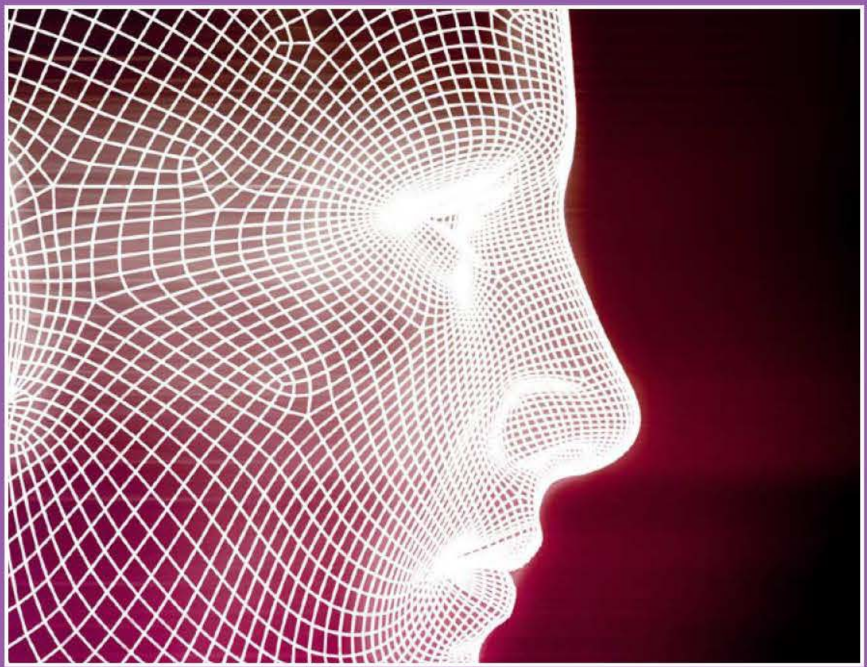
Attachment

Fiscal Year 2020 Technology Transfer (T2) Annual Summary Report

FY 2020

U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

ANNUAL Technology Transfer REPORT



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1 Introduction

The U.S. Department of Transportation (U.S. DOT) is the Federal steward of the Nation's transportation system. U.S. DOT consists of multiple modal operating administrations (OAs) that carry out mission-related research, development, and technology (RD&T) programs in support of their goals. U.S. DOT's Technology Transfer (T2) Program, which is housed in the Office of the Assistant Secretary for Research and Technology (OST-R), is responsible for coordinating, documenting, and supporting T2 activities across the Department. This report summarizes the implementation of technology transfer authorities established by the Technology Transfer Commercialization Act of 2000 (Pub. L. 106-404) and other legislation.

U.S. DOT continues to increase coordination and collaboration efforts among its OAs and Federal laboratories, as evidenced through the collection and submission of this T2 Annual Summary Report to U.S. DOT's budget examiner in the Office of Management and Budget. This report is also provided to the Department of Commerce's (DOC) National Institute of Standards and Technology in support of the DOC Secretary's Annual Summary Report to the President, Congress, and to the U.S. Trade Representative on the status of technology transfer by Federal laboratories.

U.S. DOT defines T2 as the process by which the transportation community receives and applies the results of research through dissemination and deployment activities. U.S. DOT's current approach to T2 is diverse and unique to each mode of transportation. Each modal OA conducts mission-specific deployment activities tailored to its mode and type of research. U.S. DOT's annual T2 reports are available online here.

T2 activities are executed by U.S. DOT agencies and their research centers:

- Federal Aviation Administration (FAA):
  - Civil Aerospace Medical Institute, Oklahoma City, OK
  - The William J. Hughes Technical Center (WJHTC), Atlantic City, NJ
- Federal Highway Administration (FHWA): Turner-Fairbank Highway Research Center (TFHRC), McLean, VA
- Office of the Assistant Secretary for Research and Technology (OST-R): John A. Volpe National Transportation Systems Center (Volpe Center), Cambridge, MA
- National Highway Traffic Safety Administration (NHTSA): Vehicle Research and Test Center (VRTC), East Liberty, OH
- Federal Railroad Administration (FRA): Transportation Technology Center, Pueblo, CO

More information about U.S. DOT's T2 activities and research centers is available on the following websites:

- FAA: https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/initiatives/ttp/
- FHWA:
  - https://www.fhwa.dot.gov/innovation/
  - https://www.fhwa.dot.gov/goshrp2
- OST-R: https://www.volpe.dot.gov/work-with-us/technology-transfer
- FRA: https://railroads.dot.gov/program-areas/testing-facilities-equipment/testing-facilities-equipment

U.S. DOT also cooperates with the United States Office of Management and Budget to implement Cross-Agency Priority (CAP) goals, established by the Trump administration, to tackle critical government-wide challenges that cut across agencies. One of these CAP Goals is to "Improve Transfer of Federally Funded Technologies from Lab to Market." Within U.S. DOT, OST-R leads cross-modal efforts to collaborate with the White House's Office of Science and Technology Policy, in support of the Lab-to-Market (L2M) CAP Goal. As part of this effort, OST-R has created a T2 Evaluation Working Group composed of representatives from the Department's OAs. The Working Group is assessing the effectiveness of past T2 efforts and developing recommendations for future T2 efforts.

2 U.S. DOT Invention Disclosures, Patenting, Licensing, and Other Measures

The following tables provide data on U.S. DOT's T2 activities from Fiscal Year (FY) 2015 to FY 2020. These tables conform to the guidance that the DOC has provided to Federal agencies. Table 6 contains other metrics that U.S. DOT tracks. Zeroes ("0") denote the agency did not use the mechanism in the reported year. "N/A" denotes that data was not available at the time of the report.[1]

Table 1: Invention disclosures and patents

		FY16	FY17	FY18	FY19	FY20
	Invention Disclosures					
1	New inventions disclosed	0	3	12	2	3
	Patents					
2	Patent applications filed	0	7	0	2	2
3	Patents received	1	0	0	0	1
4	Foreign patents filed	0	0	0	0	0
5	Foreign patents received	0	0	0	0	0

[1] Guidance from *Guidance for Preparing Annual Agency Technology Transfer Reports Under the Technology Transfer Commercialization Act,* p. 3. April 2013

Table 2: Income-bearing licenses

		FY16	FY17	FY18	FY19	FY20
	Licenses					
6	Total active licenses	2	5	5	5	5
7	Total new licenses	2	1	1	0	0
	Income-Bearing Licenses					
8	Total active income-bearing licenses	2	2	5	6	4
9	New income-bearing licenses	0	0	1	1	0
10	Total active invention licenses	2	0	0	1	1
11	New invention licenses	0	0	0	0	0
12	Exclusive licenses	0	0	0	0	1
13	Partially exclusive licenses	0	0	0	0	0

Table 3: Licensing income

		FY16	FY17	FY18	FY19	FY20
14	Non-exclusive licenses	2	5	5	4	4
	Note: FAA licenses are non-exclusive.					
	Elapsed Amount of Time to Grant Licenses					
15	Average (months)	N/A	N/A	N/A	N/A	N/A
16	Minimum (months)	N/A	N/A	N/A	N/A	N/A
17	Maximum (months)	N/A	N/A	N/A	N/A	N/A
	License Income ($ thousands)					
18	Total license income	N/A	$19.8	$13.7	$8.2	$19
19	Total invention license income	N/A	N/A	$0	$0	$19

Table 4: Royalty income

		FY16	FY17	FY18	FY19	FY20
	Earned Royalty Income					
20	Earned royalty income from top 1% of licenses	N/A	N/A	0	0	0
21	Earned royalty income from top 5% of licenses	N/A	N/A	0	0	0
22	Earned royalty income from top 20% of licenses	N/A	N/A	0	0	0
23	Minimum earned royalty income	N/A	N/A	0	0	0
24	Maximum earned royalty income	N/A	N/A	0	0	0
25	Median earned royalty income	N/A	N/A	0	0	0
	Disposition of Earned Royalty Income ($ thousands)					
26	Earned royalty income received ($ thousands)	$15.3	$19.8	$13.1	$8.2	$19
27	Percent of earned royalty income distributed to inventors	32	33	37	25	25
28	Percent of earned royalty income distributed to the agency or laboratory	68	67	64	75	75
29	Licenses terminated for cause	0	0	0	0	0

Table 5: Cooperative research and development agreements (CRADAs)

		FY16	FY17	FY18	FY19	FY20
	Cooperative Research and Development Agreements (CRADAs)					
30	Active CRADAs	68	65	63	44	49
31	Newly executed CRADAs	22	6	7	10	7
32	Active CRADAs with small businesses involvement	12	12	11	8	6
33	Small businesses involved in active CRADAs	12	12	11	8	0
	Traditional CRADAs					
34	Active traditional CRADAs	62	66	63	43	46
35	Newly executed traditional CRADAs	22	6	7	10	7
	Non-traditional CRADAs					
36	Active non-traditional CRADAs	1	1	0	0	0
37	Newly executed non-traditional CRADAs	1	0	0	0	0

Table 6: Small businesses, startups, and young companies

		FY16	FY17	FY18	FY19	FY20
	Others					
38	Small businesses supported	65	148	63	7	45
39	Startups and young companies supported	N/A	N/A	N/A	N/A	8

3 U.S. DOT's Efforts to Streamline Technology Transfer

The importance of T2 within U.S. DOT is reflected in its Strategic Plan for FY 2018 to FY 2022, which was released in February 2018. T2 aims to facilitate adoption and commercialization of market-ready transportation technologies.

Within U.S. DOT, OST-R leads cross-modal efforts to collaborate with the White House's Office of Science and Technology Policy, in support of the Lab-to-Market (L2M) CAP Goal.

Citing *Innovation* as one of the four main strategic goals in the plan, U.S. DOT strives to lead in the development and deployment of innovative practices and technologies that improve the safety and performance of the Nation's transportation system. Under that strategic goal, Deployment of Innovation is a key objective, and the Strategic Plan identifies T2 as one of the strategies to be used to accomplish that objective. Figure 1 shows the relationship of T2 to the Department's research and development (R&D) process and to stakeholder engagement. The T2 activities of OST-R and the different OAs within the Department are described in more detail below.

