U.S. Department
of Transportation

Office of the Secretary
of Transportation

Deputy Assistant Secretary
for Research and Technology

1200 New Jersey Avenue, S.E.
Washington, DC 20590

May 14, 2019

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

FROM: Diana Furchtgott-Roth
Deputy Assistant Secretary for Research and Technology

SUBJECT: Fiscal Year 2018 Technology Transfer (T2) Annual Performance 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 U.S. DOT's information for DOC's Fiscal Year 2018 Summary Report.

Please submit questions pertaining to this report to Santiago Navarro at Santiago.Navarro@dot.gov or 202-366-0849.

Attachment:

Fiscal Year 2018 Technology Transfer (T2) Annual Performance Report.

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Annual Technology Transfer Report FY 2018

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

MAY 2019

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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.

On October 28, 2011, following a series of reports identifying the status of technology transfer from Federal funds and Federal laboratories, the White House issued the Presidential Memorandum – "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses." Thus, 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 Performance 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's) National Institute of Standards and Technology in support of the Commerce Secretary's Annual Summary Report to the President, the 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 deployment and disseminating 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. DOT's annual T2 report is available online here.

T2 activities are executed by U.S. DOT agencies and their research centers (laboratories). The Department of Transportation's (DOT's) research centers are as follows:

- Federal Aviation Administration (FAA): William J. Hughes Technical Center (WJHTC), Atlantic City, NJ, and Civil Aerospace Medical Institute, Oklahoma City, OK
- 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 DOT's T2 activities and research centers is available on the following websites:

- FAA: https://www.faa.gov/go/techtran/
- FHWA: https://www.fhwa.dot.gov/innovation/ and https://www.fhwa.dot.gov/goshrp2
- OST-R: https://www.volpe.dot.gov/work-with-us/technology-transfer
- FRA: https://www.fra.dot.gov/Page/P0153.

DOT Invention Disclosures, Patenting, Licensing, and Other Measures

The following tables provide data on U.S. DOT's T2 activities from Fiscal Year (FY) 2014 to FY 2018. These tables conform to the guidance provided to Federal agencies by DOC. Tables 6 and 7 contain other metrics that DOT tracks.

Table 1. Invention disclosures and patents.

		FY14	FY15	FY16	FY17	FY18
	Invention Disclosure					
1	Number of new inventions disclosed	3	0	0	3	12
	Patents					
2	Number of patent applications filed	0	5	0	7	2
3	Number of patents received	1	1	1	0	0
4	Number of foreign patents filed	N/A	N/A	N/A	N/A	N/A
5	Number of foreign patents received	N/A	N/A	N/A	N/A	N/A

Table 2. Income-bearing licenses.

		FY14	FY15	FY16	FY17	FY18
	Licenses					
6	Total active licenses	1	2	2	5	6
7	Total new licenses	0	1	2	1	1
	Income Bearing Licenses					
8	Total active income-bearing licenses	1	2	2	5	6
9	New income-bearing licenses	0	0	0	1	1
10	Total active invention licenses	1	2	0	0	1
11	New invention licenses	0	0	0	0	0
12	Exclusive licenses	1	0	0	0	0
13	Partially exclusive licenses	0	0	0	0	0
14	Non-exclusive licenses	0	2	2	5	5

		FY14	FY15	FY16	FY17	FY18
	Note: FAA licenses are non-exclusive.					
	Elapsed Amount 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					
18	Total license income	N/A	N/A	N/A	19.8	27.1
19	Total invention license income	N/A	N/A	N/A	N/A	0

Table 3. Licensing income.

		FY14	FY15	FY16	FY17	FY18
	Earned Royalty Income					
20	Earned royalty income from top 1% of licenses	N/A	N/A	N/A	N/A	0
21	Earned royalty income from top 5% of licenses	N/A	N/A	N/A	N/A	0
22	Earned royalty income from top 20% of licenses	N/A	N/A	N/A	N/A	0
23	Minimum earned royalty income	N/A	N/A	N/A	N/A	0
24	Maximum earned royalty income	N/A	N/A	N/A	N/A	0
25	Median earned royalty income	N/A	N/A	N/A	N/A	0
	Disposition of Earned Royalty Income ($ thousands)					
26	Total amount of earned royalty income received	$22.6	$11.8	$15.3	$19.8	$27.1
27	Percent of earned royalty income distributed to inventors	32	42	32	33	37
28	Percent of earned royalty income distributed to the agency or laboratory	N/A	58	68	67	64
29	Licenses terminated for cause	N/A	N/A	N/A	N/A	N/A

Table 4. Cooperative research and development agreements.

		FY14	FY15	FY16	FY17	FY18
	Cooperative research and development agreements (CRADAs)					
30	Number of active CRADAs	51	48	68	65	63
31	Number of newly executed CRADAs	10	9	22	6	7
32	Active CRADAs with small businesses involvement	10	11	12	12	11
33	Number of small businesses involved in active CRADAs	5	10	12	12	11
	Traditional CRADAs					
34	Active traditional CRADAs	7	48	62	66	63
35	Newly executed traditional CRADAs	2	9	22	6	7
	Non-traditional CRADAs					
36	Active non-traditional CRADAs	0	0	1	1	0
37	Newly executed non-traditional CRADAs	0	0	1	0	0

Table 5. Small businesses, startups, and young companies.

		FY14	FY15	FY16	FY17	FY18
	Others					
38	Total number of small businesses supported	30	35	65	148	135
39	Total number of startups and young companies supported	N/A	N/A	N/A	N/A	N/A

Table 6. Other performance measures deemed important by the agency.

		FY14	FY15	FY16	FY17	FY18
	Agency specific agreements					
40	Other Collaborative relationships	30	35	152	355	314
41	University Transportation Centers	35	35	32	32	32

Table 7. Stakeholder engagement.

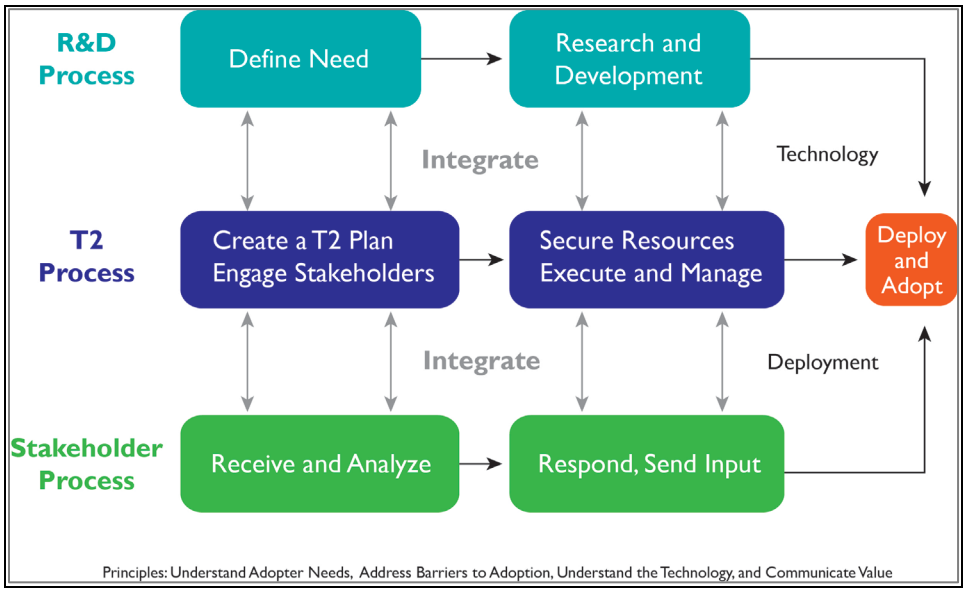
		FY14	FY15	FY16	FY17	FY18
	Vehicles used while engaging stakeholders to disseminate results					
42	New Technical publications made available to public – Volpe Center	N/A	N/A	73	71	75
43	New Technical publications made available to public – U.S. DOT OAs	N/A	N/A	N/A	180	241
46	T2 Outcomes: Number of times stakeholders used DOT innovations through funded workshops, demonstrations, pilots, etc.	N/A	N/A	N/A	437	643
47	Research agreements with technology transfer requirements	N/A	N/A	N/A	91	188

DOT's Efforts to Streamline Technology Transfer

DOT's Strategic Objective for Deployment of Innovation

Technology Transfer: Strengthen the technology transfer process to facilitate adoption and commercialization of market ready transportation technologies.

