FY 2021

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

ANNUAL Technology Transfer REPORT

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Table of Acronyms and Abbreviations

3D	Three-dimensional
AAR	Association of American Railroads
ADA	Americans with Disabilities Act
AFFF	Aqueous film forming foams
AI	Artificial intelligence
AID	Accelerated Innovation Deployment Demonstration
AIP	Airport Improvement Program
AMRP	Annual Modal Research Plan
ATC	Alternative technical concept
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
BTS	Bureau of Transportation Statistics
CAD	Computer-aided dispatch
CAMI	Civil Aerospace Medical Institute
CLEEN	Continuous Lower Energy, Emissions, and Noise Program
CMV	Commercial motor vehicle
CRADA	Cooperative research and development agreement
CV	Connected vehicle
CVSA	Commercial Vehicle Safety Alliance
D-B	Design-build
D-B-B	Design-bid-build
DOC	Department of Commerce
DoD	Department of Defense
DOT	Department of Transportation
EDC	Every Day Counts
EDC-6	Every Day Counts, sixth round (2021-2022)
EMS	Emergency medical services
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FY	Fiscal year
HCWP	Highway Construction Workforce Partnership
IKA	Innovation and Knowledge Accelerator
IT	Information technology
ITD	Innovative Technology Deployment Grant Program
ITS	Intelligent transportation systems
ITS JPO	Intelligent Transportation Systems Joint Program Office
ITS PCB	Intelligent Transportation Systems Professional Capacity Building Program
LED	Light-emitting diode
MARAD	The Maritime Administration
META	Maritime Environmental and Technical Assistance Program
NAFMP	North American Fatigue Management Program
NextGen TIM	Next-generation traffic incident management
NHTSA	National Highway Traffic Safety Administration

NTL	National Transportation Library
OA	Operating administration
OST-R	Office of the Assistant Secretary for Research and Technology
PHMSA	Pipeline and Hazardous Material Safety Administration
PTC	Positive train control
R&D	Research and development
R&T	Research and technology
RD&T	Research, development, and technology
ROSA P	Repository and Open Science Access Portal
SBIR	Small Business Innovation Research Program
STIC	State Transportation Innovation Council
T2	Technology transfer
TFHRC	Turner-Fairbank Highway Research Center
TMC	Traffic management center
TSI	Transportation Safety Institute
TTC	Transportation Technology Center
U.S. DOT	United States Department of Transportation
U.S.C.	United States Code
UAS	Unmanned aircraft system
UAV	Unmanned aerial vehicle
UTC	University Transportation Centers
V2V	Vehicle-to-vehicle
Volpe Center	John A. Volpe National Transportation Systems Center
VRTC	Vehicle Research and Test Center
WZDx	Work zone data exchange

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 related 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 T2 by Federal laboratories.

U.S. DOT defines T2 as a set of activities including information dissemination that are intended to lead to the transportation community's adoption and use of the products of research and development. U.S. DOT's current approach to T2 allows each OA to conduct deployment activities that are tailored to its mission and to the types of research it sponsors. 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
  - William J. Hughes Technical Center (FAA Technical Center), 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 (TTC), 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/activities/ttp
- FHWA: https://www.fhwa.dot.gov/innovation/
- 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

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) 2017 to FY 2021. 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] [2]

Table 1: Invention disclosures and patents

		FY17	FY18	FY19	FY20	FY21
1	New inventions disclosed	3	12	2	3	2
2	Patent applications filed	7	0	2	2	2
3	Patents received	0	0	0	1	0
4	Foreign patents filed	0	0	0	0	0
5	Foreign patents received	0	0	0	0	0

Table 2: Income-bearing licenses

		FY17	FY18	FY19	FY20	FY21
6	Total active licenses	5	5	5	5	0
7	Total new licenses	1	1	0	0	0
8	Total active income-bearing licenses	2	5	6	4	0
9	New income-bearing licenses	0	1	1	0	0
10	Total active invention licenses	0	0	1	1	0
11	New invention licenses	0	0	0	0	0
12	Exclusive licenses	0	0	0	1	0
13	Partially exclusive licenses	0	0	0	0	0
14	Non-exclusive licenses	5	5	4	4	0

Note: FAA licenses are non-exclusive.

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

[2] For FAA, the FY21 column in Table 1 reports applications and patents assigned to FAA. Additional applications and patents were generated from FAA-funded agreements (e.g., contracts, grants, and other transaction authorities: OTAs).

Table 3: Licensing income

		FY17	FY18	FY19	FY20	FY21
15	Elapsed Amount of Time to Grant Licenses: Average (months)	N/A	N/A	N/A	N/A	N/A
16	Elapsed Amount of Time to Grant Licenses: Minimum (months)	N/A	N/A	N/A	N/A	N/A
17	Elapsed Amount of Time to Grant Licenses: Maximum (months)	N/A	N/A	N/A	N/A	N/A
18	Total license income (thousands)	$19.8	$13.7	$8.2	$19	$0
19	Total invention license income (thousands)	N/A	$0	$0	$19	$0

Table 4: Royalty income

		FY17	FY18	FY19	FY20	FY21
20	Earned royalty income from top 1% of licenses	N/A	0	0	0	0
21	Earned royalty income from top 5% of licenses	N/A	0	0	0	0
22	Earned royalty income from top 20% of licenses	N/A	0	0	0	0
23	Minimum earned royalty income	N/A	0	0	0	0
24	Maximum earned royalty income	N/A	0	0	0	0
25	Median earned royalty income	N/A	0	0	0	0
26	Earned royalty income received ($ thousands)	$19.8	$13.1	$8.2	$19	$0
27	Percent of earned royalty income distributed to inventors	33%	37%	25%	25%	0%
28	Percent of earned royalty income distributed to the agency or laboratory	67%	64%	75%	75%	0%
29	Licenses terminated for cause	0	0	0	0	0

Table 5: Cooperative research and development agreements (CRADAs)