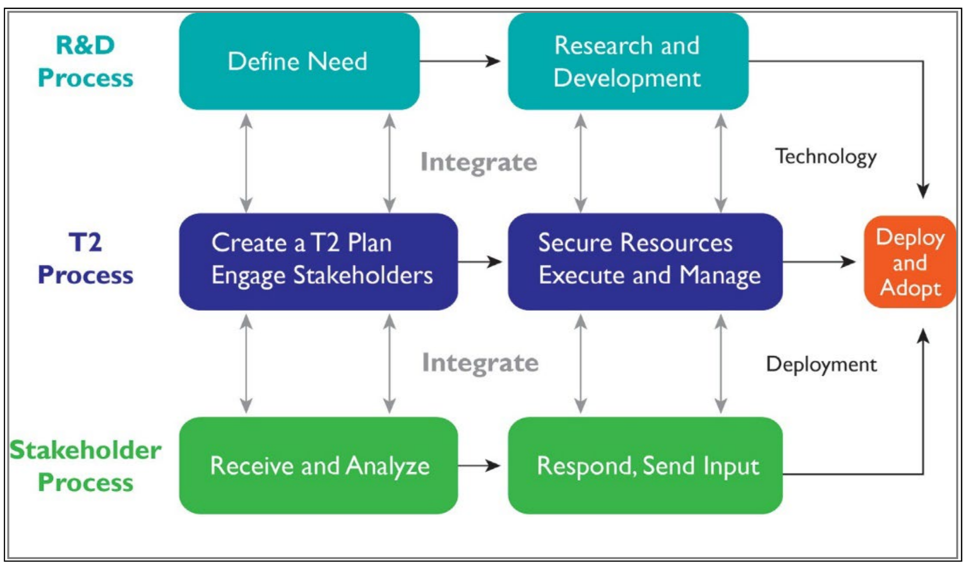

Figure 1: Relationships among research and development (R&D), T2, and stakeholders

3.1 *Office of the Assistant Secretary for Research and Technology*

OST-R is responsible for coordinating, documenting, and supporting T2 activities across the Department. The T2 activities of OST-R focus on research collaboration, knowledge transfer, and information dissemination, which all lead to the practical application of research.

Specific efforts include:

- Improving public access to the results of research funded by U.S. DOT. As detailed further below, OST-R accomplishes this task through submitting research results to the National Transportation Library (NTL), the Repository and Open Science Access Portal (ROSA P), and the U.S. DOT Research Hub.
- Tracking the progress of the Department's R&D and T2 activities through:
  - Key performance indicators for research outcomes and their uses and
  - The collection and sharing of T2 success stories.

- Developing T2 training materials to help R&D personnel incorporate various T2 practices into their research programs.
- Aligning U.S. DOT's R&D budget, research, and T2 processes by incorporating T2 deliverables into R&D funding agreements.

OST-R T2 efforts are implemented via the agencies, programs, and services listed below, each of which will be detailed in the following sections:

- Bureau of Transportation Statistics
    - National Transportation Library
- Office of Research, Development, and Technology
    - Volpe National Transportation Systems Center
        - Small Business Innovation Research Program
    - Research Hub
    - University Transportation Centers
    - Annual Modal Research Plans
- Transportation Safety Institute

3.1.1 Bureau of Transportation Statistics

The Bureau of Transportation Statistics (BTS) is the preeminent source of statistics on commercial aviation, multimodal freight activity, and transportation economics. BTS assures the credibility of its products and service through transparent data collection, thorough vetting of data quality, and rigorous analysis free from political influence. BTS promotes innovative methods of data collection, analysis, visualization, and dissemination to improve operational efficiency, examine emerging topics, and to create relevant and timely information products that foster understanding of transportation and its transformational role in society. The BTS Director is, by law, the senior advisor to the Secretary of Transportation on data and statistics.

3.1.1.1 National Transportation Library

Administered by BTS, the National Transportation Library (NTL) serves as a central clearinghouse for transportation data and information of the Federal Government. Since 2013, NTL has been the centerpiece of U.S. DOT's response to the White House Office of Science & Technology Policy's memorandum *Increasing Access to the Results of Federally Funded Scientific Research*, by serving as the public repository and point of access for research funded by U.S. DOT. NTL also collects and shares transportation data and information produced by other agencies. The NTL is the permanent, publicly accessible home for research publications from throughout the transportation community, the gateway to all DOT data, and the help line for Congress, researchers, and the public for information about transportation. NTL created an all-digital collection of transportation resources, the *Repository and Open Science Access Portal ROSA P*. The Department's Public Access Plan identifies this repository as the full-text repository for research funded by the Department. Content types found in ROSA P include text, links to websites, datasets images, video, other multimedia, and maps.

Figure 2: The ROSA P logo

3.1.2 Office of Research, Development, and Technology

Housed in DOT's Office of the Secretary, OST-R plays a lead role in research coordination within the Department and with a wide range of national and international stakeholders. OST-R focuses on collecting, synthesizing, and disseminating information and statistics on the Department's RD&T activities and its products to ensure that all Open Science, Public Access, and other research funding and product transparency mandates are met.

3.1.2.1 Volpe National Transportation Systems Center

Housed within OST-R, the Volpe Center provides multidisciplinary and multimodal transportation expertise on behalf of U.S. DOT's OAs, U.S. DOT's Office of the Secretary, and external organizations. The Volpe Center provides OST-R with a broad range of assistance, including research and implementation, process analysis, process design, and communication. Within the Volpe Center, the Innovative Research Program Office is heavily involved in U.S. DOT's T2 activities by administering U.S. DOT's Small Business Innovation Research (SBIR) program and supporting the T2 Program Office in OST-R. Other offices within the Volpe Center support the T2 efforts of the OAs.

3.1.2.1.1 Small Business Innovation Research Program

U.S. DOT's SBIR program is a highly competitive award system that provides qualified domestic small businesses with opportunities to pursue research on and develop innovative solutions to our Nation's transportation challenges. The SBIR program favors research that has the potential for commercialization through products and applications sold to the private-sector transportation industry, State DOTs, U.S. DOT, or other Federal agencies. The SBIR Program also provides commercialization services to the small businesses—market research, intellectual property protection assistance, and consulting—to promote the commercial value of innovations and technologies and support T2 activities. The Volpe Center administers the Department's SBIR program on behalf of the Office of the Secretary.

3.1.2.2 Research Hub

The U.S. DOT's Research Hub is an online, searchable database and contains all of U.S. DOT's sponsored RD&T projects. The database acts as a central repository for information on active and recently completed projects from U.S. DOT's OAs. It provides a comprehensive account ofthe Department's research portfolio at the project level. The database also provides links to research reports and other products generated by completed projects.

The Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94) requires U.S. DOT to have a consolidated research database that lists the research abstracts, activities, and outputs of U.S. DOT's research portfolio at the project level. U.S. DOT met this requirement by expanding the Research Hub database, adding new content, and improving functionality, to provide the required comprehensive account of the Department's research.

3.1.2.3 University Transportation Centers

U.S. DOT invests in the future of transportation through its University Transportation Centers (UTC) Program, which awards and administers grants to consortia of colleges and universities across the United States. Each UTC is a consortium of two- and four-year colleges and universities that come together to form a unique center of transportation excellence for transportation research, T2, education, and workforce development. In FY18, the Department implemented a T2 requirement for the UTCs. As a result, all UTC grant recipients have active T2 plans.

3.1.2.4 Annual Modal Research Plans

The FAST Act requires each OA and Joint Program Office within the Department to submit an Annual Modal Research Plan (AMRP) to the Assistant Secretary for Research and Technology for review and approval. The plans are required to provide a comprehensive research plan for the upcoming fiscal year and detailed planning for research and T2 activities. The AMRP template that OST-R provides to the OAs includes sections on T2 Deployment and Evaluation.

3.1.3 Transportation Safety Institute

For over 40 years, the Transportation Safety Institute (TSI) has provided training for safety professionals in Federal, State, and local government agencies, as well as those in private industry. TSI has courses for all modes of travel, covering the transport of either people or freight. With a small staff and adjunct faculty, TSI offers face-to-face instruction, live virtual courses, and web-based training to more than 25,000 people each year.

4 Modal T2 Activities and Programs

4.1 Federal Aviation Administration: William J. Hughes Technical Center and Civil Aerospace Medical Institute

FAA supports multiple pathways to deployment and operational transition of research results and new technologies, to advance aviation safety, efficiency, and environmental objectives. Many of these deployment pathways are created by research partnerships. FAA enhances and expands its R&D capabilities through partnerships with other government, industry, academic, and international organizations. By partnering with other organizations, FAA gains access to internal and external innovators, promotes the transfer of FAA technologies to the private sector for other civil and commercial applications, and expands the U.S. technology base.

FAA T2 efforts are implemented via the programs listed below, each of which will be detailed in the following sections:

- Airport Improvement Program
- CRADAs
- Centers of Excellence

4.1.1 Deployment of New Airport Technology to Improve Infrastructure: Airport Improvement Program

Often helped by financial assistance grants from the FAA's Airport Improvement Program (AIP), airport operators design and implement capital improvements to their airport infrastructure. The FAA provides technical and engineering design guidance to airport operators by issuing advisory circulars and engineering specifications. Airport technology research is reflected in the engineering guidance and technical instructions contained in advisory circulars, as well as in airport compliance inspections and certification procedures. To facilitate the deployment of beneficial technologies resulting from airport technology research, the FAA's airport line of business can enable AIP grant eligibility for those technologies. The AIP grant promotes operator adoption and implementation, thus serving as a deployment strategy for research products.

4.1.2 Cooperative Research and Development Agreements

The Technology Transfer Program at FAA's WJHTC uses CRADAs to facilitate the operational transition of research products. Research transition support is an important characteristic of CRADAs, because they provide an initial validation of the operational suitability and potential effectiveness of a particular technology solution. This initial validation increases the likelihoodof eventual commercialization of the technology. In FY 2020, FAA had 45 active CRADAs, including seven new CRADAs that were established during the fiscal year.

4.1.3 Centers of Excellence

FAA's Centers of Excellence (COE) program conducts and transfers research in specific mission-critical topics. The FAA establishes COEs through cooperative agreements with the Nation's premier universities, members, and affiliates, to conduct focused R&D and related activities over a period of five to ten years. The COE program facilitates collaboration and coordination between government, academia, and industry to advance aviation technologies and expand FAA research capabilities through matching contributions. Over the life of the program, the COE universities, with their non-Federal affiliates, have provided more than $400 million in matching contributions to augment FAA's research efforts. Through long-term cost-sharing activities, the FAA uses its RD&T resources while educating and training the next generation of aviation scientists and professionals.

4.2 Federal Highway Administration

FHWA has embraced a culture of innovation and actively supports and advances innovation across the broad range of its activities, devoting approximately 10 percent of its staff-years to conducting T2 activities annually. FHWA has woven innovation into its organizational structure and business practices. For example, the Office of Innovative Program Delivery works across FHWA and with its partners to identify and promote innovations for implementation. In addition, FHWA's Office of Technical Services and its Division Offices in each State provide technical assistance to FHWA's State and local partners to deploy innovations. FHWA's Federal Lands Highway program works with Federal partners, like the National Park Service to deploy innovations on transportation assets on Federal lands.