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. 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 T2 is identified as one of the strategies to be used to accomplish that objective. The relationship of T2 to the Department's research and development (R&D) process and to stakeholder engagement is shown in Figure 1.



Source: U.S. DOT.

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

The T2 activities of OST-R and the different OAs within the Department are described in more detail below.

The 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 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 performance in R&D and T2 through key performance indicators for research outcomes and their utilization, and 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.

- Coordinating the Department's response to Executive Orders and other T2 Administration mandates, such as the Presidential Memorandum, *Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses,* October 2011.

- Coordinating the Department's response to the President's Management Agenda, Cross-Agency Priority Goal #14—Lab to Market—by creating and chairing a working group for T2 and Evaluation/Performance Measures.

Highlights of specific programs or offices within OST-R that are crucial to its T2 efforts are provided next.

National Transportation Library

Established in 1998, NTL serves as a central clearinghouse for transportation data and information of the Federal Government. NTL is administered by the Bureau of Transportation Statistics, which is part of OST-R. Since 2013, NTL has been the centerpiece of U.S. DOT's response to the White House Office of Science & Technology Policy's memorandum titled *Increasing Access to the Results of Federally Funded Scientific Research*, 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.

NTL has recently created an all-digital collection of transportation resources called ROSA P. This repository is designated as the full-text repository for funded research under the Department's Public Access Plan. Content types found in ROSA P include text, links to websites, datasets, images, video, other multimedia, and maps.

Source: U.S. DOT.

Figure 2. The ROSA P logo.

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 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) 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 is meeting 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.

Volpe National Transportation Systems Center

Housed within OST-R, the John A. Volpe National Transportation Systems Center (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. 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. The Volpe Center provides OST-R with a broad range of assistance, including research and implementation, process analysis, process design, and communication. Other offices within the Volpe Center support the T2 efforts of the OAs.

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 Department's SBIR program is administered by the Volpe Center on behalf of the Office of the Secretary.

Source: U.S. DOT.

Figure 3. The logo of U.S. DOT's SBIR program.

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, education and workforce development, and T2. A T2 requirement was implemented for the UTCs in FY18. A total of thirty-five T2 plans have been developed by UTC grant recipients.

Lab to Market

In his "President's Management Agenda," President Trump established Cross-Agency Priority (CAP) Goals 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 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 to develop recommendations for future T2 efforts.

Annual Modal Research Plans

The FAST Act requires that each modal (operating) administration 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 a detailed outlook for the following fiscal year. The AMRP template that OST-R has provided to the OAs includes T2/Deployment and Evaluation/Performance Measures sections. In its AMRP, each OA must describe its planned T2 activities, performance measures, explain how those activities are coordinated within the OA, and indicate how resources are allocated.

Federal Aviation Administration

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 both 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. Other T2 mechanisms used by FAA are described below.

Deployment of New Airport Technology to Improve Infrastructure

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. Operational transition of the outputs of airport technology research is reflected in the engineering guidance and technical instructions contained in advisory circulars and the 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 incentivizes operator adoption and implementation and thus serves as a deployment strategy for research products.

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, which increases the likelihood of its eventual

commercialization. In FY 2018, FAA had 56 active CRADAs, including 5 new CRADAs that were established during the fiscal year.

Centers of Excellence

FAA's Centers of Excellence (COE) program conducts and transfers research in specific mission-critical topics. The COEs are established through cooperative agreements with the Nation's premier universities, members, and affiliates to conduct focused R&D and related activities over a period of 5 to 10 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 $300 million in matching contributions to augment FAA research efforts. Through long-term cost-sharing activities, the FAA leverages its RD&T resources while educating and training the next generation of aviation scientists and professionals.

Federal Highway Administration

The Federal Highway Administration (FHWA) has embraced a culture of innovation and actively supports and advances innovation across the entire breadth of its activities. 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 provide technical assistance to FHWA's State and local partners to deploy innovations.

FHWA works through multiple programs and initiatives to transfer technological improvements and innovative practices to State and local DOTs, which are responsible for much of the actual construction 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—the identification and development of innovative technologies and practices, and the transfer of innovation at the Federal, State, and local levels. *Approximately 10 percent of the agency's staff-years is spent on conducting technology transfer activities.*

Highlights of FHWA's T2 activities include:

- **Office of Research, Development, and Technology (RD&T):** The FHWA's Office of RD&T is located at TFHRC, a Federally owned and operated national research facility. The center houses more than 20 laboratories, data centers, and support facilities, and conducts applied and exploratory advanced research in vehicle-highway interaction, nanotechnology, and a host of other types of transportation research in safety, pavements, highway structures and bridges, human-centered systems, operations and intelligent transportation systems (ITS), and materials.

- **Every Day Counts (EDC):** The EDC program identifies and rapidly transfers and deploys proven-but-underutilized innovations to shorten the project delivery process, enhance

roadway safety, reduce congestion, and improve environmental outcomes. 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 chosen innovations. Through FY18, there have been four EDC rounds. Since the inception of EDC, each State has used 14 or more of the 43 EDC innovations, and some States have adopted more than 30 of them. Many of these innovations have become mainstream practices across the country.

- **Advanced Transportation and Congestion Management Technologies Deployment Program (ATCMTD):** ATCMTD awards competitive grants to develop model deployment sites for the implementation of cutting-edge transportation technologies. For FY 2018, the program awarded 10 grants totaling $53.2 million for projects ranging from advanced real-time traveler information to integrated corridor management and vehicle communications technologies.

- **Accelerated Innovation Deployment (AID) Demonstrations:** The 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. Through FY 2018, a total of 84 AID Demonstration grants worth over $60 million have been awarded.

- **State Transportation Innovation Council (STIC) Incentive program:** FHWA fosters collaboration between stakeholders within the transportation community through the STICs, which bring together public and private transportation stakeholders in each State to evaluate innovations and spearhead their deployment. The STIC Incentive program makes available 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 ITS 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 information technology applications, known as ITS. 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 deployers to ensure a smooth transition from initial adoption (seen as 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.

ITS Professional Capacity Building Program

The ITS PCB Program is responsible for the design, development, and delivery of educational opportunities to spur the deployment of ITS technologies. These activities keep transportation stakeholders informed about the advances in ITS technologies and how they can be applied to solve 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 PCB Program also works in partnership with professional associations, universities, and the training programs of U.S. DOT's modal administrations to engage the broad technical and organizational expertise needed to develop and deliver ITS learning. Some performance metrics of the ITS PCB's activities in FY 2017 and FY 2018 are shown in Table 8.

Table 8. Performance metrics for the ITS PCB Program, FY 2017 and FY 2018.

ITS PCB Activity	FY 2017	FY 2018
ITS PCB website	92,541 sessions (daily average: 254)	141,313 sessions (daily average: 387)
Webinars, online courses, and workshops	37 (3,032 attendees)	41 (3,972 attendees)
Archived and on-demand training content	46,042 users	42,131 users

Increasingly, the 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 and products.

A newer offering of the PCB Program is designed to assist the participants in U.S. DOT's three Connected Vehicle Pilots. This offering, known, as the Connected Vehicle Deployment Technical Assistance Program, is designed to assist the Connected Vehicle Pilots with interoperability. In 2018, the Connected Vehicle Pilot recipients gathered at TFHRC to test interoperability in staged scenarios on TFHRC's closed road course. In total, 102 interoperability test runs were conducted for four test cases.

Federal Transit Administration

The Federal Transit Administration's (FTA's) research activities are designed to respond to issues facing public transit systems today while also laying a foundation for their transitions to the future. Based upon industry feedback and the U.S. DOT strategic plan, 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—as this enables FTA to test promising research findings with public transit agencies. The evaluation of demonstration programs provides information on the results that FTA disseminates to encourage transit agencies to implement proven 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 disseminate research results. Information about research findings are shared through speaking engagements at key industry events. FTA publishes research reports and posts them on FTA's website. Social media venues such as the U.S. DOT Connections blog and posts on FTA's Facebook and Twitter accounts announce new reports and resources. FTA conducts webinars both in-house and through partner organizations.

FTA is increasing the uniformity of its activities to conduct and monitor research to practice activities across various programs. This includes the standardization of 'research to practice' language for Notices of Funding Opportunity, metrics for inclusion in Statements of Work, and in regular reporting on research results. FTA's research team is also beginning a new, quarterly deliberative process to target specific projects for L2M campaigns.