		FY17	FY18	FY19	FY20	FY21
30	Active CRADAs	65	63	44	49	45
31	Newly executed CRADAs	6	7	10	7	5
32	Active CRADAs with small businesses involvement	12	11	8	6	N/A
33	Small businesses involved in active CRADAs	12	11	8	0	1

34	Active traditional CRADAs	66	63	43	46	N/A
35	Newly executed traditional CRADAs	6	7	10	7	N/A
36	Active non-traditional CRADAs	1	0	0	0	N/A
37	Newly executed non-traditional CRADAs	0	0	0	0	N/A

Table 6: Small businesses, startups, and young companies

		FY17	**FY18**	**FY19**	**FY20**	**FY21**
38	Small businesses supported	148	63	7	45	37
39	Startups and young companies supported	N/A	N/A	N/A	8	N/A

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

The importance of T2 within U.S. DOT is reflected in the U.S. DOT Research, Development and Technology Strategic Plan FY 2022-2026, which was released in December 2022[3]. T2 aims to facilitate adoption and commercialization of market-ready transportation technologies, as shown in the plan's T2 section titled "Technology Transfer and Deployment," which details the Department's strategic vision and priorities for T2 over the next 5 years.

Citing *Transformation* as one of the six main strategic goals in the plan, U.S. DOT strives to invest in purpose-driven research and innovation to meet the challenges of the present and modernize a transportation system of the future that serves everyone today and in the decades to come.

Table 7 summarizes the T2 priorities and objectives specified in the RD&T Strategic Plan. The T2 activities of OST-R and the different OAs within the Department are described in more detail below.

Table 7. T2 priorities and objectives

T2 Priorities	2022-2026 Objectives
Ensure research investments are fully leveraged through the demonstration and deployment of the resulting products and technologies	• **Research Planning:** Require that T2 performance measures be incorporated into project lifecycle planning at an early stage • **Early-Stage Identification:** In partnership with the modes, identify potential research and lab efforts ripe for demonstration. • **AMRP Linkage:** Ensure that the deployment opportunities are connected with AMRPs.
Accelerate technology commercialization and deployment of transportation innovations	• **Technology Coordination:** Develop a centralized function to institute structured channels to commercialize transportation innovations. • **Communicate Successes:** Continually improve mechanisms to share promising research, outcomes of demonstration projects, and available patents and licenses for scalability. • **Investor Outreach:** Host investor/T2 events to raise awareness of viable technologies. • **Process Improvement:** Create processes that align statutory requirements with Federal public access and open science mandates to increase research uses.
Identify leading-edge transportation technologies or products that could be manufactured in the United States	• **Domestic Technology Scans:** Identify U.S. government-funded technologies and products that are market-ready for domestic commercialization and deployment. • **Encourage Domestic Production:** Work with stakeholders to initiate and expand U.S production pipelines for technology efforts.
Advance coordinated interagency approaches to innovation and research solicitations with the goal of reducing barriers to program participation and streamlining access to funding opportunities	• **Partnership Development:** Create novel, cross-agency approaches to solicitations that meet multi-agency goals and outcomes • **Expanded Outreach:** Continue to engage communities, partners, and consortia on upcoming opportunities.

[3] https://www.transportation.gov/rdtstrategicplan

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 and technology results.

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.
    - 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's 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 (SBIR) Program
    - U.S. DOT 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

Figure 1. The ROSA P logo

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* (2013), 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 U.S. DOT data, and the help line for Congress, researchers, and the public for information about transportation. NTL created and maintains 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.

3.1.2 Office of Research, Development, and Technology

Housed in U.S. 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 departments of transportation (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 an account of the 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) as amended by the Infrastructure Investment and Jobs Act (Pub. L. 117-58)[4] 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 portfolio.

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 Fixing America's Surface Transportation Act as amended by the Infrastructure Investment and Jobs Act,[5] 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 AMRPs include sections on T2 Deployment and Evaluation. The AMRPs also give OST-R the opportunity to identify knowledge exchange opportunities among research teams at the OAs.

[4] 49 U.S.C. 6502.
[5] 49 U.S.C. 6501

4 Operating Administration 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 through 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, serving as a deployment strategy for research products.

4.1.2 Cooperative Research and Development Agreements

The Technology Transfer Program at FAA's William J. Hughes Technical Center 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 likelihood of eventual commercialization of the technology. In FY 2021, FAA had 41 active CRADAs, including five new CRADAs that were established during the fiscal year.

4.1.3 Centers of Excellence

FAA's Centers of Excellence program conducts and transfers research in specific mission-critical topics. The FAA establishes Centers of Excellence through cooperative agreements with the Nation's premier universities, members, and affiliates, to conduct focused R&D and related activities over periods of five to ten years. This program facilitates collaboration and coordination among government, academia, and industry to advance aviation technologies and expand FAA research capabilities through matching contributions. Over the life of the program, the 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 multiplies 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 transportation innovations 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 are 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 (STIC) 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 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, or integrate automation. Every two years, FHWA works with state, local, Tribal and territorial 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.

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 DOTs, 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 (ATCMTD) Program awards competitive grants to develop model deployment sites for the implementation of cutting-edge transportation technologies. In FY 2021, 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 2021, the program provided $256 million to projects in multiple states. FHWA opened the competition for the sixth round of awards in June 2021.