FHWA works through multiple programs and initiatives to transfer technological improvements and innovative practices to State and local DOTs that are responsible for construction, operations, and maintenance of the Nation's highways. These programs, some of which are described below, reach every State and thousands of stakeholders annually.

Across the agency, FHWA advances innovation through two primary methods:

1. Identification and development of innovative technologies and practices and
2. Transfer of innovation at the Federal, State, and local levels.

FHWA T2 efforts are implemented via the agencies, programs, and services listed below, each of which will be detailed in the following sections:

- Office of RD&T at the TFHRC
- Every Day Counts
- FHWA Resource Center
- Advanced Transportation and Congestion Management Technologies Deployment Program
- Accelerated Innovation Deployment Demonstration Program
- State Transportation Innovation Council Incentive Program
- ITS Professional Capacity Building Program

4.2.1 Office of Research, Development, and Technology

The FHWA's Office of RD&T is located at the TFHRC, a federally owned and operated national research facility. The center houses more than 15 laboratories and support facilities, and conducts applied and exploratory advanced research in:

- Vehicle-highway interaction,
- Nanotechnology,
- Safety,
- Pavements,
- Highway structures and bridges,
- Human-centered systems,
- Operations,
- Intelligent transportation systems, and
- Materials.

4.2.2 Every Day Counts

A State-based program, Every Day Counts (EDC) identifies, rapidly transfers, and deploys proven but underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce congestion, and integrate automation. Every two years, FHWA works with State, local, and Tribal transportation departments to identify a new collection of innovations to champion. FHWA then provides technical assistance, training, and other resources to support the implementation and widespread adoption of the innovations identified.

Through FY 2020, there have been five EDC rounds. Since the inception of EDC, each State has used 19 or more of the 52 EDC innovations, and some States have adopted more than 40 of them. Many of these innovations have become mainstream practices across the country. FHWA launched EDC-6 in September 2020, which included seven innovations for deployment between 2021 and 2022.

4.2.3 FHWA Resource Center

The Federal Highway Administration's Resource Center is home to the agency's expert task force. The Resource Center helps FHWA's Division Offices, State Departments of Transportation, Metropolitan Planning Organizations, and other transportation partners in conquering challenging technical and partnership hurdles by providing personalized technical assistance, customized training, and ongoing support. The expert technical teams introduce and support the implementation of new innovations and share their vast knowledge of national and international best practices.

4.2.4 Advanced Transportation and Congestion Management Technologies Deployment Program

The Advanced Transportation and Congestion Management Technologies Deployment Program (ATCMTD) awards competitive grants to develop model deployment sites for the implementation of cutting-edge transportation technologies. In FY 2020, the program awarded 10 grants totaling $49.6 million for projects ranging from advanced real-time traveler information to integrated corridor management and vehicle communications technologies. From FY 2016 to FY 2020, the program provided $256 million to projects in multiple States. FHWA opened the competition for the fourth round of awards in June 2020.

4.2.5 Accelerated Innovation Deployment Demonstration Program

The Accelerated Innovation Deployment (AID) Demonstration Program provides incentive funding to State DOTs, Federal Land Management agencies, Tribal Governments, metropolitan planning organizations, and local governments to offset the risks associated with deployment of an innovation on a project. Funds are available to cover the full cost of implementation of an innovation on a project (up to $1 million) in areas such as planning, financing, operations, pavements, structures, materials, environment, and construction. To date, FHWA has awarded 110 AID Demonstration grants, worth over $80 million, as shown in Figure 3 below.

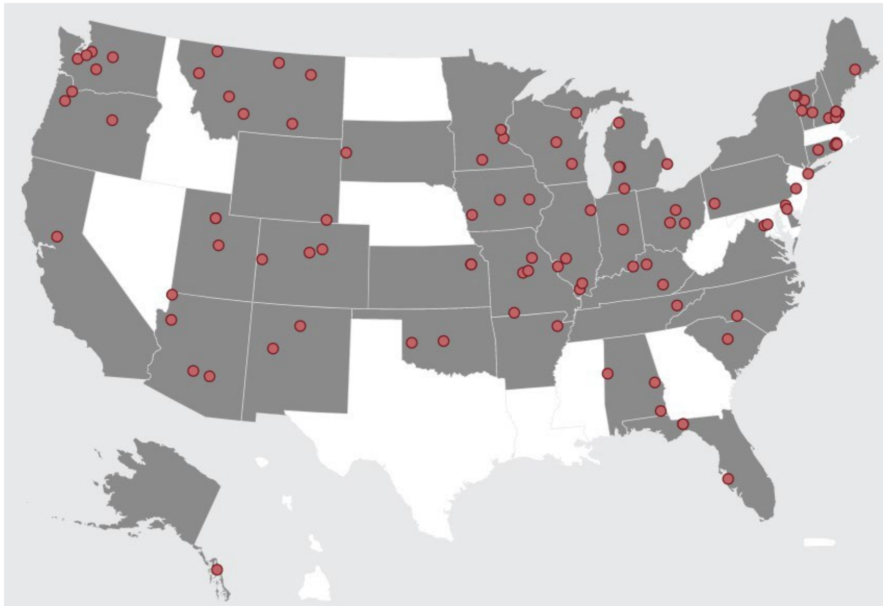

Figure 3: Map of locations of AID demonstration projects

4.2.6 State Transportation Innovation Council Incentive Program

FHWA fosters collaboration between stakeholders within the transportation community through the State Transportation Innovation Council (STIC) Incentive Program, which brings together public and private transportation stakeholders in each State to evaluate innovations and spearhead their deployments. The STIC Incentive Program funds up to $100,000 per State each year to support or offset the costs of standardizing innovative practices in a State transportation agency or another public-sector STIC stakeholder.

Intelligent Transportation Systems Joint Program Office

The Intelligent Transportation Systems Joint Program Office (ITS JPO) is responsible for conducting research on behalf of U.S. DOT and all major modes, to advance transportation safety, mobility, and environmental sustainability through electronic and intelligent transportation applications. As new ITS technologies and systems evolve into market-ready products, ITS JPO addresses issues associated with adoption and deployment. The office works closely with those deploying ITS technologies to ensure a smooth transition, from initial adoption (part of the overall R&D lifecycle) to widespread deployment. The main goal of the adoption phase is to improve market understanding of and commitment to the new technologies. ITS JPO's primary mechanism for educating the public sector's transportation workforce about ITS is the Professional Capacity Building (PCB) Program.

4.2.7 ITS Professional Capacity Building Program

The ITS Professional Capacity Building Program (ITS PCB) designs, develops, and delivers educational opportunities that spur the deployment of ITS technologies. These activities keep public and private entities informed about advances in ITS technologies and their applications for solving real-world transportation challenges. The ITS PCB Program works with the managers of U.S. DOT's ITS research programs to devise, coordinate, and implement outreach and technology transfer activities. The ITS PCB Program also partners with professional associations, universities, and the training programs of U.S.

DOT's modal administrations to engage the technical and organizational expertise needed to develop and deliver ITS learning. Some performance metrics of the ITS PCB's activities from FY 2018 through and FY 2020 are shown in Table 7.

Table 7: Performance metrics for the ITS PCB Program, FY 2017-2020

ITS PCB Activity	FY18	FY19	FY20
ITS PCB website	141,313 sessions (daily average: 387)	77,698 sessions (daily average: 213)	16,103 sessions (daily average: 44.2, based on calendar days, 64.2, based on working days)
Webinars, online courses, and workshops	41 (3,972 attendees)	41 (4,512 attendees)	43 (6,059 attendees, 140.9 participants per live training event)
Archived and on-demand training content	42,131 users	25,372 users	16,813 users

Increasingly, the ITS PCB Program partners with academic institutions to train the future workforce in new transportation technologies and applications. The program holds workshops with representatives from university, community college, and technical and trade school programs to discuss how best to incorporate relevant topics into curricula.

A newer offering of the ITS PCB Program, known as the Connected Vehicle Deployment Technical Assistance Program, is designed to assist participants in U.S. DOT's three connected vehicle pilots with interoperability. Recently, the Connected Vehicle Pilot recipients gathered at the TFHRC to test interoperability in staged scenarios on TFHRC's closed road course. More recently, the ITS PCB Program worked with the CV Pilot sites to prepare a draft document with information and best practices for deploying onboard units (OBUs) in vehicles. Sharing this knowledge will assist future deployers in understanding some of the technical challenges related to deployment so they can more easily deploy consistent and interoperable systems. The ITS PCB Program is also offering a help desk that provides technical assistance during testing and deployments of connected and automated vehicles.

4.3 Federal Transit Administration

The Federal Transit Administration's (FTA's) research activities are designed to respond to issues facing public transit systems today and in the future. FTA continues to focus on three broad research program areas: safety, infrastructure, and mobility innovation. FTA prioritizes research spending on demonstration and deployment activities—usually approximately 70 percent of available research funds. This enables FTA to test promising research findings with public transit agencies. The evaluation of demonstration programs provides information that helps encourage transit agencies to implement potential solutions.

An essential part of FTA's national leadership role is to ensure that promising research findings and technologies benefit public transportation. FTA uses a variety of mechanisms to cultivate relationships with key parties and disseminate research results. Speakers share information about research findings at key industry events. FTA also publishes research reports and posts them on its website. FTA conducts webinars in-house and through partner organizations. Additionally, in the mobility innovation research program, FTA funds the Shared-Use Mobility Center for a project called the Innovation and Knowledge

Accelerator (IKA), which is a structured, supported learning and information exchange system. The IKA also includes an initiative to enable colleagues to exchange information via communities of practice. Similarly, FTA is phasing in a standardized approach for disseminating research results in the safety and infrastructure program areas.

4.4 Federal Railroad Administration

The mission of FRA's RD&T program is to ensure the safe, efficient, and reliable movement of people and goods by rail through basic and applied research and to develop innovations and solutions to rail transit problems. Safety is one of U.S. DOT's priorities and the principal driver of FRA's RD&T program. FRA develops technology that its inspectors use to enforce safety regulations. Other technology developed by FRA was adopted by the railroad industry. In both cases, the agency funds research projects through all levels of technology readiness from basic principles to system deployment. Most funding goes toward moving projects from proof of concept to prototype demonstration in the railway environment. Suppliers to the rail industry usually use FRA prototypes to create commercial products.

FRA encourages industry involvement in its R&D program and coordinates its technology development and deployment activities with the rail industry, in part through its relationship with the Association of American Railroads (AAR). FRA's R&D program is coordinated with the AAR's Strategic Research Initiatives to avoid duplication and to cosponsor research when appropriate. In addition, FRA's Transportation Technology Center in Pueblo, Colorado is managed and maintained by a wholly owned subsidiary of AAR. The Center has nearly 50 miles of test track and numerous test facilities for conducting R&D. Since its dedication as the High-Speed Ground Test Center in 1971, the Center has played an important part in research, development,and testing of rail infrastructure and equipment.