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, as well as the development of innovations and solutions. Safety is U.S. DOT's primary strategic goal and thus serves as the principal driver of FRA's RD&T program. FRA develops technology that is used by FRA's inspectors to enforce safety regulations. Other technology developed by FRA is 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. Taking the prototype to implementation of a commercial product is usually performed by suppliers to the rail industry.

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, CO, is managed and maintained by a wholly owned subsidiary of AAR. This 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 RD&T's research projects include the description of research results through technical reports that are published on FRA's eLibrary, making the results accessible to the railroad industry's stakeholders and the American 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 FY18, FRA RD&T amended its process and will begin to publish research to the NTL as part of its process to ensure material is widely available and searchable to increase the dissemination of FRA's reports. In FY18 FRA RD&T has planned to formalize T2 by piloting T2 plans to complement its research.

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 combat human behavior, 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, vehicle cybersecurity, and new and emerging technologies, including advanced driver assistance systems and automated vehicle technologies. NHTSA uses several strategies for deploying its research and technology results into practice. These range from technology demonstrations and field tests to consumer education programs.

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. This new deployment is called the Ann Arbor Connected Vehicle Test Environment (AACVTE). When completed, the AACVTE will be the world's largest operational, real-world deployment of connected vehicles and connected infrastructure.

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 the national Click It or Ticket program, the adoption of standardized field sobriety tests by law enforcement officers, and passage of primary seat belt and distracted-driving laws. In FY 2018, NHTSA completed the first phase of the "Fatigue in Emergency Medical Services (EMS) Systems." The overall goal of this project was to develop, test, and disseminate evidence-based guidelines for fatigue risk management tailored to the EMS setting.

Vehicle Research and Test Center

Staff at the VRTC, NHTSA's in-house laboratory, conduct research and vehicle testing in support of 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; agency consumer information programs; test dummy development; injury criteria development; advanced research into cutting-edge technologies; and safety issues that require quick reaction or are sensitive in nature, including defect investigations. The full range of testing and research capabilities available to NHTSA at VRTC allows the agency to maximize its testing capabilities to study emerging safety issues more rapidly and provide benefits to the American public more 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.

Federal Motor Carrier Safety Administration

The Federal Motor Carrier Safety Administration's (FMCSA's) primary mission 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 the following programs and activities:

- **Research and Technology (R&T) Program:** FMCSA's R&T program develops the knowledge, practices, and technologies needed to solve problems and answer questions that arise in prioritizing enforcement resources and improving 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 vehicle (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.
- **Innovative Technology Deployment (ITD) Grant Program:** The ITD program is FMCSA's key mechanism for transferring proven enforcement technologies into operational systems for the States. The program provides funding for States to deploy, support, and maintain CMV information systems and networks. 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. FMCSA's State partners are also using the ITD grant program to refine and deploy safety systems for fleets such as work-zone warning systems.
- **Automated CMV Research:** FMCSA conducts research to accelerate the testing and deployment of proven safety technologies (e.g., 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.

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 in the United States. 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 actions that the researcher must take to promote project results. Mandated actions include promoting commercialization at the end of the contract. One method of doing so is to demonstrate a technology in front of pipeline operators, equipment vendors, standards organizations, and pipeline safety officials. PHMSA considers a demonstration to be just one stage in the T2 process, but it is a major milestone along the path to achieving an ultimate research goal. In addition, all technical reports produced through PHMSA-sponsored research are promoted to decision makers and stakeholders via trade journals, public conferences, or other industry events.

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 develop and carry out projects that provide all stakeholders 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 the industry.

Technology testing, validation, and verification is a fundamental part of the META program. Much of the work supports T2 opportunities and the distribution of information about the costs, benefits, and performance of technologies to assist industry in making decisions regarding capital investments and choosing among technology options that best fit their operations. 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.

Test results, reports, studies and industry guidelines are available through MARAD’s 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.

Success Stories

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

Federal Transit Administration

Valley Metro Pass2Go Phone App Pilot

Valley Metro of Phoenix, Arizona, recently launched a pilot program called "Pass2Go" that allows riders to pay for light rail and bus rides via a smart phone-based application (app). The app allows riders to download a mobile pass, do trip planning, and connect to other mobility services. Valley Metro received a $1 million Mobility on Demand (MOD) Sandbox discretionary award from FTA in 2016. This pilot is part of the first phase of the FTA Sandbox project.

Source: Valley Metro.

Figure 4. Screenshot from the Pass2Go app.

FTA's MOD Sandbox Demonstration Program provides a venue through which integrated MOD concepts and solutions—supported through local partnerships—are demonstrated in real-world settings. FTA seeks to fund project teams to innovate, explore partnerships, develop new business models, integrate transit and MOD solutions, and investigate new, enabling technical capabilities such as integrated payment systems, decision support, and incentives for traveler choices. The MOD Sandbox also provides FTA the opportunity to measure project impacts and assess how existing FTA policies and regulations may support or impede these new service transportation models through evaluation of all project efforts.

During the free Pass2Go pilot program, users will only be able to purchase full-day passes. Those will be good for all of the city's bus services—including express and rapid lines—along with the train. The app was also integrated with both Lyft and Uber, along with the GriD Bike system, to help people get from one place to another without having to use an automobile.

The app seeks to make traveling across the Phoenix area simpler. Users can enter their start and end points and the app will create a trip itinerary for them. The agency will take what it

learns from the pilot and apply it to its current app, RideKick. Several hundred people will take part in the testing phase.

Valley Metro-Waymo Automated Vehicle Pilot

In July 2018, Valley Metro of Phoenix, Arizona, announced a partnership with Waymo to provide mobility services via automated minivans to participating ambulatory customers of Valley Metro's RideChoice program. The RideChoice program is for paratransit-certified people with disabilities and seniors age 65 and above who reside in participating communities. Valley Metro is a strategic partner of FTA under the Strategic Transit Automation Research Program. FTA is providing funding for the data collection and analysis portion of this pilot.

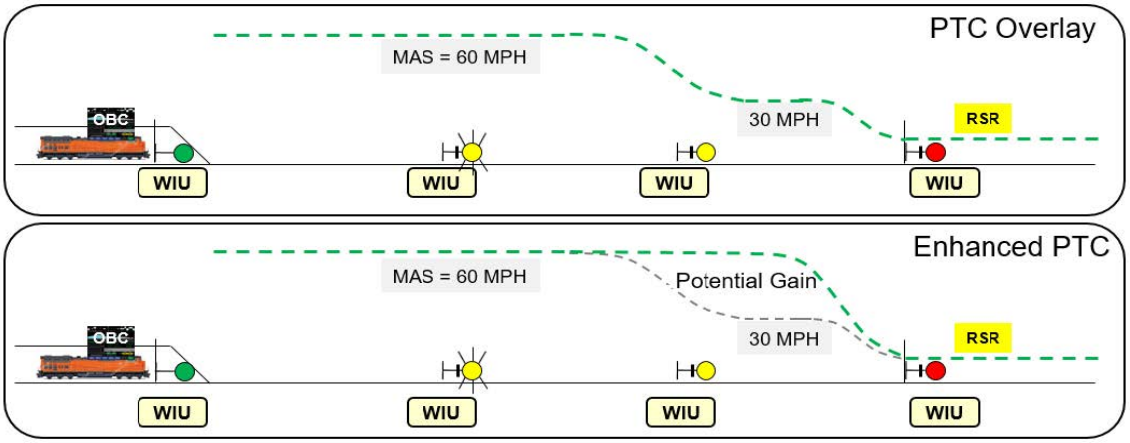
The program will focus on delivering people to bus stops and train and light-rail stations. The program initially will be offered to employees of Valley Metro. These riders will be able to use the Waymo app to hail a ride in one of the company's autonomous minivans to take them to the nearest public transportation option. Waymo will expand the program and provide first-and-last mile travel to Valley Metro RideChoice travelers.

FTA, Valley Metro, and Waymo hope to learn more about how people use public transit and what role self-driving vehicles can perform in connecting people to the buses, trains, and light-rail systems found in cities.

Federal Railroad Administration

Enhanced Overlay Positive Train Control

Traditionally, the speed of a train is reduced at approach (yellow) signals in anticipation of having to bring the train to a stop at an upcoming red signal. With the implementation of positive train control (PTC), it is now possible to control a train's approach speed based on onboard adaptive braking curves instead of wayside approach signals. Using onboard adaptive braking curves to control a train's speed can measurably improve rail network efficiency and capacity. Figure 5 shows the potential gain in efficiency by enabling trains to travel at higher speeds for longer periods.



Source: FRA.