4.2.5 Accelerated Innovation Deployment Demonstration Program

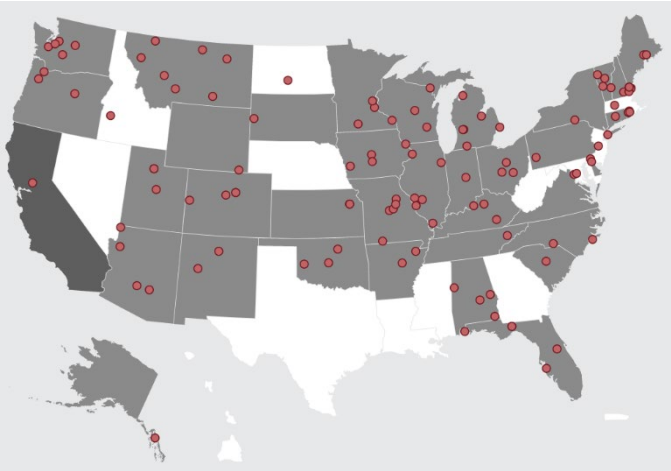

Figure 2. Map of locations of AID demonstration projects

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 117 AID Demonstration grants worth over $86.9 million, as shown in **Error! Reference source not found.**.

4.2.6 State Transportation Innovation Council Incentive Program

FHWA fosters collaboration between stakeholders within the transportation community through the 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.

4.2.7 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 surface 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 transportation workforce about ITS is the Professional Capacity Building (PCB) Program.

4.2.8 ITS Professional Capacity Building Program

The ITS Professional Capacity Building (ITS PCB) Program 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 OAs 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 2019 through and FY 2021 are shown in Table 8.

Table 8: Performance metrics for the ITS PCB Program, FY 2019-2021

ITS PCB Activity	FY19	FY20	FY21
ITS PCB website	77,698 sessions (daily average: 213)	16,103 sessions (daily average: 44)	40,513 sessions (daily average: 111)
Webinars, online courses, and workshops	41 (4,512 attendees)	43 (6,059 attendees, 140.9 participants per live training event)	25 (1,922 attendees, 76.9 participants per live training event)
Archived and on-demand training content	25,372 users	16,813 users	9,740 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 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 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.

4.3.1 Research & Technology Program

FMCSA's Research & Technology (R&T) Program develops the knowledge, practices, and technologies to improve enforcement technologies and the safety 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.

4.3.2 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.

4.3.3 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.

4.4 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. The Transportation Technology Center in Pueblo, Colorado has over 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 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.

4.6 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

4.6.1 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 (conducted in collaboration with the ITS JPO) where thousands of vehicles were equipped with dedicated short-range communications 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, is the world's largest operational real-world deployment of CVs and connected infrastructure.

4.6.2 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.

4.6.3 Vehicle Research and Test Center

Staff at the 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.

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 of 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 Maritime Administration

Through its Maritime Environmental and Technical Assistance (META) program, the 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 Aviation Administration

5.1.1 Reducing Aviation Noise and Emissions Since 2010

Figure 3. Logo of FAA's Continuous Lower Energy, Emissions, and Noise Program

The Continuous Lower Energy, Emissions, and Noise (CLEEN) Program is a public-private partnership that is a key part the FAA's overall strategy to tackle the global challenge of climate change and lower the impact of aviation on communities. The program requires the companies receiving contracts to match or exceed the FAA's investment. Through the first two phases of CLEEN, industry has contributed $388 million of cost-share to the CLEEN Program, which has far exceeded the FAA contribution of $225 million.

The third phase of the CLEEN Program focuses on advances in wing technologies; aircraft systems technologies; engine fan, nacelle, and nozzle technologies; engine core turbomachinery technologies; protective engine coatings and aircraft engine system integration. In FY21, the FAA entered into four cooperative agreements to further mature technologies and sustainable aviation fuels that will reduce fuel burn, emissions, and noise. The FAA anticipates that technologies developed under CLEEN Phase III could be introduced into commercial aircraft by 2031.

Examples of the accomplishments from the FAA's $225 million invested in the first two CLEEN phases include:

- Enhanced jet engine combustion systems have entered the aviation fleet, resulting in lower emissions.
- Advanced aircraft wings made of stronger and lighter-weight materials are supporting innovative development of current and future aircraft.
- Flight Management System algorithms have been created under CLEEN to enable aircraft to fly more fuel-efficient routes.
- Several alternative jet fuels have been certified for safe use, due in part to testing and evaluation efforts conducted under CLEEN.

Cumulatively, CLEEN Phase I and II are estimated to save the aviation industry 36.4 billion gallons of fuel by 2050, reducing airline costs by $72.8 billion and lowering carbon dioxide (CO_2) emissions by 424

million metric tons. These CO_2 reductions are equivalent to removing about 3 million cars from the road from 2020 to 2050. The technologies from the first phase of CLEEN are estimated to decrease land area exposed to noise by 14 percent.

5.1.2 New Software Capability Gets Planes Rolling Directly to the Runway, Reducing Fuel Burn and Taxi Time

In September 2021, the FAA and NASA announced the completion of research and testing on a software capability that calculates gate pushbacks at busy hub airports so that each plane can roll directly to the runway and take off. The FAA plans to deploy this capability at 27 airports as part of a larger investment in surface management technology. The innovative capability, which will be part of the FAA's Terminal Flight Data Manager program, was developed by NASA and tested for nearly four years by the FAA's NextGen group, airlines' airport operations, FAA radar facilities in Charlotte and Dallas/Fort Worth, and the centers in Atlanta and Washington, D.C., that handle high-altitude *en route* flights.

By minimizing taxi delay and ramp congestion, the program will reduce fuel burn and CO_2 emissions. When completed, the FAA anticipates a savings of more than 7 million gallons of fuel every year and the elimination of more than 75,000 tons of CO_2 emissions annually. During program testing at Charlotte Douglas International Airport, the program:

- Reduced taxi times that helped save more than 275,000 gallons of fuel annually, equivalent to the fuel burn of 185 flights between New York and Chicago by a Boeing 737.
- Reduced CO_2 emissions by 8 tons per day.
- Reduced delays by 916 hours, equivalent to shaving 15 minutes of waiting time on a taxiway for more than 3,600 departing flights.