Most of FRA's RD&T research results are described in in technical reports published in FRA's eLibrary, which makes research results accessible to the railroad industry and the public. Some RD&T contracts include funding for vendors to disseminate the RD&T research results at various events. Information regarding RD&T's work can also be found on OST-R's Research Hub. In FY 2018, FRA RD&T amended its process and began publishing research to the National Transportation Library (NTL) to ensure that research results are widely available and searchable. In FY 2019, FRA began formalizing its T2 methodology by piloting T2 plans for each of its divisions, which include business cases, operational needs, Technology Readiness Level assessments, resource strategies, risk assessments, communications, stakeholder engagement, and integration strategies.

4.5 National Highway Traffic Safety Administration

Within NHTSA, the Office of Vehicle Safety Research supports U.S. DOT's and NHTSA's safety goals by conducting research and safety testing of motor vehicles and motor vehicle equipment. It also supports advanced vehicle safety technologies to address human behavioral concerns, including distracted and impaired driving. In addition, the Office conducts testing and research on the reliability and security of complex safety-critical electronic control systems, and vehicle cybersecurity. NHTSA also tests and researches new and emerging technologies, including advanced driver assistance systems and automated vehicle technologies. The Agency uses several strategies for deploying its research and technology results. These range from technology demonstrations and field tests to behavioral research, to vehicle safety research education programs described next. In 2019, NHTSA revamped its process for the dissemination of research products. It now includes dedicated personnel to ensure work products are placed into the U.S. DOT Research Hub and National Transportation Library (NTL) Digital Library.

NHTSA T2 efforts are focused in the areas listed below, each of which will be detailed in the following sections:

- Technology Demonstrations and Field Tests
- Behavioral Safety Research
- Vehicle Research and Testing

4.5.1 Technology Demonstrations and Field Tests

NHTSA has a long history of deploying new technology developments into the field to collect data on their real-world performance and consumer acceptance. One example is the Vehicle-to-Vehicle (V2V) Model Deployment in Ann Arbor, MI, where thousands of vehicles were equipped with dedicated short-range communications (DSRC) technology. The purpose of the deployment was to test how well V2V technology performed, how it supported safety applications, and how consumers received it. The findings from this deployment have given NHTSA important data to use when developing regulatory guidelines for V2V technology.

Building on the success of the first deployment, from 2015 to 2018, the University of Michigan and its partners (with support from U.S. DOT) expanded the existing infrastructure footprint from northeast Ann Arbor to the entire 27-square miles of the City of Ann Arbor and have deployed thousands of additional connected vehicles (CVs). This new deployment, called the Ann Arbor Connected Vehicle Test Environment (AACVTE), is the world's largest operational, real-world deployment of CVs and connected infrastructure.

4.5.2 Behavioral Safety Research

The purpose of the behavioral research conducted by NHTSA is to find ways to change the behavior of drivers and other roadway users to increase safe behavior (e.g., seat belt use) and reduce unsafe behaviors (e.g., alcohol- and drug-impaired driving). This research provides the scientific basis for State and community traffic safety programs. Behavioral safety research has contributed significantly to the widespread adoption of numerous programs proven to reduce crashes. Examples include:

- National Click It or Ticket Program,
- Adoption of standardized field sobriety tests by law enforcement officers,
- Passage of primary seat belt and distracted-driving laws,
- Advancement of graduated driver licensing laws,
- A greater understanding of older-driver issues, and
- Development and testing of effective pedestrian and bicyclist safety programs.

In FY 2018, NHTSA completed the first phase of an initiative on fatigue in emergency medical service (EMS) workers. The overall goal of this project is to develop, test, and disseminate evidence-based guidelines for fatigue risk management, tailored to the EMS setting. As the project enters its second phase, researchers will test the impact of one or more evidence-based recommendations. In the third phase, the project team will develop a biomathematical model, tailored to the shift scheduling for EMS personnel.

4.5.3 Vehicle Research and Test Center

Staff at the Vehicle Research and Test Center (VRTC), NHTSA's in-house laboratory, conduct research and vehicle testing, supporting NHTSA's mission to save lives, prevent injuries, and reduce traffic-related health care and other economic costs. Research and testing activities conducted at the VRTC support agency decisions and actions with respect to:

- New vehicle systems and issues,
- Consumer information programs,
- Development of test dummies,
- Injury criteria development, and
- Safety issues that require quick reaction or are sensitive in nature (e.g., defect investigations).

The full range of testing and research capabilities available at VRTC allows the agency to study emerging safety issues rapidly and provide benefits to the American public quickly. In FY 2018, NHTSA initiated a series of postmortem human subject tests to evaluate occupant kinematics for non-standard driving postures anticipated in automated vehicles. In FY2019, NHTSA used the test data to update human body models to better reflect the kinematics of humans in reclined and rotated seating postures.

4.6 Federal Motor Carrier Safety Administration

The primary mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries, and fatalities involving large trucks and buses.

In support of that mission, FMCSA invests in the development, testing, and transfer of innovative technologies through its:

- Research & Technology Program
- Innovative Technology Deployment Grant Program
- Automated CMV Research

These programs are detailed in the following sections.

4.6.1 Research & Technology Program

FMCSA's Research & Technology (R&T) Program develops the knowledge, practices, and technologies to improve enforcement technologies and thesafety of commercial drivers, vehicles, and carriers. Each year, the R&T program sponsors and conducts numerous technology-focused projects designed to:

- Improve the safety and efficiency of commercial motor vehicles (CMVs) through technological innovation and improvement,
- Improve the technology used by enforcement officers when conducting roadside inspections and compliance reviews, and
- Facilitate the training or education of CMV safety personnel.

4.6.2 Innovative Technology Deployment Grant Program

The Innovative Technology Deployment (ITD) Grant Program is FMCSA's key mechanism for transferring proven enforcement technologies into operational systems for the States. Each year, ITD provides up to $20 million in funding for States to deploy, support, and maintain ITS and commercial vehicle information systems and networks. Grant priorities include deploying:

- Work-zone and incident electronic notification systems,
- CMV truck parking notification systems, and
- Thermal imaging technology to detect inoperable, defective, or deficient brakes, tires, or exhaust systems that may cause unsafe conditions.

One example of ITD efforts is the deployment of infrared screening tools that identify CMVs with unsafe brakes by measuring the temperature of wheels of CMVs in motion. As another example, ITD helped to implement a communications and data exchange mechanism to facilitate communicating safety and credentials within and among States, Federal agencies, and motor carriers. ITD also assisted in the implementation of cameras that can help identify noncompliant trucks by reading license plates and U.S. DOT numbers on trucks while they are traveling at highway speeds.

4.6.3 Automated CMV Research

FMCSA conducts research to accelerate the testing and deployment of proven safety technologies, like automatic emergency braking systems and partners with industry associations, original equipment manufacturers, and motor carriers to promote the acceptance and adoption of these technologies. FMCSA also promotes safe pilot testing of automated CMVs and truck platoons to further validate the safety of these technologies and support their deployment.

4.7 Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) sponsors R&D projects focused on providing near-term solutions that will increase the safety and reliability of the Nation's pipelines and the transportation of hazardous materials. PHMSA has a consensus-based, collaborative RD&T program that is bringing new technology to market and is helping to strengthen pipeline integrity. PHMSA investment continues beyond proof of concept and concludes when the pre-commercial technology is effectively demonstrated in the intended operating environment.

Through its R&D awards, PHMSA mandates several steps for researchers to undertake to promote project results. Mandated actions include promoting commercialization at the end of the contract, such as demonstrating a technology in front of pipeline operators, equipment vendors, standards organizations, and pipeline safety officials. In addition, all technical reports produced through PHMSA-sponsored research are promoted to decision makers and key entities via trade journals, public conferences, or other industry events. PHMSA also publishes pipeline research on the website for its research program, as well as in the U.S. DOT Research Hub and NTL Digital Library.

4.8 United States Maritime Administration

Through its Maritime Environmental and Technical Assistance (META) program, the United States Maritime Administration (MARAD) partners with Federal, State, and local agencies, the maritime industry, and academia to execute projects that provide all concerned parties with useful information and insight on maritime environmental issues. For the most part, this research is carried out using contracts or cooperative agreements with industry partners and academia. MARAD works closely with industry to identify research needs, formulate research initiatives to address specific issues, and transfer research findings to industry. MARAD is also partnering with ITS JPO for joint T2 activities to assist ports in the planning, funding, and deployment of ITS applications.

Technology testing, validation, and verification are fundamental parts of the META program. These activities generate information about the costs, benefits, and performance of technologies, which assists industry in choosing among technology options and making decisions regarding capital investments. At the same time, META provides opportunities that are otherwise unavailable to innovators to perform R&D outside of the laboratory in real or near-real operations.

MARAD makes test results, reports, studies, and industry guidelines available through its website, the Research Hub, and most partners' websites. Technical papers from the projects are regularly presented to journals, industry magazines, the Transportation Research Board, and other public venues.

5 Success Stories

The following success stories demonstrate how U.S. DOT-funded research results are being deployed in a wide range of transportation settings and producing public benefits.

5.1 Federal Highway Administration

5.1.1 Agencies CHANGE Hydraulic Modeling Approach

The Collaborative Hydraulics: Advancing to the Next Generation of Engineering (CHANGE) Initiative, part of the Federal Highway Administration's Everyday Counts Initiative, has encouraged transportation agencies to adopt two-dimensional (2D) hydraulic modeling, which provide a more accurate representation of real-world hydraulic conditions and better illustrate hydraulic concepts, compared to one-dimensional (1D) modeling.[2] These advantages are outlined in FHWA's reference document *Two-Dimensional Hydraulic Modeling for Highways in the River Environment*. The number of States at the demonstration, assessment, or institutionalized stage of CHANGE deployment has nearly tripled from 17 at the beginning of 2017 to 46 today. Arizona, Mississippi, and Washington State[3] are frequent users of 2D hydraulic modeling and are recipients of STIC funds to support projects that implement 2D hydraulic modeling. Compared to 1D hydraulic modeling, 2D hydraulic modeling better helps agencies understand site conditions, resulting in more reliable, resilient, and safer structures.

FHWA's CHANGE team is collaborating with the National Highway Institute to offer the training course *2D Hydraulic Modeling of Rivers at Highway Encroachments*.[4] Additionally, the 2D Hydraulic Modeling Users' Forum drew 1,500 participants to its webinars and technical assistance offerings.

5.1.2 Innovation Synergy: Crowdsourcing Improves Weather Response

The Crowdsourcing for Operations Initiative, part of the Federal Highway Administration's Everyday Counts Initiative (EDC), partners with the Weather Responsive Management Strategies EDC Initiative to help agencies promote the use of crowdsourced data from users of mobile applications to improve traffic and maintenance management in inclement weather.