Figure 5. Potential efficiency gains from enhanced overlay positive train control.

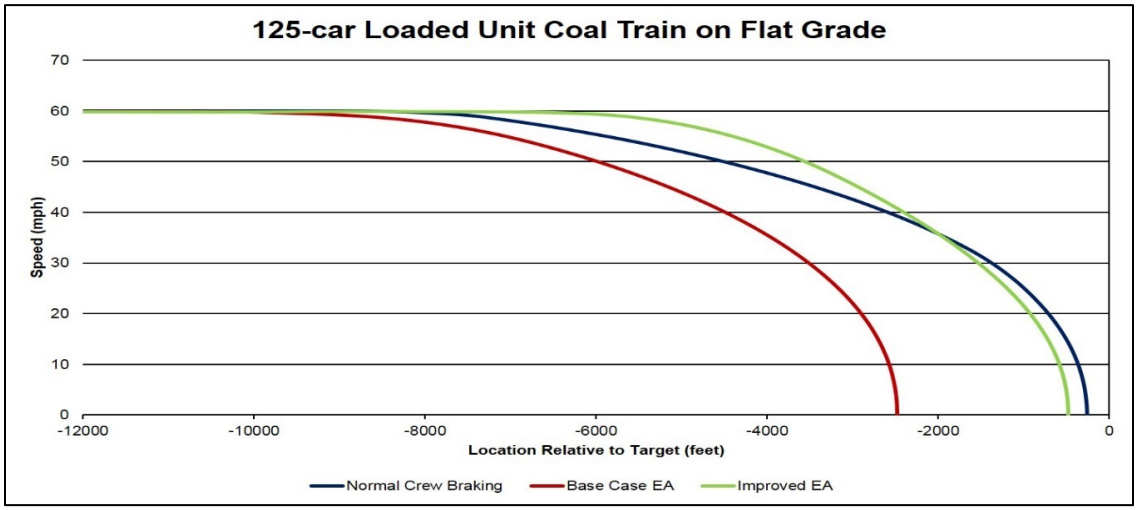
In 2017, FRA contracted with Transportation Technology Center Inc. to develop a conceptual implementation of enhanced overlay positive train control (EO-PTC). This research was done in collaboration with the Train Control Communication and Operation committee of the Association of American Railroads. At least two Class I railroads have made changes to their operations in 2018 based on the EO-PTC research. Other railroads are considering implementation of a Quasi-Moving Block signaling system, which is an evolution of the EO-PTC concept and the subject of ongoing research by FRA.

PTC Braking Algorithm

PTC is an emerging train control technology intended to enhance safety. The underlying concept of the technology is that movement authorities and speed restrictions are transmitted digitally to the controlling locomotive of each train. The locomotive monitors the train's location with respect to its authority and speed limits. It then automatically applies brakes to prevent the train from violating any limit in the event of human failure. A necessary element of PTC is a braking algorithm that can accurately predict how a train's speed and stopping distance will respond to automatic applications of the brakes.

Evaluating the modeled performance of braking algorithms for freight trains was once a months-long process, which slowed the rate at which railroads could implement improvements in those algorithms. In 2018, FRA funded the development of improved evaluation methodologies for PTC braking algorithms, which were then added to the capabilities of the PTC Test Bed and the Transportation Technology Center in Pueblo, Colorado. U.S. railroads (including all seven Class I freight railroads operating in the U.S.) and suppliers are actively using the PTC Test Bed and the subject methodologies to refine the performance of their PTC systems. With the improved evaluation methodologies, a standard set of modeled scenarios can be completed in a matter of days, accelerating the implementation of improvements to braking algorithms.

Figure 6 shows the potential gain in efficiency by enabling trains to travel at higher speeds for longer periods. In the figure, EA stands for Enforcement Application, which is the train speed at which PTC will enforce and deploy the brakes if the train operator ignores the PTC enforcement warning. The difference between the green and red curves shows the improvement that was achieved as a result of FRA's R&D.



Source: FRA.

Figure 6. Speeds and stopping locations for different braking methods for a freight train.

Predictive Analytics Using Autonomous Track Geometry Measurement System Data

Autonomous track inspection is a process in which the track is inspected using unattended instrumentation with minimal direct involvement from human operators. FRA envisions the widespread use of relatively low-cost, self-powering geometry measurement systems that are adaptable on a wide range of rail vehicles. Deployment of such measurement systems would:

- Increase inspection frequencies and productivity
- Eliminate the interference of track inspections with revenue operations
- Reduce the life-cycle costs of geometry measurement operations, and
- Provide data of the highest quality possible to support performance analysis and preventative maintenance.

Between 2008 and 2016, FRA conducted a multi-stage research program focused on the advancement and demonstration of an autonomous track geometry measurement system (ATGMS). FRA's demonstration of this technology has led to implementation of ATGMS for routine track evaluations by North American railroads. Most Class I railroads are using or actively procuring ATGMS vehicles, with more than 20 vehicles estimated to be in service currently. This hardware implementation of the FRA ATGMS technology completes one component of the industry's vision to inspect track using unattended instrumentation with minimal direct involvement from human operators.

Source: Ensco.

Figure 7. ATGMS installed on rail car operated by Metro North Railroad.

It is critical that the data generated with this autonomous inspection technology be used to generate actionable information that improves safety. In the fall of 2018, FRA initiated a cooperative research program with Metro North Railroad to develop and demonstrate automated processes to assess track geometry data collected through regular use of ATGMS. Track data collected daily by the railroad's ATGMS fleet will be automatically processed to provide continuous trending of track deterioration rates. Researchers will use several techniques, including predictive analytics, to evaluate and forecast changing track conditions. This data will provide the basis for scheduling preventative maintenance to address track issues before they become urgent safety concerns. The cooperative program is expected to serve as an example of improvements to maintenance practices and derailment risk reductions that can be realized with the use of autonomous inspection technology and automated processing techniques.

FRA Collaborates with Short Line Safety Institute for Safety Culture Assessments

The nation's short line railroads provide the first- and last-mile service for one in five cars moving in the United States each year. For large areas of rural and small-town America, short line and regional railroads (Class II and Class III) are the only way shippers can be directly connected to the national rail network, which helps businesses and employment stay local. In general, these railroads have limited resources; they are small businesses usually located in rural areas.

To improve the safety of these railroads, FRA partnered with the American Short Line and Regional Railroad Association (ASLRRA) in 2014 to develop the Short Line Safety Institute (SLSI). SLSI is a non-profit organization that has received Federal funding to help strengthen safety and safety culture in all short line and regional railroads, not just those represented by ASLRRA.

SLSI employs research-based practices and pilot-tested stakeholder engagement strategies to help small railroads perform at higher levels of safety. SLSI reaches industry stakeholders through safety culture assessments, technical tools, technical assistance, and peer exchanges. During FY18 alone, SLSI conducted 21 safety culture assessments that engaged approximately

963 short line and regional railroad employees (management and non-management). In addition to safety culture assessments, SLSI carries out the congressional mandate to build a stronger, sustainable safety culture in Class II and III railroads by:

- Providing no-cost training and education (e.g., webinars) on safety and safety culture improvement, and
- Providing railroads with communications materials (e.g., safety briefing templates) that they can use onsite with all employees.

Source: FRA.

Figure 8. Safety culture assessments by year.

Operationalizing U.S. DOT's 10 Core Elements of a Strong Safety Culture[1] in its safety culture assessment process, SLSI engages railroads that are willing to open themselves up for examination and self-improvement in service to the SLSI mission for the short line and regional railroad industry to perform at an increasingly higher level of safety.

National Highway Traffic Safety Administration

Development of a Vehicle-Centric Security Credential Management System

Connected vehicle applications will rely upon the exchange of information among vehicles, roadway infrastructure, traffic management centers, and wireless mobile devices. This cooperative exchange of messages generates data that applications use to issue alerts and warnings to drivers about the driving situation around them. It also enables applications to determine mobility and environmental conditions. However, a cooperative system can only work when drivers are able to trust the alerts and warnings issued by their connected-vehicle devices, which are based, at least in part, on information received from other connected-vehicle devices.

To ensure safety and the protection of privacy, a security credential management system (SCMS) is needed to enable users to determine the validity and integrity of information received from other system users. In collaboration with a consortium of automotive original

[1] FRA, 2017; https://www.fra.dot.gov/eLib/details/L18784.

equipment manufacturers (OEMs), the Department designed and developed a proof-of-concept SCMS for V2V and vehicle-to-infrastructure communication. Development of this proof-of-concept helped spur the development of private-sector security solutions that are now serving the marketplace.