5.1.3 Augmented Reality Weather Training

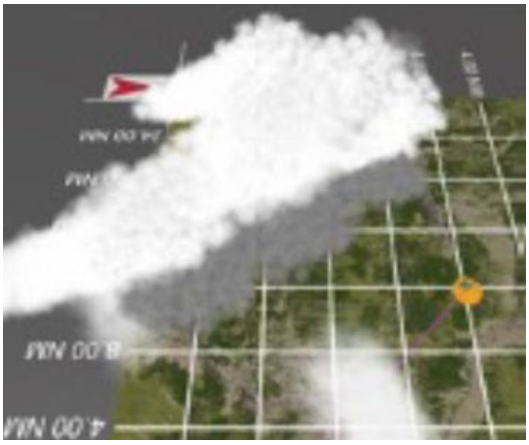

Figure 4. 3D model of a thunderstorm in the WeatherXplore app

Weather continues to be the largest cause of air traffic delays in the U.S., typically accounting for approximately 70 percent of all delays annually. To help address weather-related challenges, in FY21 the FAA completed a demonstration version of an interactive augmented-reality training program that enables pilots to experience the various stages of a thunderstorm. The WeatherXplore app presents a three-dimensional (3D) thunderstorm model to evaluate the benefits of incorporating interactive 3D models for pilot weather training.

WeatherXplore was sponsored by the FAA's Weather Technology in the Cockpit program and developed

in partnership with the FAA's Center of Excellence for General Aviation. Other partners included Western Michigan and Purdue Universities, Tietronix Software, and Fly8MA.com, an online private pilot ground school.

5.2 Federal Highway Administration

5.2.1 Next-Generation Traffic Incident Management

Every year in the United States, there are an estimated 6 million collisions reported by police, 32 million motorist assists, and 174,000 vehicle fires. Each incident places responders and motorists at high risk of secondary collisions at the scene or in the queue behind a prior incident. These incidents also cause congestion, negatively impacting the economy and the public's quality of life. Traffic incident management (TIM) has become the state of the practice to reduce the dangers and mitigate the impacts of incidents.

Through its Every Day Counts program, FHWA is helping its state, local, and Tribal partners take TIM to the next level using innovative approaches that will continue to improve safety and travel reliability while saving lives, time, and money. Next-generation traffic incident management (NextGen TIM) increases the focus on local agency TIM programs while integrating new and emerging technology, tools, and training strategies. It enables agencies to improve TIM strategies by implementing new options such as back-of-queue warning, navigation-app notification of active responders in the vicinity, notification-based incident detection using crowdsourced data, and more.

5.2.1.1 Applying TIM Locally

Although TIM efforts have been focused on high-speed roadways, the concepts of TIM are applicable to all roads. NextGen TIM applies TIM to local roadways by encouraging the application of low-cost solutions like stakeholder meetings, development of policies and procedures, and participation in TIM training. When officers from the Oro Valley Police Department in Arizona became focused on TIM practices and began tracking TIM-related metrics in computer-aided dispatch (CAD), roadway and incident clearance times were reduced by 32 percent during the first six months of 2018.

5.2.1.2 Promoting TIM Training

Figure 5. TIM strategies are applicable on local as well as high-speed roads (Credit: Grady Carrick)

NextGen TIM continues to promote TIM training with innovative remote delivery approaches and new content. NextGen TIM strives to institutionalize training through policies, ensuring training will continue

even after TIM training champions move on [6]. Technology-focused training will be available to supplement the National Responder Training Program. TIM-related lessons will provide information on integrated CAD, unmanned aerial systems (UAS), connected and automated vehicles, TIM data collection and use, and traffic management centers (TMCs). The Arizona Highway Patrol estimates that by implementing training and other TIM strategies, it saves 44,000 hours of patrol time per year, the equivalent of about 25 full-time officers.

5.2.1.3 Advancing Data Use

NextGen TIM focuses on advancing the collection, analysis, and use of incident data. With better data and analytics, agencies can quantify program performance, demonstrate program effectiveness, and improve TIM planning and resource management. TIM data can come from public safety CAD system time stamps, police traffic crash reports, or TMCs. Real-time data dashboards are an effective way to analyze and present data to promote organizational goals. Georgia reduced clearance times for commercial vehicle crashes by 82 percent with data from its Towing Recovery Incentive Program. Puerto Rico deployed a mobile app for safety service patrols to augment the exchange of incident data and accurate reporting.

5.2.1.4 Integrating Technology

CAD integration facilitates the timely sharing of information between public safety and transportation agencies and improves coordination of resources, traveler information, and safety. CAD integration streamlines and improves analysis and reporting of TIM performance measures and reduces time for law enforcement agencies to notify the public. CAD integration also allows departments of transportation (DOTs) to mobilize resources faster, improve traveler information, and enhance the depth and accuracy of data for performance analysis.

UASs reduce responder time on incident scenes, accelerate crash investigations, and offer a cost-effective measuring and mapping alternative. UASs are remotely controlled by a pilot and can be easily flown over a traffic crash scene to capture high-definition images. UAS image processing is capable of photogrammetry, in which measurements can be taken from the images. Using known measurements in the UAS image allows measurement between any two points in the image. In North Carolina, the Highway Patrol and state DOT found that UAS mapped a two-car crash in 25 minutes, while three-dimensional laser mapping required nearly two hours.