Wyoming, Utah, and Kentucky are leaders in using crowdsourced data to improve operations. Wyoming DOT staff in maintenance vehicles report conditions via a mobile application back to the traffic management center (TMC), allowing staff to adjust variable speed limits, improving operations and safety. WYDOT's 511 Mobile Application[5] can also collect data from users on road conditions and truck parking availability. The Utah Department of Transportation created a Citizen Reporter Program, which trains volunteers to report conditions to the UDOT Traffic Mobile Application, especially valuable where condition data is unavailable. Lastly, the Kentucky Transportation Cabinet integrates data from Doppler radar and the mobile application Waze with internal sources to bolster the information available to the TMC, its GoKY website, and the Snow and Ice Decision Support Dashboard, accessible by additional agencies involved in operations, including the Kentucky State Police. Crowdsourced data helps transportation agencies maintain and operate their assets efficiently, even during inclement weather and helps users make informed and safe travel decisions.

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[2] CHANGE Initiative video overview

[3] Video case study: Washington State DOT bridge replacement using 2D modeling

[4] National Highway Institute Course *2D Hydraulic Modeling of Rivers at Highway Encroachments*

[5] WYDOT 511 Mobile Application overview

5.1.3 Playing the A-GaME to Improve Reliability and Reduce Risk

The Every Day Counts Round Five (EDC-5) initiative on advanced geotechnical methods in exploration (A-GaME)[6] showcases proven but underused techniques to gather more detailed information on site conditions, like cone penetration testing (CPT), electrical geophysical techniques, measurement while drilling, seismic geophysical methods, and optical and acoustic televiewers. Conventional subsurface exploration methods often yield limited data for project design, which can result in constructability issues and increased costs.

More than 45 State and Federal agencies are using A-GaME strategies to reduce geotechnical project risks and improve reliability. Twenty-seven of those agencies are at the demonstration, assessment, or institutionalized stages of deployment, including Alaska, Indiana, Michigan, and Wisconsin. The Alaska Department of Transportation and Public Facilities (AKDOT&PF) uses ground-penetrating radar (GPR) to locate utilities when drilling investigations in urban areas, while A-GaME strategies are more portable than traditional drilling rigs when operating in rural areas. In Indiana, the Indiana Department of Transportation used electrical resistivity tomography to image the subsurface for several projects. The Michigan Department of Transportation used CPT soundings for various projects. The Wisconsin Department of Transportation conducted GPR investigations for two projects. Lastly, the Minnesota Department of Transportation uses geophysical imaging, illustrated below in Figure 4.

A-GaME techniques can improve design and construction, leading to shorter project delivery times and lowering the risks associated with limited data on subsurface conditions, benefiting all stakeholders.

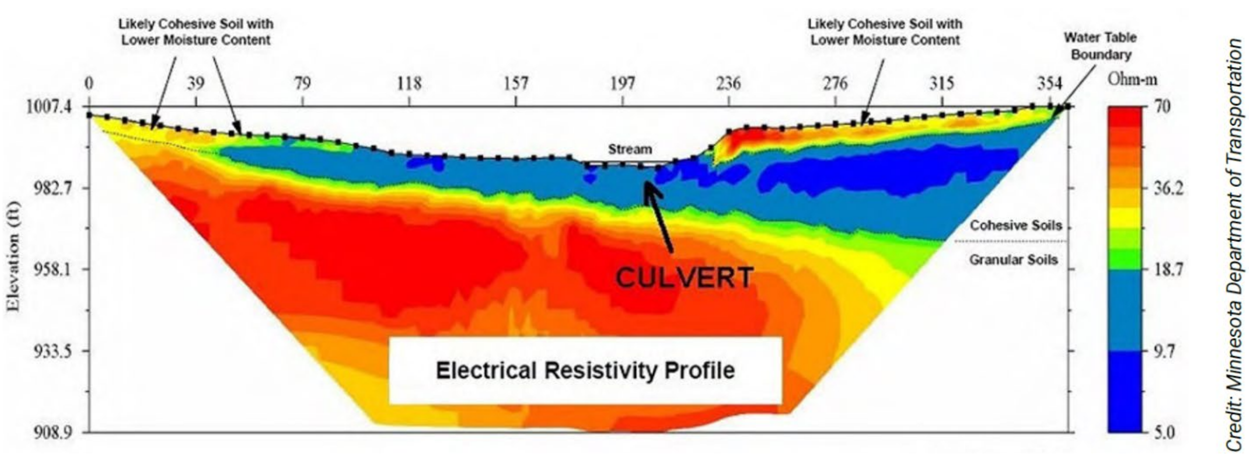

Figure 4: Geophysical imaging can distinguish material and groundwater variations across a site.

5.1.4 Public Involvement Communication Tools for a 21st Century Audience

The Public Involvement Communication Tools for a 21st Century Audience Initiative, part of the Federal Highway Administration's Everyday Counts Initiative, encourages States to implement public involvement strategies that boost collaboration and accelerate project delivery, including convenient virtual strategies, which can broaden the scope of potential stakeholders submitting feedback. 23 States are demonstrating and assessing virtual strategies to engage the public. Eight States institutionalized virtual public involvement techniques and use them regularly for planning and project development, including Colorado, Florida, Iowa, North Carolina, Ohio, Texas, Vermont, and Washington State.
Virtual public involvement strategies include:

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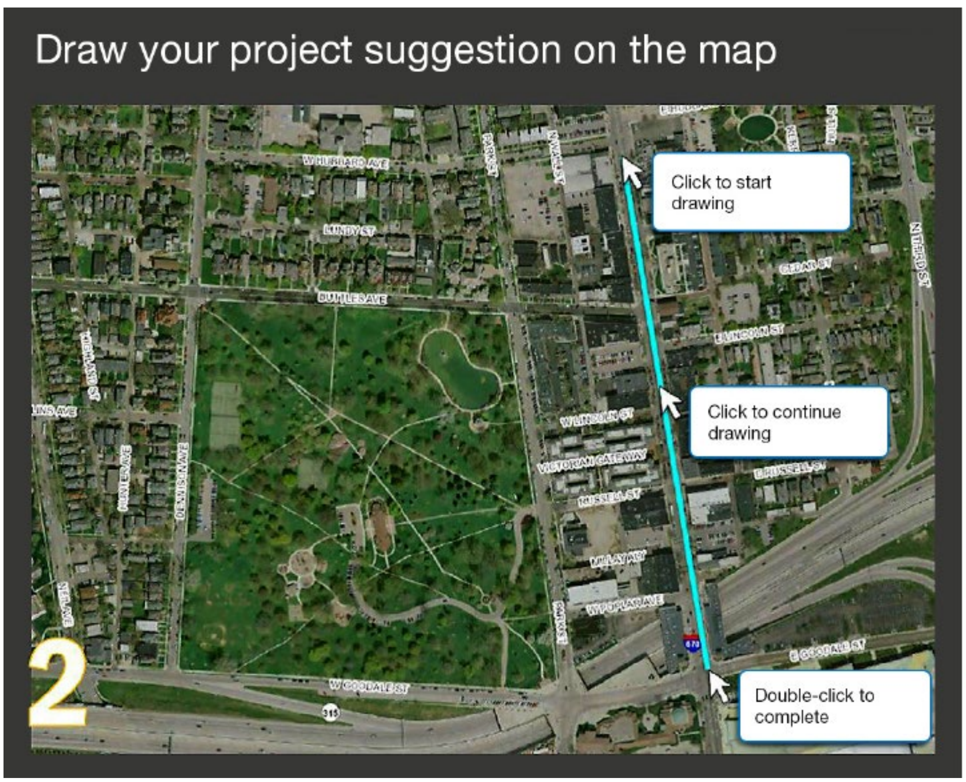
[6] Video overview of A-GaME at the design stage

- Mobile applications allow users to get information or submit their own text and images. An application can serve as a digital clearinghouse for project planning and development, public involvement opportunities, and contact information.
- Project visualization refers to techniques such as photo simulations, three-dimensional images, videos, aerial footage, and augmented reality, providing a mockup of proposed projects.
- Do-it-yourself videos are videos shot with tablets, smartphones, and digital cameras, which are affordable and accessible ways to reach stakeholders with content about plans, projects, and events.
- Crowdsourcing tools gather suggestions and provide a forum for others to weigh in on ideas and enable stakeholders to engage in the early stages of a project quickly and easily.
- Virtual town halls.
- Mapping tools communicate information in a visual format. Their interactive capabilities allow users to search, click, and query their way across a project site, neighborhood, or region to gather details not easily accessible in other formats. An example of mapping tools are interactive maps, as shown below in Figure 5.



Credit: Mid-Ohio Regional Planning Commission

Figure 5: The Mid-Ohio Regional Planning Commission encouraged the public to offer project ideas by drawing on its interactive map

- All-in-one tools combine crowdsourcing features, mapping, visualization, file sharing, and survey instruments, offering a one-stop-shop for information on a topic.
- Digital tools to enhance in-person events include live polling via mobile devices, collecting and sharing ideas with tablets, and using social media to stream public meetings in real time.

For example, the Colorado Department of Transportation (CDOT) used virtual town halls to gather input for its statewide long-range transportation plan update, allowing the agency to easily reach urban, suburban, and rural stakeholders. Fifty-eight thousand people participated in the virtual town halls, including 17,000 from rural regions. Additionally, the Mid-Ohio Regional Planning Commission developed an interactive map to gather input during the development of its metropolitan transportation plan, which yielded 300 suggestions from more than 700 people.

The virtual strategies outlined above provide transportation agencies with tools that give them the opportunity to reach more and more diverse stakeholders, while improving the quality of the feedback they receive.

5.2 Federal Aviation Administration

5.2.1 Stationary Doppler Target Suppressor Patent

The FAA was awarded United States Patent Number 10,514,454 for the Stationary Doppler Target Suppressor (SDTS) Software Tool on December 24, 2019, for a critical improvement to the detection of airborne targets over and around wind farms and turbines.