As of August 2018, multiple technology companies are leveraging the technological lessons from the SCMS proof-of-concept to provide commercial services to automotive companies that are deploying vehicle-to-everything (V2X) technology. Such commercial services did not exist prior to the Department's R&D of the SCMS proof-of-concept. The SCMS proof-of-concept is also being used for FHWA-funded deployments of V2X, including the Connected Vehicle Pilot sites and participants in the ATCMTD grant program.[2]

Consensus-Based Standards Published for Connected Vehicles and Infrastructure

The Department, in collaboration with a consortium of automotive OEMs, conducted technical research to address remaining interoperability issues in preparation for deployment of connected-vehicle safety applications using DSRC. This technical research[3] allowed standards organizations (including SAE International and IEEE) to publish a set of industry-approved standards for connected infrastructure and vehicles to ensure interoperability across manufacturers. Furthermore, this research also provided a foundation for the eventual development of cellular V2X (C-V2X) radio communications technology by providing test procedures, baseline results, and lessons learned from development of DSRC. In 2018, many of the existing DSRC standards are being reused to establish parallel standards for C-V2X technology, thus accelerating development of this alternative technology.

Connected Vehicle and Infrastructure Certification Services

For connected vehicle and infrastructure devices to be deployed widely across the country, it is important that an industry-accepted certification process exist. This certification process will ensure that the devices conform to the voluntary standards established by the SAE International and IEEE for connected vehicles and infrastructure devices. In 2018, the U.S. DOT established cooperative agreements with three test companies (7 Layers, Danlaw, and Southwest Research Institute) to develop a suite of test procedures for connected infrastructure and vehicle devices. Once developed, these test procedures were made publicly available and were used as the basis for developing commercial certification services for connected vehicle and infrastructure devices.[4] Because of this research, the OmniAir Consortium has developed commercial-based (for-fee) certification services to support the deployment of V2X technology.[5]

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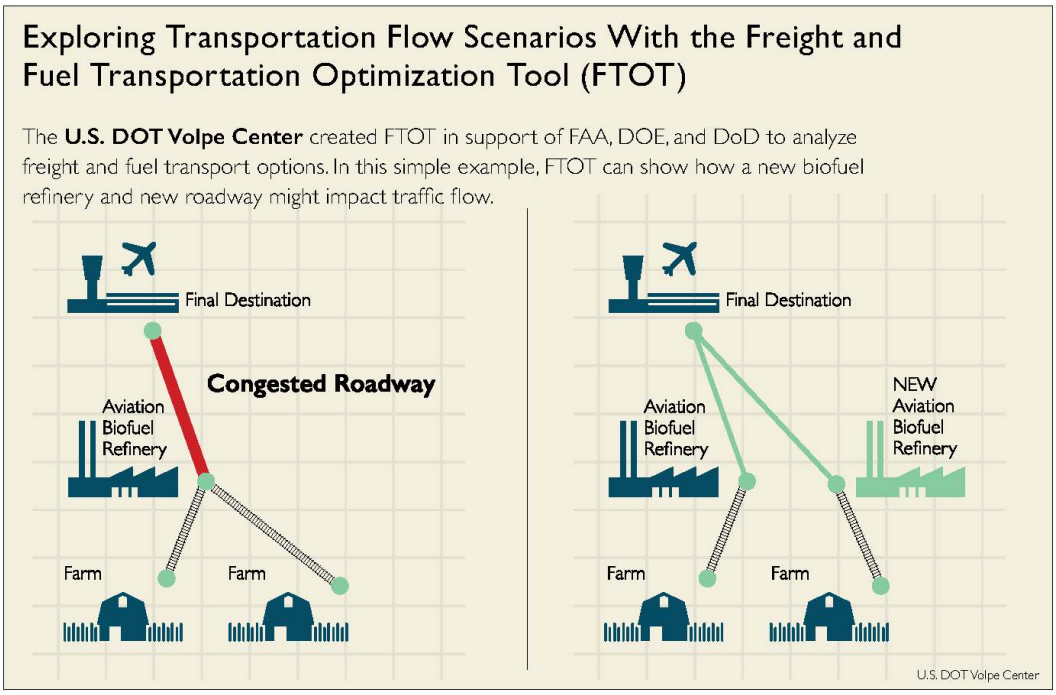
[2] Two companies offering SCMS services as of August 2018 include Green Hills (https://www.ghs.com/products/auto_secure_connect.html) and ESCRYPT (https://www.escrypt.com/en/products/cycurv2x-scms).
[3] V2V-I Phase 2 Final Report.
[4] https://github.com/certificationoperatingcouncil/COC_TestSpecs.
[5] https://omniair.org/services/connected-vehicle-certification/

Pioneering 5.9 GHz Spectrum Research to Advance Spectral Efficiency

The 5.9 GHz spectrum is currently allocated by the Federal Communications Commission (FCC) for ITS applications using DSRC. The U.S. DOT is collaborating with the FCC and the National Telecommunications and Information Administration (NTIA) to evaluate whether the 5.9 GHz spectrum can be safely shared with unlicensed Wi-Fi devices—thereby advancing the efficient use of this limited resource. In 2018, the three agencies collaboratively developed a three-phase test plan, and the FCC has completed the first phase.[6] Phases 2 and 3 of the test plan will explore potential sharing solutions under more real-world conditions. The Department has also conducted research with the U.S. Army and the automotive OEMs to analyze the potential impact of Wi-Fi devices in the 5.9 GHz spectrum. This research has informed both NTIA and FCC in our collaborative testing efforts to determine if and how the spectrum can be shared without interference.

Volpe National Transportation Systems Center

Freight and Fuel Transportation Optimization Tool Evaluates Transport Scenarios



Source: U.S. DOT Volpe Center.

Figure 9. Examples of freight flow scenarios analyzed by the FTOT tool.

The U.S. economy depends on the efficient movement of goods, including critical energy commodities. Government agencies are working to understand potential changes in freight movements and the associated impacts. To analyze freight and fuel transport scenarios, the

[6] Letter to Congress proposing the test plan: https://apps.fcc.gov/edocs_public/attachmatch/DOC-337251A1.pdf; FCC Phase 1 test plan: https://transition.fcc.gov/oet/fcclab/DSRC-Test-Plan-10-05-2016.pdf.

U.S. DOT's Volpe Center created the Freight and Fuel Transportation Optimization Tool (FTOT) on behalf of FAA, the Department of Energy, and the U.S. Navy's Office of Naval Research.

FTOT draws on a range of data to help government agencies analyze options for moving freight and fuels and hone in on optimal multimodal transportation flow patterns. The tool also estimates the emissions associated with potential freight and energy scenarios. Users can explore how potential changes in production and demand will affect those optimal patterns. In addition, users can evaluate how future infrastructure scenarios—such as the gain or loss of transportation links, or changes in the capacity of roadways or other modes—will affect a given route, and apply what they learn to freight planning.

Analyses with FTOT have been used in several peer-reviewed journal articles. One recent article discusses the potential for reaching a billion gallons of domestically produced alternative jet fuel from waste materials by 2030, which would contribute to energy security and environmental performance in the aviation sector. Volpe experts used FTOT to optimize the movement of raw materials and fuels in these future deployment scenarios to show flow patterns, potential delivery points, transportation-related costs, and modal options.

In the past, Volpe has used FTOT to analyze greenhouse gas lifecycle emissions and water usage impacts from transportation flows of canola-based alternative jet fuel. FTOT has also been used to explore potential effects of lock renovations on the flows of coal and crude oil, and analyzed potential flows and delivery patterns for alternative jet fuel. Volpe's ongoing FTOT analyses are investigating agricultural and alternative jet fuel supply chains in the southeastern U.S. and other regional-scale supply chains, crude oil movements and potential changes, and long-range freight planning.

In 2018, the Volpe team continued to enhance FTOT's suite of capabilities and is working toward a publicly releasable version of the tool, expected in 2019.

Reducing Helicopter Noise for Communities

Noise from low-flying helicopters is an issue for many communities. In particular, metropolitan areas such as New York City and Los Angeles face challenges in reducing noise from helicopter tours, charters, and emergency operations. One way to reduce helicopter noise is with noise abatement techniques. However, developing noise abatement techniques for helicopters is challenging because the noise characteristics of rotorcraft are more complex than those of fixed-wing aircraft.