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6 https://www.fhwa.dot.gov/goshrp2/Solutions/Reliability/L12_L32A_L32B/National_Traffic_Incident_Management_Responder_Training_Program

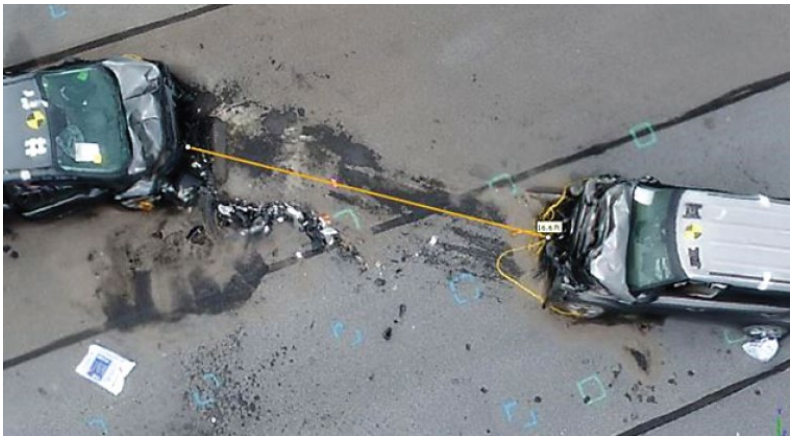

Figure 6. Using measurements from photos captured by unmanned aerial systems accelerates crash investigations. (Credit: North Carolina Department of Transportation)

Additional technologies include video-sharing and alert systems. Video sharing allows cameras mounted on service patrol vehicles to stream images from incident scenes to TMCs, as well as TMC images back to responder vehicle computers. Responder-to-vehicle alert systems improve safety by increasing advance warning of incidents. When responder vehicles are stopped along roadways, approaching drivers can be warned through in-vehicle navigation providers that receive alerts when responder vehicle emergency lighting is activated.[7]

5.2.2 Advancing Project Bundling — Old Concept, New Momentum[8] [9]

Transportation agencies are using project bundling to capitalize on economies of scale more often and on more diverse projects than ever before. Project bundling streamlines project delivery by combining environmental analysis and permitting, design, and contracting for greater efficiency. Some state, local, and tribal agencies have used their past successes to develop business rules for selecting bundles early in the planning and programming process. This creates agency-wide efficiencies by making project bundling a standard way of doing business.

FHWA has created tools to help agencies implement a more advanced approach to project bundling. A self-assessment resource is now available to help an agency work its way from a developing program to one in which bundling is the standard for delivering a program of projects. The self-assessment is based on 25 nationally proven practices, each linked to resources in a project bundling resource database that includes case studies, contracts, programs, and research. The database is available on FHWA's Bundled Facilities Overview web page, along with case studies, webinars, and lessons learned on bundling programs.[10]

5.2.2.1 Bundling Beyond Bridges

Bridge bundling took the spotlight in recent years due to the backlog of bridges in poor condition. For example, the Oregon DOT identified 271 bridges for replacement and strategically bundled the projects

[7] Additional reference: Talking TIM webinar series

[8] In this EDC Outtake, Royce Meredith of the Kentucky Transportation Cabinet (KYTC) describes how KYTC is expanding its use of project bundling. https://www.youtube.com/embed/Ry5LjSSn3NI?feature=oembed

[9] Advanced Project Bundling: Examples Beyond Bridges webinar, https://connectdot.connectsolutions.com/plvv4usybsts/

[10] Royce Meredith of the Kentucky Transportation Cabinet describes its use of project bundling.

based on location and work type. Bundling three bridges on Interstate 5 over the Willamette River saved an estimated 16 percent, or $31 million.

Figure 7. This roadway in Oakwood, GA, was improved as part of the city's pavement management. (Credit: City of Oakwood, GA)

The focus has now expanded to "project" bundling, which includes projects to alleviate traffic bottle-necks, replace culverts, create smoother pavements, address safety hot spots and high-risk rural roads, and make lighting, sign, and Americans with Disabilities Act (ADA) improvements.

Minnesota DOT removed the ADA scope from three proposed paving projects in the same city and bundled them into a new, single project that included 150 ADA ramps and sidewalks. The agency has also bundled bridges, signs, maintenance projects such as noise walls, and rural intersection safety equipment.

The city of Oakwood, Georgia, with a population of 4,000 and 22 lane miles of pavement, partnered with nearby cities to lower costs associated with pavement management and preservation treatments. Combining work with neighbors increased the scale of the project, attracting more bidders and reducing the cost of milling by nearly 80 percent.

Indiana DOT (INDOT) adopted project bundling as a standard practice based on historical data that demonstrated value when projects are bundled well, and it is incorporating artificial intelligence to further expand project bundling benefits. A machine-learning platform uses INDOT's historical and asset management data, along with business rules, to automate and optimize bundle selections over multiple program years. This approach has increased bundling savings by 40 percent and is expected to save INDOT $108 million over the next 4 years.[11]

5.2.3 Advancing Effective Contracting Method Alternatives[12] [13]

Traditionally, highway projects have been let by state DOTs and local agencies after the design is completed and awarded to the lowest responsive bidder, a contracting method known as design-bid-build (D-B-B). As part of Special Experimental Project Number 14, FHWA has partnered with state DOTs to explore contracting options that better deliver projects of an increasingly complex nature. Although

[11] View the Advanced Project Bundling: Examples Beyond Bridges webinar to learn more about the Indiana, Minnesota, and Oakwood, GA, projects.

[12] Example: The Sellwood Bridge project in Multnomah County, OR, used CM/GC contracting to incorporate innovations such as slide-in bridge construction and 3D modeling.

[13] Example: This Colorado DOT U.S. 550–U.S. 160 Connection South project video includes a segment on why the agency chose to use D-B contracting.

D-B-B is still the prevalent method, several alternatives have proven more effective for design-construction collaboration, addressing risk, and incorporating innovation by involving contractors earlier in the process. The result, as confirmed by FHWA research, is better projects that deliver transportation benefits to the public faster and often for less cost.

5.2.3.1 Expanding the Alternatives

Through its EDC initiative, FHWA has highlighted several alternative contracting methods that facilitate earlier contractor involvement. These methods have since become standard practices for most state DOTs. The first two rounds of EDC promoted the alternative contract methods known as design-build (D-B) and construction manager/general contractor (CM/GC). With D-B, an agency identifies the scope of work, solicits for and receives proposals, and selects a D-B team to assume the risk and responsibility for the design and construction phases. In CM/GC, the agency hires a contractor to act as a construction manager during the design phase. They work together, along with the agency's independent cost estimator, to establish a price and schedule for the construction portion of the contract, during which the contractor acts as the general contractor. With this design-construction integration, early work packages allow the team to complete long-lead-time construction activities more efficiently.