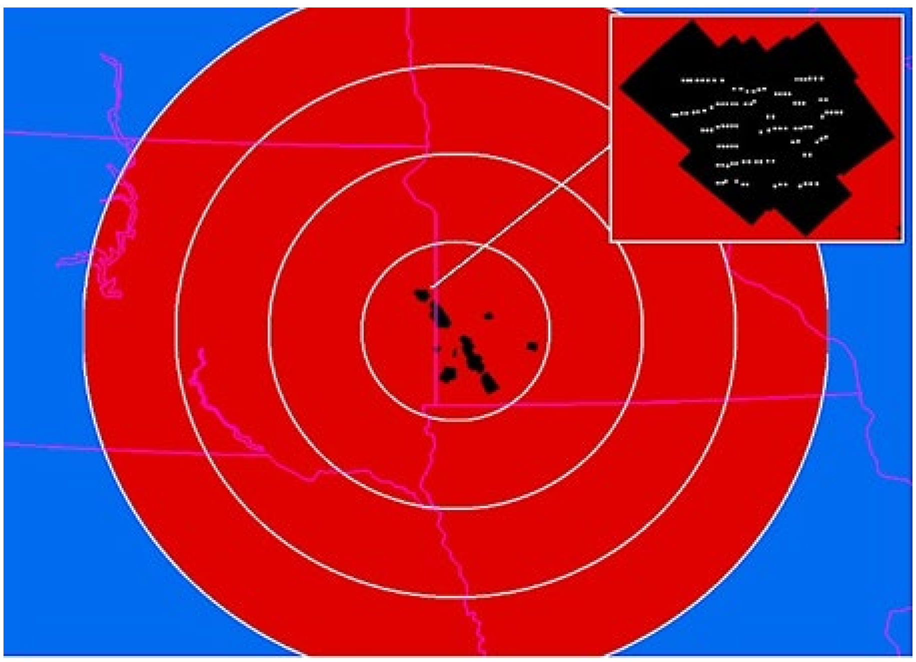


Figure 6: Radar screen capture showing the designated area where the FAA's patented SDTS detector will be applied

Deployment of large-scale wind farms using utility grade wind turbines severely impacts the current radar systems used by the FAA for air traffic control, the Department of Homeland Security (DHS) for air domain awareness, and the Department of Defense (DoD) for air defense. The FAA's patented SDTS software tool provides a critical improvement to mitigate the impacts of wind farms on radar and improve the detection of airborne targets over and around wind farms. The SDTS software tool includes a novel algorithm for dynamically adjusting radar detection threshold in a manner that strikes a balance between providing improved sensitivity in identifying a real target in a wind farm area while still eliminating clutter that would trigger false alarms. The SDTS software tool functions so well that it was deemed by North American Aerospace Defense Command (NORAD)/Northern Command as a mitigation approach for the deployment of new wind farms. Figure 6 above shows a radar screen capture, showing the designated area where the FAA's patented SDTS detector will be applied, including a wind farm installation in Tyler, Minnesota. The upper right box in this image is a magnified section, showing the individual wind turbines within the wind farm.

By roughly doubling the performance of radar systems in wind farm areas and halving the incidences of false target detections of the turbines, this FAA invention results in a significantly improved air picture to all FAA, DHS, and DoD operators, leading to greater mission success.

5.2.2 FAA Weather Program Improves Pilot Training with Augmented Reality

"Most weather-related general aviation accidents are fatal, and a failure to recognize deteriorating weather continues to be a frequent cause or contributing factor of accidents" (FAA Fact Sheet, *General Aviation Safety, 7/30/2018*).[7] To address this concerning trend, the FAA is collaborating with industry experts on several unique tools to help teach student pilots how to translate book and classroom knowledge into effective in-flight decisions. For example, the FAA's Weather in the Cockpit program coordinated with the Partnership to Enhance General Aviation Safety, Accessibility, and Sustainability, Western Michigan University, and Fly8MA, a provider of online flight training, to develop a series of pilot training videos. The 10 mini-lessons, shared by the FAA through the National Association of Flight Instructors, provide tips and techniques to enhance weather-related training, refresh knowledge, aid in knowledge correlation, and update weather and weather product knowledge.

In addition, the FAA researchers launched the WeatherXplore application, which is free to download from Google Play and the Apple Store. This educational tool uses augmented reality to bring printed training images to life through animated and videoweather information. The new tools help pilots better recognize and avoid weather dangers.

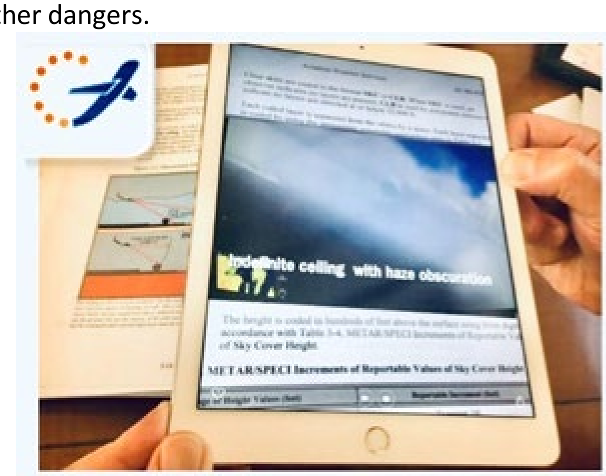


Figure 7: WeatherXplore uses augmented reality to enhance learning through animated images and videos (http://bit.ly/WeatherXplore)

[7] https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=21274

5.2.3 William J. Hughes Technical Center's Aircraft Catastrophic Failure Prevention Program

The FAA's Daniel Cordasco delivered a keynote speaker presentation representing the FAA Aircraft Catastrophic Failure Prevention Program (ACFPP) at the 16th International LS-DYNA Conference. The event was held virtually as part of the ANSYS Simulation World event in June 2020. Over 2700 participants from industry, government, and academic institutions worldwide attended the conference. Daniel Cordasco's presentation *The Long and Winding Road Towards a Predictive Material and Failure Model for Aluminum 2024-T351 Undergoing Impact* received over 800 unique views. The presentation gave a historical overview of the development, verification, and validation of a material and failure model with sufficient predictive capability for the assessment of engine debris impacts on aircraft structures. The research culminated in a creation of a methodology that could reliably predict results for wide classes of impacts, with varying projectile shapes, velocities, impact angles, as well as varying target geometries and thicknesses. Experimental testing advances and increasing computational power were critical to successful realization of the new simulation tools, which will aid in better analysis for certification of jet engines. FAA researchers featured six additional presentations on modeling of aerospace metal and composite materials for dynamic applications.

Figure 8: FAA's Daniel Cordasco presented at the 2020 LS-DYNA Conference

5.3 Federal Transit Administration

5.3.1 Mobility on Demand (MOD) Sandbox Demonstration

FTA published the final report on its Mobility on Demand (MOD) Sandbox Demonstration: DART First and Last Mile Solution (Report 0164) with the Dallas Area Rapid Transit (DART). DART collaborated with a microtransit provider to give more transit trip choices for riders in a low-density area that was difficult to serve. DART achieved most of the established goals for the project, to increase ridership and replace less-productive fixed-route systems. As a result, in areas in which the service was implemented, ridership increased with less cost, more coverage, and less travel time.[8]

[8] Overview of Mobility on Demand Sandbox Demonstration

Figure 9: Examples of Mobility on Demand Sandbox Demonstration projects

5.3.2 Novateur Research Solutions Collision Warning System

Pedestrians represent a considerable portion of the traffic-related injuries and deaths on our Nation's roadways. Most of these fatalities occur in urban areas where pedestrians, cyclists, and vehicular traffic, including transit buses, tend to comingle. Many studies have determined that a large percentage of pedestrian accidents involving transit buses are avoidable, if the threat is detected early and the driver and/or pedestrians are alerted accordingly.

During the SBIR Phase II effort, Novateur Research Solutions developed and demonstrated a robust and cost-effective pedestrian detection and collision warning system. Novateur's collision warning system (CWS) system uses inexpensive but robust sensor technologies and incorporates state-of-the-art object detection techniques to enable effective pedestrian and cyclist detection near transit buses in different environmental conditions. In addition to detection technologies, Novateur's CWS system also exploits measurements and estimates from different sensors about the presence, relative locations, and dynamics of pedestrians and cyclists near the bus and assesses the risk of collision by combining this information with the movement of the bus and environmental variables. Upon detection of an alert, a warning is intuitively relayed to the bus operator, for an immediate response. The real-time system was fully integrated on a vehicle; its capabilities were demonstrated while operating in real-world settings. Installation of CWSs on transit buses, like Novateur's system, will likely decrease pedestrian and cyclist injuries and deaths around vehicles equipped with a CWS.

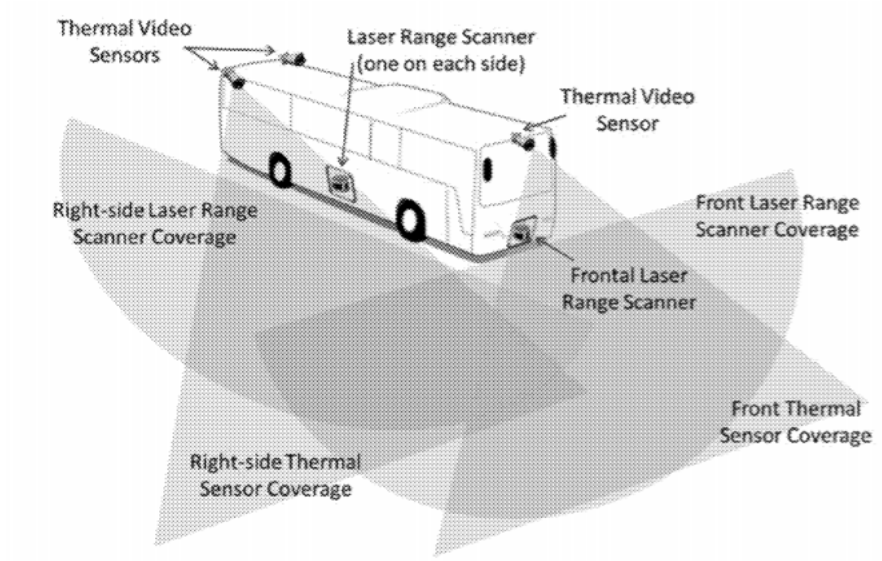


Figure 10: Overview of CWS, from United States patent application

5.3.3 Alameda County, California Transit Fuel Cell Bus Longevity Study

In July 2020, FTA published its report on the Alameda County, California (AC) Transit Fuel Cell Bus Longevity Study, conducted by the Center for Transportation and the Environment (CTE). CTE monitored 13 fuel cell electric buses (FCEBs) as a part of the FTA's National Fuel Cell Bus Program (NFCBP), working with AC Transit, UTC Power, EnerDel, Van Hool, Siemens Industries, and Dynetek Industries in this endeavor. The extended monitoring demonstrated the exceptional durability of this technology, as the buses were still exceeding their expected performance in 2019; CTE expected the buses would exceed their expected performance in 2016. The data show that these buses are durable and reliable and met or exceeded many of the performance targets identified by FTA and the U.S. Department of Energy (DOE) for determining the readiness of the technology for widespread commercialization. Deployment of FCEBs instead of diesel buses will reduce emissions and reduce operational costs long-term.