On behalf of FAA, the U.S. DOT's Volpe Center developed and scientifically validated noise abatement techniques for helicopter operations. Volpe experts partnered with FAA and the National Aeronautics and Space Administration (NASA) to develop and test helicopter noise abatement procedures. The team produced situational awareness tools and developed and conducted online and in-person training forums and courses for pilots and operators through FAA's WINGS Pilot Proficiency Program. Educational resources include videos that let students visualize noise from flight maneuvers through noise exposure heat maps generated by the helicopter flight path and overlaid on cockpit video footage. The Helicopter Association International, an FAA cooperating partner, initiated the pilot training concept—called Fly

Neighborly—to improve relationships between communities and helicopter operators using noise mitigation techniques and proactive communications.

Several U.S. airports have already adopted noise abatement procedures. Volpe is now developing a Fly Neighborly demonstration program to improve trainings, which may lead to wider adoption of flight techniques that reduce helicopter noise. Eventually, noise abatement guidance may be incorporated into mandatory FAA flight training for pilots.

With greater industry use of noise abatement procedures, helicopter industry growth can continue without a commensurate increase in public complaints and the potential burden of increased regulation and operational limits. The result will be more opportunities to provide essential helicopter transportation, emergency, and other services for tourism, offshore energy development, news media, and first responder industries.

A Safer Way to Access Freight Locomotives

U.S. DOT's SBIR program, which is managed by U.S. DOT's Volpe Center, awards contracts to American small businesses to develop and deploy innovative solutions to our Nation's transportation challenges. With support from the SBIR program and FRA, GS Engineering, Inc., developed and tested a system that makes accessing freight locomotives easier and safer for railroad engineers and workers. Railroad engineers and workers access freight locomotives every day. This can be difficult and dangerous because of tall steps, slippery conditions, and uneven or debris-covered ground. Considering those challenges, and that the rail workforce is aging, there are many chances for injury.

Source: GS Engineering, Inc.

Figure 10. An operator accessing a locomotive with (right) and without (left) the Locomotive Access System.

GS Engineering developed the Locomotive Access System to eliminate the large first step and reduce additional steps needed to board a train. This innovative access system first lowers a platform closer to the ballast level. The operator then boards the platform rising to the full deck height of the locomotive. The system also works as a conventional staircase that meets FRA and

industry standards. The technology ensures safe access to a locomotive if there is a power or other system failure, and no special training is needed to use it.

The Locomotive Access System is available as a retrofit kit for AC4400 locomotives, and the company is developing compatibility with other locomotive models. The company has established quality controls and a supply chain that can produce the Locomotive Access System at commercial scale. The company will market the systems as retrofit kits, with an emphasis on Class II and III railroads. However, the company's long-term goal is to offer the system for purchase directly from locomotive manufacturers. The SBIR program gave GS Engineering, Inc. the financial flexibility to hire talented engineers to help develop the product. The award also presented an opportunity to leverage existing skills and expertise to expand in the rail industry.

Detecting Damage in Structural Components with New Infrared Technologies

Deterioration in bridges and other structures commonly manifests from subsurface damage that cannot be detected through visual inspections. Once the subsurface damage is observed through visual inspection, deterioration has advanced to a stage where significant repairs or even replacement may be required. Technologies that can detect the onset of deterioration in its earliest stages allow for prompt detection and repair that can save money and improve safety.

With support from FHWA and U.S. DOT's SBIR program, Fuchs Consulting, Inc. (FCI) has developed a suite of infrared-based technologies that assess the condition of paint coatings, create images of subsurface damage in concrete, and measure the level of stress in steel. The suite of technologies developed by FCI addresses the need for early detection of damage and provides unique new measurements that were not previously achievable. The resulting data are then used by infrastructure owners to inform key decisions on maintenance and repairs.

The ability of ThermalStare infrared technologies to accurately detect and image subsurface damage in concrete has improved decision making for highway bridge maintenance, repair, and rehabilitation. Operating without the need for traffic control, the new technology reduces the cost and disruption associated with detailed condition assessments while providing more accurate information on hidden damage below the surface. The data's accuracy can help avoid the cost and disruption caused by project overruns and allow for early intervention to reduce repair needs.

In 2018, the ThermalStare infrared technologies were being used by State DOTs, engineering companies, and military agencies to meet their most challenging inspection and condition assessment needs. New and innovative applications are being developed that capitalize on the unique capabilities of the infrared-based technologies. The SBIR program provided resources to develop, refine, and implement instrumentation that makes it possible for the ThermalStare infrared systems to be produced and sold commercially in the United States and abroad.

Federal Highway Administration

Partially Automated Truck Platooning Demonstration

Fuel consumption of commercial trucks is significantly influenced by air resistance at highway speeds. FHWA's Exploratory Advanced Research (EAR) program, administered by TFHRC, has sponsored research on technologies that enable long-haul trucks to travel together more closely in a "platoon," which reduces aerodynamic drag and improves fuel economy. Even small improvements in fuel efficiency can have a significant payoff given the large number of miles traveled by long-haul trucks in the U.S. each year. This research has been performed by partnerships that include truck manufacturers and university researchers.

The EAR Program seeks to combine single-vehicle adaptive cruise control with additional onboard sensors and V2V communication to exchange information between the trucks and automatically adjust engine and brakes in real time as conditions vary. This system, known as cooperative adaptive cruise control (CACC), exchanges operational information between the trucks and can automatically adjust engine and brakes to maintain longitudinal control (speed and separation distance). Drivers are responsible for lateral control (steering and lane-keeping) and monitoring roadway and traffic conditions. The system makes it possible for the CACC-equipped trucks to travel closer together with more precise control than manual operations alone, thus allowing for potential fuel savings.

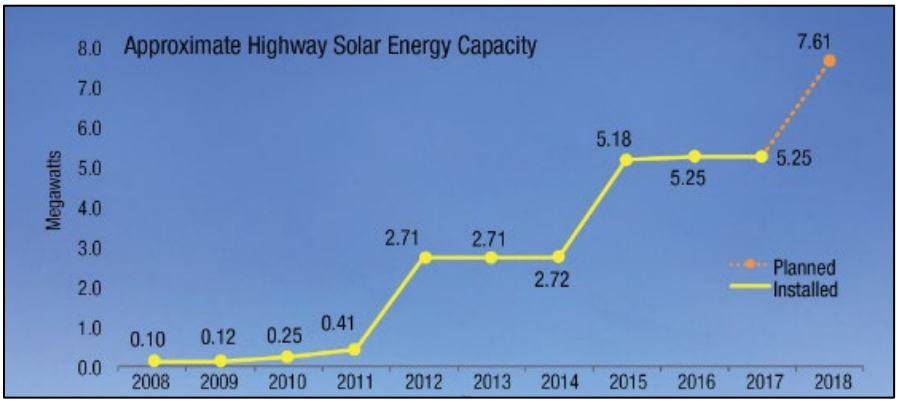
Source: FHWA.

Figure 11. Demonstration of three-truck platoon on I-66 in northern Virginia.

After four years of research, FHWA and numerous project partners conducted a demonstration of three-truck platoons on I-66 in northern Virginia and continued to analyze the results in FY18. FHWA is continuing to fund research and engage the trucking industry to identify and answer the key issues that must be addressed prior to market introduction of heavy truck CACC.

Renewable Roadsides

With support from FHWA, an increasing number of State DOTs have chosen to meet a portion of their electricity needs by installing solar energy projects in highway right-of-way (ROW) or at other State DOT facilities. Several factors are contributing to this trend. State highway departments have high electric bills from lighting roads and operating maintenance facilities. At the same time, they also own acres and acres of highway ROW where solar energy installations can be located. In addition, the price of solar photovoltaic systems has decreased significantly in recent years, making solar power more competitive with conventional sources of electricity. Finally, some State DOTs are required by State law to reduce their emissions of greenhouse gases, and the use of solar power for electricity is one way to do just that.



Source: FHWA.

Figure 12. Approximate solar capacity installed and planned along U.S. highways.

State DOTs are already seeing the benefits of installing solar power on highway ROW or at other DOT properties. As of August 2018, eight solar installations for Massachusetts DOT (MassDOT) had produced a total of 10,750 megawatt-hours of electricity. That amount has resulted in net savings to MassDOT of more than $1 million. Going forward, MassDOT expects to save approximately $525,000 annually, in addition to the $75,000 received in annual lease payments for the sites. Maryland DOT expects its 35 solar sites will generate 46,000 megawatt-hours per year, approximately 12 percent of its annual electricity usage. Maryland DOT estimates that is getting electricity cost savings of 30 to 40 percent.