EDC's second round also included alternative technical concepts (ATCs), a procurement procedure that allows proposers to submit innovative ideas during bidding that improve on the contracting agency's design or construction criteria. Agencies have used ATCs most effectively with D-B, and some have used them with D-B-B. Caltrans has estimated savings due to D-B ATCs of nine percent over a four-year program.

5.2.3.2 Partnering for Success

EDC built networks between state and local agencies and other stakeholders that facilitated working together on these mutually beneficial initiatives. Peer exchanges and other activities allowed agencies already implementing alternative contracting methods to share lessons learned and effective strategies with those new to their use, increasing their chances of success. EDC also provided technical support through its deployment teams as well as funding opportunities for pilot projects and other deployment activities. The raised awareness and acceptance of alternative contracting methods by both agencies and industry accelerated adoption in many states. For CM/GC, when the second round of EDC began in 2013, there were 10 states with enabling legislation; now, there are around 30.

"We're also starting to see more contracts where agencies are using ATCs with D-B-B, and part of that is deciding which project is a good candidate," said John Huyer, FHWA Office of Infrastructure. "FHWA recently worked out a programmatic agreement with the Missouri DOT for promoting ATCs on D-B-B projects, and it's now in Missouri DOT's strategic plan. D-B-B ATC use is also branching off into other areas. For example, Michigan DOT has used it for controlling and maintaining traffic."

5.2.4 Crowdsourced Data to Improve Real-Time Roadway Monitoring

Crowdsourcing for operations turns transportation system users into real-time sensors on system performance, providing low-cost, high-quality data on traffic operations, conditions, and patterns. Public agencies at the Federal, State, and local levels are increasing their situational awareness and the quality and quantity of operations data using crowdsourcing. Doing so enables agency staff to cost-effectively apply proactive strategies and make better decisions that lead to safer and more reliable travel. Thirty-eight States attained demonstration, assessment, or institutionalized stages of crowdsourcing for operations implementation in the fifth round of EDC (2019-2020).

Tennessee DOT (TDOT) has used crowdsourced data to detect crashes and stopped vehicles faster. In conjunction with the University of Tennessee, TDOT used Waze speed, incidents, and traffic jam data to enhance queue detection techniques that previously relied on traditional intelligent transportation system (ITS) roadway sensors. Adding crowdsourced data greatly expanded the geographic coverage area and timeliness of TDOT's queue detection and response capabilities. The crowdsourced data enabled TDOT to identify the backs of queues 1.1 minutes faster on average than by just using ITS vehicle detectors and monitoring cameras at fixed locations.

By joining the Waze Connected Citizens Program (CCP), the Maryland Department of Transportation (MDOT) can more effectively share road closure incidents in real time with users of the application. MDOT has also begun archiving and analyzing crowdsourced data available through the CCP partnership for its potential to complement the agency's robust traffic monitoring systems. Findings from data verification efforts are confirming the value of investing in this new data source. MDOT expects analyses will inform future ITS infrastructure deployment, while real-time information will help more quickly detect and respond to incidents on freeway and arterial facilities.

5.2.5 Crowdsourcing for Advancing Operations

Crowdsourcing is a low-cost, powerful tool that leverages the public to collect data to improve traveler information, traffic incident management, signal timing, weather-responsive management, work zone management, and more. Crowdsourcing overcomes gaps in geographic coverage of traditional ITS monitoring systems, lags in information timeliness, monitoring equipment costs, and jurisdictional data stovepipes. FHWA promoted the use of crowdsourced data to improve operations during the fifth round (2019-2020) of its EDC initiative.

Agencies such as the Indiana Department of Transportation (INDOT) have found that even a single integrated, archived, and shared crowd-sourced data stream can transform traffic operations. INDOT processes speed data from 6,500 interstate and 35,000 non-interstate segments every minute to provide real-time dashboards for incident detection at traffic management centers (TMC). TMC operators also use the dashboards to monitor work zone delays, and law enforcement officers at work zone sites can monitor queues and identify potential crashes. The data feed real-time travel estimates for over 200 routes through dynamic message signs. In all, INDOT uses vehicle probe data for nearly a dozen operational capabilities.

INDOT stores the vehicle probe data and enables engineers to query the data for multiple purposes. Using the data, traffic engineers now prioritize corridors for signal retiming rather than simply retiming on a three-year cycle. The data supplant costly floating car studies to confirm signal timing improvements. Retiming the nine-mile U.S. 31 arterial corridor, for example, saved 116,000 hours a year in travel time, equivalent to $2.75 million. By using vehicle probe data, INDOT has begun retiring ITS devices and will eliminate 50 percent of roadside sensors. The agency will also forego a planned ITS field device expansion. INDOT will save $28 million in ITS infrastructure deployment costs and $750,000 per year in communications service and maintenance costs by using probe data.

5.2.6 Public Involvement Communication Tools for a 21st Century Audience

Involving the public in transportation planning and project development can help agencies accelerate project delivery by identifying concerns early in the decision-making process. Virtual public involvement strategies enhance agencies' efforts to engage the public by supplementing traditional processes such as

face-to-face meetings with digital technology. Virtual public involvement strategies include mobile apps, project visualizations, crowdsourcing methods, virtual town halls, and mapping tools (as shown in Figure 9).