Figure 11: AC Transit's hydrogen fuel cell buses

5.4 *Intelligent Transportation Systems Joint Program Office*

5.4.1 2020 Consumer Electronics Show

The Intelligent Transportation Systems Joint Program Office (ITS JPO) organized the U.S. Department of Transportation (U.S. DOT) presence at the 2020 Consumer Electronics Show (CES), an annual trade show organized by the Consumer Technology Association. Held in multiple venues across the Las Vegas area, CES offers presentations of new products and technologies in the consumer electronics industry. The ITS JPO established an internal, multimodal CES task force that included staff from the FAA, OST-R, NHTSA, FHWA, PHMSA, and the TFHRC.

The Department's participation included the following:

- The Secretary delivered a keynote address on the current state of innovation at the U.S. DOT and joined the former chief technology officer of the United States, in releasing *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0* (AV 4.0).[9] The government-wide report outlines how 38 Federal agencies are working to deploy automated vehicle technology.

Figure 12: Panelists at the Consumer Electronics Show

- The ITS JPO organized a 90-minute super session titled *What's Next for Vehicle Automation?* The session was moderated by Finch Fulton, Deputy Assistant Secretary for Transportation Policy, and included several panelists including Sterling Anderson, Co-Founder and Chief Product Officer, Aurora; Steve Boyd, Chief Executive Officer, Peloton Technology; Debbie Hersman, Chief Safety Officer, Waymo; and Ralph Lauxmann, Senior Vice President Systems and Technology, Continental Automotive.
- The U.S. DOT hosted a 30-foot-by-30-foot exhibit in the Smart Cities Pavilion. There were dedicated areas for both CARMA℠ and the ITS Data program. Literature racks included overviews of U.S. DOT programs, the Inclusive Design Challenge, the Data for Automated Vehicles Initiative, CARMA, and AV 4.0. Videos of connected vehicle technology and key messaging were displayed on two monitors.
- Eight UTCs provided demonstrations of technology areas such as cybersecurity, traffic prediction, driver assistance solutions simulations, and robot deployment systems.

[9] https://www.transportation.gov/av/4

- The U.S. DOT also participated in supplemental meetings with related companies and other government organizations (primarily organized by NHTSA), which yielded positive results.

5.4.2 Artificial Intelligence Research Efforts

The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) plays a pivotal role in shaping the future of advanced technologies, such as artificial intelligence (AI) in transportation. The following highlights the ITS JPO's accomplishments in accelerating AI research.

Figure 13: The components of artificial intelligence

5.4.2.1 AI Research and Development Task Force

The U.S. DOT has started considering AI with respect to transportation as an agency R&D priority through a multimodal AI Task Force. The ITS JPO helped to stand up and now chairs the AI R&D Task Force. The task force's accomplishments have included:

- AI R&D Investment Reporting and Planning: The task force facilitated the development of a comprehensive inventory of current and planned AI R&D investments across the DOT, a compilation of information that previously needed to be collected in an ad hoc manner in response to external requests.
- Consensus on Definition of AI and Applicability to DOT Programs and Mission Areas: The task force reached consensus on a workable and practical definition of AI, and its interpretation, for R&D planning and reporting, and interagency coordination.
- Coordination of DOT Input and Feedback on Interagency AI-Focused Requests: Throughout the year, the AI R&D Task Force provided critical feedback on documents and information requests sent by the National Science and Technology Council Machine Learning and AI Subcommittee, the Office of Management and Budget, the State Department, and other groups. The existence of a focused group of pre-identified subject matter experts made compiling a consolidated DOT response a more efficient and thorough process.
- Establishment of AI Web Pages: The task force provided input on and review of a set of web pages that present the DOT's overarching approach to AI and available resources supporting AI R&D.[10]

[10] Summary of U.S. DOT Artificial Intelligence Activities

- Initial Planning of *Getting to Know AI Initiative* (originally "AI Day"): The task force provided input on the initial planning for an event focused on raising awareness and baseline knowledge within DOT of practical AI capabilities, applicable policy, and available technical resources. Task force members continued to provide input on adapting the original concept into a virtual event series due to COVID-19 pandemic-related restrictions on in-person events.
- Intermodal Information Sharing and Coordination: Modal representatives shared recent project highlights and recent/upcoming events relevant to AI.
- Identifying Real-World Transportation Applications Using AI: Plan for AI for ITS: The ITS JPO published a report outlining a five-year plan for AI for ITS. As a companion document to a five-year roadmap, the report provides recommendations on investments and program activities for the next five years to promote operational AI deployments by the end of the decade. The plan is meant to be a living document to be updated periodically in concert with the roadmap.

5.5 Federal Railroad Administration

5.5.1 Automated Track Change Detection Technology

Roughly 140,000 miles of railroad track covers the U.S. Hundreds of FRA and railroad inspectors regularly inspect every mile of track to ensure the tracks are in safe working order. Most of these inspections are completed manually, relying on human vision to detect any irregularities in the complex track structure that may impact the safety of rail operations. This is a time-consuming and labor-intensive process, required by Federal regulations.

FRA has recently sponsored research and development of a new technology to improve the quality and efficiency of visual track inspection required by 49 CFR § 213.233 – Track Inspections. The objective of this new technology, Automated Track Change Detection (ATCD), is to identify changes in the track structure that may affect the safe operation of rail traffic and automatically report these changes to decision makers for action. The technology uses invisible, laser line projectors and synchronized cameras to capture millions of high-resolution, three dimensional (3-D) images of the track. The images are compared to previous images of the same track to identify changes. The process employs cutting-edge deep neural networks and artificial intelligence techniques to isolate changes in tie spikes, rail anchors, rail fasteners, ties, rail joints, ballasts, and other critical aspects of the track system. This new technology will augment regular visual inspection activities, resulting in a more efficient and effective method of track inspection.

FRA is excited to report that its early research and development efforts on the ATCD system have been successful. This new technology is quickly reaching the stage where extended field trials are possible, and rail industry demonstrations will confirm its value to rail safety and operational efficiency. One Class I railroad has become an early adopter of this technology, having recently ordered two ATCD systems from FRA's prime contractor, Railmetrics. The FRA R&D Team looks forward to working with this railroad and others, to make ATCD technology a success.

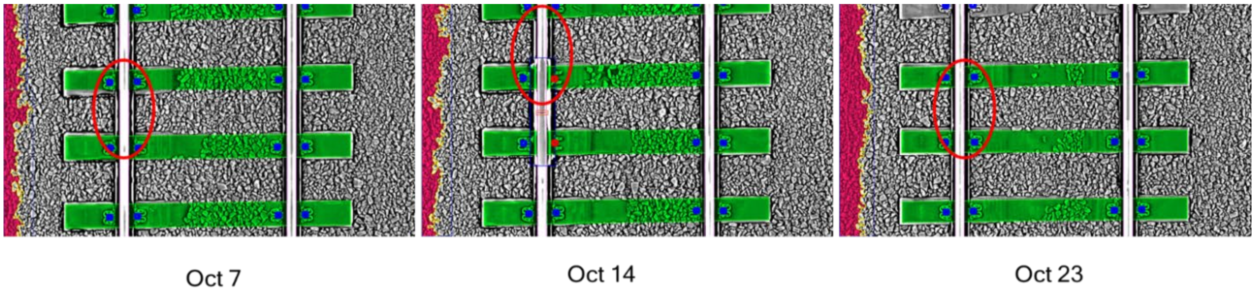
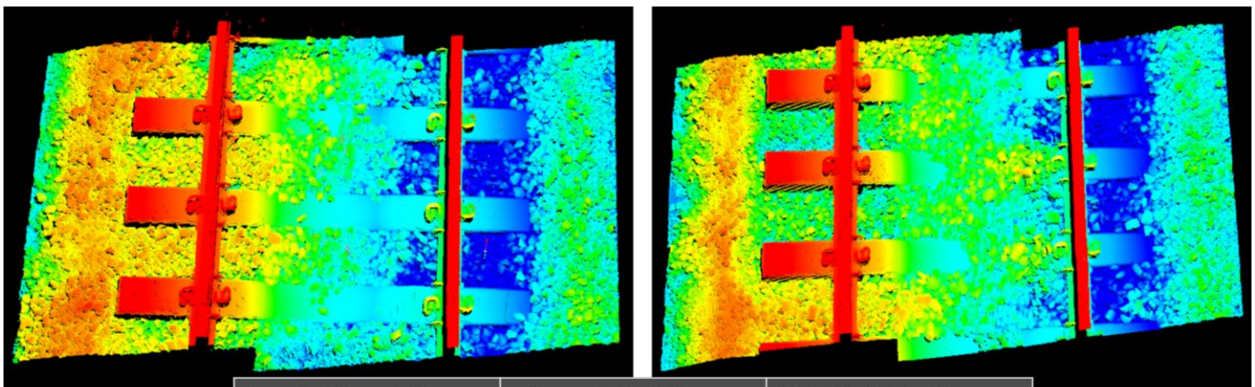


Figure 14: Welded rail section changed (rail cut and joint bars added) and then returned to welded condition



Left Rail Ballast Change	Gauge Ballast Change	Right Rail Ballast Change
-23.82	8.44	0.33

Figure 15: Colorized (heat map) illustration of ballast height change within the track structure after approximately one month of rail traffic

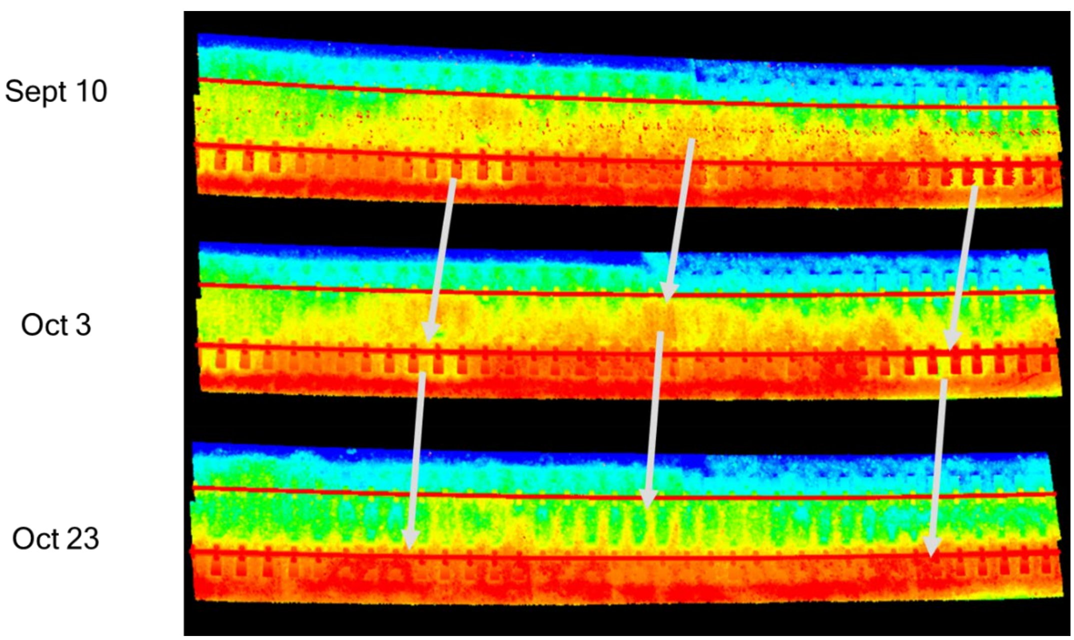


Figure 16: Colorized (heat map) illustration of ballast height change within the track structure over time