FHWA supports highway renewable energy by developing resources and funding peer exchanges where agencies can learn about efforts to implement renewable energy projects. In 2017 and 2018, FHWA held four of these peer exchanges in different parts of the country; summary reports for these peer exchanges are available on the FHWA website. Also available on the FHWA website are several references, such as a quick guide to FHWA's requirements on the use of highway ROW for renewable energy generation. FHWA has also compiled examples of lease agreements, power purchase agreements, request for proposals, and other related documentation that agencies have used to implement highway renewable energy projects. Resources are available at www.fhwa.dot.gov/real_estate/right-of-way/corridor_management/alternative_uses.cfm.

A New View for Bridge Inspectors

First-person view (FPV) goggles (paired with drones) are poised to become the next evolution in drone use for inspecting superstructures. Connected directly to a drone's video feed, the goggles give bridge inspectors a first-person visual that is equivalent to being about three feet away from the components they are inspecting. The technology has potential to enable inspectors to visually examine bridge components easily and with enough precision to see even hairline cracks in the field. It offers these benefits without requiring standard inspection techniques, such as using ladders, climbing equipment, or bridge inspection vehicles.

With funding from the FHWA Director of Field Services' T2 program, FHWA's Minnesota Division Office first tested the utility of a consumer-level drone for routine bridge inspections. The Minnesota team tested the drone on two rural bridges in the State. The initial testing showed that the approximately $1,000 drone ($2,300 full system) did meet the basic requirements to supplement routine bridge inspection practices.

The team successfully requested follow-on T2 funding to purchase FPV goggles for testing in combination with a drone. The team found that the combination of the drone's high-definition camera and the high-definition displays in the goggles provides live images that are so immersive and clear that inspectors have the ability to identify defects, even hairline cracks. It offers these benefits without requiring standard inspection techniques, such as using ladders, climbing equipment, or bridge inspection vehicles, which can be costly and potentially hazardous.

After this second demonstration, the Minnesota Division started a presentation and outreach program. In 2017, division staff gave the presentation and demonstration during 10 meetings, reaching about a third of the 87 counties in Minnesota. This led to an invitation to present the topic at the winter conference of the Minnesota County Engineers Association in 2018. As a result of these outreach efforts, several Minnesota counties have purchased drones with FPV goggles to use during routine bridge inspections or to document road construction.

The Minnesota Division is continuing to demonstrate the benefits of this technology. They have presented at a meeting of the National Association of County Engineers as well as State-level meetings of county engineers in neighboring States. Division staff are also assisting with the promotion of unmanned aerial systems as part of the fifth round of FHWA's Every Day Counts initiative.

Office of Operations R&D Keeps Traffic Flowing with Good CARMA

Cooperative Automation Research Mobility Applications (CARMA) is an open-source software platform initiated by FHWA's TFHRC to enable the testing and evaluation of cooperative automation concepts for improving safety and increasing infrastructure efficiency. The CARMA platform equips vehicles with the ability to interact and cooperate with infrastructure and other vehicles. By doing so, CARMA facilitates the research and development of cooperative interactions by infrastructure owner-operators and the automotive industry.

CARMA started in 2014 with the development and implementation of the initial proof-of-concept software platform, CARMA1. The current version, CARMA2, is now available on GitHub,

a software development platform. CARMA3 kicked off in August 2018 and will be developed in the open using agile software development.

Source: FHWA.

Figure 13. Vehicles testing CARMA's capabilities.

The CARMA2 platform includes plug-ins that support the following cooperative driving tactics:

- Vehicle Platooning—Enable collaboration between vehicles at close range in a single lane to save fuel and reduce roadway usage.
- Speed Harmonization—Follow dynamic speed commands from a cloud server that measures traffic and determines upstream speeds to minimize traffic jams and limit back-end congestion.
- Cooperative Lane Change and Merge—Coordinate with vehicle in a lane to the left or right to make space to merge and change lanes.
- Multi-intersection Approach and Departure—Cooperate with traffic signal infrastructure to safely approach and depart intersections that are enabled with Signal Phase and Timing.

Pipeline and Hazardous Materials Safety Administration

Natural Gas Pipeline Leak Rate Measurement System

Small leaks in natural gas pipelines may not pose immediate safety hazards, but they do allow the release of methane, a potent greenhouse gas, into the atmosphere. Government and industry collectively identified as a research need the development of technologies that can rapidly and cost-effectively detect low-level leaks and provide a direct measure of the rate at which natural gas is leaking. Direct measurement of leak rates allows pipeline operators to prioritize repairs that will reduce methane emissions the most.

To address this need, PHMSA co-sponsored with a commercial partner a project to develop survey technologies and methodologies to locate and quantify fluxes of non-hazardous natural gas leaks.

This project successfully demonstrated a Remote Methane Leak Detector™ system that can be deployed on vehicles to detect pipeline gas emissions. This technology is able to distinguish

between pipeline gas and other gas emission sources. The ability to survey quickly for gas leaks and distinguish gas emission sources, coupled with the sensitivity of the instrument to detect gas, is a technological success. The contractor has further developed a graphical user interface and software designed to promote ease of use and accessibility of information to pipeline operators.

This DOT-funded research, which concluded in FY 2018, has generated much interest from the gas survey industries and has led to additional and complementary field tests funded by public utilities and other industry stakeholders.

Lithium Battery Safety

Lithium batteries pose unique challenges because, unlike other hazardous materials, they contain both a chemical and an electrical hazard. This combination of hazards, when involved in a fire encompassing significant quantities of lithium batteries, poses challenges related to thermal runaway and toxic inhalation hazards, and has previously exceeded the fire suppression capabilities of aircraft, leading to catastrophic airframe failure.

For this reason, PHMSA entered into research agreements with the Naval Research Laboratory (NRL) and the Naval Surface Warfare Center Carderock (NSWCC). NRL research focused on the identification of trigger mechanisms of lithium-ion battery cell failure related to the formation of internal short circuits caused by lithium dendrites (also known as thermal runaway). NSWCC performed research into large-format batteries, internal short circuit mechanisms, and failure analysis. These projects aligned with DOT's strategic goal of safety by implementing a systematic safety approach to analyze and mitigate the risks associated with the transport of lithium batteries. The projects also resulted in risk management tools and new packaging materials and configurations to address these risks. The multiyear projects, conducted from FY 2016 to FY 2018, were extremely successful.

Highlights included the assessment of current air transport regulations limiting lithium-ion battery quantities to 35 kg per package (for cargo aircraft). The project identified when criteria for conducting shock testing on large-format batteries become unrealistic in a transportation environment.

Additional accomplishments include:

- Evaluating existing early-failure detection devices for transportation applications
- Improving understanding of lithium battery failure mechanisms, such as internal short and over-discharge, and the physical interaction of dendrite and polymer separators, which can mitigate lithium battery internal short-circuits
- Developing testing protocols that enhance, initiate, or simulate the internal shorting caused by lithium dendrites, and
- Identifying and assessing factors that contribute to battery failure in transport through abuse testing (specific abuse tests included high temperature abuse, overcharge, over-discharge, and short circuit).

Research outcomes included guidance for shippers and manufacturers on lithium battery transportation safety (short circuit causes, new packaging, etc.), as well as testing protocols to enhance, initiate, or simulate the internal shorting caused by lithium dendrites. The project identified next-generation battery and packaging materials for cylindrical cells and shipping containers and developed a lithium battery health-monitoring device to anticipate issues with battery shipments without affecting packaging capacity and weight (i.e., a battery tester that can be used to test the health of batteries in transport).

Federal Aviation Administration

FAA William J. Hughes Technical Center Flying Laboratory Sikorsky S76A Helicopter

In collaboration with industry, academic, and government partners, the FAA operates a one-of-a-kind national flying laboratory resource. The Sikorsky S76A helicopter performs flight testing in support of aviation research activities to improve helicopter safety. Research projects using the S76A helicopter support FAA and United States Helicopter Safety Team initiatives, including Helicopter Flight Data Monitoring for Aviation Safety Information Analysis and Sharing, Enhanced Helicopter Vision Systems, and other efforts. The S76A helicopter is instrumented with the latest recording technology for audio, video, and flight data, including dozens of cameras, cockpit microphones, flight data recorders, enhanced vision systems, and head-worn displays. As shown in Figure 14, the Federal Lab Consortium for Technology Transfer (FLC) showcased the Sikorsky S76A helicopter in its 2019 FLC Planner.