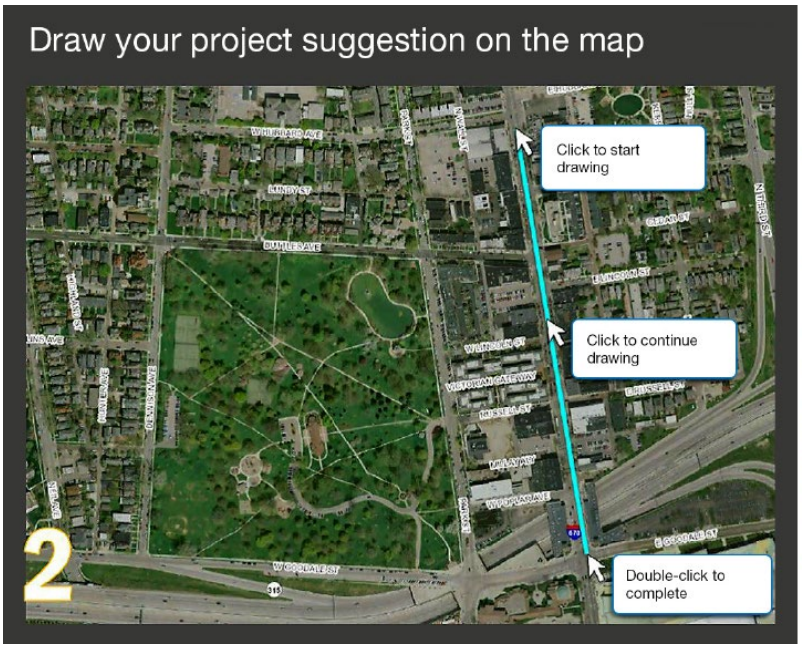

Figure 8. The Mid-Ohio Regional Planning Commission encouraged the public to offer project ideas by drawing on its interactive map

During the fifth (2019-2020) and sixth (2021-2022) rounds of its EDC initiative, FHWA has promoted the adoption of new public involvement tools, including convenient virtual strategies. Twenty-three States are demonstrating and assessing virtual strategies to engage the public. Eight States have institutionalized virtual public involvement techniques and are using them regularly for planning and project development, including Colorado, Florida, Iowa, North Carolina, Ohio, Texas, Vermont, and Washington State.

For example, the Colorado DOT 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. Roughly 58,000 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.

5.2.7 High-Friction Surface Treatments Reduce Roadway Departures

Transportation agencies are installing high-friction surface treatments (HFST), an early EDC innovation, as part of their focus on reducing rural roadway departures. HFST is a cost-effective safety countermeasure in which a polish-resistant aggregate such as calcined (heat-treated) bauxite aggregate is bonded to the pavement surface using a polymer resin binder to improve and maintain pavement friction, helping motorists keep better control in dry and wet driving conditions. HFST is used at locations with high risk for crashes—such as curves, ramps, and intersections—to reduce crashes and the related injuries and fatalities.

With funding from FHWA's Accelerated Innovation Deployment Demonstration program, South Dakota

DOT deployed HFST as a lane departure countermeasure on four curves, including two on rural U.S. 14A in the Black Hills area. In the five years after the HFST application on one of the rural curves, no crashes have been reported, compared to 12 crashes during the five years before the HFST project. Because of the success of the pilot project, SDDOT expanded HFST to 15 locations that experienced crashes with winter road conditions as a contributing factor and saw a 66 percent crash reduction over three years. SDDOT has added HFST to its safety countermeasure toolbox and plans two HFST projects every other year, bundling them by region to obtain better pricing than for individual projects.

Pennsylvania DOT has installed HFST at about 500 locations statewide, including rural roads. A PennDOT crash data analysis of 47 locations from seven contracts where HFST was installed found that for an investment of just over $3 million, the return in reduced fatalities, injuries, and property damage was more than $8.5 million. Injury crashes at these locations went from 190 to 71, a 63 percent decrease, and fatalities dropped from eight to zero.

5.3 Federal Motor Carrier Safety Administration

5.3.1 North American Fatigue Management Program

The North American Fatigue Management Program (NAFMP) was developed in 2000 by medical and sleep scientists from Canada and the United States. The program aims to prevent driver fatigue and eliminate fatigue-related crashes by offering easy-to-access online fatigue prevention training and education to commercial motor vehicle drivers, motor carrier executives and managers, freight shippers and receivers, dispatchers, driver managers, driver's spouses and families, safety managers, and trainers. In 2013, through a shared agreement between Transport Canada and FMCSA, the NAFMP was made available as a website and online interactive learning management system. Since then, it has been available at no cost to drivers, motor carrier safety officers and administrators, and government safety officials.

Over the years, responsibility for the support and operation of the NAFMP alternated between FMCSA and Transport Canada, which became contractually cumbersome and eventually led to an extended outage of the website and a significant drop in page views and overall utilization. In 2021, Transport Canada and FMCSA, working with the NAFMP Steering Committee, initiated the transfer of hosting and operation of the NAFMP to the Commercial Vehicle Safety Alliance (CVSA). Web traffic has increased significantly since CVSA adopted the site and made several functional and aesthetic enhancements in December 2021. CVSA initiated user outreach activities that included a press release to 17,000 contacts, trade press articles, and an interview in the Sirius XM Radio Road Dog Trucking with Dave Nemo. CVSA also held six webinars, two conference information sessions, two CVSA committee agenda inclusions, distributed handouts at three events, and moderated forums for each of the ten LMS Module courses. In the fourth quarter of 2021, there were 4,538 page views by 2,069 users, with a peak of 646 home page views on January 4, 2022.