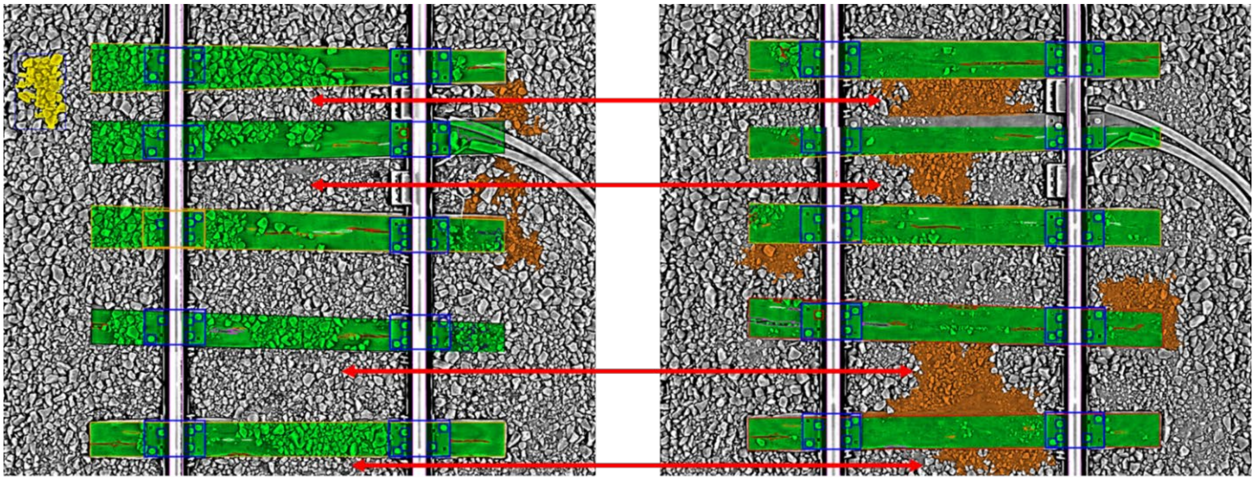


Figure 17: Change in ballast fouling condition

5.5.2 Rail Temperature Prediction Website

Track buckles are caused when continuously welded rails (CWR) heat up from solar heating and high ambient temperatures. The rails try to expand lengthwise due to the higher temperatures but are not able to do so because they are held in place by the track structure, resulting in large compressive loads on the rails that can cause the track to suddenly buckle out of alignment, which can lead to a train derailment. Track buckle derailments cost the U.S. and its railroads about $14 million per year.

Knowing the rail temperature is key to predicting when tracks might buckle. In the past, railroad operators estimated rail temperature to be about 30 °F above ambient temperatures due to solar heating. However, this is not always an accurate estimate of rail temperature, as it can be the same as the ambient temperature or even as much as 40 °F above the ambient temperature.

To more accurately predict rail temperatures, FRA turned to weather forecasting and heat transfer theory, which was significantly more cost-effective than installing and maintaining temperature sensors on tracks.

Over the years, the model has been engineered to:

1. Predict rail temperature up to 36 hours ahead in 30-minute increments,
2. Be accurate to within 5 °F,
3. Be presented in a user-friendly web application for desktop or mobile devices,
4. Provide PDFs and exportable data files,
5. Provide a seven-day rail temperature history,
6. Estimate track buckling risk, and
7. Use current location in addition to offering a location search capability.

Benefits of the model include:

- Less need for trains to slow down to prevent hot rails from buckling,
- A tool for derailment investigations and rail maintenance operations,
- Better planning for track and heat inspections,
- Assistance with continuously welded rail (CWR) procedures, and
- Better awareness of rail temperature for track personnel in real time.

Feedback gathered from industry stakeholders and the FRA Office of Railroad Safety (RRS) helped to improve the technology. Many of the capabilities of the Rail Temperature Prediction website came from suggestions by Class I railroad operators. Currently, the rail temperature prediction application is used by numerous freight and commuter railroads as well as by RRS and rail researchers.

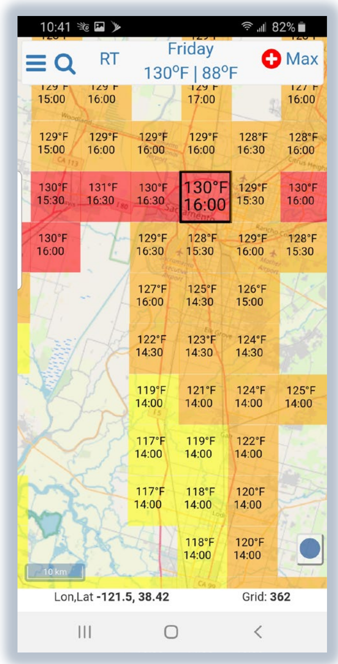


Figure 18: The web application with a map of the rail temperature in each grid

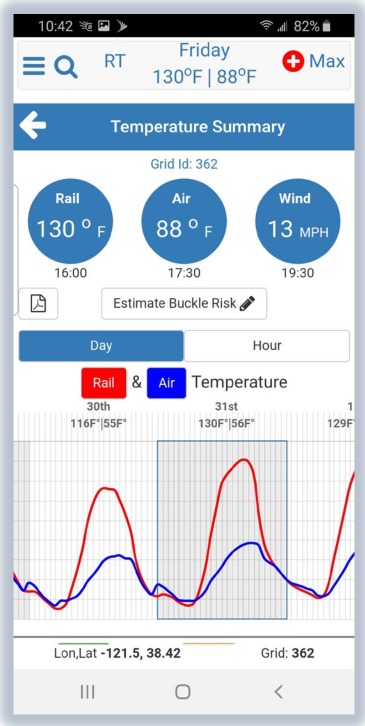


Figure 19: The web application with details from a grid location

5.5.3 Information and Communications Technology Survey of Class I Railroad Train, Yard, and Engine Workers

A recent research project funded by FRA studied the communication needs of train, yard, and engineer (TY&E) railroad employees. Two of the largest rail-related labor unions (Brotherhood of Locomotive Engineers and Trainmen, BLET and Sheet Metal, Air, Rail, and Transportation-Transportation Division, SMART-TD) participated in an industry-wide survey to identify the best ways that information and communications technology (ICT) can disseminate safety-relevant information to TY&E railroaders.

The survey's objectives were to:

- Obtain data about ICT access, use, and preferences,
- Assess familiarity with and use of the FRA-sponsored *Railroader's Guide to Healthy Sleep* website, and
- Identify demographic variations that would help FRA target safety-related communications.

Four hundred eight-five TY&E railroaders participated (348 via paper surveys and 137 via online surveys). The average participant was 49 years old, with approximately 18 years of experience.

Researchers presented the survey results to BLET and SMART-TD; an FRA technical report is forthcoming. This research has contributed to an updated baseline database of U.S. Class I TY&E railroader demographics. Additionally, it has broadened FRA's understanding of railroader ICT access, use, confidence, and preferences, which will lead to better safety-related programs and outreach campaigns for the railroad industry.

Figure 20: The logos of the entities involved in the survey: BLET, SMART-TD, and FRA

6 Acronyms and Abbreviations

1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
AACVTE	Ann Arbor Connected Vehicle Test Environment
AAR	Association of American Railroads
AC Transit	Alameda County, California Transit
ACFPP	FAA Aircraft Catastrophic Failure Prevention Program
A-GaME	Advanced geotechnical methods in exploration
AI	Artificial intelligence
AID	Accelerated Innovation Deployment Demonstration
AIP	Airport Improvement Program
AMRP	Annual Modal Research Plan
ATCD	Automated track change detection
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
AV 4.0	Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles Report
BLET	Brotherhood of Locomotive Engineers and Trainmen
BTS	Bureau of Transportation Statistics
CAMI	Civil Aerospace Medical Institute
CAP	Cross-Agency Priority
CDOT	Colorado DOT
CES	Consumer Electronics Show
CMV	Commercial motor vehicle
CPT	Cone-penetrating radar
CRADA	Cooperative Research and Development Agreement
CTE	Center for Transportation and the Environment
CV	Connected vehicle
CWR	Continuously-welded rail
CWS	Collision warning system
DART	Dallas Area Rapid Transit
DHS	Department of Homeland Security
DOC	Department of Commerce
DoD	Department of Defense
DOT	Department of Transportation
DSRC	Dedicated short-range communications
EDC	Every Day Counts
EMS	Emergency Medical Services
FAA	Federal Aviation Administration
FAST Act	Fixing America's Surface Transportation Act

FCEB	Fuel Cell Electric Bus
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FY	Fiscal Year
GPR	Ground penetrating radar
ICT	Information and communications technology
IKA	Innovation and knowledge accelerator
ITS	Intelligent transportation systems
ITS JPO	Intelligent Transportation Systems Joint Program Office
ITS PCB	Intelligent Transportation Systems Professional Capacity Building Program
L2M	Lab-to-Market
MARAD	United States Maritime Administration
META	Maritime Environmental and Technical Assistance
MOD	Mobility on demand
NFCBP	FTA National Fuel Cell Bus Program
NHTSA	National Highway Traffic Safety Administration
NORAD	North American Aerospace Defense Command
NTL	National Transportation Library
OA	Operating administration
OBU	Onboard unit
OMB	Office of Management and Budget
OST-R	Office of the Assistant Secretary for Research and Technology
PHMSA	Pipeline and Hazardous Material Safety Administration
R&D	Research and development
R&T	Research and technology
RD&T	Research, development, and technology
ROSA P	Repository and Open Science Access Portal
RRS	FRA Office of Railroad Safety
SBIR	Small Business Innovation Research Program
SMART-TD	Sheet Metal, Air, Rail, and Transportation-Transportation Division
STIC	State Transportation Innovation Council
T2	Technology transfer
TFHRC	Turner-Fairbank Highway Research Center
TMC	Traffic Management Center
TY&E	Train, yard, and engineer railroad employees
U.S. DOT	United States Department of Transportation
U.S.C.	United States Code
UTC	University Transportation Centers

V2V	Vehicle-to-vehicle
Volpe Center	John A. Volpe National Transportation Systems Center
VRTC	Vehicle Research and Test Center
WJHTC	William J. Hughes Technical Center
TSI	Transportation Safety Institute