Source: Federal Lab Consortium for Technology Transfer.

Figure 14. Description of the Sikorsky S76A Helicopter in the 2019 FLC Planner.

CAMI - Aerospace Medical Research Division - Forensic Toxicology

The Civil Aerospace Medical Institute (CAMI) is the medical certification, education, research, and occupational medicine wing of the Office of Aerospace Medicine under FAA's Office of Aviation Safety. The forensic laboratory at CAMI receives biological specimens from fatal aviation accident victims for toxicological evaluation. Postmortem fluids and tissues are analyzed for the presence of over-the-counter prescription and illicit drugs, and toxic combustion gases. Results from such testing (illustrated in Figure 15) are used to aid in the investigation of an aviation accident, and for epidemiological studies of drug prevalence and trends. As new drugs such as synthetic opioids enter the market, FAA develops methods to accurately quantify their presence in accident victims, allowing assessment of factors that may have contributed to aviation accidents.

Source: The IZone Crew.

Figure 15. Biochemists receive and record autopsy specimens from an aviation fatality.

Air Traffic Control Advanced Research Tower Simulator

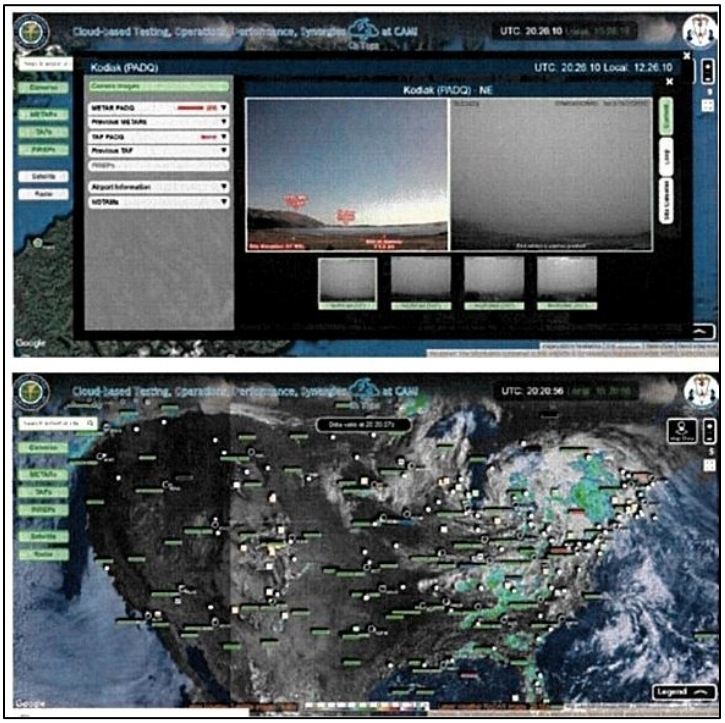
The mission of FAA's Aerospace Human Factors Research Division is to identify, examine, or evaluate risk factors associated with human behavior and human performance that can be remediated to improve the safety of the national airspace system (NAS). The division has developed a tower cab simulation lab that is used to investigate whether expert air traffic controllers use consistent visual scanning patterns, characterize the patterns found, and determine if some of them may be associated with improvements in performance. As shown in Figure 16, air traffic controller participants wear eye-tracking frames that allow researchers to observe and record controller visual scanning behavior, including when they look out the window, at a radar screen or any other visual source of information. Results will support the development of visual scanning instructional materials that can be administered to controller trainees.

Source: The IZone Crew.

Figure 16. Air traffic controller participating in research in the tower simulator.

Cloud-Based Research Platform

The innovative cloud-based research platform enables international human factors research associated with weather and advanced vision systems. The lab enables researchers to collect data on real-time visibility levels. This research informs regulatory decisions relating to the use of sensors and advanced vision systems in low-visibility operations to improve access to airports, access to runways, and improve efficiency of the NAS. What does this mean? This means increased landings and decreased delays, all while maintaining U.S. leadership in aviation safety. There is no responsibility more important in the FAA than aviation safety.



Source: The iZone Crew.

Figure 17. Screenshots from the cloud-based research platform.

Maritime Administration

Verification and Certification of Ballast Water Management Systems

MARAD works with the maritime community to address issues related to the introduction of non-indigenous aquatic species through ballast water and hull biofouling. MARAD established its Ballast Water Initiative to assist industry and government agencies in moving treatment technologies from the laboratory to shipboard application as rapidly as possible.

MARAD's ballast water efforts have grown into a multi-state and multi-agency cooperative effort that supports the development of technical and scientific protocols for technology testing and verification. In addition, there are now independent testing facilities to provide the needed data for ultimate certification of ballast water management systems (BWMS) to International Maritime Organization (IMO) and U.S. Coast Guard (USCG) standards. These facilities also conduct research and development into improved technology and processing to control the spread of non-indigenous aquatic species.

Over the past several years, over 50 BWMS or monitoring/rapid detection systems have been tested at three MARAD-supported and USCG certified facilities and the MARAD Ready Reserve Force vessel MV CAPE WASHINGTON. In FY2017 and FY 2018, five promising treatments and/or treatment systems were tested. The objective of the testing was to validate and provide data on the efficacy of systems to treat ballast water in marine, brackish, and fresh waters. In two of these cases, the data was included as part of final submissions to the IMO or USCG for approval. In other cases, additional data was needed or systems required further development, which was informed by the testing.

The Ballast Water Initiative has shown that not all systems work according to vendor claims and can be challenging to operate in the marine environment (versus in the laboratory). The facilities are in a unique position to provide unbiased, third-party data that will affect the decisions made by ship owners. Without this type of testing, there would be no credible source of data.

List of Acronyms and Abbreviations

AACVTE	Ann Arbor Connected Vehicle Test Environment
AAR	Association of American Railroads
AID	Accelerated Innovation Deployment Demonstration
AIP	Airport Improvement Program
AMRP	Annual Modal Research Plan
ASLRRA	American Short Line and Regional Railroad Association
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
ATGMS	Autonomous track geometry measurement system
BWMS	Ballast water management systems
CACC	Cooperative adaptive cruise control
CAMI	Civil Aerospace Medical Institute
CAP	Cross-Agency Priority
CARMA	Cooperative Automation Research Mobility Applications
CMV	Commercial motor vehicle
COE	Center of Excellence
CRADA	Cooperative research and development agreement
C-V2X	Cellular vehicle-to-everything
DOC	Department of Commerce
DOT	Department of Transportation
DSRC	Dedicated short-range communications
EAR	Exploratory Advanced Research
EDC	Every Day Counts
EMS	Emergency Medical Services
EO-PTC	Enhanced overlay positive train control
FAST Act	Fixing America's Surface Transportation Act
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FCI	Fuchs Consulting, Inc.
FLC	Federal Lab Consortium for Technology Transfer

FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FTOT	Freight and Fuel Transportation Optimization Tool
FY	Fiscal year
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ITD	Innovative Technology Deployment program
ITS	Intelligent transportation systems
ITS PCB	Intelligent Transportation Systems Professional Capacity Building Program
JPO	Joint Program Office
L2M	Lab-to-Market
MARAD	Maritime Administration
MassDOT	Massachusetts Department of Transportation
META	Maritime Environmental and Technical Assistance
MOD	Mobility on demand
NAS	National airspace system
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
NRL	Naval Research laboratory
NSWCC	Naval Surface Warfare Center Carderock
NTIA	National Telecommunications and Information Administration
NTL	National Transportation Library
OA	Operating administration
OEM	Original Equipment Manufacturer
OST-R	Office of the Assistant Secretary for Research and Technology
PCB	Professional capacity building
PHMSA	Pipeline and Hazardous Material Safety Administration
PTC	Positive train control
Pub. L.	Public Law

R&D	Research and development
R&T	Research and technology
RD&T	Research, development, and technology
ROSA P	Repository and Open Science Access Portal
ROW	Right-of-way
SAE	Society of Automotive Engineers
SBIR	Small Business Innovation Research Program
SCMS	Security credential management system
SLSI	Short Line Safety Institute
STIC	State Transportation Innovation Council
T2	Technology transfer
TFHRC	Turner-Fairbank Highway Research Center
U.S. DOT	United States Department of Transportation
U.S.C.	United States Code
USCG	United States Coast Guard
UTC	University Transportation Centers
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything
Volpe Center	John A. Volpe National Transportation Systems Center
VRTC	Vehicle Research and Test Center
WJHTC	William J. Hughes Technical Center