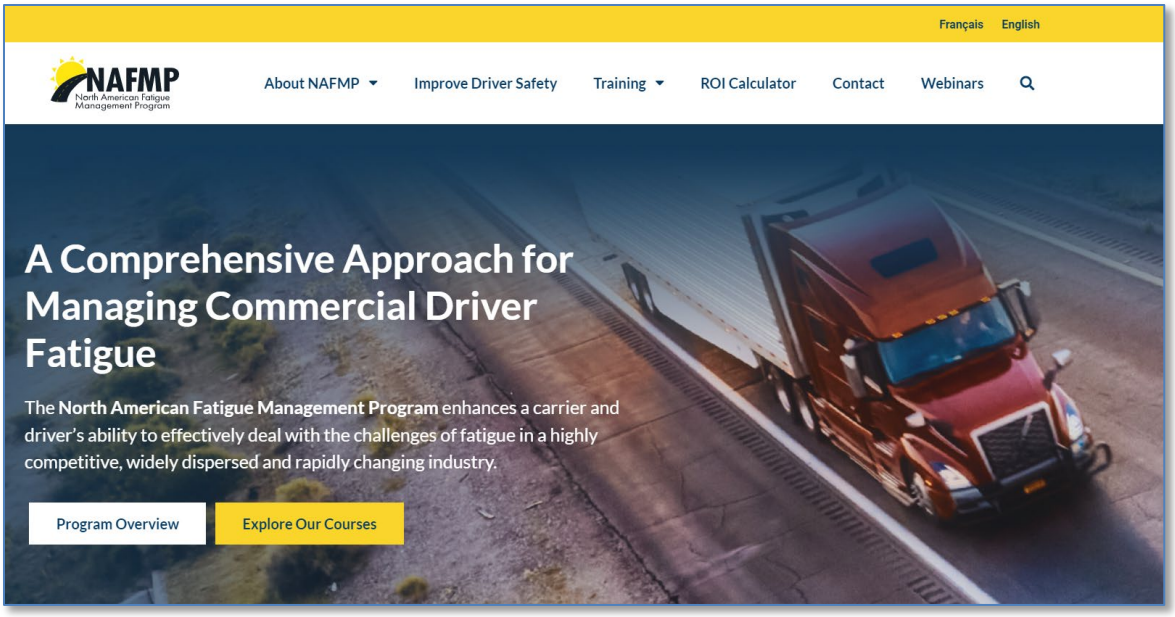

Figure 9. Screenshot of NAFMP's homepage

5.4 Federal Railroad Administration

5.4.1 Positive Train Control

Positive Train Control (PTC) systems use communication-based and processor-based train control technology to prevent train-to-train collisions, over-speed derailments, incursions into established work zones, and movements of trains through switches left in the wrong position. In 2008, Congress mandated the implementation of PTC systems on Class I railroads' main lines that annually carry 5 million or more gross tons or certain hazardous materials. The PTC requirement also applies to main lines over which intercity or commuter rail passenger transportation is regularly provided. FRA estimates that the adoption of PTC will result in annualized benefits between $42–$45 million.

On December 29, 2020, FRA announced that PTC technology was in operation on all 57,536 required freight and passenger railroad route miles, prior to the December 31, 2020, statutory deadline. FRA had certified that each host railroad's PTC system complies with Federal technical requirements. In addition, railroads have reported that interoperability has been achieved between each applicable host and tenant railroad that operates on PTC-governed main lines.

As an interoperable safety system, PTC is composed of several different technologies or "segments." For each of these segments, the FRA Office of RD&T has established performance, interface, and interoperability standards and lifecycle management requirements. FRA RD&T also developed:

- An adaptive braking algorithm, which improved calculations for freight train stopping distances
- A high-precision train positioning system
- Protocols that secure inter-segment communication to prevent hacking
- A software-defined radio that secures communications
- An employee-in-charge portable terminal, which enforces certain train speeds within employee work areas.

5.5 Federal Transit Administration

5.5.1 Mobility on Demand Demonstration

Mobility-disadvantaged people lack consistent access to employment and educational opportunities, health care and other key services, and social engagements. With a grant from FTA's Mobility on Demand (MOD) Sandbox program, the Valley Metro Regional Public Transportation Authority (Valley Metro) piloted the use of Waymo autonomous vehicles (AVs) to provide subsidized, point-to-point rides for mobility-disadvantaged citizens. The transit agency, located in the greater Phoenix metropolitan area, used the vehicles for its RideChoice program, which provides service to paratransit-certified people and to older adults aged 65 and up.

The six-month demonstration took place from September 2019 to March 2020. The project used fully autonomous (Level 4) AVs with safety operators present in the vehicles. An independent evaluation published in August 2021 found that participants felt safe, found the AV services more convenient than typical RideChoice options, and engaged in more out-of-home activities (i.e., made new trips) because of the AV option. In all cases, ratings of wait time, travel time, convenience, and comfort of the AV option were higher than for the traditional options available through RideChoice.[14] During focus groups, planners and policymakers expressed interest in exploring more use cases within the region and were keen to see additional pilot projects.

5.6 Intelligent Transportation Systems Joint Program Office

5.6.1 Ensuring Work Zone Safety

Figure 10: Definition of the Work Zone Data Exchange

In 2019, the ITS JPO's multimodal Data for Automated Vehicle Integration initiative launched a Work Zone Data Exchange (WZDx) project to get data on work zones into vehicles to help automated driving systems and human drivers navigate more safely. That project led to the WZDx specification, which was

[14] https://www.transit.dot.gov/sites/fta.dot.gov/files/2021-09/FTA-Report-No-0198%20REVISED.pdf

established to make travel on public roads safer and more efficient by providing ubiquitous access to data regarding work zone activity. In conjunction with FHWA, the ITS JPO co-led the earlier stages of the WZDx specification and remains actively involved with the project.

The WZDx specification is an open-source data specification that enables infrastructure owners and operators to make live, accurate, and actionable work zone data available for third-party use, such as by mapping companies. That means smarter roads where navigation systems, drivers, and eventually automated vehicles can be informed about work zones in their path, improving roadway safety nationwide. Work zone data can also help inform agencies who are responsible for integrating transportation systems management and operations strategies.

The Work Zone Data Working Group published version 3.1 of the WZDx specification in April 2021. Other recent developments include the Early Adopters' Guide and Work Zone Data Survey Report. The WZDx Feed Registry lists active data feeds from seven state DOTs.

To encourage adoption of WZDx, U.S. DOT awarded $2.4 million in January 2021 for 13 WZDx demonstrations projects. FHWA also launched the "Put Work Zones on the Map" campaign — an effort to raise awareness about WZDx and engage potential partners, including State and local DOTs, construction companies, mapping companies, and vehicle and vehicle technology manufacturers.